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Use of Mulberry Stalk as Biochar and its Effect on Growth, Yield and Quality of Mulberry (*Morus alba* L.)

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AUTHORS CONTRIBUTION

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ABSTRACT

A field experiment was conducted in the mulberry crop to know the effect of soil application of mulberry stalk biochar on growth, yield and quality of mulberry in farmer's field at Sidlaghatta taluk, Chikkaballapura district. The experiment was laid out in a randomized complete block design with eight treatments and replicated thrice. Among different treatments applied, combined application of biochar and FYM (T_8: Soil application of biochar @ 10 t ha^{-1} + FYM @10 t ha^{-1}) significantly recorded higher plant height (194.71 cm), number of shoots per plant (15.27), number of leaves per shoot (36.93), leaf yield (16.37 t ha^{-1}), crude fibre (3.71 %) and crude protein (21.40 %) and the next best treatment was T_7 which received soil application of biochar @ 7.5 t ha^{-1} + FYM @10 t ha^{-1} and these treatments were on par with each other but significantly superior over control. Among different levels of biochar applied @ 10 t ha^{-1} recorded higher plant height (184.00 cm), number of shoots per plant (13.80), number of leaves per shoot (31.67), leaf yield (15.17t ha^{-1}), crude fibre (2.54 %) and crude protein (20.13 %) compared to application of biohar @ 5 and 7.5 t ha^{-1}. Treatments T_3 (14.84 t ha^{-1}) and T_5 (15.17 t ha^{-1}), with biochar @ 7.5 and 10 kg ha^{-1} alone were on par with each other but significantly superior over control (13.01 t ha^{-1}). Significantly lower growth and yield parameters were recorded in the control.

Keywords : Mulberry, Biochar, Growth, Yield, Quality

CROP residue management is one of the emerging problems in agriculture sector. Crop residues in fields can cause considerable crop management problems as they accumulate in large quantity. Composting of plant twigs and woody plants plant residues becomes difficult as it takes longer time for decomposition. In such cases, farmers burn the crop residues. Residue burning generally provides a faster way to clear the agriculture field for land preparation and planting. However in addition to loss of valuable biomass and nutrients, biomass burning release toxic gases including greenhouse gases (GHG's) like carbon dioxide and methane.

In Indian conditions, there is an immense scope for converting millions of tonnes of crop residues into biochar and use the same for enriching soil carbon (Srinivasa Rao *et al.,* 2013).

Conversion of crop residue biomass into biochar is considered as an alternative way to composting and crop residue burning. Biochar is 'the black diamond' a carbon-rich product resulted from the pyrolysis of organic material at relatively low temperature (<700°C) in the absence of oxygen or at relatively low-oxygen conditions. The high surface area and porosity of biochar makes it to adsorb or retain nutrients and increase the cation exchange capacity and water holding capacity of soil. Due to this inherent chemical and physical properties, biochar can potentially influence soil conditioning. Keeping, this in view use of biochar is better option for improvement of yield in the various crops (Atkinson *et al.,* 2010).

Mulberry (*Morus alba* L.) a perennial, deep rooted, fast growing and high biomass producing foliage plant and it is the only source of food for the silkworm

(*Bombyx mori*) and is grown under varied climatic conditions ranging from temperate to tropics. The sustainable production of mulberry leaf is entirely dependent on the maintenance of the soil fertility of mulberry garden through the periodical application of organic sources and inorganic fertilizers in required quantities. Though lot of mulberry stalk has been generated throughout the year and for its management was to produce biochar from the mulberry stalks and this could have a dramatic impact on the society and on agriculture worldwide. Keeping these in view, the prseent study investigates the 'Use of mulberry stalk as biochar and its effect on growth, yield and quality of mulberry (*Morus alba* L.)'.

Material and Methods

The experiment was carried on farmer's field at Sidlaghatta taluk, Chikkaballapura district, Karnataka, India, which falls under Eastern Dry Zone of Karnataka (Agro climatic Zone No. 5) and is situated at 13^0 36' North latitude 77^0 43.49' East longitude and at an altitude of 915 meters above the mean sea level. Victory 1 (V1) variety planted at a spacing of 90 x 60 cm. The experiment was laid out in randomized complete block design and replicated thrice with 8 treatments, with mulberry as test crop during the third season *kharif* 2020-2021 to know the residual effect. The treatment details are given below.

T_1: Control (NPK alone)

T_2: POP (FYM (25 t ha^{-1})+NPK 375:140:140 kg ha^{-1})

T_3: Soil application of biochar @ 5 t ha^{-1}

T_4: Soil application of biochar @ 7.5 t ha^{-1}

T_5: Soil application of biochar @ 10 t ha^{-1}

T_6: Soil application of biochar @ 5 t ha^{-1}+ FYM @ 10 t ha^{-1}

T_7: Soil application of biochar @7.5 t ha^{-1} + FYM @ 10 t ha^{-1}

T_8: Soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1}

NPK is common for all the treatments

A composite surface soil sample (0-15 cm depth) was collected before the onset of experiment. The initial soil status of the experimental site is presented in Table 1. The soil of the experimental plot was sandy loam in nature, with a pH of 6.64, electrical conductivity of 0.21 dSm^{-1}, available nitrogen, phosphorus and potassium content was 261.37, 35.84 and 210.26 kg ha^{-1}, respectively.

Table 1

Initial physico-chemical properties of the experimental site

Particulars	Content
Texture	Sandy loam
Bulk density (Mg m^{-3})	1.34
Aggregate stability (%)	52.53
MWHC (%)	32.60
Soil pH (1:2.5)	6.64
EC (dSm^{-1}) (1:2.5)	0.21
Organic carbon (g kg^{-1})	0.40
Available nitrogen (kg ha^{-1})	261.37
Available phosphorus (P_2O_5 kg ha^{-1})	35.84
Available potassium (K_2O kg ha^{-1})	210.26
Available sulphur (ppm)	15.82
Exchangeable calcium [cmol(p$^+$) kg^{-1}]	4.52
Exchangeable magnesium [cmol(p$^+$) kg^{-1}]	1.85
DTPA extractable iron(mg kg^{-1})	12.66
DTPA extractable copper (mg kg^{-1})	1.56
DTPA extractable manganese (mg kg^{-1})	4.91
DTPA extractable zinc (mg kg^{-1})	0.83
Hot water soluble boron(mg kg^{-1})	0.33

The biometric observations like growth and yield parameters were recorded plot wise during the crop period. The crude protein content was determined by multiplying nitrogen concentration of the leaf with 6.25 (Mariotti *et al*., 2008) and crude fibre content was estimated as described by Sadasivam and Manickam (1996). Composition of biochar is presented in Table 2.

TABLE 2

Physico-chemical properties of biochar

Parameters	Value
Bulk density (Mg m^{-3})	0.32
WHC (%)	93.14
pH (1: 2.5)	8.53
EC (dSm^{-1}) (1: 2.5)	0.39
Total carbon (%)	69.37
Nitrogen (%)	0.89
Phosphorus (%)	0.22
Potassium (%)	0.65
Calcium (%)	0.96
Magnesium (%)	0.48
Sulphur (%)	0.18
Iron (ppm)	493
Manganese (ppm)	94.1
Zinc (ppm)	34.59
Copper (ppm)	20.55
Boron (ppm)	33.5

RESULTS AND DISCUSSION

Growth Parameters

Plant height: Plant height in mulberry crop was significantly influenced by soil application of biochar and FYM and the values ranged from 171.20 to 194.71 cm at harvest (Table 3).

Perusal of the data revealed that the plant height increased progressively from 30 DAP up to harvest stage. Among the different treatments, the highest plant height at 30 DAP (75.57 cm), 60 DAP (125.58) and 90 DAP (159.69) was recorded in the treatment T_8 with combined soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1}which was significantly superior to all other treatments except T_7 (soil application of biochar @ 7.5 t ha^{-1} + FYM @ 10 t ha^{-1}). The lowest plant height at 30 DAP (62.73 cm), 60 DAP (106.13 cm), 90 DAP (137.96 cm) and at harvest (171.20 cm) was recorded in control (NPK alone). Application of biochar increased the plant height with increase in crop period. The soil application of biochar in combination with FYM showed increase in plant height at different growth stages. The increase in the plant height can be attributed due to creation of favorable pH and addition of nutrients such as Ca in soil and it's ability to reduce leaching of nutrients, increase water and nutrient retention, increase microbial activity and aeration in the soil and there by slow, steady and balanced nutrients were supplied. Beneficial effects of biochar application were attributed to shift in microbial community to plant growth promoting rhizobacteria and fungi is in agreement with Dong *et al*. (2015) and Graber *et al*. (2010). There were many factors contributing to the improvement of growth attributes of crop with biochar application. Kalyani *et al*. (2016) also reported increased plant height and number of

TABLE 3

Effect of mulberry stalk biochar on plant height (cm) of mulberry at different growth stages

Treatments	30 DAP	60 DAP	90 DAP	Harvest
T_1: Control (NPK alone)	62.73	106.13	137.96	171.20
T_2: POP(FYM (25 t ha^{-1}) + NPK 375:140:140 kg ha^{-1})	63.18	108.57	140.15	175.63
T_3: Soil application of biochar @ 5 t ha^{-1}	67.89	113.18	142.60	179.89
T_4: Soil application of biochar @ 7.5 t ha^{-1}	68.86	115.17	147.71	182.64
T_5: Soil application of biochar @ 10 t ha^{-1}	70.05	118.82	150.83	184.00
T_6: Soil application of biochar @ 5 t ha^{-1} + FYM @ 10 t ha^{-1}	71.09	120.44	152.24	188.49
T_7: Soil application of biochar @7.5 t ha^{-1} + FYM @ 10 t ha^{-1}	73.60	123.46	156.09	191.23
T_8: Soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1}	75.57	125.58	159.69	194.71
S.Em±	1.40	1.34	1.33	1.19
CD @ (5%)	4.27	4.07	4.03	3.63

TABLE 4
Effect of mulberry stalk biochar on number of shoots per plant at different growth stages of mulberry

Treatments	30 DAP	60 DAP	90 DAP	Harvest
T_1: Control (NPK alone)	8.20	9.00	10.27	11.80
T_2: POP (FYM (25 t ha^{-1}) + NPK 375:140:140 kg ha^{-1})	8.53	9.53	10.60	12.13
T_3: Soil application of biochar @ 5 t ha^{-1}	9.60	10.33	11.67	13.00
T_4: Soil application of biochar @ 7.5 t ha^{-1}	10.00	10.67	12.13	13.33
T_5: Soil application of biochar @ 10 t ha^{-1}	10.33	11.13	12.80	13.80
T_6: Soil application of biochar @ 5 t ha^{-1} + FYM @ 10 t ha^{-1}	11.00	12.00	13.20	14.07
T_7: Soil application of biochar @7.5 t ha^{-1} + FYM @ 10 t ha^{-1}	11.57	12.47	13.80	14.87
T_8: Soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1}	12.53	13.40	14.27	15.27
S.Em±	0.34	0.26	0.34	0.23
CD @ (5%)	1.03	0.81	1.04	0.71

leaves of bean, fenugreek and mint with biochar in the combination of organic manure than biochar or compost alone.

Number of shoots per plant: Application of biochar with FYM significantly influenced the number of shoots per plant at different growth stages of mulberry and data is presented in Table 4.

Numbers of shoots per plant at 30 DAP ranged from 8.20 to 12.53. The highest number of shoots per plant (12.53) was recorded in the treatment T_8 with application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} which was on par with the treatment T_7 (11.57) with application of biochar @ 7.5 t ha^{-1} + FYM @ 10 t ha^{-1}. The lowest number of shoots per plant was recorded in control (8.20).

Different treatments significantly influenced the number of shoots per plant in mulberry at 60, 90 DAP and at harvest. Among different treatments, the treatment (T_8) which recieved biochar @ 10 t ha^{-1} and FYM @ 10 t ha^{-1} significantly recorded higher number of shoots per plant at 60 DAP (13.40), 90 DAP (14.72) and at harvest (15.27) and it was on par with the treatmnet T_7 (biochar @ 7.5 t ha^{-1} and FYM @ 10 t ha^{-1}) which recorded 12.47, 13.80 and 14.87 number of shoots per plant at 60 DAP, 90 DAP and at harvest stage. Significantly lower number of shoots at 60 DAP (9.00), 90 DAP (10.27) and at harvest (11.80) was recorded in control (NPK alone). The highest numbers of shoots were recorded in treatment (T_8) biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1}. This might be attributed to responses to improved physical character of the soil in a way that benefits root growth and nutrient and water retention and increased the uptake of nutrients in plants leading to enhanced chlorophyll content and carbohydrate synthesis that led to increase in cell division and enlargement of cell size and ultimately influence the number of shoots per plant. This is in line with the Lehmann *et al*. (2003).

Number of leaves per shoot : Number of leaves per shoot in mulberry crop differed significantly at 30, 60, 90 DAP and at harvest due to soil application of biochar at different levels (Table 5).

Number of leaves per shoot increased gradually with advancement of crop growth stages and significantly highest number of leaves per shoot (15.33, 18.20, 30.93 and 36.93, respectively) at 30 DAP, 60 DAP, 90 DAP and at harvest were recorded in the treatment T_8. Treatment (T_5) with soil application of biochar @10 t ha^{-1} recorded higher number of leaves per shoot at 30 DAP (13.60), 60 DAP (16.60), 90 DAP (25.67) and at harvest (31.67) compared to treatments (T_4) and (T_3) with application of biochar@5 and 7.5 t ha^{-1}

The lowest number of leaves at 30 DAS (10.13), 60 DAS (14.13), 90 DAS (20.73) and at harvest (26.73)

TABLE 5

Effect of mulberry stalk biochar on number of leaves per shoot at different growth stages of mulberry

Treatments	30 DAP	60 DAP	90 DAP	Harvest
T_1: Control (NPK alone)	10.13	14.13	20.73	26.73
T_2: POP (FYM (25 t ha^{-1}) + NPK 375:140:140 kg ha^{-1})	11.20	14.73	21.93	27.80
T_3: Soil application of biochar @ 5 t ha^{-1}	12.67	15.87	23.47	29.47
T_4: Soil application of biochar @ 7.5 t ha^{-1}	13.20	16.00	24.73	30.73
T_5: Soil application of biochar @ 10 t ha^{-1}	13.60	16.60	25.67	31.67
T_6: Soil application of biochar @ 5 t ha^{-1} + FYM @ 10 t ha^{-1}	14.00	16.93	27.93	33.93
T_7: Soil application of biochar @7.5 t ha^{-1} + FYM @ 10 t ha^{-1}	14.67	17.60	29.66	35.67
T_8: Soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1}	15.33	18.20	30.93	36.93
S.Em±	0.37	0.34	0.52	0.53
CD @ (5%)	1.14	1.05	1.58	1.61

was recorded in control. The increase in number of leaves might be due to the increased uptake of nutreints in the plants. Biochar application enhance the chlorophyll content and carbohydrate synthesis which leads to increase in cell division and enlargement of cell size. This significant increase in vegetative growth is in agreement with Rahila *et al*. (2014).

The rise of soil pH, slow release of nutrients, increased plant available water and improved microbial activity would have contributed for improvement of growth parameters of plant in biochar and FYM treated plants over only biochar application. The results are consistent with research of Liang *et al.*, 2006; Gundale & De Luca, 2007; Amonette & Joseph, 2009 and Warnock *et al.*, 2007 suggest that all such improvements in the physical and chemical qualities of soil in biochar treated soils may have boosted the growth of the crop. Nitrogen being a structural component of the plant would help in cell enlargement and crop growth. Similarly, Mauad *et al*. (2003) reported higher number of leaves due to increased N availability.

Yield Parameter

Leaf yield : The data on the leaf yield of mulberry varied from 13.01 to 16.37 t ha^{-1} due to soil application of biochar at different levels and data is presented in Fig. 1.

Fig. 1: Effect of soil application of mulberry stalk biochar on leaf yield of mulberry

Combined soil application of biochar @ 10 t ha^{-1} and FYM @ 10 t ha^{-1} (T_8) recorded higher leaf yield per hectare (16.37 t ha^{-1}) and it was on par with T_7 (15.71 t ha^{-1}) which received soil application of biochar @ 7.5 t ha^{-1} and FYM @ 10 t ha^{-1} (Fig. 1). Leaf yield per plant in mulberry were lower in the treatments with only soil application of biochar when compared to the treatments which received both biochar and FYM. The lowest leaf yield of 13.01 t ha^{-1} was recorded in control without biochar. Among different treatments, with increased level of biochar application increased the leaf yield. This might be due to increase in rate of biochar which increases the moisture content and nutrient supply in soil. Increase in leaf yield with application of biochar can be attributed to increased CEC of soil, pH and base saturation, available P, nutrient retention and increased plant-available water and also due to better partitioning and migration of the total available photosynthates to economic yield. Such responses with application rates were reported by Major *et al*. (2010), Fasiha & Devakumar (2022) and Zwieten *et al*. (2010). Addition of more nutrients through combination of biochar, FYM and inorganic fertilizers resulted in higher grain and stover yield. Many research workers have reported that biochar-induced yield increases in the sugarcane crop, rice and maize production [Chen *et al*. (2010) and Ogawa & Okimori (2010)].

Quality of Mulberry Leaf

Varied amounts of crude protein and crude fibre contents were noticed in mulberry crop among different treatments (Fig 2). However, the crude protein increased and the crude fibre content decreased with increased levels of biochar application in combination with FYM. Maximum crude protein (21.40%) and minimum crude fibre (1.57%) were recorded in T_8 (Soil application of biochar @ 10 t

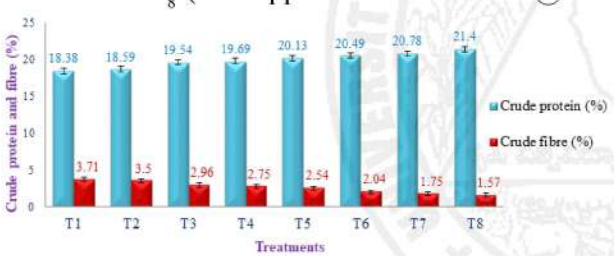

Fig. 2 : Effect of soil application of mulberry stalk biochar on quality of mulberry leaf

ha^{-1} + FYM @ 10 t ha^{-1}). The next best treatment was T_7 (Soil application of biochar @7.5 t ha^{-1} + FYM @ 10 t ha^{-1}) which showed 20.78 per cent of crude protein and 1.75% of crude fibre followed by T_6 (Soil application of biochar @ 5 t ha^{-1} + FYM @ 10 t ha^{-1}) that recorded 20.49 per cent of crude protein and 2.04 of crude fibre percentage. Soil application of biochar @ 10 t ha^{-1} recorded higher crude protein (20.13 %) and lower crude fibre (2.54%) compared to application of biochar @ 5 and 7.5 t ha^{-1}. The lowest crude protein content (18.38%) and highest crude fibre (3.71%) was noticed in the control with no biochar application. The improvement in nutritive value (more protein; less fiber) as a result of soil amendment with biochar is especially promising. A long term field demonstration in Canada, in which biochar was applied at 3.9 t ha^{-1} to mixed grass-clover forage plots (Husk & Major 2011; Ty *et al*., 2013 and Mala, 2018), demonstrated increased yields of forage (4.1%) in the third year and associated increases in nutritive value (Crude protein increased by 10 per cent and crude fibre decreased by 5.9%). These changes in botanical composition would explain part of the changes in nutritive value. Plant fibre refers to the cell-wall constituents of hemicelluloses, cellulose and lignin. The Neutral Detergent Fibre (NDF) values represent the total fibre fraction that make up cellwalls. For forage quality, the lower the NDF value, the better (-5.9% with biochar in this case). Fat (+5.3%) and starch (+2.9) content are both higher in plants from the biochar-amended plot, contributing to the higher overall plant nutrient energy value. The higher starch content is certainly related to the lower fibre content.

Similarly, Akachukwu *et al*., 2018 demonstrated in T*elfairia occidentalis*, that application of biochar @ 7.1 t ha^{-1} recorded the highest crude fibre (16.5%) in leaves which was similar to higher dose of biochar application @ 13.9 t ha^{-1}. Further increase in the application of biochar @ 28.0 t ha^{-1} recorded the least crude fibre content of 9.9 per cent.

Fru *et al*. (2018) and Rohitha *et al*. (2021) who reported that increase in protein content in mulberry might be due to increased availability of N and its uptake and storage in leaf and also due to the recalcitrant nature of the biochar which was influenced by the high pyrolysis temperatures during the production process.

Soil application of biochar and FYM appears to have more stimulating effect on the growth of mulberry, which was reflected in yield and quality of mulberry. Among all the treatments imposed, soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} recorded highest growth, yield and quality of mulberry compared to T_2 (POP). Treatments T_4, T_5 and T_6 which received biochar @ 5, 7.5 and 10 kg ha^{-1} increased the growth and yield parameters over control. From the present investigation, it is observed that combined application of biochar and FYM has significantly increased the growth, yield and also quality of mulberry.

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