Original Research Article

Effect of Mulberry Stalk Biochar and Humic acid on Growth, Yield and Quality of Mulberry (*Morus alba* L.)

ABSTRACT

A field experiment was conducted in a mulberry crop to investigate the impact of soil application of mulberry stalk biochar with FYM and foliar spray of humic acid on the growth, yield and quality of mulberry at a farmer's field in Mylandlahalli Village, Chintamani Taluk, Chikkaballapura District. The experiment was set up in a randomized complete block design with eight treatments, each replicated thrice. Among the various treatments applied, the combined application of biochar with FYM and humic acid (T_8: Soil application of biochar @ 10 t ha^{-1} + FYM @10 t ha^{-1}+2% Humic acid foliar spray) significantly resulted in higher plant height (196.10 cm), number of shoots per plant (15.06), number of leaves per shoot (31.78), leaf yield (26.22 t ha^{-1}), crude protein (20.28%) and lower crude fibre (1.56%). The next best treatment were T_7(Soil application of biochar @ 7.5 t ha^{-1}+ FYM @10 t ha^{-1}+ 1% foliar spray of humic acid) and T_6(Soil application of biochar @ 5 t ha^{-1} + FYM @10 t ha^{-1}+ 0.5% Humic acid foliar spray) and these treatments were statistically comparable but significantly superior to the package of practice (POP). The control exhibited significantly lower growth and yield parameters.

Keywords: Mulberry, Biochar, Humic acid, Growth, Yield, Quality

INTRODUCTION

The cultivation of mulberry (*Morus alba* L.) plays a pivotal role in the sericulture industry, serving as the primary feed for silkworms (*Bombyx mori*). The success of sericulture is intricately linked to the health and productivity of mulberry plants, making it imperative to explore sustainable agricultural practices that enhance growth, yield and quality. In this context, the integration of biochar and humic acid into mulberry cultivation emerges as a promising avenue, as these amendments have shown considerable potential in improving soil health and plant performance in various cropping systems.

Biochar, a carbon-rich material produced through the pyrolysis of organic matter, has gained attention for its ability to enhance soil structure, water retention and nutrient availability.

Mulberry stalk biochar, derived from the agricultural residues of mulberry plants, not only serves as a valuable waste management strategy but also presents an opportunity to harness the beneficial properties of biochar for mulberry cultivation. The addition of mulberry stalk biochar to the soil has the potential to influence plant growth parameters, yield and the overall quality of mulberry leaves, thereby impacting the sericulture industry positively.

Humic acid, a complex mixture of organic molecules derived from the decomposition of plant and animal residues, is another amendment known for its positive effects on soil fertility and plant development. The unique chemical composition of humic acid contributes to improved nutrient uptake, root development and stress tolerance in plants. Integrating humic acid into mulberry cultivation holds promise for enhancing the physiological processes of mulberry plants, potentially leading to increased productivity and improved leaf quality.

The synergy between mulberry stalk biochar and humic acid in agricultural systems has been a subject of growing interest, driven by the need for sustainable and environmentally friendly practices. These amendments, when applied together, have the potential to create a conducive soil environment that promotes optimal root development, nutrient assimilation and overall plant growth. Additionally, the combination of biochar and humic acid may contribute to enhanced water-use efficiency, an essential factor in regions where water resources are limited.

Despite the potential benefits, there is a paucity of comprehensive studies focusing on the joint influence of mulberry stalk biochar and humic acid on mulberry cultivation. This research aims to address this gap by systematically investigating the impact of different levels of mulberry stalk biochar and humic acid on the growth parameters, yield and quality of mulberry plants. Through a randomized complete block design with carefully selected treatments and replications, we aim to provide valuable insights into the synergistic effects of these amendments on mulberry cultivation.

MATERIAL AND METHODS

The experiment was conducted on a farmer's field located in Mylandlhalli Village Chintamani Taluk, Chikkaballapur District, Karnataka, India. This region is part of the

Eastern Dry Zone of Karnataka, which is designated as Agroclimatic Zone No. 5. The field is situated at 13^{o} 36' North latitude and 77^{o} 43.49' East longitude, with an altitude of 915 meters above mean sea level. The experiment was designed using a randomized complete block design, replicated three times and consisted of eight treatments. Mulberry (Victory V1 variety) was chosen as the test crop for the study.

List 1 :The treatment details are provided below.

Treatments	Details
T_1	Control (N:P_2O_5:K_2O350:140:140 kg ha^{-1})
T_2	POP (FYM (25 t ha^{-1}) + N :P_2O_5 :K_2O 350:140:140 kg ha^{-1}))
T_3	Soil application of biochar @ 5 t ha^{-1} + 0.5% Humic acid foliar spray
T_4	Soil application of biochar @ 7.5 t ha^{-1} + 1% Humic acid foliar spray
T_5	Soil application ofbiochar@10 t ha^{-1} +2%Humicacidfoliar spray
T_6	Soil application of biochar @ 5 t ha^{-1} + FYM @ 10 t ha^{-1} + 0.5% Humic acid foliar spray
T_7	Soil application of biochar @7.5 t ha^{-1} + FYM @ 10 t ha^{-1} + 1% Humic acid foliar spray
T_8	Soil applicationofbiochar @10 t ha^{-1} +FYM@10 t ha^{-1} +2%Humicacid foliar spray

A surface soil sample (0-15 cm depth) was collected before the experiment began. The soil of the experimental plot was sandy loam with a pH of 6.64 and an electrical conductivity of 0.21 dS m^{-1}**.** The initial soil status of the experimental site is presented in Table 1.

Table 1: Initial physicochemical and biological properties of the soil at the experimental site

Parameter	**Value**
Textural class	Sandy loam
Bulk density (Mg m^{-3})	1.34
Maximum water holding capacity (%)	32.60
Aggregate stability (%)	52.53

Soil pH	6.64
Electrical conductivity (dS m^{-1})	0.21
Organic carbon (%)	0.40
CEC (cmol (p^+) kg^{-1})	15.28
Available N (kg ha^{-1})	261.37
Available P_2O_5 (kg ha^{-1})	35.84
Available K_2O (kg ha^{-1})	210.26
Available S (mg kg^{-1})	15.82
Exchangeable Ca (cmol (p+) kg^{-1})	4.52
Exchangeable Mg (cmol (p+) kg^{-1})	1.85
DTPA Fe (mg kg^{-1})	12.66
DTPA Zn (mg kg^{-1})	0.83
DTPA Mn (mg kg^{-1})	4.91
DTPA Cu (mg kg^{-1})	1.56
Available B (mg kg^{-1})	0.33
Urease activity (µg NH_4^+-N g^{-1} soil h^{-1})	55.44
Dehydrogenase (µg TPF g^{-1}soil 24 h^{-1})	47.50
Phosphatase (µg PNP g^{-1} soil h^{-1})	26.36

3. Production of biochar

The mulberry stalk generated as waste residue after leaf harvest in the farmer's field was collected and air dried. Producing biochar from mulberry stalks via pyrolysis is an eco-friendly process. Mulberry stalks, a readily available agricultural byproduct, are first prepared by cutting them into uniform pieces. These prepared stalks are loaded into a pyrolysis unit designed for oxygen-free conditions. The pyrolysis process heats the stalks, breaking them down into biochar (a stable carbon-rich material), bio-oil (a liquid byproduct) and syngas (a gas mixture). After carbonization, the biochar was collected and ground to a fine powder and used for the field experiment.

4.Characterization of biochar

The biochar was characterised by various standardized analytical procedures for its specific physicochemical properties such as bulk density, water holding capacity, pH, EC and total elements composition. The powdered mulberry stalk biochar was tested for various chemical parameters and findings are shown in Table 2.

Table 2: Characterization of physicochemical properties of mulberry stalk biochar

Physical properties	
Parameters	**Value**
Bulk density (Mg m^{-3})	0.34
WHC (%)	95.05
Chemical properties	
pH (1:10)	8.53
EC (1:10) dS m^{-1}	0.39
C (%)	72.18
N (%)	0.83
P (%)	0.35
K (%)	0.98
Ca (%)	0.68
Mg (%)	0.43
S (%)	0.15
Fe (mg kg^{-1})	493
Mn (mg kg^{-1})	98.02
Zn (mg kg^{-1})	38.68
Cu (mg kg^{-1})	29.09
B (mg kg^{-1})	33.5

The data shown in Table 2 revealed that the mulberry stalk biochar has recorded a bulk density of 0.34 Mg m^{-3} and a water holding capacity of 95.05 per cent. The chemical composition of biochar was found to be alkaline in nature with a pH of 8.53 and an electrical conductivity of 0.39 dS m^{-1}. The total carbon content of 72.18 per cent was recorded and nitrogen, phosphorus and potassium were recorded at 0.83, 0.35 and 0.98 per cent, respectively. It also recorded a good amount of calcium, magnesium and sulphur with the tune of 0.68, 0.43 and 0.15 per cent, respectively. It also recorded appreciable quantities of iron, zinc, manganese, copper and boron to an extent of 493, 38.68, 98.02, 29.09 and 33.5 mg kg^{-1}, indicating sustainability for improving physic-chemical properties in the soil.

Results and Discussion

Growth Parameters

Plant height**:** Plant height in mulberry crop was significantly influenced by soil application of biochar in combination with FYM and humic acid, values ranged (Table3) from 145.63 to 196.10 cm at harvest.

A perusal of the data revealed that the plant height increased progressively from 30 DAP up to the harvest stage. Among the different treatments, the highest plant height at 30 DAP (102.24 cm),60 DAP (130.38 cm) and 90 DAP (161.24) was recorded in the treatment $T_8$with combined soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} + 2% foliar spray of humic acidwhich was significantly superior to all other treatments except T_7(soil application of biochar @ 7.5 t ha^{-1} + FYM @ 10 t ha^{-1} + 1% foliar spray of humic acid) and T_6 (soil application of biochar @ 5 t ha^{-1} + FYM @ 10 t ha^{-1} + 0.5% foliar spray of humic acid) compared to package of practise (POP). The lowest plant height at 30 DAP (71.67 cm), 60 DAP (103.78 cm), 90 DAP (128.73 cm) and at harvest (145.63 cm) was recorded in control (NPK alone). Application of biochar in combination with FYM and humic acid increased the plant height with an increase in crop period. The soil application of biochar in combination with FYM and humic acid showed an increase in plant height at all growth stages. Application of biochar and humic acid to the soil promotes vegetative growth by improving photosynthetic pigment production, rapid synthesis of protoplasm and increase in cell size which ultimately influence the vegetative growth and which is expressed morphologically through an increase in plant height. The beneficial effects of biochar application were attributed to a shift in the microbial community to plant growth promoting rhizobacteria and fungi agrees with Dong *et al*. (2015) andGraber *et al*. (2010). Kalyani *et al*. (2016) also reported that the combination of organic manure with biochar increased the plant height and number of leaves of beans, fenugreek and mint compared to compost alone application.

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
Control ($N:P_2O_5:K_2O$350:140:140 kg ha^{-1})	71.67	103.78	128.73	145.63
POP (FYM (25 t ha^{-1}) + N :P_2O_5 :K_2O 350:140:140 kg ha^{-1}))	96.61	113.10	146.32	163.95
Soil application of biochar @ 5 t ha^{-1} + 0.5% Humic acid foliar spray	94.95	108.23	141.65	160.33
Soil application of biochar @ 7.5 t ha^{-1} + 1% Humic acid foliar spray	96.70	113.35	146.78	165.44
Soil application ofbiochar@10 t ha^{-1} +2%Humicacidfoliar spray	96.88	116.08	150.97	168.51
Soil application of biochar @ 5 t ha^{-1} + FYM @ 10 t ha^{-1} + 0.5% Humic acid foliar spray	98.66	121.15	156.09	182.79
Soil application of biochar @7.5 t ha^{-1} + FYM @ 10 t ha^{-1} + 1% Humic acid foliar spray	100.90	125.24	159.07	189.90
Soil applicationofbiochar @10 t ha^{-1} +FYM@10 t ha^{-1} +2%Humicacid foliar spray	102.24	130.38	161.24	196.10
S.Em±	**2.47**	**3.07**	**3.92**	**4.51**
CD @ (5%)	**7.49**	**9.32**	**11.90**	**13.67**

* NPK 350:140:140 kg ha^{-1} is common for all the treatments DAP- Days After Pruning

Number of shoots per plant**:** Application of biochar with FYM and humic acid 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 9.63 to 11.49. The highest number of shoots per plant (11.49)was recorded in the treatment T_8 with application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} + 2% foliar spray of humic acid which was on par with the treatment T_7(11.08) and T_6(10.69). The lowest number of shoots per plant was recorded in control (9.63).

Different treatments significantly influenced the number of shoots per plant in mulberry at 60, 90 DAP and at harvest. The treatment T_8 which received soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} + 2% foliar spray of humic acid at 30DAP (11.49), 60 DAP (13.50), 90 DAP (14.56) and at harvest (15.06) significantly recorded the highest number of shoots per plant and it was at par with $T_7$and T_6but significantly superior to other treatments. Significantly lower number of shoots at30DAP (9.63), 60DAP (9.90), 90 DAP (10.71) and at harvest (11.10) 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} + 2% foliar spray of humic acid. This might be attributed to responses to improved physical character of the soil in a way that benefits root growth and or nutrient and water retention and acquisition provided by the biochar with FYM and humic acid application. This confirmed the findings of Lehmann *et al*. (2003).

Table 4: Effect of mulberry stalk biochar on the number of shoots per plant at different growth stages

Treatments	30 DAP	60 DAP	90 DAP	Harvest
Control (N:P_2O_5:K_2O350:140:140 kg ha^{-1})	9.63	9.90	10.71	8.31
POP (FYM (25 t ha^{-1}) + N :P_2O_5 :K_2O 350:140:140 kg ha^{-1}))	10.02	10.87	11.48	8.51
Soil application of biochar @ 5 t ha^{-1} + 0.5% Humic acid foliar spray	9.23	9.63	10.51	9.49
Soil application of biochar @ 7.5 t ha^{-1} + 1% Humic acid foliar spray	9.67	10.97	11.60	9.84
Soil application ofbiochar@10 t ha^{-1} +2%Humicacidfoliar	9.87	11.39	11.83	10.29

spray				
Soil application of biochar @ 5 t ha^{-1} + FYM @ 10 t ha^{-1} + 0.5% Humic acid foliar spray	10.69	11.82	12.07	10.76
Soil application of biochar @7.5 t ha^{-1} + FYM @ 10 t ha^{-1} + 1% Humic acid foliar spray	11.08	12.10	13.62	11.33
Soil applicationofbiochar @10 t ha^{-1} +FYM@10 t ha^{-1} +2%Humicacid foliar spray	11.49	13.50	14.56	11.93
S.Em±	**0.27**	**0.29**	**0.32**	**0.34**
CD @ (5%)	**0.83**	**0.87**	**0.96**	**1.04**

* NPK 350:140:140 kg ha^{-1} is common for all the treatments DAP- Days After Pruning

Number of leaves per shoot: Number of leaves per shoot inmulberry 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 (15.18, 19.60, 25.68 and 31.78, respectively) at 30, 60, 90 DAP and at harvest were recorded in the treatment T_8followed by T_7 and T_6. The lowest number of leaves at 30 DAS (10.45), 60 DAS (14.58), 90 DAS (20.77) and at harvest (26.64) was recorded in control.The increase in the number of leaves might be due to the increased uptake of nutrients in the plants leading to enhanced chlorophyll content and carbohydrate synthesis that led to the increase cell division and enlargement of the cell size which helped in increased plant height, stem girth and number of leaves. This significant increase in vegetative growth is in agreement withRahila *et al*. (2014). Foliar spray of humic acid improves plant metabolic activity, physiological and structural function *viz* increased photosynthesis and respiration rate, oxidative phosphorylation, protein synthesis and enzymatic reactions (Bing *et al*., 2012) thereby increasing plant vigour and production of metabolites responsible for cell division, cell elongation and cell differentiation. In addition, applied humic acid might have provided some essential nutrient elements which were absorbed through leaves. Similar results with foliar application of humic acid were reported by Kazemi (2014) in tomato; Manas *et al.*(2014) in pepper.

Table 5: Effect of mulberry stalk biochar on the number of leaves per shoot at different growth stages

Treatments	30 DAP	60 DAP	90 DAP	Harvest
Control ($N:P_2O_5:K_2O$350:140:140 kg ha^{-1})	10.45	14.58	20.77	26.64
POP (FYM (25 t ha^{-1}) + N :P_2O_5 :K_2O 350:140:140 kg ha^{-1}))	13.00	17.24	22.69	28.99
Soil application of biochar @ 5 t ha^{-1} + 0.5% Humic acid foliar spray	12.13	16.09	22.15	28.37
Soil application of biochar @ 7.5 t ha^{-1} + 1% Humic acid foliar spray	13.04	17.43	23.55	29.16
Soil application ofbiochar@10 t ha^{-1} +2%Humicacidfoliar spray	13.45	17.64	23.83	29.91
Soil application of biochar @ 5 t ha^{-1} + FYM @ 10 t ha^{-1} + 0.5% Humic acid foliar spray	14.37	18.46	24.55	28.21
Soil application of biochar @7.5 t ha^{-1} + FYM @ 10 t ha^{-1} + 1% Humic acid foliar spray	14.65	18.65	24.77	30.85
Soil applicationofbiochar @10 t ha^{-1} +FYM@10 t ha^{-1} +2%Humicacid foliar spray	15.18	19.60	25.68	31.78
S.Em±	**0.35**	0.46	0.62	0.75
CD @ (5%)	**1.05**	**1.39**	**1.88**	**2.28**

* NPK 350:140:140 kg ha^{-1} is common for all the treatments DAP- Days After Pruning

Yield Parameter

Application of different levels of biochar in combination with FYM and humic acid significantly influenced the leaf yield and the values ranged from and 21.14 to 26.22 t $ha^{-1}$and data is presented inFig. 1.

Combined soil application of biochar @ 10 t ha^{-1} and FYM @ 10 t ha^{-1} (T_8) recorded higher leaf yield per hectare (26.22 t ha^{-1}) and it was on par with T_7 (25.31 t ha^{-1}) and T_6(24.42). The lowest leaf yield of 21.14 t ha^{-1}was recorded in control which devoid of biochar.Among different treatments, with increased level of biochar in combination with FYM and humic acid applicationincreased the leaf yield. This might be due to increase in rate of biochar which increases themoisture content and nutrient supplyin 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 and Devakumar (2022) and Zwieten*et al*. (2010).

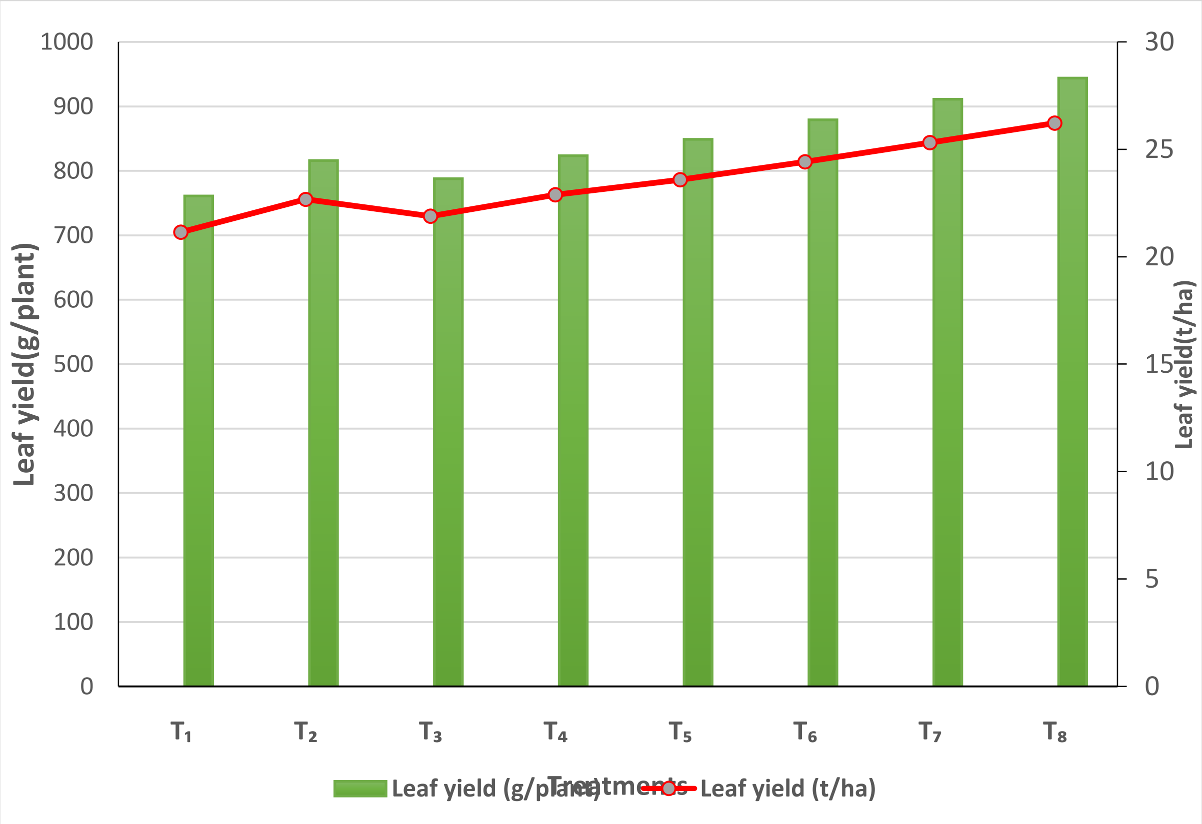

Fig. 1: Effect of soil application of mulberry stalk biochar on leaf yield of mulberry

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 (20.28%) and minimum crude fibre (1.56%) were recorded in

T_8 (Soil application of biochar @ 10 t ha^{-1} + FYM @ 10 t ha^{-1} + 2% foliar spray of humic acid). The next best treatment was T_7 which showed 19.87% of crude protein and 1.74 % of crude fibre followed by T_6which recorded 19.42 per cent of crude protein and 1.94 of crude fibre percentage. Theimprovement in nutritive value (more protein; less fibre) as a result of soil amendment with biochar is especially promising. Along term field demonstration in Canada, in which biochar was applied at 3.9 t $ha^{-1}$to mixed grass-clover forage plots (Husk and Major 2011, Ty *et al*. 2013), demonstrated increased yields of forage (4.1%) in the third year and associated increases in nutritive value (Crude protein increased by 10%, 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 most likely associated with the lower fibre content.

Foliar application of humic acid significantly increased crude protein concentration as compared to control. Increased content maybeattributedtotheincreasedavailabilityandabsorptionofnecessaryelementsrequiredforthesynthesisofaminoacids.Theproteincontentinwheatgrainwasgreatlyinfluencedby the application of biozyme (algal extract), which might be due to promotive effects on rootproliferation, thus higher uptake of nutrients particularly those needed as constituents inamino acid and protein synthesis (nitrogen, phosphorus and sulphur) resulting in higherproteinand aminoacidconcentrationin the grains(Singhand Chandel, 2005). Theapplication of humic acid resulted in a significant increase in protein due to increasedproteinbiosynthesis(AbdEl-MoniemandAbd-Allah,2008).

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.

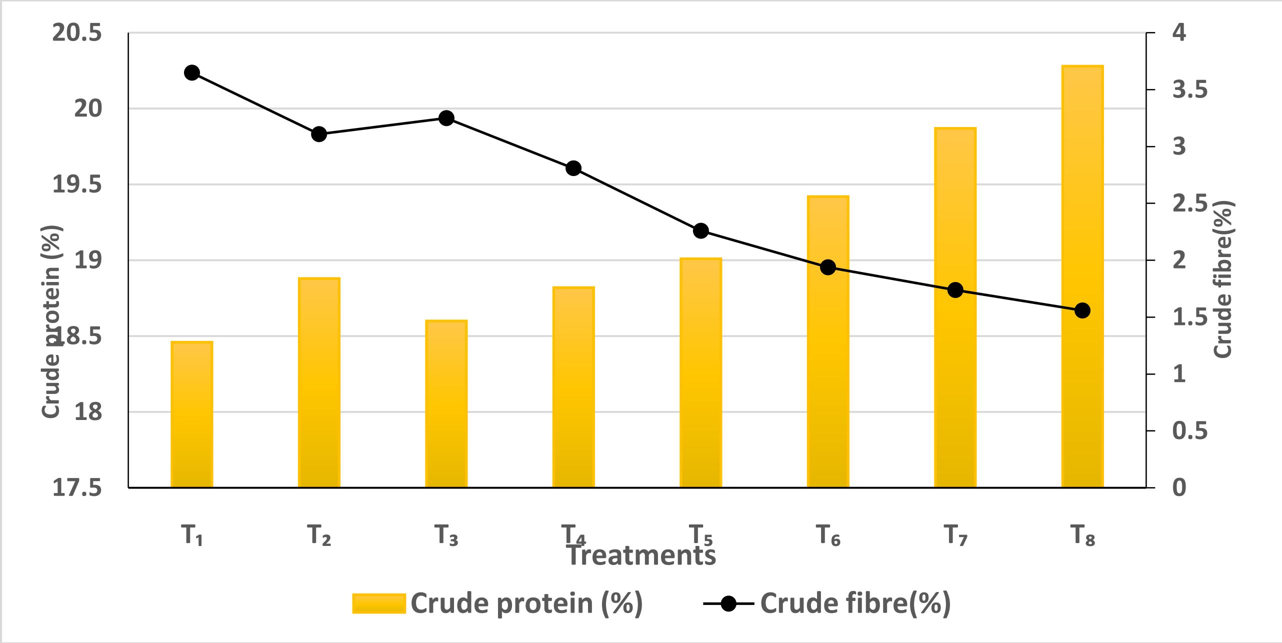

Fig: 2 Effect of soil application of mulberry stalk biochar on crude protein and crude fibre of mulberry leaf

Chlorophyll content (mg g^{-1})

Data on the chlorophyll content of mulberry at different growth stages is presented in Table 5 and Fig 3 indicates that the application of biochar in combination with FYM and humic acid recorded significantly higher chlorophyll meter readings than POP treatments.

Significantly higher chlorophyll content (3.21, 4.96, 5.72 and 6.99 mg g^{-1}) was recorded in the treatment (T_8) which received soil application of biochar @ 10 t ha^{-1} and FYM @ 10 t ha^{-1}+2%Humicacid foliar spray in the first, second and third crop cuttings compared to POP.Treatment T_8 was on par with treatment T_7(3.14, 4.69, 5.58 and 6.83) and T_6(3.04, 4.38, 5.41 and 6.75) The lower chlorophyll content was recorded in the first crop in control (NPK alone) (2.22, 3.42, 4.75 and 6.20). The chlorophyll content of leaves is a practical indicator of both potential photosynthetic productivity and general plant vigour, which is related to the N concentration in green plants. Biochar and humic acid application positively affects chlorophyll content and related parameters such as increased activity of PS II and facilitates electron transport, which boosts the total photosynthetic performance index. The increases in chlorophyll content are most likely linked to better availability of macro (K) and micronutrients (Fe, Mn, Zn) in the biochar and humic acid that play a fundamental role in the biosynthesis of chlorophyll and other pigments involved in the photosynthetic activity

(Netto *et al*., 2005) and also application of biochar to soil might have mineralized most of its N and made plant available. Nitrogen is a limiting nutrient in crop production and an increase in availability of N will increase plant height, number of shoots, number of leaves and chlorophyll content (Lyu *et al*., 2016).

Significantly higher SPAD reading upon application of humic acid might be attributed to increased chlorophyll content due to efficient absorption and uptake of N and Mg from soil which are essential components of chlorophyll. The increase in chlorophyll content increases the photosynthetic rate and efficiency of mulberry ultimately leads to better growth and yield of the crop. A similar increase in chlorophyll content upon application of humic acid was documented by Xudan (1986), El-Ghamry*et al*. (2009) and Sure *et al*. (2012) in cucumber; Arjumend*et al*. (2015) in wheat; Avinash (2016) in capsicum; Tejada *et al*. (2018); Chaitra (2018) in groundnut; Kiran (2020) in maize.

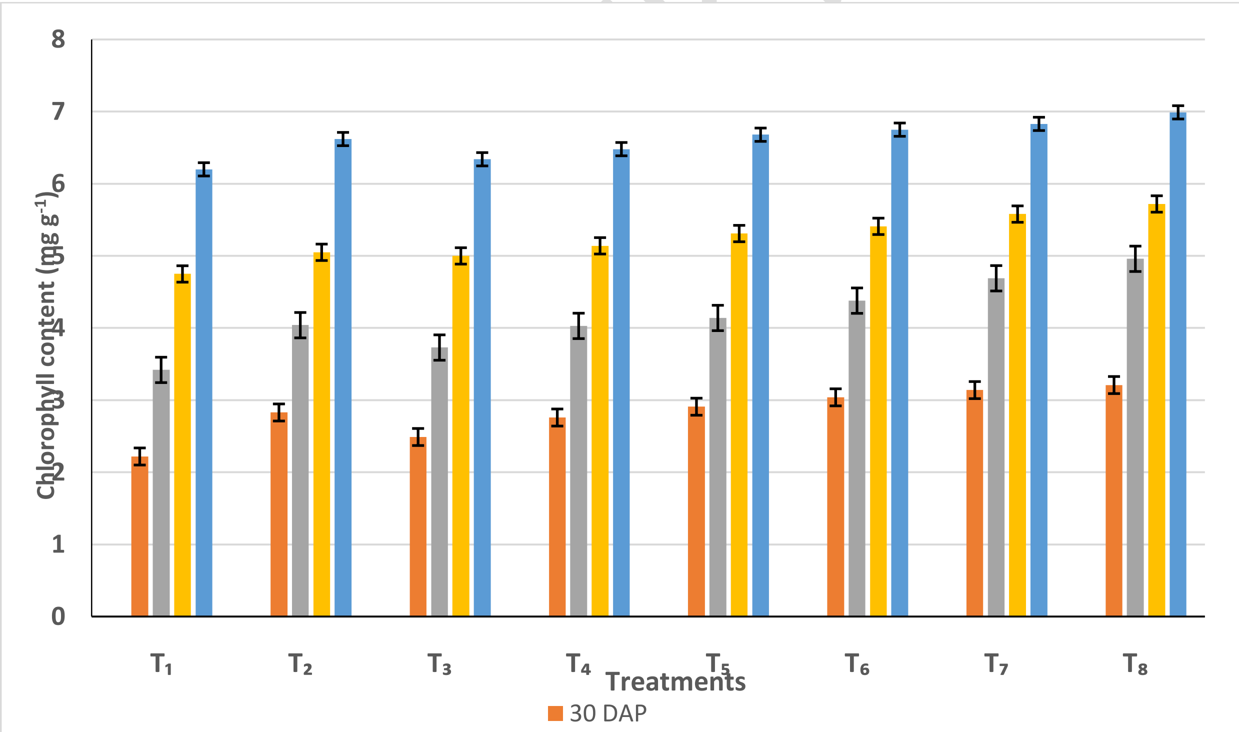

Fig 3: Effect of mulberry stalk biochar on chlorophyll content (mg g^{-1}) of mulberry at different growth stages

CONCLUSION

The combined application of biochar and farmyard manure (FYM), supplemented by a foliar spray of humic acid, demonstrated a pronounced stimulating effect on mulberry growth which was reflected in yield and quality. Among the various treatments evaluated, the combination of biochar applied at a rate of 10 t ha^{-1}, FYM at 10 t ha^{-1} and 2% foliar spray of humic acid resulted in the most significant improvements in growth, yield and quality compared to the package of practise (POP). The findings underscore the effectiveness of integrating biochar and FYM applications in enhancing mulberry production. Specifically, the synergistic effects of biochar and FYM contributed to substantial improvements in growth and yield attributes. Furthermore, humic acid foliar spray accentuated these benefits, leading to superior quality outcomes. Overall, the combined approach of biochar and FYM application, complemented by humic acid supplementation, emerged as a promising strategy for optimizing mulberry cultivation, offering significant potential for enhancing agricultural productivity and sustainability.

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