Environment and Ecology 37 (3A) : 797—802, July—September 2019
Website: environmentandecology.com ISSN 0970-0420

Influence of Different Biochars on Growth, Yield and Quality of Cotton (*Gossypium hirsutum* L.)

A. Karthik, V. K. Duraisamy, A. H. Prakash

Received 11 February 2019; Accepted 15 March 2019; Published on 6 April 2019

Abstract Crop residue accumulation and disposal is the major issue currently faced by cotton growing farmers. In order to solve it reutilization of cotton biomass for preparation of biochar at farm level and returning it back to the soil is known to have profound use to soil and environment. In this context, a field study was conducted during the year 2017-18 and 2018-19 to find the influence of different doses of different biochars on cotton crop. The results revealed that application of prosopis biochar and cotton biochar @ 4.0 t/ha effectively improved the plant height, dry matter production, number of sympodial branches, number of bolls and thereby increased yield of cotton crop (2,376 kg/ha and 2,341 kg/ha). Significant influence on improvement in quality parameters was also observed between the treatments. Addition of prosopis biochar and cotton biochar @ 4.0 t/ha increased fiber fineness, fiber strength, fiber elongation over the control plot. Among the different treatments, fiber length and uniformity was increased in biochars applied plots, but no significance difference was noticed. The Bartlett's index which indicates crop earliness shows that boll bursting was advanced in biochar applied plots than control. From the study it can be indoctrinated that application of prosopis biochar @ 4.0 t/ha followed by cotton biochar @ 4.0 t/ha increases the productivity of cotton and its preparation at farm level is a better solution for disposal of crop residue and it also improves soil quality in sustainable manner.

Keywords : Biochar, Boll weight, Cotton, Fiber quality, Yield.

A. Karthik
PhD Scholar,
Department of Agronomy, TNAU, Coimbatore 641003, India

V. K. Duraisamy*
Professor
(Agronomy), TNAU, Coimbatore 641003, India

A. H. Prakash
Project Co-ordinator & Head,
ICAR-Central Institute for Cotton Research, Regional Station, Coimbatore 641003, India
e-mail : vkduraisamy@yahoo.com
*Corresponding author

Introduction

Cotton is one of the most important fiber and cash crop of India and plays a dominant role in the industrial and agricultural economy of India. In order to attain higher yields, indiscriminate use of inorganic fertilizers and pesticides has led to decline in soil fertility and undesirable side effects leading to soil salinity, decreased soil productivity, reduction in beneficial microorganisms and contamination of food, water and environmental pollution leading to endangerment of human health. This phenomenon has urged to improve the soil health and quality in sustainable manner along with attaining higher yield.

The entry of biochar, a carbonaceous material produced via pyrolysis of locally available biomass has been shown profound effectiveness in improving the physical, chemical and biological properties with effective retaining capability of most nutrients to the crop (Singh et al. 2012). Most of the crop and agroforestry residues from rainfed areas are burnt in the field due to difficulties in disposing the heavy residues creating a necessity for biochar production (Venkatesh et al. 2018). Biochar can be produced from agricultural residues and by products which cannot fatch monetary return like cobs of maize and pearl-millet, stalks from cotton and maize, straws from rice and wheat, along with agro-industrial waste like paper mill waste, jatropha husk, coffee husk, coconut shell and cocoa pod husk can be effectively utilized for the preparation of biochar (Purakayastha et al. 2015).

Biochar application results in decrease in soil bulk density, increasing soil fertility and structure, improved water holding capacity, organic carbon content, availability of nutrients and biological properties (Berihun et al. 2017). Moreover, it also serves as a better alternate for other organic manures as it does similar work as that of FYM and other composts, but, in a compact and effective way yielding earlier crop response. The present study has been formulated in order to evaluate the impact of different sources of Biochar supplied in different doses on the growth, yield and quality parameters of cotton.

Materials and Methods

a field experiment was conducted at ICAR —Central Institute for Cotton Research (field No. 18) farm during the year 2017-18 and 2018-19. The farm is situated in the Western agroclimatic zone of Tamil Nadu at 11°N latitude and 77°E longitude and at an altitude of 426.7 meters above mean sea level (MSL). Soil type of experimental location is sandy clay loam of Typic Ustropept order. The initial soil samples were collected from the experimental site and analyzed under the laboratory for physical, chemical and biological properties and are presented in Table 1. To avoid cumulative effect of biochars during succeeding year, different field sites were used for the conduct of experiment. Soil of experimental site was slightly alkaline in nature with pH around 7.90, EC value 0.34 dSm^{-1}, bulk density of 1.38 g cm^{-3} and porosiy 47.2%, hence moderately well drained. Organic carbon content of the soil was 3.81 g kg^{-1} with available N, P_2O_5 and K_2O of 172.0,12.1 and 730 kg/ha respectively.

The experiment was laid out in Randomized Block Design (RBD) with 11 treatments and three replications. The treatments viz.,T_1–Control, T_2–Farm yard manure (FYM) @ 12.5 t ha^{-1}, Maize biochar @2.0 t/ha (T_3), 3.0 t/ha (T_4) and 4.0 t/ha (T_5), Cotton biochar @ 2.0 t/ha (T_6), 3.0 t/ha (T_7) and 4.0 t/ha (T_8) and Prosopis biochar@ 2.0 t/ha (T_9) , 3.0 t/ha (T_{10}) and 4.0 t/ha (T_{11}). The recommended dose of fertilizers 60 : 30 : 30 kg of N, P_2O_5 and K_2O was applied to all

Table 1. Physico-chemical properties of the experimental field.

Parameters	Field No. 18 (2017–18)	Field No. 06 (2018–19)	Authors
Texture	Sandy clay loam	Sandy clay loam	Source : CICR Report
Bulk density (g/cm^3)	1.38	1.34	Gupta and
Particle density	2.64	2.67	Dakshinamoorthy
Porosity (%)	47.2	49.8	(1981)
Organic carbon (g/kg)	3.80	3.70	Walkley and Black (1934)
pH	7.90	8.10	Jackson (1973)
EC (dS/m)	0.38	0.34	Jackson (1973)
Available nitrogen (kg/ha)	172	165	Subbiah and Asija (1956)
Available phosphorus (kg/ha)	12.1	10.9	Olsen et al. (1954)
Available potassium (kg/ha)	730	765	Stanford and English (1949)

Table 2. Physico-chemical properties of maize, cotton and Prosopis biochar.

Parameters	Maize biochar	Cotton biochar	Prosopis biochar
Bulk density (g cm^{-3})	0.36	0.44	0.50
Particle density (g cm^{-3})	0.75	0.84	0.91
Pore space (%)	47.9	52.4	55.3
pH	7.80	8.30	8.70
EC (dSm^{-1})	1.15	1.42	1.87
CEC (cmol kg^{-1})	12.8	15.1	17.9
Organic carbon (g/kg^{-1})	71.6	77.7	81.5
C : N ratio	52:1	47:1	63:1
Total nitrogen (g kg^{-1})	2.29	2.74	2.15
Total phosphorus (g kg^{-1})	2.77	3.26	1.31
Total potassium (g kg^{-1})	6.64	3.45	3.10
Total calcium (g kg^{-1})	0.67	0.71	0.86
Total magnesium (g kg^{-1})	0.44	0.48	0.53
Ash content (%)	22.7	28.5	32.6
Conversion (%)	32.2	39.7	42.3

the plots irrespective of treatments. Cotton variety Suraj released from ICAR-CICR was used for the experiment.

The biomass materials of maize stover and cotton stalk required for preparation of biochar was collected from the farm of TNAU, Coimbatore, Tamil Nadu and ICAR-CICR, Regional Station, Coimbatore. Prosopis wood material was collected in and around farm premises of ICAR-CICR. Collected biomasses were chopped into small pieces for easy loading into the biochar preparation chamber. Biochar required for conduct of experiment was produced through the pyrolysis machine available at Dept of Bioenergy, TNAU, Coimbatore and produced biochar were made into powder form for easy incorporation in to the field. Properties of biochars were analyzed in the laboratory and presented in Table 2.

Sowing of cotton seeds were done on the side of the ridges with recommended spacing of 75 × 45 cm. Gap filling and thinning of excess population was done so as to maintain plant stand. The fertilizers were applied to all plots as per the recommended dose (60 : 30 : 30 of N, P_2O_5 and K_2O kg/ha). Weed management was done with pre-emergence application of pendimethalin @ 2.51 t/ha and also through manual weeding on 40 and 60 DAS. Irrigation was given with an interval of 15 days and also depends upon occurrence of rainfall. Plant protection measures were taken at appropriate time for the control of bollworms and sap sucking pests.

Results and Discussion

Biochar quality

The conversion efficiency of prosopis biochar (PB) was highest with value of 42.3% followed by cotton biochar (CB) (39.7%), while maize biochar (MB) recorded the lowest conversion efficiency of 32.2%. The variations in the recovery of biochars are mainly due to nature and density of the feedstocks used and pyrolysing temperature adopted during preparation of biochars. This is in confirmation with the results of Pandian et al. (2016). The biochar yield is related to the content of cellulose and lignin in the biomass and less recovery was due to presence of less volatile compounds compared to parent biomass (Shalini et al. 2017). Among the different feedstocks, biochar produced from prosopis had the highest pH value of 8.70 and electrical conductivity (EC) value of 1.87 dSm^{-1} and CB recorded the pH of 8.30 with EC of 1.42 dSm^{-1}. Organic carbon content of biochar, PB and CB registered the highest value (81.5 and 77.7 g/kg) followed by MB (71.6 g/kg). Higher total nitrogen content was recorded in CB (2.74 g/kg) while lower nitrogen content was observed in PB (2.15 g/kg). The biochar produced from cotton stalk registered the highest total P (3.26 g/kg) and total K (6.64 g/kg) in MB. The Ca and Mg were higher in PB followed by CB. The variation in nutrient composition of different biochar materials was found to be highly influenced by the source of feedstock material.

Plant height

Plant height recorded at harvest stage of crop was significantly affected by the source and quantity of biochar applied. During both the years plant height was higher (103.6 cm) in prosopis biochar @4.0 t/ha (T_{11}) applied plots and it was at par with cotton biochar @ 4.0 t/ha (T_8) incorporated plots (100.5) followed by T_{10} (Prosopis biochar @4.0 t/ha with RDF) and T_2 (FYM @ 12.5 t/ha with RDF). Lowest plant height (79.4) was recorded in control plots with recommended dose of fertilizers (Table 3). The

Table 3. Effect of biochars on the growth, yield attributes and yield of cotton during winter irrigated season (pooled data of 2 years). All treatments were applied with recommended dose of fertilizers (60 : 30 : 30 kg of N, P_2O_5 and K_2O.

Treatments	Plant height (cm)	Dry matter (kg/ha)	Sympo-dia (No.)	No. of Bolls/ plant	Boil weight (g)	Yield (kg/ha)
T_1 : Control (No. manure)	79.4	3889	15.1	14.7	4.33	1634
T_2 : FYM @ 12.5t/ha	92.3	4984	20.4	18.4	4.59	2072
T_3 : Maize Biochar @ 2.0 t/ha	79.3	3981	16.4	15.0	4.35	1670
T_4 : Maize Biochar @ 3.0 t/ha	83.9	4332	17.8	15.9	4.37	1811
T_5 : Maize Biochar @ 4.0 t/ha	89.8	4760	19.9	17.4	4.54	1980
T_6 : Cotton Biochar @ 2.0 t/ha	81.4	4060	16.8	15.2	4.30	1687
T_7 : Cotton Biochar @ 3.0 t/ha	84.5	4430	18.4	16.5	4.42	1846
T_8 : Cotton Biochar @ 4.0 t/ha	100.5	5596	23.2	20.5	4.81	2314
T_9 : Prosopis Biochar @ 2.0 t/ha	85.7	4637	19.3	17.2	4.49	1933
T_{10} : Prosopis Biochar @ 3.0 t/ha	96.4	5315	22.1	19.6	4.68	2190
T_{11} : Prosopis Biochar @ 4.0 t/ha	103.6	5768	24.1	21.1	4.87	2376
SEm ±	4.10	173	0.76	0.96	0.17	97.6
CD (p=0.05)	12.1	5212	2.25	2.84	NS	287

increased plant height might have been due to application of biochar which increased the availability of nutrients throughout growing period of the crop. Similar results were recorded by Elangovan and Chandrasekaran (2014).

Dry matter production

In case of dry matter production, highest accumulation was cobserved in prosopis biochar @ 4.0 t/ha with RDF treated plots recording 5768 kg/ha and was followed by cotton biochar @ 4.0 t/ha with RDF (5,596 kg/ha). The dry matter production was lowest in maize biochar @ 2.0 t/ha with RDF applied plots (3,981 kg/ha) and control (3,889 kg/ha). This shows that the biochar from prosopis and cotton applied with higher doses increased dry matter production. Biochars reduced nutrient leaching especially nitrogen that facilitating more vegetative growth resulting in higher dry matter production. The results are in confirmation with study of Pandian et al. (2016), Utomo et al. (2017).

Number of Sympodia

Application of different biochars along with RDF significantly influenced number of sympodia. Prosopis biochar @ 4.0 t/ha (24.1) and was at par with cotton biochar @ 4.0 t/ha (23.2). Control plot (T_1) and maize biochar @ 2.0 t/ha recorded lowest number of sympodial branches (15.1 and 16.4 respectively). Production of higher number of sympodial branches may be due to improvement in soil characters during biochar application as it possesses higher porosity with more surface area that facilitated root growth, nutrient, water retention and acquisition. This is in line with the findings of Gu et al. (2016).

Number of bolls and boll weight

Significant influence on boll numbers was observed in plots applied with different sources and doses of biochar supplemented with RDF. Highest number of bolls (21.1) was recorded in prosopis biochar @ 4.0 t/ha and this was at par with cotton biochar @ 4.0 t/ha and prosopis biochar @ 3.0 t/ha (20.5 and 19.6 bolls respectively. The plot receiving RDF alone recorded lowest number of bolls (14.7) which was at par with maize biochar @ 2.0 t/ha (15.0 bolls/plant). Application of biochars did not significantly produce results in term of boll weight. The boll weight was maximum (4.87) in prosopis biochar @ 4.0 t/ha and lowest weight was recorded in control (4.33). Increased nutrient availability through addition of biochar stimulates the mobilization and accumulation of photosynthates in newly form bolls, thus it increase the number of bolls and their weight. The same results is also reported by Verma et al. (2017).

Yield

Supplementary to the recommended dose of fertiliz-

Table 4. Effect of biochars on the quality parameters of cotton during winter irrigated season (pooled data of 2 years). All treatments were applied with recommended dose of fertilizer (60 : 30 : 30 kg of N, P_2O_5 and K_2O).

Treatments	Fiber length (mm)	Fiber fineness (µg inch^{-1})	Fiber strength (g tex^{-1})	Fiber elongation (%)	Uniformity (%)	Bartlet index
T_1 : Control (No manure)	30.2	3.37	22.1	6.66	48.2	0.458
T_2 : FYM @ 12.5 t/ha	31.0	3.96	23.2	7.32	51.5	0.520
T_3 : Maize Biochar @ 2.0 t/ha	30.2	3.42	22.2	6.71	48.6	0.489
T_4 : Maize Biochar @ 3.0 t/ha	30.3	3.56	22.4	6.88	49.4	0.489
T_5 : Maize Biochar @ 4.0 t/ha	30.9	3.79	22.9	7.13	50.6	0.510
T_6 : Cotton Biochar @ 2.0 t/ha	30.1	3.45	22.2	6.74	48.7	0.479
T_7 : Cotton Biochar @ 3.0 t/ha	30.5	3.66	22.6	6.98	49.9	0.489
T_8 : Cotton Biochar @ 4.0 t/ha	31.8	4.29	23.9	7.70	53.5	0.541
T_9 : Prosopis Biochar @ 2.0 t/ha	30.7	3.77	22.8	7.10	50.5	0.510
T_{10} : Prosopis Biochar @ 3.0 t/ha	31.4	4.14	23.5	7.53	52.6	0.531
T_{11} : Prosopis Biochar @ 4.0 t/ha	32.0	4.40	24.0	7.81	54.0	0.552
SEm ±	1.27	0.13	0.37	0.27	2.18	0.019
CD (p=0.05)	NS	0.40	1.08	0.81	NS	0.056

er, prosopis biochar @ 4 t/ha (2376 kg/ha) recorded superior yield over the other treatment and was found at par with the cotton biochar @ 4 t/ha (2314 kg/ha) and prosopis biochar @ 3 t/ha (2190 kg/ha). Application of FYM @ 12.5 t/ha recorded yield advantage of 26.8% over the control while, prosopis biochar @ 4 t/ha out performed by 14.7% over the FYM indicating its advantage. Lower yields were recorded in maize biochar followed by cotton biochar @ 2 t/ha. Similar results were recorded by Tian et al. (2018) as cotton being a heavy feeder exhibits vigorus growth and dry matter production, yield and is responsive to application biochar along with fertilizers. This is due to presence of carboxylate anion which is mainly responsible for the chelation of applied nutrients higher cation exchange capacity (CEC) and nutrient content of biochar resulted in increased yield of cotton crop. This is in confirmation with result of Younis et al. (2017).

Quality parameters

Application of biochar as amendments not only improved soil fertility and crop yields, but also influenced the quality parameters of cotton (Table 4). Even though the fiber length was non-significant, variation between the treatments was observed and highest fiber length of 32.0 mm was recorded when prosopis biochar @ 4.0 t/ha was applied. Fiber fineness can be taken as the effective diameter of a fiber and it is considered more important in spinning. Significantly higher fiber strength and fineness was recorded in prosopis biochar @ 4.0 t/ha (4.40 µg/inch and 24.0 g/tex) which was at par with cotton biochar @ 4.0 t/ha and prosopis biochar @ 3.0 t/ha. Bartlett index which gives earliness of boll bursting showed that the different levels of biochars resulted in early opening of bolls, facilitating synchronized boll bursting. The highest fiber elongation percent of 7.81 was observed in prosopis biochar @ 4.0 t/ha applied and lower fiber elongation (6.66%) was recorded in control plot. Different source and doses of biochar not significantly influenced the uniformity ratio of cotton and the value ranged from 54 to 48.2%. The increased quality parameters of cotton due to higher availability of nitrogen and potassium as it plays major role in the improvement of fiber properties and it is confirmed by Verma et al. (2017).

Conclusion

The study revealed that application of biochars as amendment to soil, improved fertility by retaining applied nutrients and increased the nutrient availability throughout crop growing period. The chelation effect of biochars reduced nutrient losses and improved uptake of nutrients. Application of cotton biochar or prosopis biochar @ 4.0 t/ha could not just improve the growth and productivity of cotton but also initiate a turn towards sustainable agriculture by preventing the burning of crop residues in large quantities.

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