__Original Research Article__

Use of Biochar, Vermicompost and Microorganisms to Enhance the Cotton Yield and Build the Soil Health in Yavatmal and Amravati Districts of Maharashtra

ABSTRACT

Biochar is considered as a possible and potential tool for soil fertility improvement, climate change mitigation and long-term sink for atmospheric carbon dioxide. Soil application of biochar improves the soil health indirectly. A field experiment was conducted to evaluate the influence of biochar andvermicompost along with biofertilizers on soil propertiesand yield of cotton in thesoils of Yavatmaland Amravati districts ofMaharashtra. Cotton is an important cash crop cultivated in abundance in the Vidarbha region of Maharashtra. The experiment was conducted with two treatments comprising T_1*i.e.* controland T_2*i.e.* biochar @ 2.5 t ha^{-1} +vermicompost @ 2.5 t ha^{-1} + biofertilizers. The recommended dose of fertilizers for cotton (100:50:50 NPK Kg ha^{-1}) was applied to both the treatments. The field experiment was laid out in paired T test and was replicated with20 farmers.Each treatment was applied on 0.2 ha area of each farmer.

Results revealed that, the application of biochar @ 2.5 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} along with biofertilizer significantly improves the water holding capacity, cation exchange capacity, organic carbon, available nitrogen, phosphorous and potassium content in soil over control treatment. Same treatment slightly reduces the bulk density of soil and increase the pH and electrical conductivity of soil as compare with control but did have significant effect. Application of biochar @ 2.5 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} along with biofertilizer significantly increase the yield of cotton. From the results, it could be concluded that, the combined application of biochar, vermicompost along with biofertilizers to cotton crop is essential during the *Kharif* season improves the soil health and maximize the yield as compare with control.

Keywords:*Biochar, Vermicompost,Biofertilizers,Soil health, Cotton, Yavatmal, Amravati etc.*

Introduction:

Maharashtra state has more heterogeneity in crop production and cropping pattern arising from its varied agro-climatic conditions. Cropping pattern in the state varies from region to region. Cotton is one of the important commercial crops and is grown predominantly under rainfed condition in Vidarbha region (Tupe and Joshi, 2019).Cotton ‘the king of apparel

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fibers' is an important cash crop and it supplies a major share of raw material for the textile industry and playing a key role in the economic and social affairs of the world (Hosamani *et al*., 2013).In India, cotton is grown on 122.38 lakh ha with production of 361 lakh bales. In Maharashtra, cotton is grown on 41.19 lakh ha with production 81 lakh bales (Anonymous, 2019) where Vidarbha region accounts for area under cotton cultivation about 16.18 lakh ha with production of about 30.50 lakh bales. Yavatmal is a major cotton producing district of Maharashtra and cotton occupied 4,05,000 ha area of the district during *Kharif* season (Tupe and Joshi, 2019). It is grown chiefly for its fiber which is used in the manufacture of cloths, making of threads and extraction of oil from cotton seed (Deshmukh *et al*., 2013).

Agricultural practices that improve soil quality and agricultural sustainability have received much attention from researchers and farmers. The role of organic fertilizers in plant nutrition is now attracting the attention of agriculturists and soil scientists throughout the world. Chemical fertilizers no doubt have boosted the production and productivity of any crop but continuous and imbalanced use of high analysis chemical fertilizer badly influences production potential and soil health (Aziz *et al*., 2019). Imbalanced use of fertilizers resulted in deterioration of soil fertility, decline in productivityand increasing cost of production. The problem is more severe in soils which are under intensive cropping. Use of chemical fertilizers in combination with organic manure is essentially required to improve soil health (Raghuwanshi *et al*. 2016).Use of biofertilizers not only supplements the nutrient but also improves the efficiency of applied nutrients. The over use of the chemical fertilizers to obtain high yield often neglects the environmental hazards and lead to great problem while solving the existing one.

The cotton plays an important role to the farmers of Vidarbha region as it is main cash crop of the region, however cotton crop residues management is one of the largest challenges ahead of the farmers in the Yavatmaland Amravati district. Farmers burn out this cotton crop residues to prepare their field for next crop. Open burning of cotton crop residues contributes to global warming and greenhouse gas emission. To reduce the open burning of cotton crop residues BAIF established a Farmer Producer Company, Tulja FPC at Athmurdi village of Yavatmal district. This FPC was engaged in collecting, processing and converting the cotton crop residue in to Biochar by pyrolysis which then sold back to its farmer members and other farmers for soil application.

The hypothesis of this study is to test the impact of combined application of biochar and vermicompost along with biofertilizers on soil properties and yield of cotton crop.

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Material and Methods:

1. Location, climate and agriculture:

The targeted locations for the study were Ralegaon and Kalamb blocks of Yavatmal district and Morshi block from Amaravati district. Amaravati district is located at longitude 21.1162 ^{0}N and latitude 77.6536 ^{0}E while Yavatmal district at longitude 20.3888 ^{0}N and latitude 78.1204 ^{0}E. The average annual rainfall in Amaravati district is 889 mm while Yavatmal receives 889 to 1095 mm rainfall and is not uniform in all parts of the district. The rainfall pattern is irregular in both the districts. The climate of the districts is hot and dry in summer with moderately cold winters. The major crops grown in the districts are cotton, soybean, pigeon pea, wheat and gram. The type of the soil in the districts is mainly black (Anonymous (b), 2015).

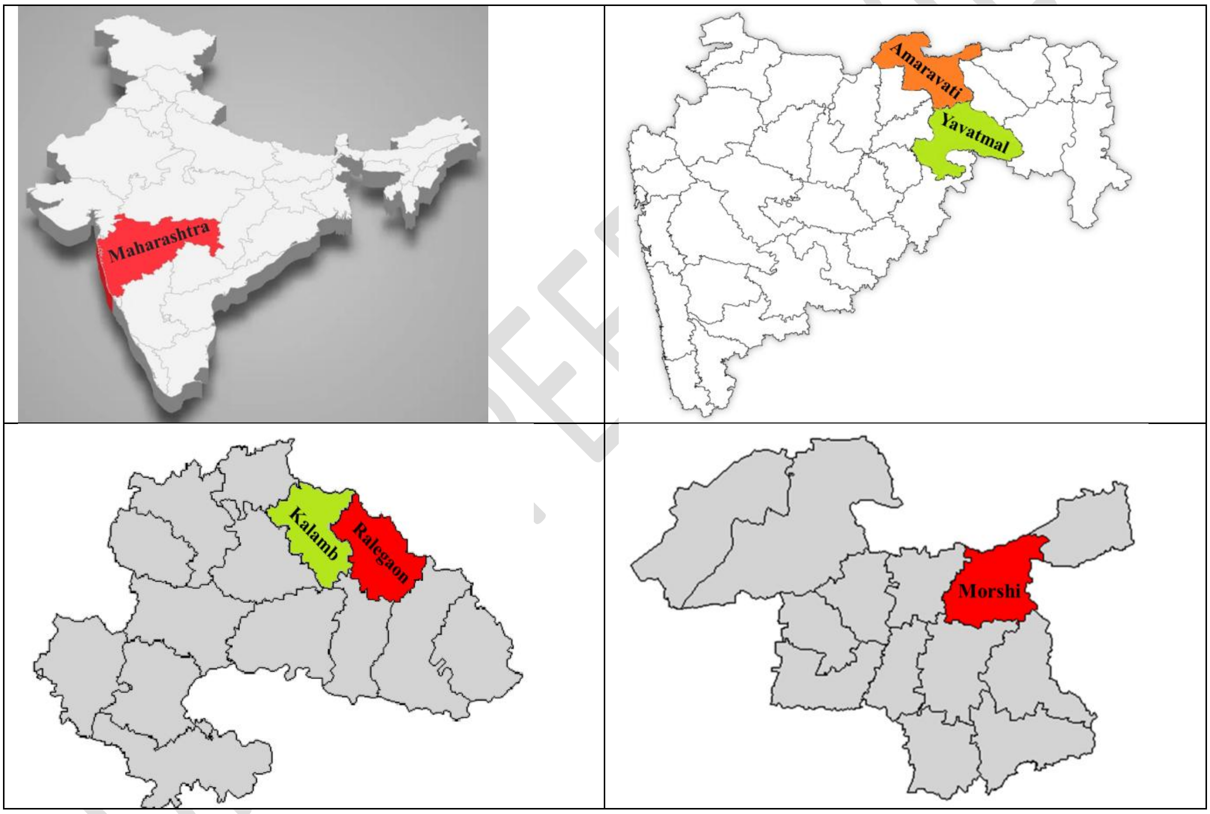

Fig. 1: Location map of study area

2. Study details:

Cotton was taken as a test crop during the *Kharif* season of the year 2021.The land was ploughed once before commencement of experiment with mould board plough and later harrowed twice to bring the soil to fine tilth. The cotton were dibbled @ two seeds per hill to a depth of 4 cm with the row-to-row distance of 90 cm and plant to plant distance of 45 cm. Gap filling was done 10 days after sowing. The experiment was undertaken with two treatments comprising T_1*i.e.* controland T_2*i.e.* biochar @ 2.5 t ha^{-1} +vermicompost @ 2.5 t

ha^{-1} + Biofertilizers (Azotobacter @ 5 liter per hectare).In the treatment T_2, biochar, vermicompost and azotobacter solutionwas mixed uniformly and applied in the plotbefore second harrowing. The recommended dose of fertilizers for cotton (100:50:50NPK Kg ha^{-1})was applied to both the treatments. The 50 percent of recommended dose of nitrogen and full dose of phosphorus and potassium were applied at the time of sowing and the remaining 50 per cent of nitrogen was applied after 30 days of sowing. The field experiment was laid out in paired T test and was replicated with20farmers.Each treatment was applied on 0.2 ha area of each farmer.For the research trial biochar was prepared from cotton crop residueswith the help of Tulja FPC at Athmurdi village of Yavatmaldistrict.

The properties of biochar used for research trial are as follows: Bulk density (0.28 g cm^{-3}), Particle density (0.51 g cm^{-3}), Water holding capacity (283%), Pore space (52.4 %) pH (9.15), Electrical conductivity (1.49dSm^{-1}), Cation exchange capacity (51.3cmol (P^+) kg^{-1}), Carbon to nitrogenratio (42.03)and Total carbon inbiochar (66.83%). The soils of experimental plots was slightly alkaline in nature, normal in electrical conductivity, medium in available phosphorous and potassium, low in organic matter and available nitrogen content in soil.

Yield of cottonwas measured in kg per plot and converted it into bales per hectare (bales ha^{-1}). Cotton association of India considers 170 kgs weight of cotton for bale size.Initial and after harvest soil samples were collected as per standard procedure given by (Anonymous, 2011). The soil samples were air-dried, ground (< 2 mm) and analyzed for chemical and fertility parameters such as bulk density, maximum water holding capacity (MWHC), cation exchange capacity (CEC), pH, electrical conductivity (EC), organic carbon (OC), available nitrogen (N), available phosphorous (P_2O_5) and available potassium (K_2O) in the soil. The pH (1:2.5) and electrical conductivity (EC) (1:2.5) of soils were measured using standard procedures as described by Jackson (1973). Organic carbon (OC) was determined using the Walkley and Black method (Nelson andSommers, 1996). Available nitrogen (N) was estimated by modified alkaline permanganate method (Sahrawat and Burford,1982). Available phosphorous (P_2O_5) of the soils was determined by Olsen’s method as outlined by Olsen and Sommers, 1982. Available potassium (K_2O) was determined using the ammonium acetate method (Helmke and Sparks, 1996).

3. Statistical analysis:

The statistical analysis of experimental data was done by paired T test given by Panse and Sukhatme (1985). In the T test star was used to show the flag level of significance. If a p-value is less than 0.05, it is flagged with one star (*). If a p-value is less than 0.01, it is

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flagged with two stars (**). If a p-value is less than 0.001, it is flagged with three stars (***). This research trial was conducted at farmers field therefore, data was tested at 5 per cent (0.05) flag level of significance.

Result and Discussion:

Effect on bulk density of soil:

Glimpses of the data presented in Table 1, the bulk density of soilwas ranges from 1.33 to 1.37 g cm^{-3} and did not show significant difference in both the treatments. The application of biochar @ 2.5 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} along with biofertilizersshowed lowestbulk density of soiland the highest was observed in control treatment.

The observed decrease in bulk density could have several reasons, which may be related to the biochar properties such as particle size, active surface area, porosity as well as relatively low bulk density of biochar as compare with soil. Further, the ability of biochar to form the soil aggregates in combination with soil particles leading to a decrease in bulk density could also play a role (Tokova *et al*., 2020). Biochar supplied to the soil is a substrate for soil fauna. Its particles can be mixed with the soil particles in a digestive tract of the earthworms creating coprolites that are agronomically valuable soil aggregates. These products contribute to more favorable soil structure (Simansky *et al.*, 2019) with consequently lower bulk densityvalues.Therefore, being a porous material when added to the soil, it increases its porosity and thus reduced bulk density (Nyambo*et al*, 2018).

Table. 1: Effect of combined application of biochar and vermicompost along with biofertilizers on bulk density, maximum water holding capacity and cation exchange capacity of soil

Parameter	**Bulk Density (g cm^{-3})**	
Treatment	Control	2.5 t biochar + 2.5 t vermicompost + Biofertilizers
Mean	1.37	1.33
Variance	0.01	0.01
No. of observations	20	20
T test value	1.21	
Standard error	0.03	
Parameter	**Maximum Water Holding Capacity (%)**	
Mean	27.67	29.79
Variance	3.78	4.72
No. of observations	20	20
T test value	3.25*	
Standard error	0.65	
Parameter	**Cation Exchange Capacity(cmol (P^+) kg^{-1})**	
Mean	38.68	45.92

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Variance	7.39	11.21
No. of observations	20	20
T test value	7.51*	
Standard error	0.96	

Effect on maximum water holding capacity of soil:

The results from the study indicated that, themaximum water holding capacity of experimental plots ranges from 27.67 to 29.79 per cent (Table 1). The soil amended with biochar @ 2.5 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} along with biofertilizersshowed significantly highest (29.79 %) maximum water holding capacity of the soil and the lowest was observed in control (27.67 %).

Application of biochar increases the moisture content inthe soil compared with control treatment. This could be adducedto biochar applied soils having more micropores to physicallyretain water and improved aggregation that resulted increating more pore spaces as a result of greater earthwormburrowing. Another reason for the differences in watercontent between biochartreated plots and the controlplot could probably due to the differences in bulkdensity between treatments(Adekiya*et al*., 2019). Chan *et al*. (2008) also reportedthat the water retention ability of biochar could be as aresult of increase in overall net soil surface area in soilafter biochar application.

Effect on cation exchange capacity of soil:

Significantly higher cation exchange capacity of soil was observed in the biochar applied plots over control plot (Table 1). The cation exchange capacity of research plots varies from 38.68 to 45.92 cmol (P^+) kg^{-1}. The application of biochar @ 2.5 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} along with biofertilizers showed significantly highest (45.92 cmol (P^+) kg^{-1}) cation exchange capacity of soil as compare with control (38.68 cmol (P^+) kg^{-1}) treatment.

The increase in cation exchange capacity in biochar-applied soils was due to the presence of cation exchange sites on the surface of biochar (Jones*et al*., 2012 and Sohi*et al*., 2010). Another reason for the high amount of cation exchange capacity in biochar applied soils may be due to the oxygen active groups present on the biochar surface, such as $COOH^-$ or OH^- react with metal cations in the soil and form metal ion complexes and due to negative charge of these ions, biochar has a high CEC (Gan *et al.*, 2012). Bhattacharjya*et al.* (2015) also confirmed that the CEC of biochar influenced the soil CEC, which improved the physical and chemical properties.

Effect on soil pH:

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The soils of experimental location belongs to slightly alkaline in nature, the application of biochar had less influence in increasing pH of the soil and no significant difference was observed between the treatments (Table 2). The soil pH of experimental plot ranges from 7.75 to 7.77. The lowest soil pH (7.75) was observed in the control treatment whereas, the highest (7.77) in the treatment of application of biochar @ 2.5 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} along with biofertilizers.

The application of biochar treatment observed that the slightly increment in soil pH as compare with control might be due to pH of biochar prepared from cotton crop residues is alkaline in nature. Natarajaet al. (2021) reported that the pH of biochar prepared from cotton crop residues ranges from 8.83 to 9.30.Similar findings were reported by Pandian *et al*. (2016) in groundnut while applying *prosopis* biochar at the rate of 5 t ha^{-1} in sandy loam soil and Kannan *et al*. (2021) reported in *Vigna mungo* with the application of biochar and phosphor-bacteria that increased soil pH than biochar alone.The application of biochar treatment did not show significant effect due to additional application of vermicompost secrets the acids during its further decomposition.

Table. 2: Effect of combined application of biochar and vermicompost along with biofertilizers onpH, electric conductivity (EC) and organic carbon (OC) of soil

Parameter	**pH**	
Treatment	Control	2.5 t biochar + 2.5 t vermicompost + Biofertilizers
Mean	7.75	7.77
Variance	0.30	0.32
No. of observations	20	20
T test value	0.114	
Standard error	0.176	
Parameter	**Electrical conductivity (dSm^{-1})**	
Mean	0.320	0.334
Variance	0.001	0.001
No. of observations	20	20
T test value	1.869	
Standard error	0.007	
Parameter	**Organic carbon (%)**	
Mean	0.415	0.472
Variance	0.002	0.001
No. of observations	20	20
T test value	4.710*	
Standard error	0.012	

Effect on electrical conductivity (EC) of soil:

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The variation inelectrical conductivity of soil due to application of biochar, vermicompost and biofertilizers was observed from 0.320 to 0.334 (Table 2). The highest electrical conductivity of soil was found in the treatment of application of biochar @ 2.5 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} along with biofertilizers as compare with control treatment but it did not show significant difference.

The increased electrical conductivity of biochar and vermicompost treated soil as compare with control might be due to the higher electrical conductivity of biochar and releasing the different soluble salts in soil during the decomposition of vermicompost.The application of biochar in soil leads to an increase the electrolyte concentrationby addition of soluble salts.

Effect on organic carbon (OC) content in soil:

Significantly higher organic carbon content was observed in all biochar applied plots over control plot (Table 2). The highest organic carbon content was observed in the treatment of application of biochar @ 2.5 t ha^{-1} + vermicompost @ 2.5 t ha^{-1}+ biofertilizers (0.472%) and the lowest organic carbon was recorded in control plots (0.415 %). The study revealed that the addition of fertilizers along with biochar and vermicompost increased organic carbon content in soil. This is might be due to the higher amount of carbon present in biochar, resulted in increased the carbon content of the soil. The results were in accordance with the findings of Oladele *et al.* (2019).

Effect on available nitrogen (N) content in soil:

Combined application of biochar, vermicompost and biofertilizers significantly influenced the available nitrogen content in soil (Table 3). The available nitrogen in the soil ranged from 251.39 to 287.62 kg ha^{-1}.Among the treatments, the application of biochar @ 2.5 t ha^{-1} + vermicompost @ 2.5 t ha^{-1}+ biofertilizers showed significantly highest available nitrogen content in soil as compare with control treatment. The combined application of biochar @ 2.5 t ha^{-1} + vermicompost @ 2.5 t ha^{-1}+ biofertilizers increased 14.42 per cent available nitrogen content in soil over control treatmentdue to higher nutrient retention capacity and reduced nutrient leaching of the soils treated with biochar. Further, the efficient adsorption of ammonia (NH_3) at the planar surface of biochar might have reduced the volatilization loss, thus increasing the available nitrogen status in the soils. Availability of nitrogen content in soil was increased also might be due to applied nitrogen fixing biofertilizers in this treatment fixes the atmospheric nitrogen content in the soil.

Table. 3: Effect of combined application of biochar and vermicompost along with biofertilizers on available N, P_2O_5 and K_2O content in soil

Parameter	**Available Nitrogen (kg ha^{-1})**

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Treatment	Control	2.5 t biochar + 2.5 t vermicompost + Biofertilizers
Mean	251.39	287.62
Variance	229.69	230.95
No. of observations	20	20
T test value	7.55*	
Standard error	4.80	
Parameter	**Available P_2O_5 (kg ha^{-1})**	
Mean	28.60	35.84
Variance	4.03	6.82
No. of observations	20	20
T test value	9.82*	
Standard error	0.74	
Parameter	**Available K_2O (kg ha^{-1})**	
Mean	204.07	241.53
Variance	205.74	226.47
No. of observations	20	20
T test value	8.06*	
Standard error	4.65	

Effect on available phosphorous (P_2O_5) content in soil:

From the data presented in Table 3 revealed that, the application of biochar in combination with vermicompost and biofertilizers increases the available phosphorous (P_2O_5) content in soil. The available phosphorous content in soil was varies from 28.60 to 35.84kg ha^{-1}.The significantly highest amount of available phosphorous content in soil was found in the treatment of application of biochar @ 2.5 t ha^{-1} + vermicompost @ 2.5 t ha^{-1}+ biofertilizers (35.84kg ha^{-1})and the lowest organic carbon was recorded in control plots (28.60 kg ha^{-1}). A significantly higher amount of soil available phosphorous in biochar applied plots might be due to its influence on cations (Ca, Mg, Al, Fe) that interacts with phosphorous. Further, biochar's adsorption and desorption ability were found to influence the soil available phosphorous as already suggested by Kannan *et al*. (2021) in *Vigna mungo* with the combined application of red gram stalk biochar and phosphobacteria. Bornemann *et al*. (2007) reported that the application of biochar along with phosphorous protects phosphorous from the precipitation in soil, thus enhancing its availability compared to control plots. The higher carbon content of biochar might have increased the microbial activity facilitating the insoluble form of phosphorous into plantavailable form of phosphorous.

Effect on available potassium (K_2O) content in soil:

The available potassium content in soil was presented in Table 3. The significantly highest amount of soil available potassium (241.53 kg ha^{-1}) was observed in soils that received

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biochar @2.5 t ha^{-1}+ vermicompost @ 2.5 t ha^{-1} along with biofertilizers. The lowest amount of available potassium content in soil were observed in control plots (204.07 kg ha^{-1}). The increase in available potassium content in soil was observed due to combined application of biochar and vermicompostalong with biofertilizers which increases the organic matter content in soil and increases the cation exchange capacity of soil. Therefore, the increased cation exchange capacity of soil reduces the leaching losses of potassium and thereby increases the availability of potassium in soil.Similar findings have also been observed by Pandian *et al*. (2016), who reported that applying red gram and cotton stalk biochar increases soil available potassium in groundnut.

Yield of cotton:

The perusal of the data presented in Table 4 revealed that the application of biochar @2.5 t ha^{-1}+ vermicompost @ 2.5 t ha^{-1} along with biofertilizersshowed significant effect on yield of cotton. The yield of cottonranges from 9.36 to 10.66 bales ha^{-1}. As shows in the results, the significantly highest yield of cotton(10.66 bales ha^{-1}) was recorded by the application of biochar @2.5 t ha^{-1}+ vermicompost @ 2.5 t ha^{-1} along with biofertilizersas compare with control (9.36 bales ha^{-1}). This may be due to the nutrients supplied by NPK fertilizer in this experiment might have been prevented from leaching in biochar treated plots, thus increasing the retention of these nutrients in the soil and by the crop contributing to higher yield. Similarly, Di *et al*. (2019) reported combined application of wheat straw biochar with vermicompost increased the rice yield compared to that vermicompost without biochar. Adekiya*et al*. (2020) reported increased rhizome yield of ginger with the application of hardwood biochar plus NPK fertilizer.

Table. 4: Effect of combined application of biochar and vermicompost along with biofertilizers on yield of cotton (bales ha^{-1})

Treatment	Control	2.5 t biochar + 2.5 t vermicompost + Biofertilizers
Mean	9.36	10.66
Variance	0.99	1.37
No. of observations	20	20
T test value	3.79*	
Standard error	0.34	

Conclusion:

From the above results it could be concluded that,the combined application of biocharproduced from cotton crop residues and vermicompost along with biofertilizershas a great potential for carbon sequestration, soil health improvement and enhance the yield of

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cotton,is essential during the *Kharif* season.

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