



Influence of biochar derived from Maize stover and Maize cobs on growth and yield of sweet corn in Sandy Loam Soils

B Prudhvi Lal, P Ravindra Babu, P R K Prasad and N Venkata Lakshmi

Department of Soil Science and Agricultural Chemistry, Agricultural College,
Bapatla-522 101

ABSTRACT

The experiment was conducted at Agricultural College Farm, Bapatla using sweet corn hybrid maize Sugar-75 as a test crop. The experimental soil was sandy loam in texture, slightly alkaline, low in organic carbon (0.49 g kg^{-1}), available nitrogen (182.7 kg ha^{-1}), low in available P_2O_5 (16.7 kg ha^{-1}), medium in available K_2O (171.5 kg ha^{-1}). All the micronutrients were sufficient in the soil with values above their critical limits. The experiment was laid out in Split Plot Design with 3 main plots (M_1 - 50% RDF, M_2 - 100% RDF, M_3 - 50% RDF+ Microbial consortium) and 5 sub plot treatments (S_1 - Control, S_2 - Biochar derived from maize stover @ 2 t ha^{-1} , S_3 - Biochar derived from maize cobs @ 2 t ha^{-1} , S_4 - Biochar derived from powdered maize stover @ 2 t ha^{-1} , S_5 - Biochar derived from powdered maize cobs @ 2 t ha^{-1}) with three replications. The plots those received 100% RDF along with the fine powdered biochar derived from maize stover @ 2 t ha^{-1} were significantly influenced on growth parameters (plant height and dry matter production at knee high, tasseling and harvest) and yield attributes (length and girth of the cob, number of kernels and rows per cob, test weight) which were superior to control.

Key words: Biochar, Maize cobs, Maize stover, Sandy loam soils

Sweet corn (*Zea mays* L. *saccharata*) also known as sugar corn, has become very popular, as the cob by virtue of its tenderness and taste, is accepted for direct consumption. Cultivation of sweet corn is found very remunerative and can be grown throughout the year with successful returns. Sweet corn is rapidly gaining popularity in all population groups as it is rich in nutrients, protein and fibre.

Its consumption is picking up among the urban communities, particularly "health conscious" and diabetes-prone Indians. In India it covers an area of 8.6 million hectares producing 20.5 million tonnes while, in Andhra Pradesh, it occupies an area of 8.5 lakh hectares producing 42.2 lakh tonnes (Ministry of Agriculture, Government of India, 2011-2012).

Biochar is a fine grained, carbon rich, porous product remaining after plant biomass has been subjected to thermo-chemical conversion process (pyrolysis) in an environment with little or no oxygen. Biochar shows depletion of nitrogen and sulphur as they volatilize at $200 \text{ }^\circ\text{C}$ and $375 \text{ }^\circ\text{C}$,

respectively. Whereas, K and P retained in the biochar as they volatilize between $700 \text{ }^\circ\text{C}$ and $800 \text{ }^\circ\text{C}$. Several studies emphasized the positive role of biochar in improving soil physical, physico-chemical, biological properties and fertilizer use efficiency.

The effectiveness of using biochar as an approach to mitigate climate change rests on its relative recalcitrance against microbial decay and thus on its slower return of terrestrial organic carbon as carbon dioxide (CO_2) to the atmosphere. Both the composition of the decomposer community as well as metabolic processes of a variety of soil organism groups may be important in determining to what extent biochar is stable in soils, as is known for wood decay.

Changes in microbial community composition or activity induced by biochar may not only affect nutrient cycles and plant growth, but also the cycling of soil organic matter. In addition, biochar may change emissions of other greenhouse gases from soil such as nitrous oxide (N_2O) or methane (CH_4).

MATERIAL AND METHODS

The experiment was conducted at Agricultural College Farm, Bapatla using sweet corn hybrid maize Sugar-75 as a test crop. The experimental soil was sandy loam in texture, slightly alkaline, low in organic carbon (0.49 g kg^{-1}), available nitrogen (182.7 kg ha^{-1}), low in available P_2O_5 (16.7 kg ha^{-1}), medium in available K_2O (171.5 kg ha^{-1}). All the micronutrients were sufficient in the soil with values above their critical limits. The experiment was laid out in Split Plot Design with 3 main plots (M_1 - 50% RDF, M_2 - 100% RDF, M_3 - 50% RDF + Microbial consortium) and 5 sub plot treatments (S_1 - Control, S_2 - Biochar derived from maize stover @ 2 t ha^{-1} , S_3 - Biochar derived from maize cobs @ 2 t ha^{-1} , S_4 - Biochar derived from powdered maize stover @ 2 t ha^{-1} , S_5 - Biochar derived from powdered maize cobs @ 2 t ha^{-1}) with three replications. Five plants at random were collected from each of the treatmental plots for recording plant height, yield attributes (length and girth of the cob, number of kernels and rows per cob, test weight) and yield.

RESULTS AND DISCUSSION

Plant height

Plant height recorded at knee high, tasseling and at harvest stages were statistically analysed and furnished in table 1. At all stages of crop growth plant height was significantly influenced by the imposed treatments. Highest plant height with 80.43, 233.69 and 243.04 cm at knee high, tasseling and harvest stages, respectively was observed in the plots those received 100% RDF (M_2) followed by (M_3) 50% RDF + microbial consortium (74.33, 218.28 and 224.35 cm, respectively). Whereas, M_1 and M_3 were on par with each other at tasseling and harvesting stage. Minimum plant height was observed in 50% RDF (M_1) with 67.78, 211.32 and 219.77 cm at knee high, tasseling and at harvest stages, respectively). The lowest plant height at all stages with low levels of nitrogen fertilisers indicated the importance of nitrogen in plant metabolism and growth. Nitrogen was associated with increase in chlorophyll in turn the photosynthesis, cell division and cell elongation resulting in taller plants at all growth stages (Tisdale *et al.*, 1985; Vasanti and Kumarswamy (2000). At knee high stage, powdered biochar derived from maize stover @ 2 t ha^{-1} (S_4) showed highest plant height of 77.82 cm and was on par with the plots those received powdered biochar derived from maize cobs @ 2 t ha^{-1} (S_3) (76.25 cm) and biochar derived from maize stover @ 2 t ha^{-1} (S_2) (75.43

cm). The plots of S_1 and S_3 treatments were on a par with each other and significantly inferior over other treatments. At tasseling and harvesting stage, powdered biochar derived from maize stover @ 2 t ha^{-1} (S_4) plots showed highest plant height (250.03 and 260.03 cm, respectively) followed by powdered biochar derived from maize cobs @ 2 t ha^{-1} (S_3) (233.38 and 242.71 cm, respectively), biochar derived from maize stover @ 2 t ha^{-1} (S_2) (220.96 and 225.35 cm, respectively) and biochar derived from maize cobs @ 2 t ha^{-1} (S_3) (206.47 and 214.73 cm, respectively). Control (S_1) recorded lowest values (69.45, 194.66 and 202.44 cm at knee high, tasseling and harvest stages, respectively) of plant height. The interaction effect of treatments on plant height was found non significant. Whereas, M_2S_4 (powdered biochar derived from maize stover along with 100% RDF) was recorded best at all the stages of crop growth. Relatively higher plant height in fertilizer treatments combined with organic treatments might be due to quick release of nutrients and more availability of nitrogen.

Length and girth of the cob

Length and girth of the cob were statistically analysed and furnished in table 2. These were significantly influenced by the imposed treatments. The highest length and girth of the cob (14.39 and 11.88 cm, respectively) were observed in the treatments supplied with 100% RDF (M_2) were on par with (M_3) 50% RDF + microbial consortium (14.11 and 11.64 cm, respectively). Minimum values were recorded in 50% RDF (M_1) with 12.84 and 10.24 cm, respectively. M_3 was significantly on par with M_1 in case of girth of the cob. Highest girth of the cob (11.75 cm) was noticed in powdered biochar derived from maize stover @ 2 t ha^{-1} (S_4) which was on par with the plots those received biochar imposed treatments. Control (S_1) recorded lowest values (and 10.06 cm) and was significantly inferior over the other treatments. Highest length of the cob (14.87 cm) was noticed in powdered biochar derived from maize stover @ 2 t ha^{-1} (S_4) were on par with S_3 and S_2 . Similarly S_2 and S_3 were on a par with each other and significantly superior over control. Timely availability of nutrients mainly nitrogen from organic source (biochar) might have increased the length of the cob. Arif *et al.* (2012) reported that the integrated application of biochar and mineral nitrogen resulted in lengthy ear which was at par with mineral nitrogen application. The interaction effect of treatments on length and girth of the cob found non significant at all the stages of crop growth.

Table 1: Influence of biochar on plant height (cm) at different growth stages of sweet corn

Treatments	AT KNEE HIGH			AT TASSELING			AT HARVESTING					
	M1	M2	M3	Mean	M1	M2	M3	Mean	M1	M2	M3	Mean
S1	64.17	74.97	69.22	69.45	188.10	204.75	191.12	194.66	195.62	212.94	198.76	202.44
S2	68.09	81.25	76.94	75.43	208.69	232.05	222.13	220.96	217.04	241.33	217.68	225.35
S3	65.51	78.73	71.64	71.96	196.63	220.22	202.55	206.47	204.50	229.03	210.66	214.73
S4	71.11	84.56	77.79	77.82	239.01	264.81	246.27	250.03	248.57	275.40	256.12	260.03
S5	70.02	82.66	76.05	76.25	224.17	246.61	229.35	233.38	233.14	256.47	238.52	242.71
Mean	67.78	80.43	74.33		211.32	233.69	218.28		219.77	243.04	224.35	
	SEm ±	CD	CV		SEm ±	CD	CV		SEm ±	CD	CV	
		(p=0.05)	(%)			(p=0.05)	(%)			(p=0.05)	(%)	
M	1.52	6.00	7.98		3.55	13.96	6.22		3.96	15.55	6.69	
S	0.92	2.69	3.72		1.95	5.69	2.64		2.63	7.70	3.45	
M x S Interaction												
S at same M	NS	NS			NS	NS			NS	NS		
M at same or diff. S level	NS				NS				NS			

Table 2 : Influence of biochar on yield attributes of sweet corn

Treatments	GIRTH JOF COB (cm)			LENGTH OF COB (cm)			NO OF KERNELS PER COB					
	M1	M2	M3	Mean	M1	M2	M3	Mean	M1	M2	M3	Mean
S1	9.20	10.67	10.29	10.06	10.43	11.83	11.26	11.17	203.71	235.18	227.73	222.21
S2	10.39	12.10	12.16	11.55	13.25	14.84	14.99	14.36	240.91	289.01	282.13	270.68
S3	10.20	12.02	11.56	11.26	12.95	14.65	14.19	13.93	235.57	281.55	266.99	261.37
S4	10.72	12.38	12.16	11.75	13.93	15.41	15.26	14.87	257.84	301.43	292.32	283.86
S5	10.70	12.25	12.05	11.67	13.66	15.22	14.86	14.58	250.85	293.15	282.38	275.46
Mean	10.24	11.88	11.64		12.84	14.39	14.11		237.78	280.06	270.31	
	SEm ±	CD	CV		SEm ±	CD	CV		SEm ±	CD	CV	
		(p=0.05)	(%)			(p=0.05)	(%)			(p=0.05)	(%)	
M	0.26	1.02	8.95		0.27	1.08	7.76		4.73	18.59	6.98	
S	0.18	0.52	4.80		0.18	0.54	4.08		2.62	7.65	2.99	
M x S Interaction												
S at same M	NS	NS			NS	NS			NS	NS		
M at same or diff. S level	NS				NS				NS			

S₃ - Biochar derived from maize cobs @ 2 t ha⁻¹
 S₄ - Biochar derived from powdered maize stover @ 2 t ha⁻¹
 S₅ - Biochar derived from powdered maize cobs @ 2 t ha⁻¹

S-Sub plots
 S₁ - Control
 S₂ - Biochar derived from maize stover @ 2 t ha⁻¹

M - Main plots
 M1 - 50% RDF
 M2 - 100% RDF
 M3 - 50% RDF + Microbial consortium

Number of kernels and rows per cob

No. of kernels and rows per cob (Table 2 and 3) were significantly influenced by the imposed treatments. The highest no. of kernels and rows per cob was observed in the treatment supplied with 100% RDF (M_2) (280.06 and 11.63, respectively) and were on par with (M_3) 50% RDF + microbial consortium (270.31 and 11.49, respectively) which were significantly superior to 50% RDF (M_1) (237.78 and 10.1, respectively). Highest number of kernels per cob (283.86) was noticed in powdered biochar derived from maize stover @ 2 t ha⁻¹ (S_4) followed by the plots those received powdered biochar derived from maize cobs @ 2 t ha⁻¹ (S_5) (275.46) and biochar derived from maize stover @ 2 t ha⁻¹ (S_2) (270.68) and were on par with each other. Highest number of rows per cob (11.68) was noticed in powdered biochar derived from maize stover @ 2 t ha⁻¹ (S_4) on par with the remaining plots received powdered biochar derived from maize cobs @ 2 t ha⁻¹ (S_5) (11.47), biochar derived from maize stover @ 2 t ha⁻¹ (S_2) (11.43) and biochar derived from maize stover @ 2 t ha⁻¹ (S_3) (10.99). Control (S_1) recorded lowest values in both number of kernels and rows per cob. The interaction effect of treatments found non significant. Integrated application of biochar and mineral nitrogen resulted in more number of rows and grains per cob. The possible explanation might be improved uptake of nitrogen by maize through enhancing the organic matter decomposition (Arif *et al.*, 2012).

Test Weight

The test weight (fresh and dry weight) of sweet corn presented in table 3 indicated a significant influence of imposed treatments. The test weight (fresh and dry weight) was observed in the treatment supplied with 100% RDF (M_2) (28.87 and 7.02g, respectively) on par with (M_3) 50% RDF + microbial consortium (28.23 and 6.72g, respectively) which were significantly superior to 50% RDF (M_1) (24.82 and 5.91g, respectively). Highest test weight (fresh) (30.24g) was noticed in powdered biochar derived from maize stover @ 2 t ha⁻¹ (S_4) which was on par with the plots those received powdered biochar derived from maize cobs at 2 t ha⁻¹ (S_5) (29.25g) and followed by plots received biochar derived from maize stover at 2 t ha⁻¹ (S_2) (28.88g). Whereas, S_2 , S_3 and S_5 were on par with each other and significantly superior over control (S_1) which recorded lowest values (20.05g). Highest test weight (dry) (7.29g) was recorded in powdered biochar derived from maize stover @ 2 t ha⁻¹ (S_4) followed by the plots those received

powdered biochar derived from maize cobs @ 2 t ha⁻¹ (S_5) (6.98g) and biochar derived from maize stover @ 2 t ha⁻¹ (S_2) (6.80g). Whereas, S_3 and S_2 were on par with each other and significantly superior over control (S_1) which recorded lowest values (5.10g). The interaction effect of treatments on test weight found non significant. Similar results were observed by Arif *et al.* (2012). They reported that test weight of sweet corn grown in the soils supplied with biochar + mineral fertilizer was at par with the treatments imposed of FYM + mineral fertilizer and mineral fertilizer alone. Higher number of kernels cob⁻¹ and higher test weight with increased nitrogen application was the result of better kernel filling due to increased photosynthetic activity due to larger leaf area and higher dry matter production. Increased supply of nitrogen to maize either through inorganics or through organics might have also resulted in the production of longer cobs accompanied by increased kernel filling.

DRYMATTER PRODUCTION

Sweet corn cobs are consumed fresh immediately after harvest while the green stover has high fodder value. However to find out the nutrient contents and uptake of nutrients at different stages the dry matter production was calculated and presented in table 4.

At Knee High Stage and Tasseling Stage

The dry matter production in main plots those received inorganics at knee high stage and tasseling stage ranged from (1171 to 1324 kg ha⁻¹ and 2054 to 2315 kg ha⁻¹, respectively) in 50% RDF (M_1) and 100% RDF (M_2), respectively. At both stages, highest (1324 and 2315 kg ha⁻¹) dry matter production was observed in 100% RDF (M_2), which was statistically on par with treatments supplied with 50% RDF + microbial consortium (M_3) (1229 and 2162 kg ha⁻¹, respectively) and were superior to 50% RDF (M_1). However, M_1 and M_3 were on par with each other. The dry matter production in sub plots those received organics (biochar), powdered biochar derived from maize stover @ 2 t ha⁻¹ (S_4) produced highest dry matter at knee high stage of crop growth (1317 kg ha⁻¹) which was on par with plots those received powdered biochar derived from maize cobs @ 2 t ha⁻¹ (S_5) (1293 kg ha⁻¹) and biochar derived from maize stover @ 2 t ha⁻¹ (S_2) (1265 kg ha⁻¹). At tasseling stage of crop growth, plots those received powdered biochar derived from maize cobs @ 2 t ha⁻¹ (S_5) recorded highest value (2406 kg ha⁻¹) which was on par with plots received powdered biochar derived from maize stover @ 2 t ha⁻¹ (S_4) (2341 kg ha⁻¹) and biochar

derived from maize stover at 2 t ha⁻¹ (S₂) (2278 kg ha⁻¹). Whereas, treatmental plots S₂ and S₃ were on par with each other. As expected, control performed poorly in terms of dry matter production at knee high stage and tasseling stage of crop growth observed (1108 and 1703 kg ha⁻¹, respectively).

Harvest

Grain yield

The mean grain yield ranged from 1906 to 2179 kg ha⁻¹ among the main plot treatments. The highest grain yield of 2179 kg ha⁻¹ was recorded with the application of 100% RDF (M₂) followed by M₃ (1997 kg ha⁻¹) and 50% RDF (M₁) (1906 kg ha⁻¹) treatments. Grain yield (mean) ranged from 1790 to 2157 kg ha⁻¹ among the biochar imposed sub plot treatments. The highest grain yield of 2157 kg ha⁻¹ was recorded with the application of powdered biochar derived from maize stover @ 2 t ha⁻¹ (S₄) which was on par with plots received powdered biochar derived from maize cobs @ 2 t ha⁻¹ (S₅) (2132 kg ha⁻¹). The plots those received S₅ and S₂ were on par with each other. Lowest grain yield of 1790 kg ha⁻¹ was obtained in control (S₁). The yield increase might had been attributed largely to the ability of the biochar to increase N availability. Significantly higher growth stature and larger yield structure associated with the highest level of nitrogen might have enabled to produce greater sink size. Sufficient and balance supply of nitrogen through organics might have enabled maize crop to produce larger leaf area and higher chlorophyll content, essential for higher photosynthetic efficiency to assimilate large quantity of photosynthates to kernels. The performance of integrated treatments similar to that of sole inorganics might be due to a better and continuous availability of nutrients to the plants up to cob development which ultimately increased the grain yield. Addition of biochar along with NPK improves nitrogen availability to plants (Gokila and Baskar., 2015).

Stover yield

The results indicated that stover yield (mean values) among the main plot treatments ranged from 3329 to 3753 kg ha⁻¹. The highest stover yield was recorded in the treatments M₂ (3753 kg ha⁻¹) followed by M₃ (3454 kg ha⁻¹). The lowest grain yield was observed in M₁ (3329 kg ha⁻¹). However, M₃ was on par with M₁. Mean values of stover yield ranged from 3200 to 3671 kg ha⁻¹ among the biochar imposed sub plot treatments. Lowest grain yield of 3200 kg ha⁻¹ was obtained in control (S₁). The

highest grain yield of 3671 kg ha⁻¹ was recorded with the application of powdered biochar derived from maize stover @ 2 t ha⁻¹ (S₄) which was on par with S₅ and S₂ (3611 and 3593 kg ha⁻¹, respectively). Timely availability of nitrogen from organic source and less subjected to losses might have increased the photosynthetic surface, greater chlorophyll content, enhanced intermodal length contributed to larger dry matter accumulation and better crop growth. Significantly higher dry matter on application of biochar along with mineral fertilizer was observed. These results were in confirmation with Arif *et al.* (2012). Even though the interaction effect between the treatments on dry matter production was found statistically non significant. Among all the treatments, powdered biochar derived from maize stover along with 100% RDF (M₂S₄) had produced highest yield values at all the stages of crop growth.

CONCLUSION

Based on the above results and discussion, it can be concluded that the plots those received 100% RDF along with the fine powdered biochar derived from maize stover @ 2 t ha⁻¹ (M₂S₄) were significantly influenced on growth parameters (plant height and dry matter production at knee high, tasseling and harvest) and yield attributes (length and girth of the cob, number of kernels and rows per cob, test weight) which were superior to control.

LITERATURE CITED

- Arif, M Ali, A Umair, M Munsif, F Ali, K Inamullah, Saleem M and Ayub G. 2012 Effect of biochar, FYM and mineral nitrogen alone and in combination on yield and yield components of maize. *Sarhad Journal of Agriculture*. 28(2): 191-195.
- Gokila B and Baskar K 2015 Influence of biochar as a soil amendment on yield and quality of maize in alfiosl of Thoothukudi district of Tamilnadu, India. *International Journal of Plant, Animal and Environmental Sciences*. 5(1): 152 – 155.
- Ministry of Agriculture, Government of India, 2011- 2012.
- Tisdale S L, Nelson W L and Beaton J D 1985 soil fertility and fertilizers. Macmillan publications cooperation, New York.
- Vasanthi D and Kumarswamy K 2000 Effect of manure fertilizer schedules on the yield and uptake of nutrients by cereal fodder crops and on soil fertility. *Journal of the Indian Society of Soil Science*. 48(3):513-515.