

Original Research Article

<https://doi.org/10.20546/ijcmas.2017.607.159>

Effect of Nutrient Enriched Biochar on Yield and NPK Uptake of Maize Grown in Alfisol

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ABSTRACT

Keywords

Biochar, Alfisol, Maize, Yield, Sugar industry wastes, Nutrient uptake and Soil fertility.

Article Info

Accepted:
17 June 2017
Available Online:
10 July 2017

Agro-industrial wastes such as sugarcane bagasse, molasses and press mud are giving rise to huge amounts of agricultural residues. These wastes have the potential to supply feedstock for biochar production. The Nutrient Enriched Biochar (NEB) was prepared by utilizing these wastes with the nutrient composition (NPK) of 7 : 7 : 7. A field experiment was conducted during 2016-17 by following randomized block design to study the effect of nutrient enriched biochar from sugar industry wastes on yield of hybrid maize (NK6240) on Typic Rhodustalf (Alfisol) of Tamil Nadu. The treatments were Absolute Control (T₁), 50% RDF through NEB (T₂), 75% RDF through NEB (T₃), 100% RDF through NEB (T₄), 125% RDF through NEB (T₅), 50% RDF through NEB and 50% RDF through inorganic fertilizers (T₆) and 100% RDF through inorganic fertilizers (T₇). The results of the field experiment revealed that the grain yield (5677 kg ha⁻¹) and stover yield (9504 kg ha⁻¹) significantly increased up to 125% RDF through NEB (T₄) which is 23% higher than the yield of nutrients supplied through 100% RDF through inorganic fertilizers (T₇). Since the nutrient supplied through NEB is released in a phased manner, it enhanced the uptake of nutrients and there by enhanced the yield of hybrid maize.

Introduction

In the present scenario, food security is the major challenge that is being faced by the ever expanding world population. According to the United Nations, the global population is expected to increase from 7.0 billion to 9.2 billion by 2050. To nourish another 2 billion people, food production must increase by 60% to solve the future food crisis (FAO, 2017). Commercial fertilizer is responsible for 40 to 60% of the world's food production. But the applied fertilizers cannot be fully utilized by the plants as it prone to leaching, volatilization, immobilization and fixation as

insoluble precipitates. Our responsibility is to develop and follow management practices that use fertilizer effectively and efficiently.

In India, many industries are consuming agricultural produce as their raw material and generate various types of wastes. In which, sugar industry is the second largest agricultural industry in the country and generating huge amount of by-products, such as bagasse, molasses and pressmud, which are creating the storage problem (Dotaniya *et al.*, 2016). For every 100 lakh tonne of sugar

produced, the sugar industry produces 45 lakh tonne of molasses, 32.1 lakh tonne of press mud and 333 lakh tonne of bagasse. These by-products are potential pollutants unless disposed off safely (National Federation of Co-operative Sugar Factories Ltd, 2016). Several workers are reported that these wastes as well as other by-products are usable resources for pyrolysis bio energy and could be used in agriculture for improving the soil fertility and productivity (Bridgewater, 2003).

Pyrolysis is a relatively simple, inexpensive, and robust thermo chemical technology (Laird *et al.*, 2009) that can be used to transform low-density biomass and other organic materials into a high-energy density solid known as biochar (Ioannidou *et al.*, 2009). When biochar is applied to soils, it has potential advantages such as improvement in soil fertility, plant growth and yield through increase in water holding capacity, soil aggregation and soil strength (Major *et al.*, 2010), increased soil aeration (Van Zwieten *et al.*, 2009), increase in cation exchange capacity (Topoliantz *et al.*, 2002), availability of major nutrients (Glaser *et al.*, 2002; Lehman *et al.*, 2003), increase in microbial population (Rondon *et al.*, 2007) and besides, the overall sorption capacity of the soil (Verheijen *et al.*, 2009).

Maize is one of the most important cereal crops of the world and contributes to food security in most of the developing countries. The maize plant produces high dry matter yields and therefore has a high requirement for nutrients especially nitrogen (N), phosphorus (P) and potassium (K). However, applied fertilizers not fully utilized by the plants due to above mentioned losses. In order to overcome these losses and to sustain soil fertility and improve nutrient use efficiency, we can use slow release nutrient sources like nutrient enriched biochar. By considering these above statements a field investigation

was undertaken to study the effect of nutrient enriched biochar from sugar industry wastes and its effect on yield and NPK uptake of hybrid maize.

Materials and Methods

A field experiments was conducted during 2016-17 to study the effect of nutrient enriched biochar on yield and NPK uptake by hybrid maize et (NK6240) on a Alfisol (Typic Rhodustalf) at Farmer's field, Nachalur, Karur district, Tamil Nadu, India.

Nutrient enriched biochar

The nutrient enriched biochar was procured from M/s EID Parry (I) Ltd, Nellikuppam, Cuddalore District, Tamil Nadu which was prepared by utilizing the sugar and distillery industry waste *viz.*, press mud, concentrated spent wash and bagasse. The nutrient composition (NPK) of NEB was 7: 7: 7.

Experimental site

A field experiment was conducted at Farmer's field, Nachalur, Karur district on Alfisol. The soil of the experimental filed belongs to Typic Rhodustalf having sandy loam texture with pH of 6.71 and electrical conductivity (EC) of 0.19 dSm^{-1} , black clay loam, moderately deep and well drained. The initial soil available N, P and K status were 165, 11 and 118 kg ha^{-1} , respectively. The DTPA extractable iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn) was in sufficient range (Table 1).

The experiment was laid out in a randomized block design with three replications. Plant spacing of $60 \times 25 \text{ cm}$ with recommended dose of fertilizers for the maize hybrid is $250:75:75 \text{ NPK kg ha}^{-1}$ were followed as per the guidelines of Crop Production Guide (2012). The treatments were Absolute Control (T_1), 50% RDF through NEB (T_2), 75% RDF

through NEB (T₃), 100% RDF through NEB (T₄), 125% RDF through NEB (T₅), 50% RDF through NEB and 50% RDF through inorganic fertilizers (T₆) and 100% RDF through inorganic fertilizers (T₇).

Maize hybrid (Syngenta NK6240) a high yielding single cross hybrid released by Syngenta India Ltd. was chosen for the study. As per the treatment schedule, Nutrient enriched biochar was calculated based on the recommended dose of Phosphorus and potassium and the entire dose of phosphorus and potassium was applied basally. Nitrogen was applied in three splits as basal, 25 and 45 DAS, respectively. In the inorganic treatment plots, The N, P and K fertilizers were applied in the form of urea (46 % N), Di ammonium phosphate (46 % P₂O₅) and muriate of potash (60 % K₂O), respectively. The fertilizers were placed at 5 cm depth on sides of the ridges by forming small furrows.

The oven dried plant samples of maize were chopped and ground in Wiley mill and was analyzed for total plant N, P₂O₅, K₂O. The nitrogen, phosphorus and potassium content were analyzed by the standard procedure given by Yoshida *et al.*, (1971), Olsen and Sommers (1982) and Piper, (1966), respectively. The nutrient values obtained as percentage in the analysis were computed to kg ha⁻¹ by multiplying with the corresponding DMP obtained for each treatment. The grain yield was recorded for individual treatment at 14 per cent seed moisture and expressed in kg ha⁻¹.

Results and Discussion

Grain yield and stover yield

The effect of nutrient enriched biochar on grain and stover yield of hybrid maize were given in table 2. The grain yield was increased with increasing levels of NPK

applied through nutrient enriched biochar. The grain yield ranged from 2281 kg ha⁻¹ to 5677 kg ha⁻¹. The highest grain yield (5677 kg ha⁻¹) was registered by 125% RDF through NEB (T₅) which is followed by nutrient supplied through NEB @ 100 % RDF (T₄). This was followed by 50% RDF through NEB and 50% RDF through inorganic fertilizer (T₆), 75% RDF through NEB (T₃) which is on par with nutrient supplied through 100% inorganic fertilizer (T₇).

The nutrient supplied through NEB @ 125% RDF (T₄) has registered 23% higher yield than nutrient supplied through inorganic fertilizer @ 100% RDF (T₇). This increase in the yield was due to slow release of nutrients in a phased manner by NEB which enhanced uptake of nutrients and thereby it caused significant increase in the grain yield. The nutrient supplied through NEB @ 100% RDF (T₃) has registered 19% higher yield than nutrient supplied through inorganic fertilizer @ 100% RDF (T₇) which revealed the nutrient use efficiency of NEB was higher than the inorganic fertilizer.

The stover yield of hybrid maize with respect to different treatments followed the same trend as that of grain yield. The stover yield ranged from 3780 kg ha⁻¹ to 9504 kg ha⁻¹ (Table 2). The highest mean yield of 9504 kg ha⁻¹ was registered by 125% RDF through NEB (T₅) and the lowest yield of 3780 kg ha⁻¹ was recorded in absolute control (T₁).

Similar results were reported by Yamato *et al.*, (2006) stated that yield of maize was significantly higher after the application of biochar due to higher retention of the nutrients in biochar than inorganic fertilizer. Milla *et al.*, (2013) also stated that applied biochar improved the biomass production by increased plant weight, increased the root size and leaf width. Since NEB having high surface area (liang *et al.*, 2006), it adsorbs the

nutrients like NH_4^+ , NO_3^- , K^+ , Ca^{2+} , Zn^{2+} thereby it reduces the leaching losses and offers a mechanisms for developing slow release fertilizer which in turns improves nutrient use efficiency and increase the crop yield (Sarkhot *et al.*, 2012). Similar results were also reported by Hema *et al.*, (2016) who stated that application NEB @ 75 % RDF of P and K has significantly increased the rice yield compared to inorganic fertilizer.

Nutrient uptake

Among treatments significant variations observed in the uptake of nutrient pattern. Nitrogen uptake was significantly influenced by various NPK levels supplied by NEB and inorganic fertilizer. The N uptake of stover varied between 4.87 to 13.33 kg ha^{-1} at 30 DAS (Table 3), 16.92 to 39.47 kg ha^{-1} at 60 DAS and 23.63 to 66.79 kg ha^{-1} at harvest stage. The highest N uptake of stover (66.79 kg ha^{-1}) at harvest stage was recorded under 125% RDF through NEB (T5) and the lowest N uptake of 23.61 kg ha^{-1} was recorded in absolute control (T1). The grain uptake of nitrogen ranged from 27.60 kg ha^{-1} to 73.23 kg ha^{-1} . The highest nitrogen uptake in the grain (73.23 kg ha^{-1}) was recorded under 125% RDF through NEB (T5) and the lowest N uptake (27.60 kg ha^{-1}) of grain was recorded in absolute control (T1). Similar results were reported by DeLuca *et al.*, (2009) who stated that biochar added to soil with an organic N source yielded an increase in net nitrification and improves the nitrogen availability to the plants.

The phosphorus uptake of stover varied between 1.86 to 5.00 kg ha^{-1} at 30 DAS (Table 3), 5.50 to 13.16 kg ha^{-1} at 60 DAS and 6.67 to 24.29 kg ha^{-1} at harvest stage. The highest P uptake of stover (24.29 kg ha^{-1}) at harvest stage was recorded under 125% RDF through NEB (T5) and the lowest N uptake of 6.67 kg ha^{-1} was recorded in absolute control

(T1). The grain uptake of phosphorus ranged from 14.60 kg ha^{-1} to 39.74 kg ha^{-1} . The highest phosphorus uptake in the grain (39.74 kg ha^{-1}) was recorded under 125% RDF through NEB (T5) and the lowest P uptake (14.60 kg ha^{-1}) of grain was recorded in absolute control (T1). The addition of nutrient enriched biochar increases the soil pH, thereby increasing available phosphorus. This is in line with the findings of Milla *et al.*, (2013).

The potassium uptake of stover varied between 5.68 to 13.80 kg ha^{-1} at 30 DAS (Table 3), 21.57 to 43.86 kg ha^{-1} at 60 DAS and 28.48 to 85.01 kg ha^{-1} at harvest stage. The highest P uptake of stover (85.01 kg ha^{-1}) at harvest stage was recorded under 125% RDF through NEB (T5) and the lowest N uptake of 28.48 kg ha^{-1} was recorded in absolute control (T1). The grain uptake of phosphorus ranged from 11.41 kg ha^{-1} to 33.49 kg ha^{-1} . The highest potassium uptake in the grain (33.49 kg ha^{-1}) was recorded under 125% RDF through NEB (T5) and the lowest P uptake (11.41 kg ha^{-1}) of grain was recorded in absolute control (T1). Similar results were reported by Lehmann (2007) who stated that higher charcoal additions significantly increase the uptake of P, K, Ca, Zn, and Cu by the plants. Xu *et al.*, (2011) also reported that bioavailability and plant uptake of primary nutrients increases in response to biochar application, particularly when in the presence of added fertilizer. Lehmann (2007) also reported that addition of biochar significantly increased plant growth and nutrition. While N availability and uptake of P, K, Ca, Zn, and Cu by the plants increased with higher charcoal additions. Similar trend was reported by Angst and Sohi (2013) and Yao *et al.*, (2013) they stated that biochar adsorb N and P more efficiently and become bio-available over a period of time which stimulated the plant growth.

Table.1 Initial characters of experimental soil

S.No	Particulars	Values
1.	pH (1:2.5 soil: water)	6.71
2.	EC (dS m ⁻¹)	0.19
3.	Organic Carbon (g kg ⁻¹)	3.81
4.	CEC (c mol (p ⁺) kg ⁻¹)	7.07
4.	Alkaline KMnO ₄ - N (kg ha ⁻¹)	165
5.	Olsen- P (kg ha ⁻¹)	11
6.	Neutral N NH ₄ OAc- K (kg ha ⁻¹)	118
10.	DTPA Zn (mg kg ⁻¹)	0.77
11.	DTPA Cu (mg kg ⁻¹)	0.56
12.	DTPA Fe (mg kg ⁻¹)	9.81
13.	DTPA Mn (mg kg ⁻¹)	4.07

Table.2 Effect Nutrient enriched biochar on grain yield and stover yield of hybrid maize

Trt.	Treatment Details	Grain Yield (Kg/ha)	Stover yield (Kg/ha)
T1	Absolute control	2281	3780
T2	50% RDF through NEB	3831	6337
T3	75% RDF through NEB	4628	7635
T4	100% RDF through NEB	5461	9116
T5	125% RDF through NEB	5677	9504
T6	50% through NEB and 50% RDF through inorganic fertilizer	4946	8162
T7	100% RDF through inorganic fertilizers	4631	7616
SED		95.4	159
CD (0.05)		208	347

Table.3 Effect of NEB on nutrient uptake of hybrid maize

Trt.	Treatment Details	Stover uptake (kg/ha)									Grain uptake (kg/ha)		
		N uptake			P uptake			K uptake			N	P	K
		30 DAS	60 DAS	HS	30 DAS	HS	HS	30 DAS	60 DAS	HS			
T1	Absolute control	4.87	16.92	23.63	1.86	5.50	6.67	5.68	21.57	28.48	27.60	14.60	11.41
T2	50% RDF through NEB	6.35	22.84	40.64	2.26	7.27	10.16	7.33	28.55	50.80	47.12	24.90	19.92
T3	75% RDF through NEB	9.75	29.58	51.32	3.58	10.93	17.11	10.75	36.01	63.54	58.31	31.47	25.45
T4	100% RDF through NEB	11.71	33.50	62.65	4.42	12.06	21.86	12.60	39.53	80.14	69.35	37.68	31.13
T5	125% RDF through NEB	13.33	39.47	66.79	5.00	13.16	24.29	13.80	43.86	85.01	73.23	39.74	33.49
T6	50% through NEB and 50% RDF through inorganic	10.71	33.45	56.33	4.33	11.37	19.65	11.74	39.47	72.05	61.83	34.13	28.19
T7	100% RDF through inorganic	9.02	28.04	50.18	3.65	9.97	15.91	10.56	34.89	67.32	57.42	30.56	25.01
	SED	0.149	0.657	0.93	0.088	0.161	0.399	0.172	0.952	0.145	1.393	0.749	0.685
	CD	0.313	1.432	2.023	0.193	0.352	0.871	0.375	2.075	3.172	3.035	1.631	1.492

Since NEB is produced from the organic biomass from sugar industry, it contains high level of organic carbon and considerable amount of micronutrients viz., Zn, Fe, Cu and Mn might have slightly increased the nutrient uptake by hybrid maize. Kolb *et al.*, (2009) reported that biochar additions affected microbial biomass and microbial activity, as well as nutrient availability which resulted in better crop growth and caused increase in yield and nutrient uptake of hybrid maize.

In conclusion, the results of the experiment revealed that the grain and stover yield was higher under 125% RDF through nutrient enriched biochar. The nutrient supplied through NEB @ 100% RDF (T3) has registered 19% higher yield than nutrient supplied through inorganic fertilizer @ 100% RDF (T7). Grain and stover yield increased with increasing levels of NPK applied through NEB. Since the nutrient supplied through NEB is released in a phased manner, it enhanced the uptake of nutrients and there by enhanced the yield of hybrid maize. This nutrient enriched biochar can be used as an effective slow-release nutrient source with the added bonus of sugar industry waste management.

Acknowledgement

Author thankful to Department of Soil Science and Agricultural Chemistry, Anbil Dharmalingam Agricultural College and Research Institute (ADAC&RI), Tamil Nadu Agricultural University, Tiruchirapalli - 620 009, Tamil Nadu

Abbreviations

NEB- Nutrient Enriched Biochar
DAS - Days After Sowing
K – Potassium
N – Nitrogen
P – Phosphorus
@ - at the rate of
HS - Harvest stage

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How to cite this article:

Eazhilkrishna, N., T. Thilagavathi and Baskar, M. 2017. Effect of Nutrient Enriched Biochar on Yield and NPK Uptake of Maize Grown in Alfisol. *Int.J.Curr.Microbiol.App.Sci.* 6(7): 1326-1334. doi: <https://doi.org/10.20546/ijcmas.2017.607.159>