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Research Article

ECO FRIENDLY UTILIZATION OF NUTRIENT ENRICHED BIOCHAR FROM SUGAR INDUSTRY WASTES AND ITS EFFECT ON YIELD AND NPK UPTAKE BY HYBRID MAIZE GROWN IN VERTISOL

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Abstract- 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. 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 2015-16 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 Chromustert of Tamil Nadu. The treatments were Absolute Control (T_1), 50% RDF through NEB (T_2), 75% RDF through NEB (T_3), 100% RDF through NEB (T_4), 125% RDF through NEB (T_5), 50% RDF through NEB and 50% RDF through inorganic fertilizers (T_6) and 100% RDF through inorganic fertilizers (T_7). The results of the field experiment revealed that the grain yield (5821 kg ha^{-1}) and stover yield (9788 kg ha^{-1}) significantly increased upto 100% RDF through NEB (T_4) which is 19% higher than 100% RDF through inorganic fertilizers (T_7). 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.

Keywords- Biochar, Vertisol, Maize, Yield, Sugar industry wastes, Nutrient uptake and Soil Fertility.

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Introduction

The major challenge confronting India during 21st century is to produce enough food, fodder, fibre, fuel so as to meet the diversified need of the burgeoning human and animal population of the country [1]. The increased food production will have to occur on less available arable land and this can only be accomplished by intensifying production. As commercial fertilizers account for 40 - 60% of the world's food production, developing management practices for effective utilization of fertilizers are essential and inevitable.

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 [2]. 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 [3]. 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 [4].

Pyrolysis is a relatively simple, inexpensive, and robust thermo chemical technology [5] that can be used to transform low-density biomass and other organic materials into a high-energy density solid known as biochar [6]. 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 [7], increased soil aeration [8], increase in cation exchange capacity [9], availability of major nutrients [10], increase in microbial population [11] and besides, the overall sorption capacity of the soil [12].

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 2015-16 to study the effect of nutrient enriched biochar on yield and NPK uptake by hybrid maize et (NK6240) on a Vertisol (Typic Chromustert) at Cotton research station, Tamil Nadu Agricultural University, Veppanthattai, Perambalur. 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 Cotton research station, Tamil Nadu Agricultural University, Veppanthattai, Perambalur on Vertisol. The soil of the experimental filed belongs to Typic Chromustert having clay loam texture with pH of 8.10 and electrical conductivity (EC) of 0.27 dSm^{-1}, black clay loam, moderately deep and well drained. The initial soil available N, P and K status were 228, 19.5 and 248 kg ha^{-1}, respectively. The DTPA extractable iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn) was in sufficient range [Table-1].

Table-1 *Initial characters of experimental soil*

S.No	Particulars	Values
1.	pH (1:2.5 soil : water)	8.20
2.	EC (dS m^{-1})	0.27
3.	Organic Carbon (g kg^{-1})	4.86
4.	CEC (c mol (p^+) kg^{-1})	34.8
4.	Alkaline $KMnO_4$- N (kg ha^{-1})	228
5.	Olsen- P (kg ha^{-1})	19.5
6.	Neutral N NH_4OAc- K (kg ha^{-1})	248
10.	DTPA Zn (mg kg^{-1})	0.82
11.	DTPA Cu (mg kg^{-1})	2.52
12.	DTPA Fe (mg kg^{-1})	10.2
13.	DTPA Mn (mg kg^{-1})	3.45

The experiment was laid out in a randomized block design with three replications. Plant spacing of 60 x 25 cm with recommended dose of fertilizers for the maize hybrid is 250:75:75 NPK $kgha^{-1}$ were followed as per the guidelines of Crop Production Guide [13]. The treatments were Absolute Control (T_1), 50% RDF through NEB (T_2), 75% RDF through NEB (T_3), 100% RDF through NEB (T_4), 125% RDF through NEB (T_5), 50% RDF through NEB and 50% RDF through inorganic fertilizers (T_6) and 100% RDF through inorganic fertilizers (T_7).

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 % P_2O_5) and muriate of potash (60 % K_2O), 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, P_2O_5, K_2O. The nitrogen, phosphorus and potassium content were analyzed by the standard procedure given by Olsen and Sommers [14], Piper [15] 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

On perusal of maize grain yield, significant variations were observed by different NEB levels [Table-2]. The grain yield was increased with increasing levels of NPK applied through nutrient enriched biochar. The grain yield ranged from 2896 kg ha^{-1} to 5914 kg ha^{-1}. The highest grain yield (5914 kg ha^{-1}) was registered by 125% RDF through NEB (T5) which is on par with nutrient supplied through NEB @ 100 % RDF (T4) and followed by nutrient supplied through 50% RDF through NEB and 50% RDF through inorganic fertilizer (T6). This was followed by the treatment 75% RDF through NEB (T3) which is on par with nutrient supplied through 100% inorganic fertilizer (T7). Though the higher yield was recorded in 125% RDF through NEB (T5), the nutrient supplied through NEB @ 100% RDF (T4) is sufficient to meet the nutrient demand required by the crop.

The nutrient supplied through NEB @ 100% RDF (T4) has registered 19% 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 @ 75% RDF (T3) has registered higher yield than nutrient supplied through inorganic fertilizer @ 100% RDF (T7) which revealed the nutrient use efficiency of NEB was higher than inorganic fertilizer .

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	2896	4662
T2	50% RDF through NEB	4312	7028
T3	75% RDF through NEB	5126	8457
T4	100% RDF through NEB	5821	9788
T5	125% RDF through NEB	5914	10080
T6	50% through NEB and 50% RDF through inorganic fertilizer	5321	8939
T7	100% RDF through inorganic fertilizers	4895	8174
	SED	**107**	**123**
	CD (0.05)	**235**	**269**

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 4662 kg ha^{-1} to 10080 kg ha^{-1} [Table-2]. The highest mean yield of 10080 kg ha^{-1} was registered by 125% RDF through NEB (T_5) and the lowest yield of 4662 kg ha^{-1} was recorded in absolute control (T1). Similar results were reported by Yamato *et al.* [16] and 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.* [17] 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[18], 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 [19]. Similar results were also reported by Hema *et al.,* [20] 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 7.25 to 15.92 kg ha^{-1} at 30 DAS [Table-3], 20.58 to 49.96 kg ha^{-1} at 60 DAS and 31.71 to 82.89 kg ha^{-1} at harvest stage. The highest N uptake of stover (82.89 kg ha^{-1}) at harvest stage was recorded under 125% RDF through NEB (T5) and the lowest N uptake of 31.71 kg ha^{-1} was recorded in absolute control (T1). The grain uptake of nitrogen ranged from 36.20 kg ha^{-1} to 78.06 kg ha^{-1}. The highest nitrogen uptake in the grain (36.20 kg ha^{-1}) was recorded under 125% RDF through NEB (T5) and the lowest N uptake (78.06 kg ha^{-1}) of grain was recorded in absolute control (T1). Similar results were reported by DeLuca *et al.* [21] 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 2.72 to 6.26 kg ha^{-1} at 30 DAS [Table-3], 6.37 to 15.07 kg ha^{-1} at 60 DAS and 7.55 to 25.50 kg ha^{-1} at harvest stage. The highest P uptake of stover (25.50 kg ha^{-1}) at harvest stage was recorded in 125% RDF through NEB (T5) and the lowest N uptake of 7.55 kg ha^{-1} was recorded in absolute control (T1). The grain uptake of phosphorus ranged from 19.69 kg^{-1} to 43.17 kg ha^{-1}. The highest phosphorus uptake in the grain (43.17 kg ha^{-1}) was recorded in 125% RDF through NEB (T5) and the lowest P uptake (19.69 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.* [19].

The potassium uptake of stover varied between 7.70 to 16.44 kg ha^{-1} at 30 DAS [Table-3], 24.50 to 51.55 kg ha^{-1} at 60 DAS and 36.24 to 89.26 kg ha^{-1} at harvest stage. The highest P uptake of stover (89.26 kg ha^{-1}) at harvest stage was recorded under 125% RDF through NEB (T5) and the lowest N uptake of 36.24 kg ha^{-1} was recorded in absolute control (T1). The grain uptake of phosphorus ranged from 13.90 kg^{-1} to 33.12 kg ha^{-1}. The highest potassium uptake in the grain (33.12 kg ha^{-1}) was recorded under 125% RDF through NEB (T5) and the lowest P uptake (13.90 kg ha^{-1}) of grain was recorded in absolute control (T1). Similar results were reported by Lehmann [22] who stated that higher charcoal additions significantly increases the uptake of P, K, Ca, Zn, and Cu by the plants.

Table-3 *Effect of NEB on nutrient uptake of hybrid maize*

Trt.	Treatment Details	Plant uptake (kg/ha)									Grain uptake (kg/ha)		
		N uptake			P uptake			K uptake			N	P	K
		30 DAS	60 DAS	HS	30 DAS	60 DAS	HS	30 DAS	60 DAS	HS			
T1	Absolute control	7.25	20.58	31.71	2.72	6.37	7.55	7.70	24.50	36.24	36.20	19.69	13.90
T2	50% RDF through NEB	8.65	29.14	48.76	3.11	8.68	12.47	9.34	34.72	53.30	54.33	29.75	21.13
T3	75% RDF through NEB	12.47	37.89	62.47	4.62	11.15	17.65	13.17	43.84	69.26	66.13	36.39	27.17
T4	100% RDF through NEB	15.05	42.57	79.61	5.87	13.16	23.42	15.30	47.21	84.29	75.67	41.91	32.02
T5	125% RDF through NEB	15.92	49.96	82.89	6.26	15.07	25.50	16.44	51.55	89.26	78.06	43.17	33.12
T6	50% through NEB and 50% RDF through inorganic	13.51	40.04	68.45	5.21	12.32	19.96	13.75	46.97	75.58	68.64	38.31	27.67
T7	100% RDF through inorganic	11.75	35.72	57.46	4.52	10.94	15.67	12.43	42.28	66.61	62.17	34.27	24.96
	SED	0.244	0.892	1.214	0.092	0.187	0.410	0.381	0.669	0.600	1.616	0.789	0.364
	CD	0.533	1.941	2.646	0.200	0.408	0.895	0.835	1.450	1.309	3.521	1.710	0.790

Xu *et al*. [23] 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 [22] 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 [24] and Yao *et al.* [25] they stated that biochar adsorb N and P more efficiently and become bio-available over a period of time which stimulated the plant growth. 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.,* [26] 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.

Conclusion

The results of the experiment revealed that the grain and stover yield was higher under 125% RDF through nutrient enriched biochar. Though the higher yield was recorded in 125% RDF through NEB (T5), the nutrient supplied through NEB @ 100% RDF (T4) is sufficient to meet the nutrient demand required by the crop and to achieve economical yield. 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.

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Abbreviations

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

Author Contributions:

1. Corresponding Author (EAZHILKRISHNA.N) - designed the study and carried out the implementation including field work and analysis (both samples and data) and interpretation of data. Drafting the research work and revised it critically for important contents and approved the research paper for publication
2. Co-Author (T.THILAGAVATHI) - Acted as a guide (Chairperson) and provided substantial contribution to design the work to be carried out and contributed to interpretation of data and drafting the research work and critically reviewed the data and also approved the revised article to be published. This author also contributed equally to this work
3. Co-Author (M.BASKAR) - Acted as a member of the advisory committee and provided substantial contribution to design the work to be carried out and contributed to interpretation of data and drafting the research work and critically reviewed the data and also approved the revised article to be published. This author also contributed equally to this work

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Conflict of Interest: None declared

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