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Eco-Friendly Utilization of Nutrient Enriched Biochar from Sugar Industry Wastes and Its Effect on Nitrogen Use Efficiency

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An experiment was conducted to study the nitrogen use efficiency of nutrient enriched biochar (NEB) from sugar industry wastes with seven treatments comprising T_1 (absolute control), T_2 (50% RD of PK through NEB), T_3 (75% RD of PK through NEB), T_4 (100% RD of PK through NEB), T_5 (125% RD of PK through NEB), T_6 (50% through NEB + 50% through inorganic fertilizer) and T_7 (100% RD of PK through inorganic fertilizer) in RBD using the rice variety TRY 3. In all treatments, nitrogen was supplied based on LCC reading. The result revealed that application of N through NEB could release the nitrogen slowly and steadily, thereby increasing the nitrogen use efficiency and crop yield. Since the yield of T_3 treatment (6103 kgha^{-1}) was on par with T_4 (6165 kgha^{-1}) and T_5 (6269 kgha^{-1}) treatments, which indicated that the plants received the essential nutrients in required quantities at 75 % RD of PK through NEB itself. On optimization of graded levels of NEB, the application of 75% RD of Pk through NEB was found to be the best treatment with respect to nitrogen use efficiency and grain yield in response to the quantity of nitrogen applied.

Key words: Nitrogen use efficiency, Biochar, Sugar industry waste, Rice

Biochar is a carbonaceous material produced by thermo – chemical conversion of organic materials under reduced oxygen condition. It is mostly used for carbon sequestration, but now, it is used as amendment and also as a carrier for slow release of fertilizer to enhance the soil fertility and improve the crop productivity by increasing the nutrient use efficiency (Sarkhot *et al.,* 2012). India is the largest producer of sugarcane and the second largest consumer of sugar in the world. The potential of biochar prepared from various crop residues are being studied as soil input to enhance SOC, increase nutrient use efficiency, improve physical and chemical health and thereby crop productivity. However, the biochar produced from sugar industry wastes like press mud, bagasse and spent wash are rich in nutrients, it reduces the nutrient losses by adsorption of nutrients in its matrix, which will be slowly released for plant requirement (Sohi *et al.,* 2010). Hence, the present investigation was undertaken to study the eco – friendly utilization of nutrient enriched biochar from sugar industry wastes and its effect on nitrogen use efficiency.

Material and Methods

A field experiment was conducted at ADAC & RI, Trichy in a Randomized Block Design (RBD) with seven treatments comprising T_1 (absolute control), T_2 (50 % RD of PK through NEB), T_3 (75% RD of PK through biochar), T_4 (100 % RD of PK through biochar), T_5 (125% RD of PK through biochar) , T_6 (50% RD of PK through biochar + 50% RD of PK through inorganic fertilizer) and T_7 (100% RD of PK through inorganic fertilizer) using rice (TRY 3) as the test crop. In all treatments, the nitrogen was supplied based on LCC reading. The nutrient enriched biochar (NEB) from sugar industry wastes used for the experiment was collected from EID Parry (I) Ltd, Nellikuppam, Cuddalore district having N, P_2O_5, K_2O content of 7: 7: 7.

The experimental soil was *Vertic Ustropept* having low in $KMnO_4$ - N, medium in $NaHCO_3$- P and medium in NH_4OAc- K status (197 kg ha^{-1}, 12.8 kg ha^{-1}, 136 kg ha^{-1}, respectively).The plant samples collected at active tillering (AT), panicle initiation (PT), and post harvest stage (straw) and grain were analyzed for N uptake (Jackson, 1973) and the nitrogen use efficiency was calculated following Cassman *et al*. (1996). LCC was used to correlate the nitrogen requirement of plants. The critical value for the LCC reading is 4. The soil samples were collected from each experimental plot at active tillering (AT), panicle initiation (PI) and post harvest (PH) stage were analyzed for NH_4-N, NO_3-N and available nitrogen.

Results and Discussion

LCC Reading

LCC readings were recorded above the threshold value without addition of N fertilizer up to 21 days in all treatments (Table 2). Since the most of the nitrogen supplied by NEB in 125 % RD (62.5 kg ha^{-1}) it has been released in a phased manner and matched the N demand of the rice crop up to 42 days. In general, all NEB applied treatments recorded below the critical level at 2 stages only (21 and 63 DAT). In case of inorganic fertilizer applied treatment, it recorded

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below the critical level at 3 stages (21, 42 and 63 DAT). This might be due to the losses by leaching and volatilization. The slight decrease in the LCC reading after the PI stage might be due to transfer of N from leaf to reproductive parts.

Table 1. Total quantity of N (kg ha^{-1}) applied in field experiment

Treatments	Basal	21 DAT	42 DAT	63 DAT	Total
T_1 - Absolute control	-	-	-	-	-
T_2 - 50 % RD of PK through NEB	25	30	-	30	85
T_3 - 75 % RD of PK through NEB	37.5	30	-	30	97.5
T_4 - 100 % RD of PK through NEB	50	30	-	30	110
T_5 - 125 % RD of PK through NEB	62.5	-	30	-	92.5
T_6 - 50 % RD of PK through NEB + 50 % RD of PK through inorganic fertilizer	37.5	30	-	30	97.5
T_7 - 100 % RD of PK through inorganic fertilizer	37.5	30	30	30	127.5

Soil available nitrogen

Nitrogen (N) is often the most limiting factor in crop production (Vitousek and Howarth, 1991). Increase in the rate of NEB application increased the available N content of the soil (Table 3). During active tillering stage, an increase of 21, 42, 57, 69, 39 and 38 kg ha^{-1} were observed in T_2, T_3, T_4, T_5, T_6 and T_7, respectively over control. The same trend of available N was observed at both panicle initiation and post harvest stage. This is in line with the findings of Angst and Sohi (2013). Biochar has been shown to have promise in reducing inorganic-N leaching (Singh *et al*., 2010). According to Lehmann *et al*. (2003), the application of biochar to the soil caused a decrease in N leaching by 60 %, and increased crop productivity by 38-45%.

Table 2. LCC reading during field experiment (at 7 days interval)

Treatment	Days										
	14	21	28	35	42	49	56	63	**70**	**77**	**84**
T_1	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.5	3.0	3.0
T_2	4.0	3.5	4.0	4.0	4.0	4.0	4.0	3.0	4.0	4.0	4.0
T_3	4.0	3.5	4.0	4.0	4.0	4.0	4.0	3.5	4.0	4.0	4.0
T_4	4.0	3.5	4.0	4.0	4.0	4.0	4.0	3.5	4.0	4.0	4.0
T_5	4.0	4.0	4.0	4.0	3.5	4.0	4.0	4.0	4.0	4.0	4.0
T_6	4.0	3.5	4.0	4.0	4.0	4.0	4.0	3.5	4.0	4.0	4.0
T_7	4.0	3.0	4.0	4.0	3.5	4.0	4.0	3.0	4.0	4.0	3.5

Table 3. Effect of NEB on available N content (kg ha^{-1}) of soil at different growth stages of rice

Treatments	Maximum tillering	Panicle initiation	Post harvest
T1	199	190	186
T2	220	209	205
T3	241	215	214
T4	256	238	224
T5	268	254	242
T6	238	213	206
T7	237	211	201
SEd	5	6	4
CD (0.05)	10	14	8

Soil ammoniacal and nitrate nitrogen

The results of field experiment showed that the transformation and the availability of N in soil were greatly influenced by NEB application. At tillering stage, NH_4-N and NO_3-N content increased with increase in dose of NEB, which indicated that the application of NEB added certain amount of N and increased the ammonification and nitrification (Table 4 and Table 5). Similar result was observed by Castaldi *et al.* (2012), Ball *et al.* (2010) and De Luca *et al*. (2006). The increase in NO_3-N content of the soil from panicle initiation to post harvest stage might be due to microbial oxidation of NH_4-N to NO_3-N (Liang *et al.,* 2006).

Table 4. Effect of NEB on NH4 - N content (kg ha-1) of soil at different growth stages of rice

Treatments	Active tillering	Panicle initiation	Post harvest
T1	110	99	75
T2	132	109	99
T3	152	123	102
T4	173	141	110
T5	183	155	120
T6	150	120	97
T7	149	116	93
SEd	3	2	2
CD (0.05)	7	4	5

Nitrogen use efficiency parameters

The N use efficiency parameters such as agronomic efficiency (AE) and apparent nutrient recovery (ANR) were found to be the highest in T_5 followed by T_3 (Table 6). Due to the continuous supply of N, the requirement would have been less inturn increasing the efficiency. In case of factor productivity (FP), 50 % RD of P and K through NEB recorded the highest value. Zhang *et al.* (2012) reported that the biochar application increases the total soil N content and agronomic N use efficiency. Glaser *et al.* (2002) observed that the addition of biochar had enhanced the nutrient retention and nutrient availability due to their high surface area..

Table 5. Effect of NEB on NO_3 -N content (kg ha^{-1}) of soil at different growth stages of rice

Treatments	Active tillering	Panicle initiation	Post harvest
T1	66	65	72
T2	69	66	95
T3	74	75	97
T4	78	81	104
T5	81	86	107
T6	72	71	92
T7	72	71	85
SEd	2	2	3
CD (0.05)	4	3	6

Grain and straw yield

An increase in grain yield of 74.9, 113.0, 115.2, 118.8, 108.7 and 104.7 % and straw yield of 78.1, 118.7, 122.8, 128.6, 114.3 and 110.2 % were recorded in T_2, T_3, T_4, T_5, T_6 and T_7, respectively over control (Table 6). The results of the field experiment revealed that the application of NEB, had increased the yield significantly. Though, the treatment T_5 registered the highest grain yield, it was found to be on par with T_4 and T_3. Hence, it is concluded that only the yield increase was significant up to 75 % RD of P and K applied through NEB, which indicated that the plants received the essential nutrients in required quantities at 75 % RD of P and K through NEB itself.

Table 6. Effect of NEB on nitrogen use efficiency parameters and yield of rice

Treatments	ANR	AE	FP	Grain yield (kg.ha^{-1})	Straw yield (kg.ha^{-1})
T_1	0.0	0.0	0.0	2865	3209
T_2	27.3	25.3	33.7	5012	5714
T_3	37.0	33.2	29.4	6103	7019
T_4	33.5	30.0	26.0	6165	7151
T_5	43.0	36.8	31.0	6269	7335
T_6	35.6	31.9	29.4	5979	6876
T_7	25.5	23.5	22.5	5865	6745
SEd	0.03	0.7	0.6	109	126
CD (0.05)	0.06	1.6	1.2	239	277

On optimization of graded levels of NEB, the application of 75 % RD of P and K through NEB along with LCC based N application was found to be the best treatment with respect to nitrogen use efficiency and grain yield in response to the quantity of nitrogen applied.

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