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Ecofriendly utilization of nutrient enriched biochar from sugar industry wastes and its effect on nutrient use efficiency and yield of rice

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Abstract
An experiment was conducted to study the nutrient 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 at Anbhil Dharmalingam Agricultural College and Research Institute, Trichy District, Tamil Nadu. In all treatments, nitrogen was supplied based on LCC reading. The result of the field experiment revealed that application of NPK through NEB favourably influenced the yield contributing parameters *viz.*, number of tillers per hill, productive tillers per hill, length of panicle, number of filled grains per panicle which will release the nutrients slowly and steadily to maintain the availability of nutrients throughout the crop period thereby increasing the nutrient 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 nutrient use efficiency and grain yield in response to the quantity of nutrient applied.

Keywords: Nutrient use efficiency, biochar, sugar industry waste, rice, vertic ustropept, sodic soil

Introduction

Biochar is a carbonaceous material produced by thermo – chemical conversion of organic materials under reduced oxygen condition (Shackley and Sohi, 2010) [13]. 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) [11]. 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) [13]. 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.

Materials 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, P and K uptake (Jackson, 1973) [8] and the nutrient use efficiency was calculated following Cassman *et al*. (1996) [3]. LCC was used to correlate the nitrogen requirement of plants. LCC was used to correlate the nitrogen requirement of plants. LCC readings were recorded at 7 – 10 days interval from 14 DAT. 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, available nitrogen (N), available phosphorus (P) and available potassium (K).

Results and Discussions

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 of PK (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 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.

Soil available nitrogen

Nitrogen (N) is often the most limiting factor in crop production (Vitousek and Howarth, 1991) [15]. 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) [1]. Biochar has been shown to have promise in reducing inorganic-N leaching (Singh *et al*., 2010) [12]. According to Lehmann *et al*. (2003) [9], the application of biochar to the soil caused a decrease in N leaching by 60%, and increased crop productivity by 38-45%.

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). Similar result was observed by Castaldi *et al.* (2012) [5], Ball *et al.* (2010) [2] and De Luca *et al*. (2006) [6]. 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) [10].

Soil available phosphorus

Among the treatments, the highest available P content was obtained in 125% RD of PK through NEB in all three stages but there was a little decrease in available P with growth stages due to uptake by plants (Table 3). A steady supply of available P might be due to the formation of chelates (Topoliantz and Ponge, 2005) [14]. They also stated that, biochar indirectly influenced the P availability by interfere with the interaction of Al^{3+}, Fe^{2+}, Fe^{3+}, and Ca^{2+} by sorbing organic molecules that act as chelates. In 100% RD of PK through inorganic fertilizer, a tremendous decrease was observed with growth stages. This might be due to conversion of labile P to the insoluble phosphates (Tricalcium phosphate).

Soil available potassium

The available K status was increased with the increased level of NEB application but there was a decreased trend was occurred between the stages. Tremendous decrease in K content was observed in 100% RD of PK through inorganic fertilizer (Table 3) which might be due to uptake of K by plants and also by leaching loss. A steady rate of decrease was observed in NEB applied plots occurred only due to uptake by plants because biochar lower the leaching loss. Similar work was done by Widowati *et al*. (2014) [17] and reported that the higher rate of biochar application would lower the leaching of potassium although the amounts of K in the soil increased and he also observed that potassium retention was also high with biochar.

Nutrient use efficiency parameters

The N use efficiency parameters such as agronomic efficiency (AE), recovery efficiency (RE) and utilization efficiency (UE) were highest in 125% RD of PK through NEB. The quantity of N supplied through NEB was more in this treatment (62.5 kg ha^{-1}). Hence, it require nitrogen at only one time during the crop period as evidenced in LCC and SPAD readings. Due to the slow release of N the requirement will be less which inturn increases the efficiency. In case of physiological efficiency (PE) and factor productivity (FP), 50% RD of PK through NEB recorded the highest value. The similar trend was followed in P and K use efficiency in physiological efficiency and factor productivity parameters except in agronomic efficiency (AE), recovery efficiency (RE) and utilization efficiency (UE) where the highest value was registered in 75% RD of PK through NEB (Table 6). Wang *et al*. (2012) [16] also reported that, the biochar enriched with P are the potential P sources with high agronomic efficiency.

Cassman and Pingali (1995) [4] reported that timing and formulation of applied N improved the agronomic efficiency from 24 to 33 in rice. Glaser *et al.* (2002) [7] observed that the addition of biochar enhanced the nutrient retention and nutrient availability due to their high surface area. Higher nutrient retention ability, in turn improved the fertilizer use efficiency and reduces leaching.

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 5). 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 1: Total quantity of nutrients (kg ha^{-1}) applied in field experiment

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

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

	Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
Treatments	AT	PI	PH	AT	PI	PH	AT	PI	PH
T_1	199	190	186	13.7	13.3	13.0	139	136	134
T_2	220	209	205	15.9	15.4	15.1	158	153	149
T_3	241	215	214	17.5	17.1	16.7	166	161	154
T_4	256	238	224	18.0	17.4	17.0	175	169	163
T_5	268	254	242	18.9	17.7	17.3	184	178	171
T_6	238	213	206	16.8	16.4	16.2	163	157	153
T_7	237	211	201	16.2	15.3	14.7	164	156	147
SEd	5	6	4	0.4	0.3	0.3	3	2	3
CD (0.05)	10	14	8	0.9	1.3	0.7	6	5	7

Table 4: Effect of NEB on NH_4 – N and NO_3 - N content (kg ha^{-1}) of soil at different growth stages of rice

	NH_4 - N content (kg ha^{-1})			NO_3 - N content (kg ha^{-1})		
Treatments	AT	PI	PH	AT	PI	PH
T_1	110	99	75	66	65	72
T_2	132	109	99	69	66	95
T_3	152	123	102	74	75	97
T_4	173	141	110	78	81	104
T_5	183	155	120	81	86	107
T_6	150	120	97	72	71	92
T_7	149	116	93	72	71	85
SEd	3	2	2	2	2	3
CD (0.05)	7	4	5	4	3	6

Table 5: Effect of NEB on Drymatter production (kgha^{-1}) at different stages of rice and yield of rice

Treatments	Drymatter production (kgha^{-1})		Straw yield (kgha^{-1})	Grain yield (kgha^{-1})
	Active Tillering	Panicle Initiation		
T_1	1565	3085	3209	2865
T_2	2198	5547	5714	5012
T_3	2390	6812	7019	6103
T_4	2399	7008	7151	6165
T_5	2447	7190	7335	6269
T_6	2324	6739	6876	5979
T_7	2279	6612	6745	5865
SEd	45	130	126	109
CD (0.05)	98	284	277	239

Table 6: Effect of NEB on nutrient use efficiency parameters

Treatments	Nitrogen use efficiency					Phosphorus use efficiency					Potassium use efficiency				
	ANR	AE	RE	FP	UE	ANR	AE	RE	FP	UE	ANR	AE	RE	FP	UE
T_1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_2	27.3	25.3	0.4	33.7	54.7	430.7	85.9	0.4	114.6	186.1	97.1	85.9	1.9	114.6	186.1
T_3	37.0	33.2	0.6	29.4	72.3	400.5	86.3	0.5	76.4	187.9	93.5	86.3	2.0	76.4	187.9
T_4	33.5	30.0	0.5	26.0	65.8	389.4	66.0	0.4	57.3	144.8	87.3	66.0	1.7	57.3	144.8
T_5	43.0	36.8	0.7	31.0	81.4	321.8	50.4	0.3	42.4	111.6	84.6	50.4	1.3	42.4	111.6
T_6	35.6	31.9	0.6	29.4	69.5	355.0	62.3	0.4	57.3	135.6	91.3	62.3	1.5	57.3	135.6
T_7	25.5	23.5	0.4	22.5	51.3	413.7	60.0	0.3	57.3	130.7	91.7	60.0	1.4	57.3	130.7

Conclusions

The study on the effect of NEB on nutrient use efficiency and yield of rice was carried out in field experiment. 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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