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Effect of nitrogen enriched biochar pellets on nutrient use efficiency in maize

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Abstract
Recently great emphasis has been given to working out strategies to increase the use efficiency of soil-applied nutrients. It is presumed that fertilizer enriched biochar pellets can slowly release nutrients in synchrony with crop demand and facilitate optimum nutrient uptake. The experiment was conducted to assess the effects of nitrogen enriched biochar pellets on the nutrient use efficiency in maize. The green house pot experiment was conducted during Kharif 2022-23 at College of Agriculture, Raichur by employing an RCBD design having thirteen treatments with three replications. The study revealed that treatment with the application of nitrogen enriched biochar pellets @ 7.5 MT ha^{-1} (N as Ammonium sulfate) + recommended doses of phosphorus and potassium (T_{13}) recorded significantly higher nutrient use efficiency for NPK *i.e.* 40.27, 22.96 and 61.55 percent respectively. The lowest nutrient use efficiency (NUE) for NPK was recorded in treatment T_7, which receives biochar pellets @ 7.5 MT ha^{-1}. Further, the study revealed that the translocation factor of NPK was more than that of micronutrients. The findings suggest that N enriched biochar pellets can serve as a slow-release fertilizer to improve crop NUE. Hence, based on the results of this pot study, it is advised that nitrogen-enriched biochar pellets be considered for maize production. However, further confirmation of these findings is needed through a long-term field study.

Keywords: Biochar, pellets, nutrient use efficiency

1. Introduction

Recently, great emphasis has been given to work out the new strategies to increase the use efficiency of soil applied nutrients and thereby reduce the quantum of fertilizer application without compromising on crop yield reductions. As for as Indian agriculture is concerned, India's NUE remained below the global average, as plants utilized less than 50 percent of supplied nutrients. Lately, the soil application of nutrient-enriched biochar pellets has gained significant importance as an amendment and nutrient source. Blending biochars with fertilizers and pelletizing improved their handling, transportation, and application convenience.

Biochar is a carbon-rich material produced through the pyrolysis (thermal decomposition) of organic biomass, such as wood, crop residues, or animal manure, in a low-oxygen environment. Nitrogen enriched biochar pellets are a type of agricultural amendment, in which biochar is infused or treated with nitrogen-containing compounds, typically in the form of nitrogen-based fertilizers or organic sources of nitrogen (Yu *et al.*, 2022) [1].

It is assumed that there is an increase in nutrient use efficiency owing to application of biochars blended with fertilizers and is due to the combined effects of improved soil properties, better water and nutrient retention, and gradual nutrient release aligned with crop requirements. With this perspective, the research study on “Effect of nitrogen-enriched biochar pellets on nutrient use efficiency in maize” was conducted during Kharif - 2022 at the College of Agriculture, Raichur with the following objective: To assess the nutrient use efficiency owing to nitrogen enriched biochar pellets application in maize.

2. Materials and Methods

2.1 Production of biochar & nitrogen enriched biochar pellets

Biochar pellets were produced by blending biochar obtained from the pyrolysis of pigeonpea stalks with synthetic starch followed by pelletization using a single punch pellet press. Similarly, the nitrogen enriched biochar pellets were prepared using the same procedure except that the required quantity of either urea or ammonium sulfate was added during blending.

The quantity of urea or ammonium sulfate used for making N enriched biochar pellets was worked out in such a way that application of N enriched biochar pellets @ 7.5 MT ha^{-1} was equivalent to the application of nitrogen @150 kg of per ha.

2.2 Soil collection and pot preparation

A pot culture experiment was conducted during *Kharif* 2022-23 in glass house at college of agriculture Raichur, Karnataka (15.21ºN, 77.35ºE, with altitude of 389 m). The representative soil samples were collected from from Plot No. 62, AICRP - Groundnut, Main Agricultural Research Station Raichur. The soil was red sandy loamy in texture having bulk density 1.56 Mg m^{-3} and 36.50 percent of Maximum water holding capacity (MWHC). The soil has a slightly acidic pH (6.51), low EC (0.21 dS m^{-1}) and low soil organic carbon content (1.82 g kg^{-1}). Further, the soil was moderately low in available nitrogen (275.5 kg ha^{-1}) while medium in both available phosphorous (22.51 kg ha^{-1}) and potassium (254.45 kg ha^{-1}).

2.3 Experimentation

The experiment was laid out in randomized complete block design (RCBD) with thirteen treatments and each treatment replicated for thrice (Table 1.0). The pot having size of 25 cm height and 26.5 cm diameter and each pot carried 8 kg of soil. Maize hybrid NK-6240 was selected for the study. Each treatment pot received a calculated quantity of respective inputs. Biochar and nitrogen enriched biochar pellets were incorporated into the pots as per the recommended dosages one week before the sowing of the test crop. Each pot was sown with 4 certified seeds of NK-6240 hybrid maize on 29th August 2022 and after germination, they were thinned and only one healthy seedling per pot were maintained. Pots were kept moist approximately at 60 percent of field capacity by watering regularly as and when required by crop. and harvested 30th October 2022.

The plant samples were analyzed to determine nutrient use efficiency for NPK in Maize (the test crop) by using a standardized formula.

$$\textbf{Nutrient use efficiency} = \frac{NU_1 - NU_2}{Na}$$

Where,

NU1: Amount of N, P or K uptake by a crop in the fertilized pot (kg ha^{-1})

NU2: Amount of N, P or K uptake by a crop in the control pot (kg ha^{-1})

Na: Amount of N, P or K applied in the treated pot (kg ha^{-1})

The observation on Bioconcentration factor of root, Bio concentrations factor of shoot and Translocation Factor for NPK and micronutrients.

2.4 The bioconcentration factor (BCF)

Assessed metal accumulation in plant roots and shoots relative to rhizosphere soil, crucial in environmental studies to understand potential bioconcentration of metal ions.

Root bio concentration factor (BCF) = C_{root} / C_{soil}

Shoot bio concentration factor (BCF) = C_{shoot} / C_{soil}

The translocation factor is a crucial parameter in plant physiology that measures the movement of nutrients within a plant. It was estimated by dividing the BCF of the shoot by the BCF of the root (Bose and Bhattacharya, 2008) [2].

Translocation factor = BCF_{shoot} / BCF_{root}

Data analysis and interpretation was done using Fisher's method of analysis and variance technique as given by Panse and Sukhatme (1967) [3].

3. Results and Discussion

3.1 Effect of various treatments on nutrient use efficiency of NPK in maize

The data pertaining to the nutrient use efficiency of nitrogen, phosphorus and potassium, assessed at 60 DAS of maize crop, exhibited significant variations among the treatments. The results were presented in Table 2 and the same is depicted in Figure 1.

3.1.1 Nitrogen use efficiency in maize

The Nitrogen use efficiency ranged from 2.43 – 40.27 percent, across various treatments. Among the various treatments, the treatment, T_{13} which received nitrogen enriched biochar pellets @ 7.5MT ha^{-1} (N as AS) + RD of P&K recorded the highest nutrient use efficiency for N (40.27%). However, treatment T_{13}, followed by treatment T_{11}, which received nitrogen enriched biochar pellets @ 7.5 MT ha^{-1} along with RD of P & K (N as urea) as compared to other treatments. In contrast, the treatment that received only biochar pellets @ 7.5 MT ha^{-1} exhibited the very lowest use efficiencies for N in maize at 60 DAS. Significant increase in nitrogen use efficiency in maize might be due to the fact that the biochars' high carbon content and porous structure may help in facilitating the nitrogen-enriched biochar pellets to act as a stable nitrogen reservoir apart from minimizing nitrogen losses through leaching, volatilization, and denitrification if any. These findings align with the reported works of Liu *et al.* (2017) [4], Abbruzzini *et al.* (2019) [5], Lee *et al.* (2021) [6], Li *et al.* (2022) [7], Roy *et al.* (2021) [8] and Sun *et al.* (2018) [9]. Meanwhile, Sun *et al.* (2018) [9] studied the response of wheat crop to varied quantity of biochar application ranging from 5 to 20 Mg ha^{-1} and have observed the proportionate increase in NUE ranging from 5.20 – 37.90 percent and also grain yield increase by 2.90-19.40 percent owing to varied quantity of biochar application.

3.1.2 Phosphorus use efficiency in maize

The phosphorus use efficiency was ranged from 0.61- 22.96 percent. Among the various treatments, the treatment, T_{13} which received nitrogen enriched biochar pellets @ 7.5MT ha^{-1} (N as AS) + RD of P&K recorded the highest nutrient use efficiency for P (22.96%). However, treatment T_{13}, followed by treatment T_{11}, which received nitrogen enriched biochar pellets @ 7.5 MT ha^{-1} along with RD of P & K (N as urea) as compared to other treatments. In contrast, the treatment that received only biochar pellets @ 7.5 MT ha^{-1} exhibited the very lowest use efficiencies for P in maize at 60 DAS. The nitrogen-enriched biochar pellets play a pivotal role in enhancing phosphorus use efficiency in maize through several interconnected mechanisms. The application of these pellets to the soil creates a conducive environment for the proliferation of beneficial microorganisms, particularly phosphate-solubilizing bacteria. These microorganisms contribute significantly to the conversion of insoluble phosphorus compounds in the soil into more accessible forms for plant uptake. he nitrogen-enriched biochar pellets exhibit a higher surface area, a characteristic that proves instrumental in nutrient absorption. Specifically, the pellets act as efficient carriers, absorbing essential nutrients, with a notable emphasis on phosphorus. This absorption process not only prevents the precipitation of phosphorus in the soil but also ensures that a greater quantity of this vital nutrient is made readily available to the maize plants. By mitigating nutrient losses through precipitation and increasing the accessibility of phosphorus, the nitrogen-enriched biochar pellets contribute substantially to elevating phosphorus use efficiency in maize cultivation. These findings conformity with research studies of Nardis *et al.* (2021) [10] and Gunes *et al*. (2014) [11].

3.1.3 Potassium use efficiency in maize

The potassium use efficiency was ranged from 3.40-61.55percent. Among the various treatments, the treatment, T_{13} which received nitrogen enriched biochar pellets @ 7.5MT ha^{-1} (N as AS) + RD of P&K recorded the highest nutrient use efficiency for K (61.55%). However, treatment T_{13}, followed by treatment T_{11}, which received nitrogen enriched biochar pellets @ 7.5 MT ha^{-1} along with RD of P & K (N as urea) as compared to other treatments. In contrast, the treatment that received only biochar pellets @ 7.5 MT ha^{-1} exhibited the very lowest use efficiencies for K in maize at 60 DAS. The augmentation of potassium use efficiency in maize through the application of nitrogen-enriched biochar pellets is a result of multifaceted interactions within the soil-plant system. The nitrogen enrichment in the biochar pellets initiates a cascade of effects, starting with the promotion of beneficial microbial activity in the soil. These microbes contribute to the solubilization of potassium, transforming it into more accessible forms for plant uptake. Similar results were reported by Fachini *et al*. (2023) [12], Karim *et al.* (2017) [13] and Wang *et al*. (2018) [14]

3.2 Effect of various treatments on BCFr and BCFs of NPK and micronutrients in maize

The bioconcentration factor (BCF) was determined separately for root (BCFr) and shoot (BCFs) of maize crop by dividing the concentration of specific nutrients in the root and shoot by the concentration of those nutrients in the soil.

3.2.1 BCFr and BCFs of NPK in maize

The BCF values for nitrogen ranged from 34.70 – 57.97 and 39.16 – 119.37 in root and shoot, respectively. Similarly, for phosphorus BCF values of root and shoot ranged from 127.7-269.00 and 212.74 – 493.18 in root & shoot respectively and for potassium, the BCF values ranged from 41.59 - 53.71 and 93.65 – 173.83 in root and shoot, respectively. Among the various treatments, treatment $T_{13,}$ which received nitrogen enriched biochar pellets @ 7.5 MT ha^{-1} along with RD of P & K recorded highest bioconcentration factor value of both root and shoot for NPK (57.97, 119.37, 269.00 respectively) next best treatment found to be T_{11} as compared to other treatments. The lowest BCF value of root and shoot for NPK was recorded in treatment T_1. This outcome was attributed due to application of the nitrogen enriched biochar pellets along with RD of P & K enhanced absorption of essential elements, leading to a higher concentration of nutrients in both the roots and shoots of maize plants. The results were presented in Table 3 and the same is depicted in Figure 2.

3.2.2 BCFr and BCFs of micronutrients in maize

The BCF values of root and shoot for copper were ranged from 2.08 – 9.40 & 2.16 – 6.30, for iron ranged from 0.66 – 2.08 & 0.50 – 1.45, for manganese ranged from 0.43 – 0.80 & 0.64 – 1.19, for zinc ranged from 1.11- 1.87 & 0.78 – 1.18, respectively. There were significant variations occurs with regards to BCF of root and shoot for micronutrients, among various treatments, T_{13} which received the nitrogen enriched biochar pellets along with RD of P & K was recorded highest BCF of both root and shoot for micronutrients. In contrast, lowest values were recorded in T_1 *i.e.*, absolute control. A higher BCF value indicates a greater capacity for micronutrient uptake and storage, implying enhanced nutrient utilization and potential for improved plant health. The results were presented in Table 4.

3.3 Translocation factor of NPK and micronutrients in maize

the translocation factor (TF) is a crucial parameter in plant physiology that measures the movement of nutrients within a plant. It quantifies the efficiency of transportation from one part of the plant (root) to another (shoot), often indicating the distribution of essential elements to move within the plant system. The translocation factor (TF) was estimated by dividing the BCF of shoot by the BCF of root.

3.3.1 Translocation factor of NPK in maize

The data pertaining to the translocation factor for NPK were presented in the Table 3. The treatments exerted a noticeable impact on TF for NPK. The TF value for nitrogen was ranged from 1.13-2.13. Similarly, the TF value for phosphorus ranged from 1.43-1.87. Likewise, the TF value for potassium ranged from 1.81-3.39. TF values are indicative of the plant's ability to distribute nutrients from the roots to the shoots, and the variations observed among the treatments offer insights into the complex mechanisms governing nutrient transport and allocation. The higher TF values observed across the treatments for all the three major nutrients indicate that the treatments have positively influenced nutrient mobility and translocation. Among the major nutrients, potassium showed higher translocation factor across the treatments, thus indicating that K moves quickly from root to shoot in comparison to N & P due to the increased availability K nutrients in the soil. As a result, this nutrient was transferred from the roots to the above-ground parts of the maize crop.

3.3.2 Translocation factor of micronutrients in maize

The data related to the translocation factor for micronutrients were presented in the Table 4. The treatments exerted a noticeable impact on TF for micronutrients the TF value for copper was ranged from 0.59 – 1.04, for iron ranged from 0.65 – 1.02, for manganese ranged from 1.39 – 1.56, for zinc ranged from 0.63 – 0.86. the observed TF values provide insights into the plants' capacity to translocate micronutrients from the roots to the aerial parts. Higher TF values suggest efficient nutrient transport within the plant, contributing to overall micronutrient distribution and utilization. The discrepancies observed among the treatments in terms of BCF for root & shoot values emphasize the role of nutrient management strategies, particularly the application of nitrogen-enriched biochar pellets combined with RD of P&K fertilizers, in influencing the absorption, accumulation, and distribution of micronutrients. Among the micronutrients, manganese showed higher translocation factor across the treatments. The above results were in conformity with findings of the Kirkham *et al.* (2006) [15] and Usman *et al.* (2022) [16].

Table 1: Treatments details of pot culture study

Treatments		
T_1	:	**Absolute control**
T_2	:	Soil receiving 100% RDN as Urea + RD of P&K
T_3	:	Soil receiving 100% RDN as AS + RD of P&K
T_4	:	*Soil treated with Biochar @ 7.5MT ha^{-1} only*
T_5	:	T2 + T4 *i.e.* 100% RDN as urea + RD of P&K *Plus* Biochar @ 7.5MT ha^{-1}
T_6	:	T3 + T4 *i.e.* 100% RDN as AS + RD of P&K *Plus* Biochar @ 7.5 MT ha^{-1}
T_7	:	*Soil treated with Biochar pellets @ 7.5MT ha^{-1} only*
T_8	:	T2 + T7 *i.e.* 100% RDN as urea + RD of P&K *Plus* Biochar pellets @ 7.5MT ha^{-1}
T_9	:	T3 + T7 *i.e.* 100% RDN as AS + RD of P&K *Plus* Biochar pellets @ 7.5 MT ha^{-1}
T_{10}	:	*Soil treated with N enriched Biochar pellets @ 7.5MT ha^{-1} (N as Urea) only*
T_{11}	:	Soil treated with N enriched Biochar pellets @ 7.5MT ha^{-1} (N as Urea) + RD of P&K
T_{12}	:	*Soil treated with N enriched Biochar pellets @ 7.5MT ha^{-1} (N as AS)*
T_{13}	:	Soil treated with N enriched Biochar pellets @ 7.5MT ha^{-1} (N as AS) + RD of P&K

Note:
1. RDF: 150:65:65 Kg NPK ha^{-1}
2. Each pot holds 8 Kg of soil
3. RDN, RDP, RDK: Recommended dosage of Nitrogen, Phosphorus and Potassium respectively
4. Nutrient source: N source Urea & Ammonium sulfate; P source: Single Super Phosphate (SSP); K Source: Murate of Potash (MOP)
5. In RDF treatment, 50 percent N was the basal dose and the remaining 50 percent applied at 30 DAS

Table 2: Effect of various treatments on nutrient use efficiency of NPK in maize

Treatment	N use efficiency	P use efficiency	K use efficiency
T_1	0.00	0.00	0.00
T_2	4.88	7.05	27.58
T_3	7.40	9.64	33.37
T_4	8.73	5.95	13.24
T_5	12.40	8.20	28.96
T_6	19.89	11.99	35.21
T_7	2.43	0.61	3.40
T_8	26.37	15.95	36.95
T_9	29.52	15.28	34.95
T_{10}	5.99	5.86	16.36
T_{11}	32.18	16.54	40.78
T_{12}	17.19	12.37	26.32
T_{13}	40.27	22.96	61.55
S.Em±	0.59	0.53	1.59
CD.@ 1%	2.34	2.10	6.29

Note: T_1: Absolute control, T_2: 100% RDN as Urea + RD P&K, T_3: 100% RDN as Amm. sulfate + RD P&K, T_4: Biochar @ 7.5MT ha^{-1} only, T_5: Biochar + 100% RDN as Urea + RD P&K, T_6: Biochar + 100% RDN as Amm. sulfate + RD P&K, T_7: Biochar pellets @ 7.5 MT ha^{-1} only, T_8: Biochar pellets @ 7.5 MT ha^{-1} + 100% RDN as Urea + RD P&K, T_9: Biochar pellets @ 7.5 MT ha^{-1} + 100% RDN as Amm. sulfate + RD P&K, T_{10}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as Urea) only, T_{11}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as Urea) + RD P&K, T_{12}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as AS), T_{13}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as AS) + RD P&K.

Table 3: Effect of various treatments on BCFr, BCFs and TF of NPK in maize

Treatment	Nitrogen			Phosphorous			Potassium		
	BCFr	BCFs	TF	BCFr	BCFs	TF	BCFr	BCFs	TF
T_1	34.70	39.16	1.13	127.77	212.74	1.67	41.59	93.65	2.25
T_2	36.97	42.49	1.15	169.13	312.32	1.84	44.59	128.0	2.85
T_3	37.74	43.27	1.15	177.77	325.65	1.83	52.60	151.0	2.87
T_4	41.00	60.42	1.47	156.65	223.11	1.43	42.89	125.6	2.93
T_5	45.10	72.97	1.62	160.99	300.80	1.87	49.24	122.5	2.49
T_6	47.76	82.88	1.74	132.08	235.96	1.79	47.98	120.4	2.51
T_7	35.45	61.61	1.74	193.52	343.86	1.78	52.39	94.5	1.81
T_8	44.55	90.80	2.04	128.95	225.51	1.75	52.56	117.0	2.23
T_9	45.77	97.26	2.13	142.91	213.73	1.50	53.39	114.1	2.14

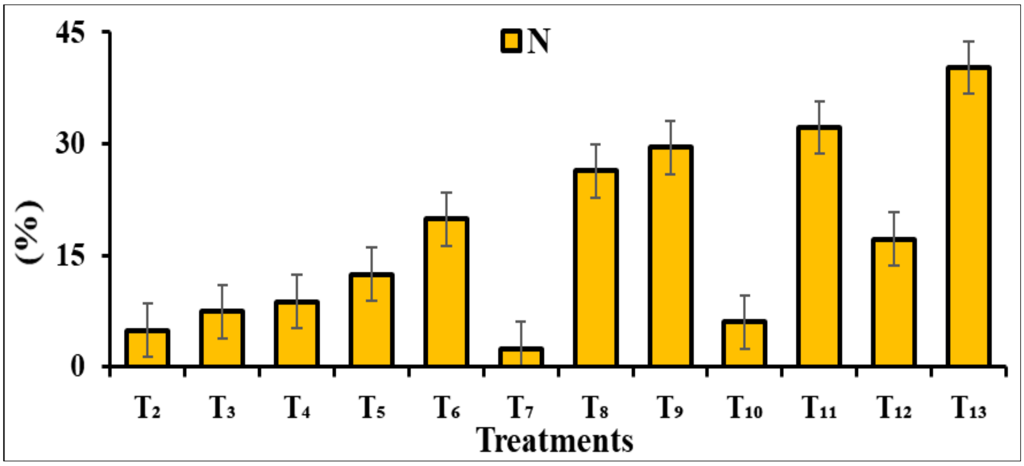
T_{10}	41.97	61.57	1.47	153.38	273.51	1.79	44.67	124.8	2.80
T_{11}	53.48	110.1	2.06	231.07	413.86	1.77	50.19	157.4	3.14
T_{12}	44.86	81.23	1.81	164.77	294.46	1.79	45.91	126.6	2.76
T_{13}	57.97	110.3	1.90	269.00	493.18	1.83	53.71	173.8	3.24
S.Em±	0.61	0.61	0.03	4.32	7.83	0.10	0.75	1.75	0.12
CD@ 1%	2.40	2.43	0.10	17.10	30.96	0.38	2.98	6.93	0.39

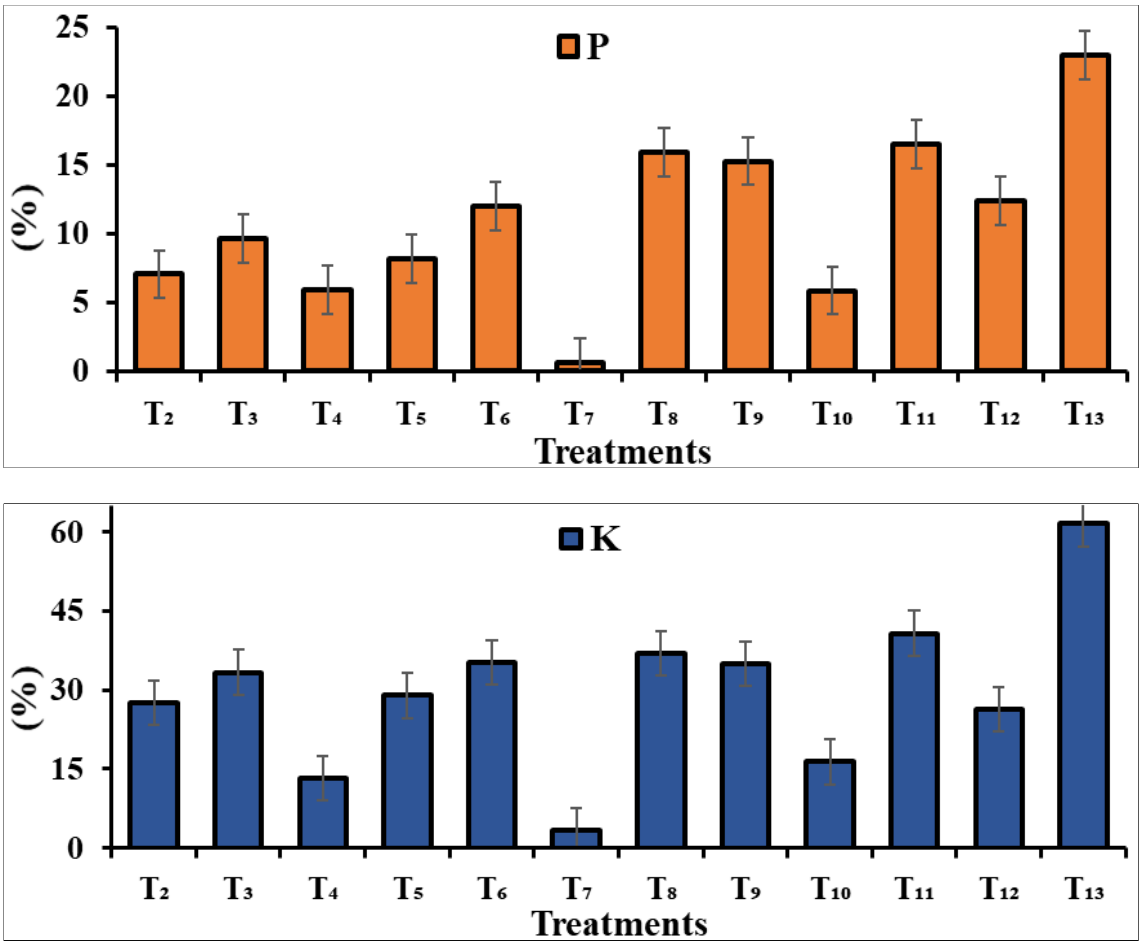
Note:
T_1: Absolute control, T_2: 100% RDN as Urea + RD P&K, T_3: 100% RDN as Amm. sulfate + RD P&K, T_4: Biochar @ 7.5MT ha^{-1} only, T_5: Biochar + 100% RDN as Urea + RD P&K, T_6: Biochar + 100% RDN as Amm. sulfate + RD P&K, T_7: Biochar pellets @ 7.5 MT ha^{-1} only, T_8: Biochar pellets @ 7.5 MT ha^{-1} + 100% RDN as Urea + RD P&K, T_9: Biochar pellets @ 7.5 MT ha^{-1} + 100% RDN as Amm. sulfate + RD P&K, T_{10}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as Urea) only, T_{11}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as Urea) + RD P&K, T_{12}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as AS), T_{13}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as AS) + RD P&K.

Table 4: Effect of various treatments on BCFr, BCFs and TF of micronutrients in maize

Treatment	Copper			Iron			Manganese			Zinc		
	BCFr	BCFs	TF	BCFr	BCFs	TF	BCFr	BCFs	TF	BCFr	BCFs	TF
T_1	2.08	2.16	1.04	0.70	0.50	0.71	0.43	0.64	1.48	1.11	0.78	0.70
T_2	3.15	2.60	0.83	0.73	0.61	0.83	0.45	0.68	1.51	1.12	0.87	0.77
T_3	3.21	2.70	0.84	0.88	0.61	0.70	0.50	0.73	1.46	1.19	0.92	0.77
T_4	3.83	2.66	0.70	0.74	0.55	0.74	0.47	0.66	1.39	1.21	1.04	0.86
T_5	4.92	4.01	0.82	0.79	0.75	0.96	0.55	0.81	1.47	1.38	1.05	0.77
T_6	4.89	4.61	0.94	0.87	0.78	0.90	0.61	0.87	1.42	1.38	1.09	0.79
T_7	3.04	3.09	1.02	0.92	0.82	0.89	0.55	0.77	1.40	1.31	0.85	0.65
T_8	8.15	5.27	0.65	0.91	0.93	1.02	0.63	0.97	1.54	1.40	1.15	0.82
T_9	8.50	6.17	0.73	1.27	1.02	0.81	0.68	1.02	1.50	1.34	1.11	0.83
T_{10}	4.94	4.28	0.87	0.66	0.67	1.00	0.50	0.78	1.56	1.26	0.89	0.71
T_{11}	9.28	6.47	0.59	1.87	1.21	0.65	0.74	1.09	1.48	1.69	1.12	0.66
T_{12}	8.09	5.11	0.63	1.09	0.87	0.80	0.63	0.88	1.40	1.27	0.97	0.76
T_{13}	9.40	6.30	0.67	2.08	1.45	0.70	0.80	1.19	1.49	1.87	1.18	0.63
S.Em±	0.16	0.38	0.06	0.03	0.02	0.03	0.01	0.02	0.03	0.03	0.03	0.04
CD@ 1%	0.83	1.52	0.23	0.10	0.09	0.10	0.05	0.08	0.13	0.11	0.12	0.16

Note:
T_1: Absolute control, T_2: 100% RDN as Urea + RD P&K, T_3: 100% RDN as Amm. sulfate + RD P&K, T_4: Biochar @ 7.5MT ha^{-1} only, T_5: Biochar + 100% RDN as Urea + RD P&K, T_6: Biochar + 100% RDN as Amm. sulfate + RD P&K, T_7: Biochar pellets @ 7.5 MT ha^{-1} only, T_8: Biochar pellets @ 7.5 MT ha^{-1} + 100% RDN as Urea + RD P&K, T_9: Biochar pellets @ 7.5 MT ha^{-1} + 100% RDN as Amm. sulfate + RD P&K, T_{10}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as Urea) only, T_{11}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as Urea) + RD P&K, T_{12}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as AS), T_{13}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as AS) + RD P&K.





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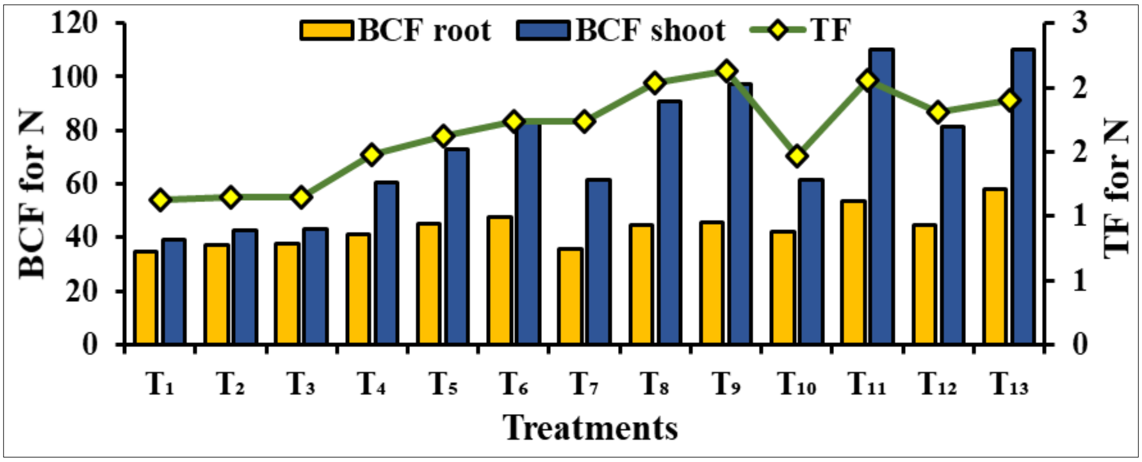
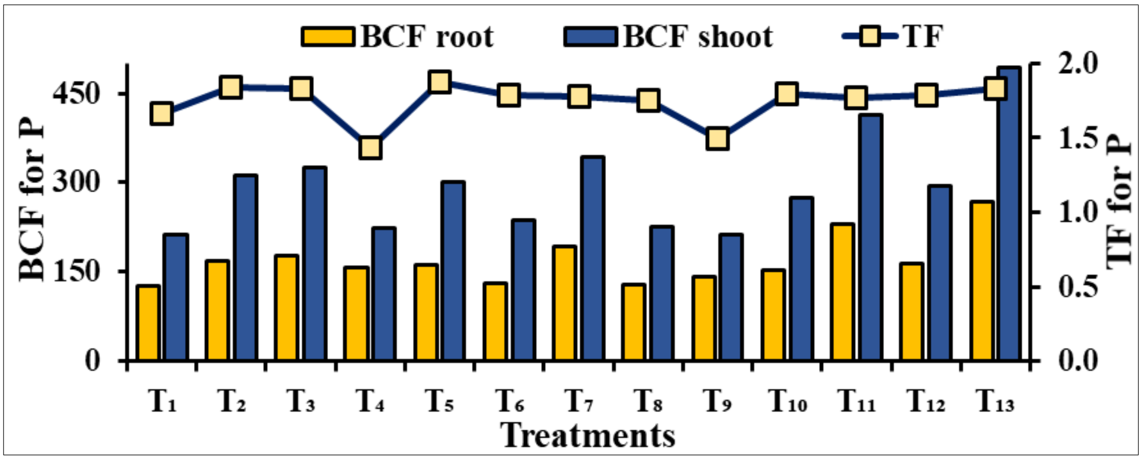
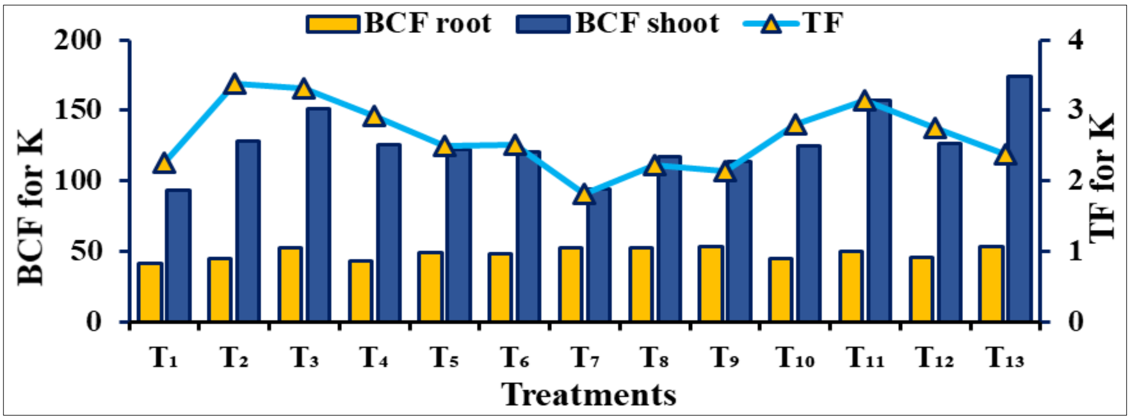
T_1: Absolute control, T_2: 100% RDN as Urea + RD P&K, T_3: 100% RDN as Amm. sulfate + RD P&K, T_4: Biochar @ 7.5MT ha^{-1} only, T_5: Biochar + 100% RDN as Urea + RD P&K, T_6: Biochar + 100% RDN as Amm. sulfate + RD P&K, T_7: Biochar pellets @ 7.5 MT ha^{-1} only, T_8: Biochar pellets @ 7.5 MT ha^{-1} + 100% RDN as Urea + RD P&K, T_9: Biochar pellets @ 7.5 MT ha^{-1} + 100% RDN as Amm. sulfate + RD P&K, T_{10}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as Urea) only, T_{11}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as Urea) + RD P&K, T_{12}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as AS), T_{13}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as AS) + RD P&K.

Fig 1: Effect of various treatments on NPK use efficiency (%) in maize







Note:

T_1: Absolute control, T_2: 100% RDN as Urea + RD P&K, T_3: 100% RDN as Amm. Sulfate + RD P&K, T_4: Biochar @ 7.5MT ha^{-1} only, T_5: Biochar + 100% RDN as Urea + RD P&K, T_6: Biochar + 100% RDN as Amm. Sulfate + RD P&K, T_7: Biochar pellets @ 7.5 MT ha^{-1} only, T_8: Biochar pellets @ 7.5 MT ha^{-1} + 100% RDN as Urea + RD P&K, T_9: Biochar pellets @ 7.5 MT ha^{-1} + 100% RDN as Amm. Sulfate + RD P&K, T_{10}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as Urea) only, T_{11}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as Urea) + RD P&K, T_{12}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as AS), T_{13}: N enriched Biochar pellets @ 7.5 MT ha^{-1} (N as AS) + RD P&K.

Fig 2: Effect of various treatments on BCFr, BCFs and TF for NPK in maize

4. Conclusion

It was concluded that application of nitrogen enriched biochar pellets @ 7.5MT ha^{-1}(N as Ammonium sulfate) + RD of P & K was recorded higher nutrient use efficiency of NPK and BCFr & BCFs of NPK & micronutrients in maize as compared to other treatments. However, it was found on par nitrogen enriched biochar pellets @ 7.5MT ha^{-1} (N as Urea) + RD of P & K fertilizer Lowest was noticed under absolute control.

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