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Response of Maize (*Zea mays* L.) to nitrogen enriched biochar pellets

Halesh DS, Veeresh H, Narayana Rao K, Bhat SN, Devanand Maski, Beladhadi RV, Ajaykumar MY and Pooja V

Halesh DS
Department of Soil Science and Agricultural Chemistry, College of Agriculture, Raichur, University of Agricultural Sciences, Raichur, Karnataka, India

Veeresh H
Associate Professor, Department of Soil Science & Agricultural Chemistry, College of Agriculture, Raichur, University of Agricultural Sciences, Raichur, Karnataka, India

Narayana Rao K
Professor and Head, Department of Soil Science & Agricultural Chemistry, College of Agriculture, Raichur, University of Agricultural Sciences, Raichur, Karnataka, India

Bhat SN
Scientist, Department of Soil Science, ICAR - KVK, University of Agricultural Sciences, Raichur, Karnataka, India

Devanand Maski
Assistant Professor, Department of Farm Machinery and Power Engineering, College of Agricultural Engineering, Raichur, University of Agricultural Sciences, Raichur, Karnataka, India

Beladhadi RV
Associate Professor and Head, Department of Agricultural Biochemistry, College of Agriculture, Raichur, University of Agricultural Sciences, Raichur, Karnataka, India

Ajaykumar MY
Senior Scientist, Department of Agronomy, AICRP on Cotton, Main agricultural research station Raichur, University of Agricultural Sciences, Raichur, Karnataka, India

Pooja V
Department of Agricultural Extension Education, College of Agriculture, Raichur, University of Agricultural Sciences, Raichur, Karnataka, India

Corresponding Author:
Halesh DS
Department of Soil Science and Agricultural Chemistry, College of Agriculture, Raichur, University of Agricultural Sciences, Raichur, Karnataka, India

Abstract
A greenhouse pot culture experiment was carried out during kharif, 2022 at College of Agriculture, Raichur, University of Agricultural Sciences, Raichur, Karnataka, India to study the response of maize to nitrogen enriched biochar pellets application. The experiment was laid out in Randomized Complete Block Design with thirteen treatments and each treatments replicated thrice. The results of the experiment revealed that application of biochar in different forms along with recommended dose of fertilizer had recorded significant variations in both growth parameters and root distributions *Viz*., plant height, number of leaves per plant, leaf area, leaf area index, total dry matter production, root length and root weight in maize. Among various treatments, the application of nitrogen enriched biochar pellets @ 7.5 MT ha^{-1} Plus recommended dose of P & K fertilizer recorded the highest growth parameters of maize at 30, 45 and 60 DAS and also better root distribution at 60 DAS. On the other hand, the treatment absolute control (T_1) recorded the lowest growth parameters as well as poor root distribution in maize. Apart from the above, the biochemical (SPAD) and biophysical (NDVI) values recorded during the course of investigations showed significant variations across the treatments at different stages of crop growth. Based on the overall results of the study it was perceptible that nitrogen enriched biochar pellets act as a slow nitrogen releasing resource material and thus benefits crops' growth and development.

Keywords: Biochar, Pellets, Growth parameters and SPAD & NDVI

1. Introduction

Biochar is a char produced by pyrolysis of biomass from different sources (wood chips, crop residues, dairy manure, etc.) with high carbon content. It is produced at high (above 500 °C) or low (<400 °C) pyrolysis temperature under limited or in the complete absence of oxygen. Several beneficial properties of biochar applications were documented, such as, soil cation exchange capacity, water holding capacity and soil organic matter. Moreover, biochar positively affects plant growth and development, provides nutrients, and even increases nutrient availability. Application of biochar regulates the availability and solubilisations or mineralization of the essential nutrients mainly, NPK by influencing the soil pH (Xiao *et al*., 2016) [1]. Additionally, biochar increases nitrogen retention in soil by reducing leaching and gaseous loss and also increases phosphorus availability by decreasing the leaching process in soil and even for potassium and other nutrients, biochar shows inconsistent (positive and negative) impacts on soil, which leads the more availability of the essential nutrients to crop growth and development. Further, biochar also alters soil biological properties by increasing microbial populations, enzyme activity, soil respiration, and microbial biomass (Hossain *et al*., 2020) [2].

In current days, very few studies emphasized the efficacy of nutrient-enriched biochar and also reported that the blending of biochar with nutrient-rich manures, compost (vermicompost) or poultry litter and fertilizers is gaining popularity as a strategy of value addition to biochar to increase its usage in agriculture and also to achieve the increased nutrient use efficiency in crop production. Further, the storage, transportation and soil application of biochar became challenging because biochar is dusty with low mechanical strength, brittle and has wide particle size distribution with low density (Husk and Major, 2008) [3]. This can be addressed through the pelletization of biochar which can significantly reduce the transportation, handling costs and decrease the loss of biochar during soil application. Biocharpellets can be produced by blending lignocellulosic and vermicompost feed stocks, pelletized and slowly pyrolyzed. There is also an opportunity to convert biochar pellets as value-added organic mineral fertilizer through fortification with inorganic fertilizers, particularly nitrogenous fertilizers.

Further, Lee *et al*. (2021) [4] opined that blending of fertilizers with biochar and turning them into pellets can serve as a slow-release fertilizer to improve crop nutrient use efficiency in sweet corn.

Maize (*Zea mays* L.) the Indian and American word for corn means literally which "sustains life". It is the third most important cereal in India in terms of both area and production after rice and wheat. Maize is an important crop for billions of people as food, feed and industrial raw material. The Central Statistical Agency report indicated that maize is grown on acreage of around 2.5 million hectares, accounting for approximately 23.97 percent of all cereal crops areas. Globally maize occupies an area of 197 million ha, with a production of 1210.7 million tonnes and productivity of 5.75 t ha^{-1}.

Several attempts were being made by researchers to increase the nutrient use efficiencies through the blending of fertilizer inputs with organic materials. blending of fertilizers with biochars' and further converting into a pellet gives the added advantages of easy handling, transportation, dust free application to achieve the objectives of higher input use efficiency through improved soil physico-chemical properties, water and nutrient retention and slow release of nutrients, which interns improves the growth of the maize. Hence, this experiment was conducted with an objective to study the response of maize to nitrogen enriched biochar pellets.

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 laid out in randomized complete block design (RCBD) with thirteen treatments and each treatment replicated for thrice (Table 1). 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 slightlyacidic pH (6.51), low EC (0.21dS 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

Each treatment pot receiveda 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.

2.4 Observations on maize growth parameters

Biometric observations on morpho-physiological parameters *Viz.*, plant height, number of leaves, leaf area, leaf area index, total dry matter, leaf chlorophyll content (SPAD and NDVI) were conducted at various stages.

Plant height was recorded from base of the plant to the base of the full opened leaf, the number of functional green leaves per plant were counted and recorded from the tagged plants of each treatment then averaged, total dry matter production was worked out by uprooting plants from destructive sampling area, sun drying, weighing and averaged, leaf chlorophyll content was measured by using the SPAD meter and Green seeker. Leaf area and leaf area index (LAI) were worked by using the following formulas given by Saxena and Singh, (1965) [5] and Sestak *et al*. (1971) [6], respectively.

Leaf area (cm^2 $plant^{-1}$) =	Avg.length	×	Avg.breadth	×	0.75

$$LAI = \frac{\text{Leaf area plant}^{-1}\ (cm^2)}{\text{Pot area occupied by the plant}\ (cm^2)}$$

2.5 Observations on plant roots

Observations on plant roots at harvest such as root length and root weight at 60 DAS (At harvest). Root length was measured using a linear meter scale from the main root point to the last end tip of the tertiary roots and expressed in centimeters and Oven dry root weight was measured by using a weighing balance and expressed in grams.

3. Results and Discussion

Growth parameters (plant height, number of leaves, leaf area, leaf area index and total dry matter production), crop sensor observations were recorded at 30, 45, 60 DAS. Further, root distributions (root length and root weight) were recorded at 60 DAS (At harvest).

3.1 Plant height

The findings from the plant height data indicate a noteworthy impact of treatments on the growth of maize crops, with a considerable variation observed at 30, 45, and 60 days after sowing (DAS). The results were presented in Table 2 and the same is depicted in Figure 1.

Among the various treatments, the treatment (T_{13}) which received the nitrogen enriched biochar pellets @ 7.5MT ha^{-1}(N as AS) + RD of P&K recorded higher plant heights of 36.04, 68.53 and 123.03 cm at 30, 45 and 60 DAS, respectively. However, the treatment T_{11} emerged as the next best treatment that received the nitrogen enriched biochar pellets @ 7.5MT ha^{-1} (N as Urea) + RD of P&K. While, the treatment absolute control (T_1) recorded the lowest plant heights at all the stages of crop growth.

Significantly taller plant height was observed in the treatment which received nitrogen enriched biochar pellets @ 7.5MT ha^{-1}(N as AS) + RD of P&K which might be due to the N enriched biochar pellets serves as a carbon-rich soil amendment, enhancing soil structure and water retention. This improved soil condition facilitates better root development and nutrient uptake by the maize plants. Moreover, the nitrogen enrichment in the biochar provides a supplemental source of nitrogen, a crucial nutrient for plant growth. This additional nitrogen supply likely promotes vigorous vegetative growth, contributing to taller maize plants. The slow-release nature of biochar also ensures a sustained availability of nutrients over an extended period, supporting continuous and steady growth throughout the different stages of maize development (Xu *et al*., 2022 [7]; Li *et al*., 2022 [8]; Choudary *et al*., 2021 [9]; Shi *et al*., 2020 [10]; Utomo *et al*., 2017 [11] and Tufa *et al*., 2022 [12]).

3.2 Number of leaves per plant

The recorded data for the mean number of leaves per maize plant at 30, 45, and 60 days after sowing (DAS) exhibited significant variations across various treatments. Generally, the tally of leaves per plant displayed a steady and incremental rise as the crop matured (Table 2).

Significant variations in the mean number of leaves per maize plant were recorded among different treatments at 30, 45, and 60 (DAS). Treatment T13 which recived the nitrogen enriched biochar pellets @ 7.5MT ha^{-1}(N as AS) + RD of P & K fertilizer recorded highest number of leaves per plant *Viz*., 8.05, 10.50, and 13.97 at 30, 45 and 60 DAS, respectively. However, these values were on par with the treatment T_{11}, which was almost as same as T_{13} with respect to the quantity of nitrogen supplied but only differed in nitrogen source i.e.as urea. The treatment absolute control (T_1) recorded the lowest average leaf count per plant at 30, 45, and 60 DAS when compared to other treatments.

In current investigations, significant increase in the number of leaves per plant in maize was in treatment that received the nitrogen enriched biochar pellets @ 7.5MT ha^{-1}along with RD of P & K fertilizer. This outcome was attributed due to the N enriched biochar pellets serves as a carrier for nitrogen, gradually releasing it into the soil. This sustained release provides a continuous supply of nitrogen, a key element for leaf development. Further, the synergistic effect of nitrogen from biochar and essential nutrients from P & K fertilizer creates an optimal nutrient balance for maize plants. This balanced nutrition supports robust vegetative growth, resulting in an increased number of leaves during the different growth stages (Egamberdieva *et al*., 2022 [13] and Wan *et al*., 2023 [14]).

3.3 Leaf area and Leaf area index

The mean leaf area and leaf area index of maize were measured at 30, 45, and 60 days after sowing (DAS), revealing significant variations across various treatments. The results were presented in Table 2.

In general, both the leaf area and leaf area index increased with the increase in the number of days at which observations were recorded. Among the treatments, treatment T_{13} which received the nitrogen enriched biochar pellets @ 7.5MT ha^{-1}(N as AS) + RD P&K recorded the highest leaf area and leaf area index *Viz*., 201.92, 842.02 & 1801.20 cm^2 plant^{-1} and 0.31, 1.27, and 2.72 at 30, 45 and 60 DAS, respectively and it was on par with treatment T_{11}. The lowest leaf area and leaf area index were recorded in absolute control, T_1.

In the current study, treatments that received nitrogen enriched biochar pellets @ 7.5 MT ha^{-1}(N as AS) + RD of P&K have recorded higher leaf area and leaf area index at 30, 45 and 60 DAS. This can be attributed to higher nutrient availability, good microbial and enzymatic activity through improved nutrient retention and availability in N enriched biochar amended treatments (Shi *et al*., 2020 [10]; Utomo *et al*., 2017 [11] and Tufa *et al.,* 2022 [12]). Further, Tufa *et al*. (2022) have observed highest leaf area index of maize (5.56) due to combined application of biochar @ 8.0 MT ha^{-1} plus 100 kg ha^{-1} NPS.

3.4 Total dry matter

Plant total dry matter was determined by uprooting the whole plant at 60 DAS. Subsequently, plant shoots, leaves and roots were separated, washed, and sun-dried followed by drying at 65 °C in a hot air oven. The average dry weights were recorded in grams (Table 3).

Among the various treatments, the treatment T_{13} which received the nitrogen enriched biochar pellets @ 7.5MT ha^{-1} (N as AS) + RD of P&K recorded the highest total dry matter *Viz*., 74.27 g plant^{-1}. It should be noted that total dry matter recorded at 60 DAS was highest in T_{13} and significantly higher than all other treatments. In contrast, the lowest total dry matter, root weight and root length were recorded in absolute control, T_1.

Significant variations in total dry matter was observed owing to different treatments in maize. Notably, the treatment T_{13}, which involved the application of nitrogen enriched biochar pellets @ 7.5MT ha^{-1}(N as AS) + RD of P&K, exhibited the highest total dry matter production (Figure 2). The increased total dry matter was usually associated with the higher number of green leaves per plant, stem and root weight. Nitrogen source significantly impacted total dry matter, underscoring nitrogen-enriched biochar pellets and RD of P&K's growth role. This combination provided a favourable environment for enhanced nutrient uptake, which subsequently translated into increased biomass production. The results of the present study were comparable to the research findings of Li *et al*. (2022) [8], Xiang *et al*. (2017) [15], and Banik *et al*. (2023) [16]. The combined application of N fertilizer and biochar can significantly increase the crop N uptake and N content resulting in higher leaf photosynthetic efficiency, dry matter accumulation and grain yields (Li *et al*., 2022) [17].

3.5 Observations on root distributions

Root distributions (root length and root weight) were determined by uprooting the whole plant at 60 DAS. Root length spanning from the primary root to the farthest tip of tertiary roots was measured using a linear meter scale without damage to uprooted plant (Table 3).

Among the various treatments, the treatment T_{13} which received the nitrogen enriched biochar pellets @ 7.5MT ha^{-1} (N as AS) + RD of P&K recorded the highest root length and root weight *Viz*., 64.73 cm and 6.5 g plant^{-1} respectively. However, the observations on root length and root weight were on par with the treatment T_{11} when compared to the other treatments. In contrast, the root weight and root length were recorded in absolute control, T_1.

Significant variations in root length, and root weight were observed owing to different treatments in maize. Notably, the treatment T_{13}, which involved the application of nitrogen enriched biochar pellets @ 7.5MT ha^{-1}(N as AS) + RD of P&K, exhibited the highest root length and root weight. The enhancement of root length and weight was likely attributed to improved phosphorus fertilizer availability and solubility, facilitated by the application of nitrogen-enriched biochar pellets. Nitrogen-enriched biochar contributed to the development of robust root systems, leading to increased root length and overall development in maize. The results of the present study were comparable to the research findings of Li *et al*. (2022) [8], Xiang *et al*. (2017) [15], and Banik *et al*. (2023) [16]. Upon, application of biochar, there was increase in the root biomass, root length, and root tip number and thus strengthening the ability of plants to access resources and the effect was more noticeable at elevated levels of biochars application (Xiang *et al*., 2017) [15].

3.6 Leaf chlorophyll content (SPAD and NDVI)

The crop optical sensor readings related to chlorophyll content and vegetation indices were collected using the SPAD meter and Green seeker respectively at three different crop growth stages 30, 45, and 60 DAS, and the data were presented in Table 4.

Amid 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 higher SPAD values (38.68 & 67.11 values at 30 and 60 DAS, respectively) and NDVI values (0.66, 0.76 and 0.69 at 30, 45 & 60 DAS, respectively). These values were found to be on par with the treatment (T_{11}) that received nitrogen enriched biochar pellets @ 7.5MT ha^{-1}(N as Urea) + RD of P&K [(SPAD: 37.16 & 64.85 at 30 and 60 DAS, respectively) and (NDVI: 0.64, 0.74 & 0.66 values at 30, 45 and 60 DAS, respectively)] as compared to remaining of the treatments. Whereas, the lowest SPAD and NDVI values were recorded in absolute control (T_1).

The leaf chlorophyll content served as an indicator of the plant's photosynthesis rate, which was evaluated using SPAD and NDVI values. In the current study, the high SPAD meter and NDVI readings at different growth stages could signify that the maize crop had undergone significant growth and development, resulting in an increase in chlorophyll production. This can be attributed to the incorporation of nitrogen-enriched biochar, which has the potential to mitigate nutrient deficiencies. These recordings were found statistically superior over absolute control. Moreover, the expanded leaf area of maize plants grown in pots treated with nitrogen-enriched biochar pellets has the potential to enhance photosynthesis. This was due to the greater surface area available for light absorption. As a result, there could be improved nutrient and water uptake facilitated by heightened transpiration rates, leading to an overall enhancement in SPAD and NDVI values. Further, the result was in acquiescence with those of Pushpakumara *et al*. (2020) [17], Ming *et al*. (2019) [18] and Harell *et al*. (2011) [19].

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 Biocharpellets @ 7.5MT ha^{-1}(N as Urea) only*
T_{11}	:	Soil treated with N enriched Biocharpellets @ 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

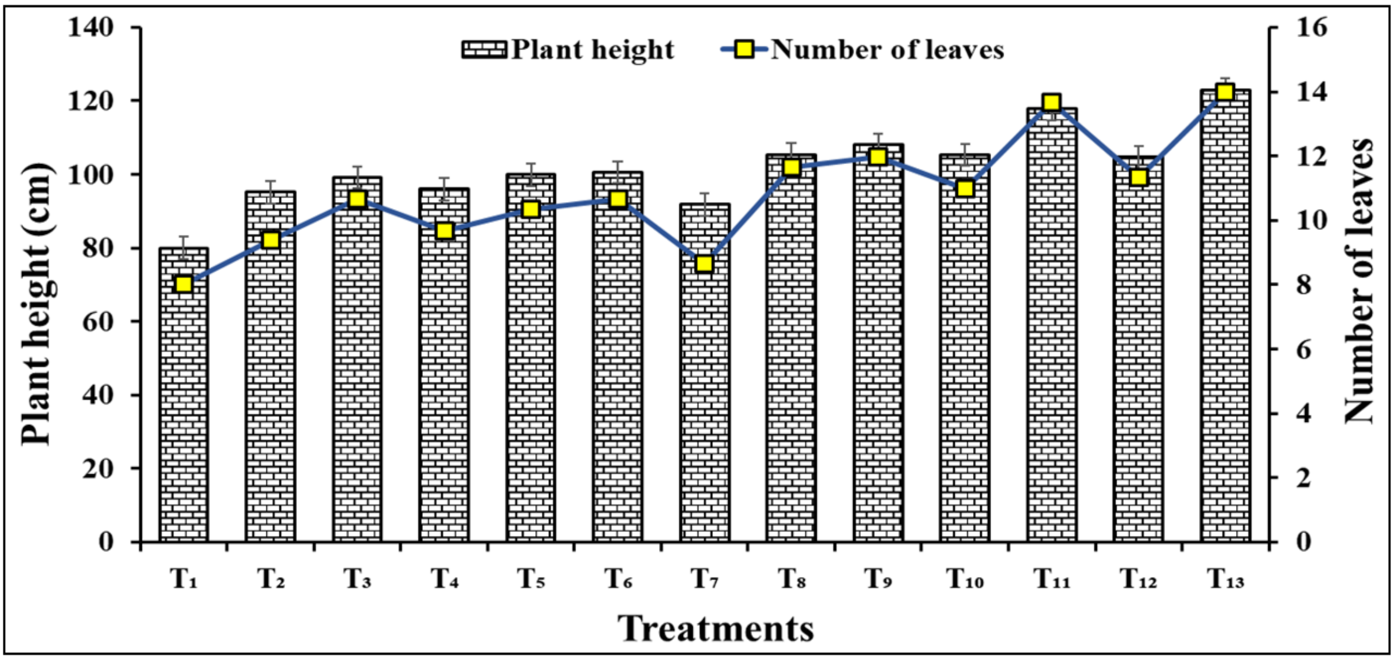
1. RDF: 150:65:65 Kg NPK ha^{-1}
2. Each pot holds 8 Kg of soil
3. RDN, RDP, RDK- Recommended dosage of Nitrogen, Phosphorus and Potassium respectively
4. Nutrient source: N source Urea & Ammonium sulfate; P source: Single Super Phosphate (SSP); K Source: Murate of Potash (MOP)
5. In RDF treatment, 50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

Table 2: Effect of different treatments on average plant height, number of leaves, leaf area and leaf area index of maize at different crop growth stages

Treatment	Plant height(cm)			Number of leaves			Leaf area (cm2 plant^{-1})			Leaf area index		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T_1	27.17	44.03	80.00	5.67	5.33	8.01	134.54	364.51	834.14	0.20	0.55	1.26
T_2	33.25	55.81	95.22	6.29	6.49	9.39	134.79	480.56	1190.22	0.20	0.86	1.80
T_3	33.58	58.59	99.17	5.83	7.97	10.66	141.52	572.30	1415.33	0.21	0.90	2.14
T_4	29.22	48.47	96.00	6.17	7.83	9.66	135.97	552.03	1283.72	0.20	0.73	1.94
T_5	26.97	50.51	99.90	6.01	8.11	10.33	147.15	593.93	1429.53	0.22	0.83	2.16
T_6	28.97	55.76	100.55	6.31	8.28	10.66	159.69	635.97	1433.12	0.24	0.96	2.16
T_7	29.87	45.26	91.80	6.34	6.17	8.66	157.13	470.59	1056.64	0.24	0.71	1.59
T_8	34.65	60.99	105.40	6.99	8.79	11.67	180.13	718.28	1556.41	0.27	1.08	2.35
T_9	34.75	62.13	108.08	7.14	8.97	11.97	182.62	732.93	1604.53	0.28	1.11	2.42
T_{10}	34.28	57.92	105.33	6.62	8.43	10.97	167.82	691.07	1456.63	0.25	1.06	2.20

T_{11}	34.92	65.15	117.84	7.39	9.90	13.67	186.75	791.05	1667.03	0.29	1.19	2.52
T_{12}	34.05	54.59	104.67	6.78	8.60	11.33	176.79	700.00	1534.48	0.26	1.04	2.32
T_{13}	36.04	68.53	123.03	8.05	10.50	13.97	201.92	842.02	1801.20	0.31	1.27	2.72
S.Em±	0.79	1.29	1.56	0.18	0.17	0.24	4.66	15.62	40.02	0.01	0.02	0.06
C.D @ 1%	3.11	5.11	6.15	0.70	0.66	0.96	18.44	61.8	158.31	0.02	0.09	0.24

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



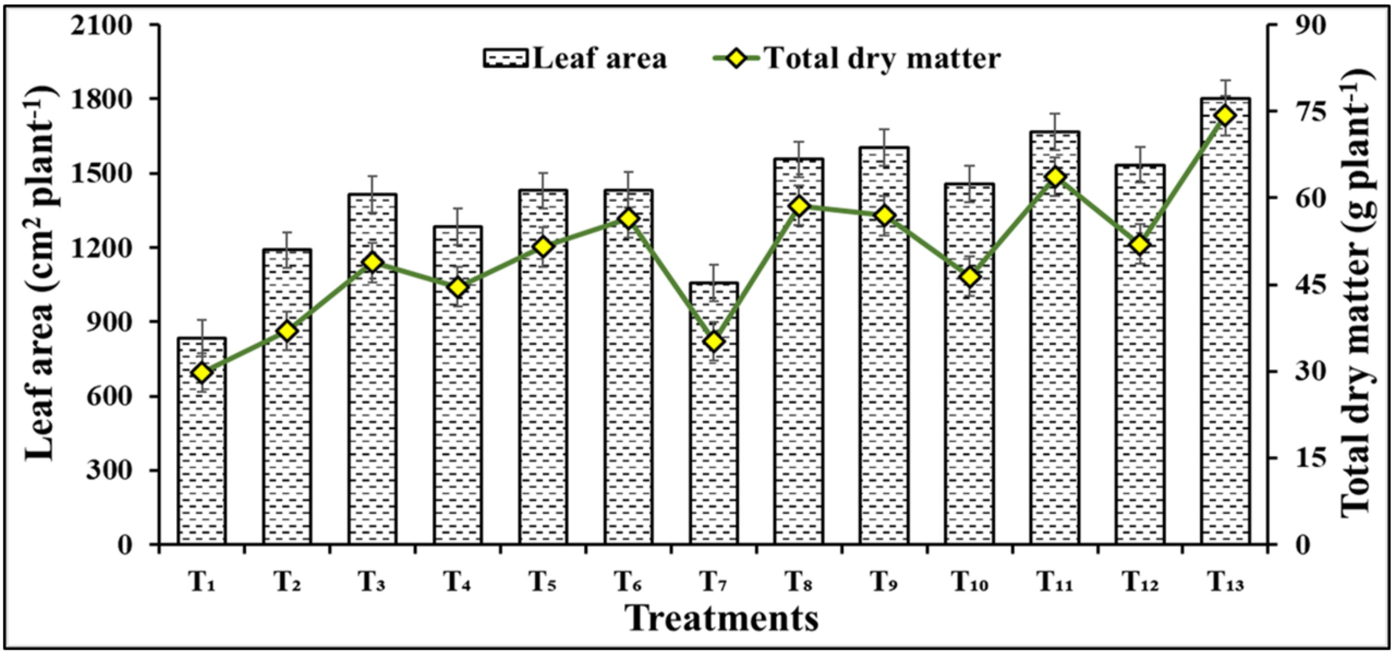
Note:
T_1: Absolute control, T_2: 100% RDN as Urea + RD P&K, T_3: 100% RDN as Amm. sulfate + RD P&K, T_4: Biochar @ 7.5MT ha^{-1} only, T_5: Biochar + 100% RDN as Urea + RD P&K, T_6: Biochar + 100% RDN as Amm. sulfate + RD P&K, T_7: Biochar pellets @ 7.5MT ha^{-1} only, T_8: Biochar pellets @ 7.5MT ha^{-1}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

Fig 1: Average plant height and number of leaves of maize as influenced by various treatments at 60 DAS

Table 3: Effect of treatments on total dry matter, root length and root weight recorded in maize at 60 DAS

Treatment	Total dry matter (g $plant^{-1}$)	Root length (cm)	Root weight (g $plant^{-1}$)
T_1	29.77	28.83	1.60
T_2	36.96	49.62	3.00
T_3	48.86	53.00	4.28
T_4	44.65	54.63	3.77
T_5	51.52	53.90	4.65
T_6	56.51	55.63	5.41
T_7	35.17	46.47	2.26
T_8	58.70	59.67	6.10
T_9	56.94	60.72	6.36
T_{10}	46.44	57.90	3.60
T_{11}	63.70	63.50	6.44
T_{12}	52.01	60.37	3.44
T_{13}	74.27	64.73	6.50
S.Em±	0.70	0.82	0.12
C.D @ 1%	2.77	3.19	0.48

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.



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

Fig 2: Effect of treatments on leaf area and total dry matter in maize at 60 DAS

Table 4: SPAD and NDVI values recorded at different intervals of maize crop growth as influenced by various treatments

Treatment	SPAD Values		NDVI values		
	30 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T_1	27.82	27.07	0.41	0.46	0.35
T_2	27.93	36.48	0.42	0.53	0.42
T_3	32.73	40.07	0.45	0.55	0.47
T_4	32.83	44.58	0.50	0.56	0.50
T_5	34.23	46.17	0.58	0.62	0.55
T_6	35.57	46.62	0.59	0.64	0.56
T_7	32.97	45.52	0.51	0.58	0.51
T_8	36.67	51.47	0.61	0.67	0.63
T_9	36.90	52.35	0.62	0.73	0.64
T_{10}	33.48	46.13	0.52	0.61	0.52
T_{11}	37.16	64.85	0.64	0.74	0.66
T_{12}	35.90	48.83	0.60	0.65	0.62
T_{13}	38.68	67.11	0.66	0.76	0.69
S.Em±	0.41	0.73	0.002	0.02	0.01
C.D @ 1%	1.61	2.89	0.02	0.04	0.04

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.

4. Conclusion

Overall, the outcome of the present study is that application of biochars in different forms had positive effect on the growth parameters, root distributions and leaf chlorophyll content in maize at different stages. Among the different forms of biochars studied, the nitrogen enriched biochar pellets @ 7.5 MT ha^{-1}(either Ammonium sulfate or Urea) along with the recommended doses of P & K fertilizers performed much better and therefore keeping this in view it is suggested to take up field trials on this aspect to acquire in-depth information before utilizing nitrogen enriched biochar pellets in agriculture as a slow releasing nitrogen resource material for sustaining the crop production.

5. References

1. Xiao Q, Zhu LX, Zhang HP, Li XY, Shen YF, Li SQ. Soil amendment with biochar increases maize yields in a semi-arid region by improving soil quality and root growth. Crop Pasture Sci. 2016;67(2):495-507.
2. Hossain MZ, Bahar MM, Sarkar B, Donne SW, Ok YS, Palansooriya KN, *et al*. Biochar and its importance on nutrient dynamics in soil and plant. Biochar.

2020;2(1):379-420.
3. Husk B, Major J. Commercial Scale Agricultural Biochar Field Trial in Quebec, Canada, Over Two Years: Effects of Biochar on Soil Fertility, Biology, Crop Productivity and Quality. Dynamotive Energy Systems. 2008;22(1):1-38.
4. Lee YL, Ahmed OH, Wahid SA, AB Aziz ZF. Biochar tablets with and without embedded fertilizer on the soil chemical characteristics and nutrient use efficiency of maize (*Zea mays* L). Sustainability. 2021;13(9):4878.
5. Saxena MC, Singh Y. A note on area estimation of intact maize leaves. Indian J Agron. 1965;10(4):437-439.
6. Sestak Z, Castky J, Jarris PG. Plant Analysis in Production Manual of Methods (Ed. Jonk, W.), N. V. N. V. Publications, The Hague. 1971;5:343-381.
7. Xu Q, Wang J, Liu Q, Chen Z, Jin P, Du J, *et al*. Long-Term Field Biochar Application for Rice Production: Effects on Soil Nutrient Supply, Carbon Sequestration, Crop Yield and Grain Minerals. Agronomy. 2022;12(8):1924.
8. Li C, Zhao C, Zhao X, Wang Y, Lv X, Zhu X, *et al*. Beneficial effects of Biochar application with nitrogen fertilizer on soil nitrogen retention, absorption and utilization in maize production. Agronomy. 2022;13(1):113.
9. Choudhary TK, Khan KS, Hussain Q, Ashfaq M. Nutrient availability to maize crop (*Zea mays* L.) in biochar amended alkaline subtropical soil. Journal of Soil Science and Plant Nutrition. 2021;21(1):1293-1306.
10. Shi W, Ju Y, Bian R, Li L, Joseph S, Mitchell DR, *et al*. Biochar bound urea boosts plant growth and reduces nitrogen leaching. Sci. Total Environ. 2020;701:134424.
11. Utomo WH, Islami T, Wisnubroto E, Soelistyari HT. Biochar as a carrier for nitrogen plant nutrition: 3. Effect of enriched biochar on rice (*Oryza sativa* L.) yield and soil qualities. Int. J Appl. Eng. Res. 2017;12(20):10426-10432.
12. Tufa A, Hunduma A, Hasan MNS, Asefa F, Nandeshwar BC. Levels of biochar and NPS fertilizer rates on growth, yield component, and yield of maize (*Zea mays* L.) at gusto Gida, western Ethiopia. Adv Agric. 2022;10(1):1-10.
13. Egamberdieva D, Ma H, Reckling M, Omari RA, Wirth S, Bellingrath-Kimura SD. Interactive effects of biochar, nitrogen, and phosphorous on the symbiotic performance, growth, and nutrient uptake of soybean (*Glycine max* L.). Agronomy. 2021;12(1):27.
14. Heng W, Chen Y, Cui B, Liu X, Hou J, Zhenhua Wei, *et al*. Biochar Amendment Increases C and N Retention in the Soil–Plant Systems: Its Implications in Enhancing Plant Growth and Water-Use Efficiency Under Reduced Irrigation Regimes of Maize (*Zea mays* L.). J Soil Sci. Plant Nutr. 2023;23(2):1-13.
15. Xiang Y, Deng Q, Duan H, Guo Y. Effects of biochar application on root traits: A meta-analysis. Global Change Biol. Bioenergy. 2017;9(10):1563-1572.
16. Banik C, Bakshi S, Laird DA, Smith RG, Brown RC. Impact of biochar-based slow-release N-fertilizers on maize growth and nitrogen recovery efficiency. 2023;52(3):630-640.
17. Pushpakumara AWS, Senadheera HRS, Weerakkody WJSK, Ranaweera B, Disanayake DMPS. Enhancement of growth and yield of Maize (*Zea mays* L.) using co compost pellets with biochar, 2020.
18. Ming L, Ying-Dong B, Wei L, Miao L, Ling W, Shu-Feng D, *et al*. Effects of interaction of biochar and nitrogen fertilizer on growth, yield and yield components of soybean. Bangladesh J Bot. 2019;48(4):1001-1010.
19. Harrell DL, Tubana BS, Walker TS, Philips SB. Estimating rice grain yield potential using Normalized Difference Vegetation Index. Agron. J. 2011;103(7):1717-1723.