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Response of groundnut (*Arachis hypogaea* L.) to biochar application with respect to quality parameters, nutrient uptake and soil properties

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Abstract

A field experiment was conducted at Zonal Agricultural and Horticultural Research Station, Navile, Shivamogga during *khariif*-2024 to evaluate the effect of biochar application on quality of groundnut. The experiment was laid out in Randomized Complete Block Design with ten treatments and replicated thrice. Among the different tested treatments application of 7.5 t ha⁻¹ biochar along with 125 per cent recommended dose of fertilizer (T₉) was recorded significantly higher protein content and oil content (25.18% and 50.00%, respectively), protein yield and oil yield (693.00 and 1377.00 kg ha⁻¹, respectively). It also recorded significantly higher nutrients uptake like nitrogen uptake (165.73 kg ha⁻¹), phosphorous uptake (50.99 kg ha⁻¹), potassium uptake (72.52 kg ha⁻¹), sulphur uptake (17.69 kg ha⁻¹), calcium uptake (40.89 kg ha⁻¹) and boron uptake (0.39 kg ha⁻¹), which was statistically on par with the T₆ (7.5 t ha⁻¹ biochar along with 125 per cent recommended dose of fertilizer). In contrast to this the treatment received 2.5 t ha⁻¹ biochar along with 75 per cent recommended dose of fertilizer (T₁) recorded higher available nutrients in the soil like nitrogen (223.00 kg ha⁻¹), P₂O₅ (83.47 kg ha⁻¹), K₂O (259.13 kg ha⁻¹), sulphur (34.91 mg kg⁻¹), exchangeable calcium (4.70 c mol p⁺ kg⁻¹) and boron (0.50 mg kg⁻¹).

Keywords: Biochar, groundnut, quality, recommended dose of fertilizer, nutrient, uptake, physico-chemical

1. Introduction

Groundnut (*Arachis hypogaea* L.) is an important legume crop in the world, known for its high protein content and oil-rich seeds. In addition to having 42-50 per cent oil, 26 per cent protein, 18 per cent carbohydrates, 5 per cent fibre and ash (Noubissié, 2012) ^[16]. Groundnut kernels are rich in riboflavin, thiamine, nicotinic acid, and vitamin E all of which are deficient in cereals. In addition to providing protein and edible oil.

Crop residue management is one of the emerging problems in agriculture sector. Utilization of crop residue is very low now-a-days. Approximately 500-550 million tonnes (Mt) of crop residue are generated on-farm and off-farm annually from its production of 110 Mt of wheat, 122 Mt of rice, 71 Mt of maize, 26 Mt of millets, 141 Mt of sugarcane, 8 Mt of fibre crops (jute, mesta, cotton) and 28 Mt of pulses (Devi *et al.*, 2017) ^[4]. These residues are either partially utilized or unutilized due to various constraints.

Converting waste biomass into biochar would transfer very significant amounts of carbon from the active to inactive carbon pool, presenting a compelling opportunity to intervene in the carbon cycle. The use of biochar as soil amendment is proposed as a new approach to mitigate man-induced climate change along with improving soil productivity which turns biochar as a useful produce and using it as soil amendment is a nascent approach, an alternative to composting and crop residue burning.

One of the major causes of soil health degradation is excessive and continuous use of chemical fertilizers. The repeated application of nitrogenous fertilizers, particularly urea and ammonium sulphate, leads to soil acidification, which reduces the availability of essential nutrients and negatively impacts beneficial microorganisms. Over-reliance on chemical fertilizers also causes a decline in soil organic matter, resulting in poor soil structure, reduced water-holding capacity, and lower aeration.

In addition, the imbalance of nutrients due to the preferential use of specific fertilizers can lead to deficiencies of secondary and micronutrients such as calcium, magnesium, and zinc. Continuous fertilizer use may also increase soil salinity, impairing plant root growth and nutrient uptake. Moreover, chemical fertilizers disrupt the biological balance of the soil, reducing microbial diversity and enzymatic activity essential for nutrient cycling. Overall, indiscriminate use of chemical fertilizers contributes to soil degradation, loss of fertility, and long-term decline in soil productivity (Savci, 2012) ^[18].

One of the effective approaches to improving soil health is the application of soil amendments such as biochar. Biochar is defined as charcoal obtained when organic materials are burned under low pressure and high temperature (300-400°C) condition through pyrolysis process under low or absence of oxygen. It is a fine-grained charcoal, high in organic carbon and largely resistant to decomposition. Biochar is the carbon rich product. It is also highly porous charcoal substance. Biochar can act as a soil conditioner by improving the physical and biological properties of soils such as water holding capacity, soil nutrients retention, enhance nutrient availability, improves soil structure, increase cation exchange capacity, regulates soil pH, reduce soil bulk density, enhance carbon sequestration, improves soil fertility in the long term and thereby enhancing plant growth. As biochar is broadly stable in soil, it has potential to provide a direct and long-term modification to soil water holding capacity through its often-microporous nature (Glaser *et al.*, 2002) ^[6]. The ability of biochar to increase the capacity of soils to absorb and store water makes it all important.

Biochar application to soil has beneficial effect on crop productivity and quality through increased nutrient use efficiency, increased water holding capacity and decreased bulk density. It is well known that the quantity, quality and distribution of soil amendments affect the structure of the soil. If the biochar becomes widely used for soil improvement tool, it will involve globally significant amounts of carbon sequestration helping remediate global warming. Keeping in the purview of the gaps in groundnut yield, quality, nutrient uptake and available soil nutrients a field experiment was conducted to know the effect of biochar application on quality of groundnut, nutrients uptake and physico-chemical properties of soil.

2. Materials and Methods

2.1 Site description

The experiment was conducted at Zonal Agricultural and Horticultural Research Station, Shivamogga during *Kharif* 2024. The research station is situated in the Southern Transition Zone (Zone-7) of Karnataka state at 13°58' North longitude and 75°34' East longitude with an altitude of 569 meters above mean sea level. The investigation site had sandy loam in texture, slightly acidic pH (6.3) and non-saline (EC: 0.42 dSm⁻¹), low in organic carbon (0.45%), medium in available nitrogen (290.02 kg ha⁻¹), medium in available phosphorus (40.05 kg ha⁻¹), medium in available potassium (270.15 kg K₂O ha⁻¹), medium in available sulphur (mg kg⁻¹), medium in exchangeable calcium (cmol p⁺ kg⁻¹) and low in available boron (mg kg⁻¹).

2.2 Experimental details

The field experiment was conducted in Randomized Completely Block Design (RCBD) involving ten treatments and 3 replications with plot size of 4.5 m × 4.0 m respectively. The treatments comprised of 2.5 t ha⁻¹ Biochar + 75 per cent

Recommended dose of fertilizer (T₁), 2.5 t ha⁻¹ Biochar + 100 per cent Recommended dose of fertilizer (T₂), 2.5 t ha⁻¹ Biochar + 125 per cent Recommended dose of fertilizer (T₃), 5 t ha⁻¹ Biochar + 75 per cent Recommended dose of fertilizer (T₄), 5 t ha⁻¹ Biochar + 100 per cent Recommended dose of fertilizer (T₅), 5 t ha⁻¹ Biochar + 125 per cent Recommended dose of fertilizer (T₆), 7.5 t ha⁻¹ Biochar + 75 per cent Recommended dose of fertilizer (T₇), 7.5 t ha⁻¹ Biochar + 100 per cent Recommended dose of fertilizer (T₈), 7.5 t ha⁻¹ Biochar + 125 per cent Recommended dose of fertilizer (T₉) and control (Package of practice) (T₁₀). Seeds of groundnut (Var. GPBD - 4) were sown in 30 × 10 cm spacing. FYM and biochar (Coconut biochar was used for experiment as a source of biochar) were applied 15 days before sowing. At the time of sowing fertilizers applied (25:75:37.5 kg ha⁻¹ of (N: P₂O₅: K₂O), Gypsum - 500 kg ha⁻¹ FYM - 10 t ha⁻¹, 10 kg ha⁻¹ of Zinc sulphate and Borax) at different rates as per the treatment requirements using urea, Diammonium phosphate, muriate of potash, Gypsum (applied at 45 DAS), Zinc sulphate and Borax as source.

2.3 Collection of experimental data

Quality parameters *i.e.*, protein content (%), oil content (%), protein yield (kg ha⁻¹), oil yield (kg ha⁻¹). Seed samples from each treatment were ground into a fine powder. About 0.2 g ground seed material was taken for the estimation of nitrogen by Micro Kjeldahl's method. (Jackson, 1973). The total protein in the sample was calculated by multiplying the nitrogen content in the seed with a conversion factor of 5.46 and then expressed in percentage (Merrill, A. L. And Watt, B. K., 1955) ^[13]. Approximately 15 g of kernels taken randomly from each treatment were oven-dried at 55°C temperature and oil content was estimated by Nuclear magnetic resonance (NMR) (Ramamurthi *et al.*, 1985) ^[17].

Representative soil samples from 0 to 15 cm depth were collected before land preparation in the experimental site for analysis before the commencement of the experiment and analysed for different physico-chemical properties by standard procedures. Similarly, representative samples from each treatment plot at 0 to 15 cm depth were collected after the harvest of the crop and brought to the laboratory, air dried and ground using wooden pestle and mortar, passed through 2 mm sieve and stored in an airtight container for further analysis. Soil samples were analysed for pH, EC (Electric conductivity), OC (Organic carbon), Available N, P, K, Ca, S and B.

Plant samples were collected from the field at the time of harvest and dried at 65 °C in a hot air oven till the constant weight was achieved. After complete drying, the samples were powdered with the help of a grinder and preserved in airtight polythene bags. The powdered plant samples were subjected to digestion. The digested plant sample was used for further analysis of nitrogen, phosphorous, potassium, calcium, sulphur and boron content.

2.4 Statistical analysis: The data recorded on various observations on quality parameters, nutrient uptake by the crop and available nutrients status in the soil were subjected to analysis of variance (ANOVA) as outlined by Gomez and Gomez 1984. The level of significance used in the 'F' test was at 5 per cent. The critical difference (CD) values were given in the table at 5 per cent level of significance, wherever the 'F' test was significant. Otherwise against CD values abbreviation NS (Non-significant) was indicated.

3. Results and Discussion

3.1 Quality parameters

3.1.1 Protein content (%) and protein yield (kg ha⁻¹)

The data on the protein content and protein yield as influenced by application of biochar at different levels on groundnut after harvest are furnished in Table 1. Application of 7.5 t ha⁻¹ biochar along with 125 per cent recommended dose of fertilizer (T₉) has recorded significantly higher protein content (25.18%) and protein yield (693.00 kg ha⁻¹) which was found to statistically on par with the treatment (T₆) received 5 t ha⁻¹ biochar applied along with 125 per cent recommended dose of fertilizer (25.00% and 681.00 kg ha⁻¹, respectively). Significantly higher protein content and protein yield in biochar-treated plots result from improved soil fertility, nutrient availability, and plant metabolism. Biochar enhances nitrogen and sulphur retention, supports amino acid and protein synthesis, improves soil structure and moisture, and promotes root growth and nodulation. This boosts Biological Nitrogen Fixation, leading to greater nitrogen uptake and higher protein accumulation in plants and kernels leading to a significant enhancement in protein content and overall protein yield. Equivalent results were observed by Vallabhbai *et al.* (2020) [21]. In contrast, the treatment received 2.5 t ha⁻¹ biochar and 75 per cent recommended dose of fertilizer (T₁) treatment recorded a significantly lower protein content (21.10% and 467.00 kg ha⁻¹, respectively).

3.1.2 Oil content (%) and Oil yield (kg ha⁻¹)

The data on the oil content and oil yield as influenced by application of biochar at different levels on groundnut after harvest are furnished in Table 1. Application of 7.5 t ha⁻¹ biochar along with 125 per cent recommended dose of fertilizer (T₉) has recorded significantly higher oil content (50.00%) and oil yield (1377.00 kg ha⁻¹) which was found to statistically on par with the treatment (T₆) received 5 t ha⁻¹ biochar applied along with 125 per cent recommended dose of fertilizer (49.34% and 1345.00 kg ha⁻¹, respectively). The increase in oil content and oil yield can be primarily attributed to the enhanced formation of glucosides, such as allyl isothiocyanate. The application of biochar improves soil conditions, soil fertility and nutrient availability, particularly of phosphorus, potassium, and micronutrients essential for lipid biosynthesis. These favourable conditions support enhanced photosynthetic activity and efficient assimilation of carbohydrates, which are precursors for oil synthesis, which may stimulate the biosynthesis of these glucoside compounds. This biochemical enhancement contributes to greater oil accumulation within the seeds, thereby resulting in higher oil content and overall oil yield. The observations matched with previous reports reported by Gowthami *et al.* (2019) [8]. In contrast, the treatment received 2.5 t ha⁻¹ biochar and 75 per cent recommended dose of fertilizer (T₁) treatment recorded significantly lower oil content (44.09% and 976.00 kg ha⁻¹, respectively).

3.2 Nutrient uptake by the crop

3.2.1 Nitrogen uptake (kg ha⁻¹)

The data relevant to the total nitrogen uptake by groundnut crop are furnished in Table 2. Application of 7.5 t ha⁻¹ biochar along with 125 per cent recommended dose of fertilizer (T₉) recorded significantly higher total nitrogen uptake (165.73 kg ha⁻¹), which was statistically on par with the treatment (T₆) received 5 t ha⁻¹ biochar applied along with 125 per cent recommended dose of fertilizer with total nitrogen uptake (165.36 kg ha⁻¹). This might be due to that the inorganic nitrogen acts as an immediate source

of nitrogen for plant growth and also biochar promotes mineralization of native organic matter by meeting the nitrogen requirement of decomposers. Higher nitrogen uptake of plants throughout the growing season in biochar applied treatments might be due to controlled supply of nitrogen from added fertilisers and encouraging BNF and also reduction of leaching due to biochar application might have played a crucial role in improving nitrogen retention and subsequently improved nitrogen uptake by the groundnut plant. Laxman Rao *et al.* (2017) [12] also supported the improvement in nitrogen uptake with the biochar addition which was due to multiplication effect of higher nitrogen absorption as well as high biomass production. In contrast, the treatment (T₁) received 2.5 t ha⁻¹ biochar and 75 per cent recommended dose of fertilizer recorded a significantly lower total nitrogen uptake (139.54 kg ha⁻¹).

3.2.2 Phosphorous uptake (kg ha⁻¹)

The data relevant to the total phosphorous uptake by groundnut crop are furnished in Table 2. Application of 7.5 t ha⁻¹ biochar along with 125 per cent recommended dose of fertilizer (T₉) recorded significantly higher total phosphorous uptake (50.99 kg ha⁻¹), which was statistically on par with the treatment (T₆) received 5 t ha⁻¹ biochar applied along with 125 per cent recommended dose of fertilizer with total phosphorous uptake (50.06 kg ha⁻¹). Significantly higher phosphorus uptake might be due to high biomass production. Significant increase in phosphorus uptake with the biochar addition was also supported by Supriyadi *et al.* (2012) [20] and reported that priming effects, competitive sorption processes or improvement of root growth might have contributed to the increased P recovery and its uptake by the plant. In contrast, the treatment (T₁) received 2.5 t ha⁻¹ biochar and 75 per cent recommended dose of fertilizer recorded a significantly lower total phosphorous uptake (36.46 kg ha⁻¹).

3.2.3 Potassium uptake (kg ha⁻¹)

The data relevant to the total potassium uptake by groundnut crop are furnished in Table 2. The application of 7.5 t ha⁻¹ biochar along with 125 per cent recommended dose of fertilizer (T₉) recorded significantly higher total potassium uptake (72.52 kg ha⁻¹), which was statistically on par with the treatment (T₆) received 5 t ha⁻¹ biochar applied along with 125 per cent recommended dose of fertilizer with total potassium uptake (72.16 kg ha⁻¹). The increase in potassium uptake might be due to higher cation exchange capacity of biochar decreased the losses of potassium and thus increased its uptake. When biochar was added to the soil its surface oxidation by biotic and abiotic agents resulted in development of negative charges that give ability to biochar to sorbs more cations like potassium which leads to increase in uptake of nutrients easily. The results validated prior research conducted by Abrishamkesh *et al.* (2015) [1]. In contrast, the treatment (T₁) received 2.5 t ha⁻¹ biochar and 75 per cent recommended dose of fertilizer recorded a significantly lower total potassium uptake (51.92 kg ha⁻¹).

3.2.4 Sulphur uptake (kg ha⁻¹)

The data relevant to the total sulphur uptake by groundnut crop are furnished in Table 3. The application of 7.5 t ha⁻¹ biochar along with 125 per cent recommended dose of fertilizer (T₉) recorded significantly higher total sulphur uptake (17.69 kg ha⁻¹), which was statistically comparable to the treatment (T₆) received 5 t ha⁻¹ biochar applied along with 125 per cent recommended dose of fertilizer with total sulphur uptake (17.56 kg ha⁻¹). The increased sulphur uptake might be due to that in

almost all the treatments application of gypsum supplied sulphur to the plant tissues and hence increased its uptake. The enhanced nutrient retention capacity of biochar incorporated in soil coupled with inorganic fertilizers had enhanced the dry matter production which in turn resulted in higher sulphur uptake. These findings were congruent with earlier reports by Gowthami *et al.* (2019)^[8] In contrast, the treatment (T₁) received 2.5 t ha⁻¹ biochar and 75 per cent recommended dose of fertilizer recorded a significantly lower total sulphur uptake (8.92 kg ha⁻¹).

3.2.5 Calcium uptake (kg ha⁻¹)

The data relevant to the total calcium uptake by groundnut crop are furnished in Table 3. The application of 7.5 t ha⁻¹ biochar along with 125 per cent recommended dose of fertilizer (T₉) recorded significantly higher total calcium uptake (40.89 kg ha⁻¹), which was statistically comparable to the treatment (T₆) received 5 t ha⁻¹ biochar applied along with 125 per cent recommended dose of fertilizer with total calcium uptake (40.69 kg ha⁻¹). The increased calcium uptake might be due to that in biochar-treated soils, groundnut plants exhibit higher calcium uptake due to a combination of factors: biochar's ash fraction contains calcium that directly adds to the soil's nutrient pool, increasing available calcium levels. Simultaneously, biochar raises soil pH (the "liming effect") and enhances cation exchange capacity (CEC), which together improved calcium retention and reduce leaching, making Ca more accessible to plant roots. These findings were congruent with earlier reports by Nguyen *et al.* (2012)^[14]. In contrast, the treatment (T₁) received 2.5 t ha⁻¹ biochar and 75 per cent recommended dose of fertilizer recorded a significantly lower total calcium uptake (25.26 kg ha⁻¹).

3.2.6 Boron uptake (kg ha⁻¹)

The data relevant to the total boron uptake by groundnut crop are furnished in Table 3. The application of 7.5 t ha⁻¹ biochar along with 125 per cent recommended dose of fertilizer (T₉) recorded significantly higher total boron uptake (0.39 kg ha⁻¹), which was statistically comparable to the treatment (T₆) received 5 t ha⁻¹ biochar applied along with 125 per cent recommended dose of fertilizer with total boron uptake (0.37 kg ha⁻¹). In soils amended with biochar, groundnut plants often show enhanced boron uptake because biochar improves crucial soil properties and nutrient retention: it's high porosity and negative surface charge along with increased cation exchange capacity (CEC) help retain soluble boron and reduce leaching in sandy or acidic soils, which typically lose boron rapidly. Although boron is primarily taken up in the form of boric acid or borate depending on soil pH biochar's effect in raising pH can shift boron into forms more amenable to plant absorption. The results reflected those of earlier investigations by Barik *et al.* (2006)^[3]. In contrast, the treatment (T₁) received 2.5 t ha⁻¹ biochar and 75 per cent recommended dose of fertilizer recorded a significantly lower total boron uptake (0.15 kg ha⁻¹).

3.3 Soil chemical properties and nutrient availability

3.3.1 Soil reaction (pH)

The data presented in the Table 4. indicated that there was no significant effect on soil pH. There was increase in soil pH over control by the application of biochar. With application of biochar there was increase in soil pH (T₉ - 6.51) over control (T₁₀ - 6.13) might be due to alkaline nature of biochar. Increase in soil pH with biochar addition might be due to high porous nature of biochar that increases the cation exchange capacity of soil and enhances the Fe and Al to bind with the exchange sites of biochar which in turn decreased the exchangeable Al and

soluble Fe in biochar amended soil was observed by Nigussie *et al.* (2012)^[15]. Increase in soil pH with application of biochar might be due to release of basic cations to soil Habibullah and Alam. (2018)^[9].

3.3.2 Electrical conductivity (EC)

The data presented in the Table 4. indicated that there was no significant effect on soil EC. Increase in soil EC over control by the application of biochar. The increase in EC (T₉ - 0.60 dS m⁻¹) over control (T₁₀ - 0.50 dS m⁻¹) with the application of biochar might be due to ash residues in biochar which was dominated by carbonates of alkali and alkaline earth metals (Nigussie *et al.*, 2012)^[15]. Elangovan and Chandrasekharan (2014)^[5] were observed that the increase in EC of soil by application of biochar might be due to non-saline nature of biochar and presence of more alkali salts.

3.3.3 Organic carbon (%)

The organic carbon content of soil was significantly influenced with the addition of biochar (Table 4.). The organic carbon content was highest in the soil treated with biochar. Significantly highest organic carbon content was recorded (0.56%) in T₉ treatment which received 7.5 t ha⁻¹ biochar along with 125 per cent recommended dose of fertilizer and this was on par with treatment received 7.5 t ha⁻¹ biochar applied along with 100 per cent recommended dose of fertilizer. The Lowest organic carbon content was recorded (0.45%) in treatment T₁₀ (Control). Elangovan and Chandrasekharan (2014)^[5] reported that biochar itself is a matrix of organic complex and its application to soil system increases soil organic carbon. Increase in carbon content might be due to the carbon content of the applied biochar, which released carbon into the soil system from its labile pools and also due to mineralization of organic matter adsorbed by biochar particles.

3.3.4 Soil Available nutrients status: Effect of biochar on soil available nitrogen, phosphorous, potassium, sulphur, calcium and boron were presented in Table 5 and Table 6. After harvesting, higher levels of soil nitrogen (N), phosphorous (P), potassium (K), sulphur (S), calcium (Ca) and boron (B) was found under the treatment (T₁) received 2.5 t ha⁻¹ biochar applied along with 75 per cent recommended dose of fertilizer (223.00 kg ha⁻¹, 83.47 kg ha⁻¹, 259.13 kg ha⁻¹, 34.91 mg kg⁻¹, 4.70 c mol p⁺ kg⁻¹ and 0.50 mg kg⁻¹ of nitrogen, phosphorous, potassium, sulphur, calcium and boron respectively). These findings suggest that nutrient accumulation in the soil is higher due to reduced plant uptake and the fixation of applied nutrients. In contrast, treatment (T₉) with 7.5 t ha⁻¹ biochar along with 125 per cent recommended dose of fertilizer (195.31 kg ha⁻¹, 71.67 kg ha⁻¹, 239.68 kg ha⁻¹, 30.10 mg kg⁻¹, 2.69 c mol p⁺ kg⁻¹ and 0.35 mg kg⁻¹ of N, P, K, S, Ca and B respectively). This treatment yielded higher results compared to using only the recommended dose of fertilizers while keeping soil nutrient levels similar to those with the recommended dose. The stable soil health observed can be attributed to the improved nutrient availability achieved by combining conventional fertilizers with biochar. Biochar offers a slow release of nutrients, which maintains their availability to crops throughout the growth cycle. This gradual nutrient release helps minimize losses due to denitrification, volatilization, and leaching and soil fixation. The controlled release and delivery of nutrients ensure a continuous supply of essential nutrients over time minimize losses due to denitrification, volatilization, leaching and soil fixation. The results corresponded with previous observations made by Husien *et al.* (2017)^[10] and Siva Devika *et al.* (2018)^[19].

Table 1: Quality parameters (Protein content, Protein yield, Oil content and Oil yield) of groundnut as influenced by biochar application

Treatments	Protein content (%)	Protein yield (kg ha ⁻¹)	Oil content (%)	Oil yield (kg ha ⁻¹)
T ₁ = Biochar 2.5 t ha ⁻¹ + 75% RDF	21.10	467.00	44.09	976.00
T ₂ = Biochar 2.5 t ha ⁻¹ + 100% RDF	22.59	553.00	45.23	1108.00
T ₃ = Biochar 2.5 t ha ⁻¹ + 125% RDF	23.43	594.00	46.84	1187.00
T ₄ = Biochar 5 t ha ⁻¹ + 75% RDF	21.82	509.00	44.88	1047.00
T ₅ = Biochar 5 t ha ⁻¹ + 100% RDF	22.94	570.00	45.62	1134.00
T ₆ = Biochar 5 t ha ⁻¹ + 125% RDF	25.00	681.00	49.34	1345.00
T ₇ = Biochar 7.5 t ha ⁻¹ + 75% RDF	22.17	530.00	45.01	1075.00
T ₈ = Biochar 7.5 t ha ⁻¹ + 100% RDF	23.34	585.00	46.63	1170.00
T ₉ = Biochar 7.5 t ha ⁻¹ + 125% RDF	25.18	693.00	50.00	1377.00
T ₁₀ = Control (POP)	21.36	485.00	44.41	1008.00
SEm. ±	0.44	11.93	0.77	26.84
C.D. at 5%	1.29	113.00	2.24	113.00

Table 2: Total Nitrogen, Phosphorous and Potassium uptake (kg ha⁻¹) by the groundnut crop as influenced by biochar application

Treatments	Nitrogen uptake (kg ha ⁻¹)	Phosphorous uptake (kg ha ⁻¹)	Potassium uptake (kg ha ⁻¹)
T ₁ = Biochar 2.5 t ha ⁻¹ + 75% RDF	139.54	36.46	51.92
T ₂ = Biochar 2.5 t ha ⁻¹ + 100% RDF	153.52	43.72	61.85
T ₃ = Biochar 2.5 t ha ⁻¹ + 125% RDF	161.56	47.85	68.70
T ₄ = Biochar 5 t ha ⁻¹ + 75% RDF	146.23	40.07	55.82
T ₅ = Biochar 5 t ha ⁻¹ + 100% RDF	157.28	45.82	64.91
T ₆ = Biochar 5 t ha ⁻¹ + 125% RDF	165.36	50.06	72.16
T ₇ = Biochar 7.5 t ha ⁻¹ + 75% RDF	149.82	41.91	58.57
T ₈ = Biochar 7.5 t ha ⁻¹ + 100% RDF	161.29	47.74	68.33
T ₉ = Biochar 7.5 t ha ⁻¹ + 125% RDF	165.73	50.99	72.52
T ₁₀ = Control (POP)	142.74	38.19	53.41
SEm. ±	0.62	0.34	0.51
C.D. at 5%	1.81	0.99	1.50

Table 3: Total Sulphur, Calcium and Boron uptake (kg ha⁻¹) by the groundnut crop as influenced by biochar application

Treatments	Sulphur uptake (kg ha ⁻¹)	Calcium uptake (kg ha ⁻¹)	Boron uptake (kg ha ⁻¹)
T ₁ = Biochar 2.5 t ha ⁻¹ + 75% RDF	8.92	25.26	0.15
T ₂ = Biochar 2.5 t ha ⁻¹ + 100% RDF	13.10	32.27	0.24
T ₃ = Biochar 2.5 t ha ⁻¹ + 125% RDF	15.98	37.58	0.33
T ₄ = Biochar 5 t ha ⁻¹ + 75% RDF	11.14	27.76	0.19
T ₅ = Biochar 5 t ha ⁻¹ + 100% RDF	14.30	34.76	0.27
T ₆ = Biochar 5 t ha ⁻¹ + 125% RDF	17.56	40.69	0.37
T ₇ = Biochar 7.5 t ha ⁻¹ + 75% RDF	11.79	30.06	0.23
T ₈ = Biochar 7.5 t ha ⁻¹ + 100% RDF	15.88	37.39	0.32
T ₉ = Biochar 7.5 t ha ⁻¹ + 125% RDF	17.69	40.89	0.39
T ₁₀ = Control (POP)	9.95	25.75	0.18
SEm. ±	0.27	0.54	0.01
C.D. at 5%	0.79	1.57	0.03

Table 4: Soil chemical properties (pH, EC and OC) after harvest of groundnut as influenced by biochar application

Treatments	pH	Electric conductivity (dS m ⁻¹)	Organic carbon (%)
T ₁ = Biochar 2.5 t ha ⁻¹ + 75% RDF	6.40	0.50	0.49
T ₂ = Biochar 2.5 t ha ⁻¹ + 100% RDF	6.42	0.55	0.50
T ₃ = Biochar 2.5 t ha ⁻¹ + 125% RDF	6.43	0.58	0.51
T ₄ = Biochar 5 t ha ⁻¹ + 75% RDF	6.44	0.53	0.52
T ₅ = Biochar 5 t ha ⁻¹ + 100% RDF	6.45	0.56	0.52
T ₆ = Biochar 5 t ha ⁻¹ + 125% RDF	6.46	0.59	0.53
T ₇ = Biochar 7.5 t ha ⁻¹ + 75% RDF	6.47	0.54	0.54
T ₈ = Biochar 7.5 t ha ⁻¹ + 100% RDF	6.49	0.57	0.55
T ₉ = Biochar 7.5 t ha ⁻¹ + 125% RDF	6.51	0.60	0.56
T ₁₀ = Control (POP)	6.13	0.51	0.45
SEm. ±	0.18	0.03	0.01
C.D. at 5%	NS	NS	0.03

Table 5: Available nutrients (Nitrogen, P₂O₅ and K₂O kg ha⁻¹) status in the soil after harvest of groundnut as influenced by biochar application

Treatments	Available Nitrogen (kg ha ⁻¹)	Available P ₂ O ₅ (kg ha ⁻¹)	Available K ₂ O (kg ha ⁻¹)
T ₁ = Biochar 2.5 t ha ⁻¹ + 75% RDF	223.00	83.47	259.13
T ₂ = Biochar 2.5 t ha ⁻¹ + 100% RDF	203.32	77.50	249.17
T ₃ = Biochar 2.5 t ha ⁻¹ + 125% RDF	198.04	73.68	243.32
T ₄ = Biochar 5 t ha ⁻¹ + 75% RDF	211.07	80.86	253.15
T ₅ = Biochar 5 t ha ⁻¹ + 100% RDF	200.03	75.83	246.51
T ₆ = Biochar 5 t ha ⁻¹ + 125% RDF	196.36	72.02	241.00
T ₇ = Biochar 7.5 t ha ⁻¹ + 75% RDF	207.68	79.10	252.16
T ₈ = Biochar 7.5 t ha ⁻¹ + 100% RDF	198.69	74.01	244.04
T ₉ = Biochar 7.5 t ha ⁻¹ + 125% RDF	195.31	71.67	239.68
T ₁₀ = Control (POP)	221.00	82.17	256.20
SEm. ±	0.53	0.39	0.97
C.D. at 5%	1.56	1.13	2.83

Table 6: Available Sulphur (mg kg⁻¹), Boron (mg kg⁻¹) and Exchangeable Calcium (c mol p⁺ kg⁻¹) in the soil after harvest of groundnut as influenced by biochar application

Treatments	Available Sulphur (mg kg ⁻¹)	Available Boron (mg kg ⁻¹)	Exchangeable Calcium (c mol p ⁺ kg ⁻¹)
T ₁ = Biochar 2.5 t ha ⁻¹ + 75% RDF	34.91	0.50	4.70
T ₂ = Biochar 2.5 t ha ⁻¹ + 100% RDF	33.13	0.44	3.87
T ₃ = Biochar 2.5 t ha ⁻¹ + 125% RDF	31.40	0.39	3.14
T ₄ = Biochar 5 t ha ⁻¹ + 75% RDF	34.34	0.46	4.32
T ₅ = Biochar 5 t ha ⁻¹ + 100% RDF	32.57	0.43	3.41
T ₆ = Biochar 5 t ha ⁻¹ + 125% RDF	30.70	0.37	2.90
T ₇ = Biochar 7.5 t ha ⁻¹ + 75% RDF	33.73	0.46	4.15
T ₈ = Biochar 7.5 t ha ⁻¹ + 100% RDF	32.02	0.40	3.26
T ₉ = Biochar 7.5 t ha ⁻¹ + 125% RDF	30.10	0.35	2.69
T ₁₀ = Control (POP)	35.43	0.48	4.49
SEm. ±	0.04	0.01	0.01
C.D. at 5%	0.13	0.02	0.02

4. Conclusion

The application of biochar significantly improved the quality parameters of groundnut. The treatment involving 7.5 t ha⁻¹ biochar combined with 125 per cent of the recommended dose of fertilizer (T₉) played a crucial role in enhancing quality parameters like protein content and oil content of groundnut. While this treatment was also found to be recorded higher nutrients (N, P, K, S, Ca and B) uptake by the crop compared to the recommended dose of fertilizer alone. In contrast to this the higher available nutrients (N, P, K, S, Ca and B) were recorded in treatment received 2.5 t ha⁻¹ biochar combined with 125 per cent of the recommended dose of fertilizer (T₁).

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References

1. Abrishamkesh S, Gorji M, Marandi GH, Pourbabaee AA. Effects of rice husk biochar application on the properties of alkaline soil and lentil growth. *Plant Soil and Environment*. 2015;61(11):475-482.
2. Anonymous. Directorate of Economics and Statistics. Government of India, New Delhi; 2024.
3. Barik AK, Das A, Giri AK, Chattopadhyay GN. Effect of integrated plant nutrient management on growth, yield and production economics of wet season rice. *Indian Journal of Agricultural Sciences*. 2006;76(11):657-660.
4. Devi S, Gupta C, Jat SL, Parmar MS. Crop residue recycling for economic and environmental sustainability: The case of India. *Open Agriculture*. 2017;2(1):486-494.
5. Elangovan R, Chandrasekharan N. Effect of biochar application on soil properties and quality parameters in cotton. *Asian Journal of Social Sciences*. 2014;9(1):1-10.
6. Glaser B, Lehmann J, Zech W. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal: A review. *Biology and Fertility of Soils*. 2002;35:219-230.
7. Gomez KA, Gomez AA. Data that violate some assumptions of the analysis of variance. In: Gomez KA, Gomez AA, editors. *Statistical procedures for agricultural research*. 2nd ed. New York: John Wiley and Sons; 1984. p. 294-315.
8. Gowthami B, Murthy PG, Rao CS, Rekha MS. Effect of biochar on soil quality index in red sandy loam soils under rabi groundnut crop of North coastal Andhra Pradesh. *Pharma Innovation Journal*. 2019;8(11):171-175.
9. Habibullah, Alam S. Impact of biochar and nitrogen application on soil physicochemical attributes at various growth stages of maize and subsequent wheat crop. *Sarhad Journal of Agriculture*. 2018;34(2):368-377.
10. Husien A, Bedadi B, Dechassa N. Effect of biochar, farmyard manure and nitrogen fertilizers on soil chemical properties in Sinana district, South eastern Oromia, Ethiopia. *International Journal of Applied Agricultural Sciences*. 2017;3(6):148-153.
11. Jackson ML. *Soil chemical analysis*. New Delhi: Prentice Hall of India; 1973.
12. Laxman Rao P, Jayasree G, Prathiba G, Ram Prakash T. Effect of soil amendments on dry matter production, nutrient uptake and yield in maize (*Zea mays* L.). *Environment and Ecology*. 2017;35(3A):1898-1902.
13. Merrill AL, Watt BK. *Energy value of foods: Basis and derivation*. Washington (DC): Human Nutrition Research Branch, Agricultural Research Service, US Department of

Agriculture; 1955.

14. Nguyen H, Blair G, Guppy C. Effect of rice husk biochar and nitrification inhibitor treated urea on nitrogen and other macronutrient uptake by maize. In: Proceedings of the 16th ASA Conference; 2012 Oct 14-18; Armidale, Australia.
15. Nigussie A, Kissi E, Misganaw M, Ambaw G. Effect of biochar application on soil properties and nutrient uptake of lettuces (*Lactuca sativa*) grown in chromium polluted soils. American-Eurasian Journal of Agricultural and Environmental Sciences. 2012;12(3):369-376.
16. Noubissié TJB, Njintang NY, Dolinassou S. Heritability studies of protein and oil contents in groundnut (*Arachis hypogaea* L.) genotypes. International Journal of Innovative Bio-Sciences. 2012;2(3):162-171.
17. Ramamurthi J, Madhusudana Raju S, Shubhada PB. Analysis of oil content of groundnuts by nuclear magnetic resonance spectrometry. Journal of the Science of Food and Agriculture. 1985;36:162-166.
18. Savci S. An agricultural pollutant: Chemical fertilizer. International Journal of Environmental Science and Development. 2012;3(1):73-80.
19. Siva Devika O, Ratna Prasad P, Prasuna Rani P, Lakshmi Pathy R. Nutrient status of soils influenced by the interaction of biochar and FYM with chemical fertilizers. Pharma Innovation Journal. 2018;7(10):708-711.
20. Supriyadi S, Cowie AL, Guppy C, McLeod MK, Daniel H. Effect of biochar on phosphorus uptake from two acid soils. In: Proceedings of the 16th ASA Conference; 2012; Armidale, Australia.
21. Vallabhbhai HK. Influence of biochar on growth, yield and quality of summer sesame (*Sesamum indicum* L.) and soil properties [MSc thesis]. Junagadh: Junagadh Agricultural University; 2020.