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RESEARCH PAPER

Effect of biochar-based rhizobium biofertilizer on groundnut production

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Key Message: The study demonstrates that biochar-based biofertilizers significantly enhance groundnut (*Arachis hypogaea* L.) production compared to traditional synthetic fertilizers. The combination of biochar with half the recommended nitrogen/phosphorus resulted in superior yield parameters, while maintaining soil health. This approach offers a promising, eco-friendly alternative to synthetic fertilizers for improving groundnut yield.

Abstract

Groundnut (*Arachis hypogaea* L) belongs to the leguminosae family and is cultivated as cash and oil crop. To obtain its high yield, synthetic fertilizers are being used, but they have negative effects on soil microbes including Rhizobium. To resolve this issue, the use of biofertilizer instead of synthetic fertilizer is an alternative option. Therefore, this study was planned to use biochar-based biofertilizers for groundnut production. Quality parameters of biochar based biofertilizers were observed. The four treatments T1 (Control), T2 (Recommended fertilizer N/P 30-100 kg ha^{-1}), T3 (Biochar + Half N/P 15-50 kg ha^{-1}) and T4 (Biochar) were used for the production of groundnut (*Arachis hypogaea* L.) variety "Bari 2016". The quality parameters results revealed that after six months, the number of cells reduced from 10^6/g carrier to 10^4/g carrier and moisture content from 40% to 16% while there was no change in pH (7). In a field experiment, Data indicated that T3 (Biochar + Half N/P 15-50 kg ha^{-1}) showed the best results as compared to other treatments. T3 showed the maximum number of pods per plot (633), pods per plant (64), mature pods (59), and immature pods (5). Out of 59 mature pods, T3 showed 58 filled pods and 1 unfilled pod. Among 58 filled pods, T3 showed 15 pods had 1 seed, 19 pods had 2 seeds and 24 pods had 3 seeds. Similarly, T3 showed maximum plant height (21.2 inches), no of branches (36), No. of lateral roots (142), root length (9.8 inches) and root nodules (115) per plant. The data was recorded at harvesting time. The 100 seed weight 65.3 g and shelling percentage 68.9 % were recorded. It was concluded that biochar has a positive impact on groundnut yield. The research finding will be helpful in future for farmers to select biofertilizers as an alternative to synthetic fertilizers for obtaining high yield and maintaining soil health.

Keywords: Biochar, Biofertilizer, Groundnut, Pressmud, Rhizobium

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Introduction

Groundnut (*Arachis hypogaea* L.) belongs to the family Fabaceae (Leguminosae) which is an annual tetraploid plant. It is a cash crop which is cultivated for food and oil purposes (Roomi et al., 2016; Ahmad et al., 2020). It is consumed as a confectionary snack and peanut butter. It is also used in bakery products. Moreover, its seed is used for cooking lubricants, cosmetics and soaps etc. It is cultivated in Barani areas of Punjab, irrigated areas of Sindh and Khyber Pakhtunkhwa (Pardee, 2002). Pakistan accounts for about 0.4 percent of the world groundnut area and 0.2 percent of its production. Most of the areas of Pakistan in which groundnut is being cultivated excessively are district Rawalpindi, Attock, Chakwal in Punjab, district Karak and Swabi in NWFP and Sanghar in Sindh. In an area of about 1 million hectare numerous varieties of erect and spreading groundnut are grown with an average yield of about 1.1 t ha-1 in comparison to the average yield of United States and China that is about 4 t ha^{-1} (Khalid et al., 2015).

Biofertilizers are the crucial components of organic farming as they play an essential role in improving the soil fertility through nitrogen fixation by solubilizing soil phosphate minerals that are insoluble as a result they produce substances in the soil needed for plant growth. Microorganisms play a vital role in a sufficient supply of nutrients to host plants for their proper growth and development. For biofertilizer preparation, suitable and effective microorganisms are used; such biofertilizers are used to gather naturally occurring, biological systems of nutrient mobilization. Several authors have reviewed the role and significance of biofertilizer in crop production (Bahadur et al., 2014). The selection of suitable carriers such as biochar also plays a vital role for growth of plant (El-Fattah et al., 2013). It is a carbon rich source that is produced via thermal decomposition of organic matter such as wood, leaves or manure with limited supply of oxygen (Shareef et al., 2017). Biochar is a carbon rich source that is produced via thermal decomposition of organic matter such as wood, leaves or manure. The organic matter is heated in a closed container that is usually air tight with limited supply of oxygen and temperature of about (<700 °C) (Shareef et al., 2017).

Carrier based biofertilizers are beneficial because the shelf life of the biofertilizer is determined by the carrier. So maintaining the shelf life of the inoculant during storage and for improving its performance when applied in the field application, selection of suitable carrier is required (Gandhi & Saravanakumar, 2009).

The role of fertilizers is to add nutrients in the soil for increasing the fertility of soil thus promoting plant growth. Biofertilizers are rich with organic elements and are non-toxic as well. Most importantly biofertilizers maintain the normal soil fertility and enrich the soil with nutrients. Chemical fertilizers on the other hand give short term benefits they can increase the production of crops but have negative impact as well. Chemical fertilizers contain chemicals that are not only harmful to the consumers but also reduce the fertility of the soil. Long term exposure of humans to chemical fertilizers revealed their greater impact on human health as it not only causes neuron disorders in humans but causes cancer as well. Similarly heavy metals including Lead, Mercury, Lead, Uranium and Cadmium are present in chemical fertilizers and these heavy metals are responsible for causing disturbances in lungs, liver, and kidneys and are carcinogenic (WHO, 1990). Keeping in view of these constraints, this study was planned to formulate biochar based biofertilizer and its positive effect on groundnut production.

Materials and Methods

Formulation of groundnut bio-fertilizer and monitoring of quality parameters

Biochar (source wood chips) and the Rhizobium strain were obtained from soil microbiology laboratory, Institute of Soil and Environmental Science, Pir Mehr Ali Shah Arid Agriculture University Rawalpindi (PMAS-AAUR). Potential Rhizobium strain was refreshed and placed in nutrient medium i.e. Yeast extract mannitol media (YEM Media). The media having Rhizobium culture was placed in an incubator for growth at 28 degree Celsius for 48 hours. Then this mother culture was mixed with biochar (carrier). This formulated bio-fertilizer was stored in a cool and dry place for six months to check its quality parameters. Quality parameters (cell number, pH and moisture level) of formulated bio-fertilizer were monitored at the date of manufacturing and after six months. After monitoring these quality parameters, sugar solution was prepared for coating of bio-fertilizer on seed surface. For this purpose, in 500 ml water about 25 g of sugar was dissolved in order to prepare sugar solution. The sugar solution was sprayed on the seed surface, then was left for 1 hour. After one hour a kg of bio-fertilizer formulated with biochar was mixed with sugar coated seeds. Now it was allowed to stay for 12 hours before sowing in the field.

Field experiment

Field experiment was performed at the field of Groundnut Research Station Attock. Groundnut variety BARI 2016 was cultivated in the field. The experimental design was RCBD. The plant to plant distance 15 cm and row to row distance 45 cm were maintained respectively. Plot size was 3.6 m^2. The four treatments were applied before sowing and each treatment has three replications. Biochar coated seeds were planted at the depth of 10cm, NP fertilizer was also added in treatments where required at the time of planting:

T1 = Control
T2 = Recommended fertilizer (NP 30-100 kg ha^{-1})
T3 = Biochar bio-fertilizer + (half NP 15-50 kg ha^{-1})
T4 = Biochar

Data collection

Data were recorded from 12 plants that were randomly selected, 3 from each treatment. The following parameters were observed at the harvesting time and the data was recorded.

Grain yield

For grain yield, following parameters were measured. i.e., Number of pods per plot and number of pods per plant (The number of pods per plot and the number of pods per plant were counted at the time of harvesting). Mature and immature pods (The number of mature and immature pods were counted at the time of harvesting). Filled and unfilled pods (The number of filled and unfilled pods were counted after harvesting). Fresh weight, dry weight (The fresh and dry weight of the plant was measured using a digital balance in gram).100 seed weight (The 100 groundnut seeds were counted and weighed in grams by using digital weighing balance). Shelling percentage (The pods from the net plots of groundnut were each air-dried thoroughly. The harvest from tagged groundnut plants was weighed before and after shelling, then the weight of shelled nuts was measured and recorded).

Growth data

The following crop parameters of the field experiment were determined from 12 randomly selected plants, and 3 plants from each treatment. Branches (At the time of harvest, the number of branches were counted). Plant height (Height of the crop was also measured at harvest time by using a measuring scale in inches). Root length (The crop's root length was measured at the time of harvest using the measuring scale in inches). Nodule number (The plant roots were uprooted at the time of harvest and their total nodules were counted. Lateral roots (The number of lateral roots was counted at the time of harvest).

Statistical analysis

For field experiments, a randomized complete block design (RCBD) was used. One way ANOVA was applied which is also known as one factor ANOVA. Additionally, the Least Significant Difference (LSD) test was used to analyze each parameter.

Results and Discussion

Monitoring of quality parameters

The quality parameters of Rhizobium based biofertilizer formulated with biochar were monitored at date of manufacturing and after six months, which are shown in Table 1.

Table 1 Quality parameters of Rhizobium based bio-fertilizer with biochar

Parameters	At manufacture time	After six months
The number of cells	10^6 /g carrier within the 15 days of manufacture	10^4/g carrier within the 15 days before the expiry
pH	7	7
Moisture content	40%	16%

Table1 shows that the number of cells decreased from 10^6 /g carrier to 10^4/g carrier after six month, there was no change in pH. The moisture content decreased from 40% to 16%. The results of these parameters revealed that biochar based biofertilizers have good shelf life and it can be stored and used in the field for good results.

Field experiment

On the basis of quality parameters, biochar biofertilizer was applied in the field for groundnut production. Its different traits were observed. For grain yield following parameters were observed as shown in Table 2 and 3.

Total number of pods per plot and pods per plant

As shown in Table 2, out of four treatments T1 (Control) has the number of pods per plot (399 pods) and number of pods per plant (39). Whereas T2 (NP 30-100 kg ha^{-1}) has number of pods per plot (467) and number of pods per plant (46), T3 (Biochar + half NP 15-50 kg ha^{-1}) has number of pods per plot (663) and number of pods per plant (64). The fourth treatment involving Biochar, yields an average of about 587 pods per plot and 59 pods per plant. This shows that the average yield of pods per plant increases in treatment 3 that involves the application of biochar + half N/P. These results indicated that when Rhizobium based biofertilizer was used with half concentration of N/P then its uptake by plants increases. The Rhizobium makes the fertilizer in a suitable form so that the plant can easily uptake hence enhances the yield as presented in Table 2.

Filled and unfilled pods

The total number of filled and unfilled pods of groundnuts was counted at the harvesting time. Table 2 shows the number of filled and unfilled pods of groundnut. The treatment (T3) produced the highest number of filled pods (58). Whereas treatment showing lesser number of filled pods was T1 (control) with 37 filled pods. T2 has 43 whereas T4 has 54 filled pods. The table shows that T1 has 0 unfilled pods. Similarly T2 shows a mean of about 1 unfilled pod, T3 indicates mean of 1 unfilled pod and T4 shows a mean of 1 unfilled pod. The treatment bearing a greater number of filled pods (58) was T3 which involves Biochar + half N/P application. These results also indicated that Rhizobium based biofertilizer enhances the yield with a combination of half N/P fertilizer.

Mature and immature pods

The total number of mature and immature pods was counted at the time of harvesting. Table 2 shows the number of mature and immature pods of groundnut. As shown in Table 2, T1 has an average of about 37 mature pods and 2 immature pods. Similarly, T2 shows a mean of about 43 mature pods and 3 immature pods, T3 indicates mean of 59 mature pods and 6 immature pods and T4 shows a mean of 55 mature pods and 4 immature pods. Whereas treatment showing a lesser number of mature pods is T1 (Control) with 37 mature pods. The treatment bearing a greater number of mature pods (59) is T3 which involves Biochar + half N/P application. Therefore, biochar application has a significant impact on groundnut yield.

Table 2 Number of pods per plot, number of pods per plant, filled and unfilled pods, mature and immature pods of groundnut (Each parameter was separately analyzed. i.e., one factor ANOVA; α=0.05)

Treatments	No of pods per plot	No. of pods per plant	Filled pods	Unfilled pods	Mature pods	Immature pods
Control	399^d	39^d	37^c	0^a	2^c	37^d
Recommended fertilizer 30-100 kg ha^{-1}	467^c	46^c	43^b	1^a	3^{bc}	43^c
Biochar+half NP 15-50 kg ha^{-1}	663^a	64^a	58^a	1^a	6^a	59^a
Biochar	587^b	59^b	54^a	1^a	4^{ab}	55^b
Standard error	31.26	3.1	2.62	0.193	2.69	0.51

Pods having 1 seed, 2 seeds and 3 seeds

The number of pods having one seed, two seeds and three seeds were counted at the harvest time. Table 3 shows the Number of pods having 1 seed, 2 seeds and 3 seeds. As shown in table 3, the treatment 1 (T1) (Control) showed a mean of about 10 pods having 1 seed, 12 pods having 2 seeds and 15 pods having 3 seeds. The treatment two (T2) showed a mean of 11 pods having 1 seed, 14 pods having 2 seeds and 19 pods having 3 seeds. The treatment 3 (T3) showing mean of 16 pods having 1 seed, 19 pods having 2 seeds and 24 pods having 3 seeds. Finally the treatment four (T4) showed a mean of 15 pods having 1 seed, 17 pods having 2 seeds and 23 pods having 3 seeds. The above data reveals that the number of pods having maximum seed were in treatment 3 (T3) that involves the application of Biochar + half N/P. This proves that combined application of Biochar and N/P fertilizer increases the groundnut yield.

Fresh weight, dry weight and 100 seed weight

The fresh weight, dry weight of groundnut was measured using the digital balance. Table 3 shows fresh weight, dry weight and 100 seed weight. The treatment one (T1) has shown fresh weight 51.2 g, dry weight 17.4 g and 100 seed weight (61.2 g). Similarly, the treatment two (T2) shows fresh weight (54.5 g), dry weight (19.4 g) and 100 seed weight (61.8 g). The treatment three (T3) indicates fresh weight (66.5 g), dry weight (23.6 g) and 100 seed weight (65.3 g) whereas the treatment four (T4) indicates fresh weight (63.5 g), dry weight (21.4 g) and 100 seed weight (65.3 g). Therefore maximum fresh weight (63.5 g), dry weight (21.4 g) and 100 seed weight (63.3 g) was attained in treatment three (T3) that involves combined application of Biochar + half N/P.

Shelling percentage

The pods from the net plots of groundnut were each air-dried thoroughly. The harvest from tagged groundnut plants was weighed before and after shelling, then the weight of shelled nuts was measured and recorded. The shelling percentage of groundnut variety Bari 2016 is shown in Fig. 1. Treatment one (T1) shows shelling percentage of 63.4% whereas treatment two (T2) shows shelling percentage of 65.1%. The treatment three (T3) shows a shelling percentage of 68.9%. Treatment four (T4) shows shelling percentage of 65.8 %. The maximum shelling percentage was attained in treatment four (T3) that involves application of Biochar and half N/P.

Table 3 Fresh weight, dry weight, 100 seed weight, pods having 1 seed, 2 seeds and three seeds

Treatments	Fresh weight (g)	Dry weight (g)	100 seed weight (g)	Pods having 1 seed	Pods having 2 seeds	Pods having 3 seeds
Control (T1)	51.2^{d}	17.4^{d}	61.2^{d}	10^{b}	12^{b}	15^{c}
Recommended fertilizer NP 30-100 kg ha^{-1} (T2)	54.5^{c}	19.4^{c}	61.8^{c}	11^{b}	14^{ab}	19^{b}
Biochar + half NP 15-50 kg ha^{-1} (T3)	66.5^{a}	23.6^{a}	65.3^{a}	16^{a}	19^{a}	24^{a}
Biochar (T4)	63.5^{b}	21.4^{b}	63.3^{b}	15^{a}	17^{ab}	23^{a}
Standard error	3.62	1.33	0.91	1.5	1.6	2.1

Note: For each parameter separate test was used i.e., one factor ANOVA ($\alpha = 0.05$)

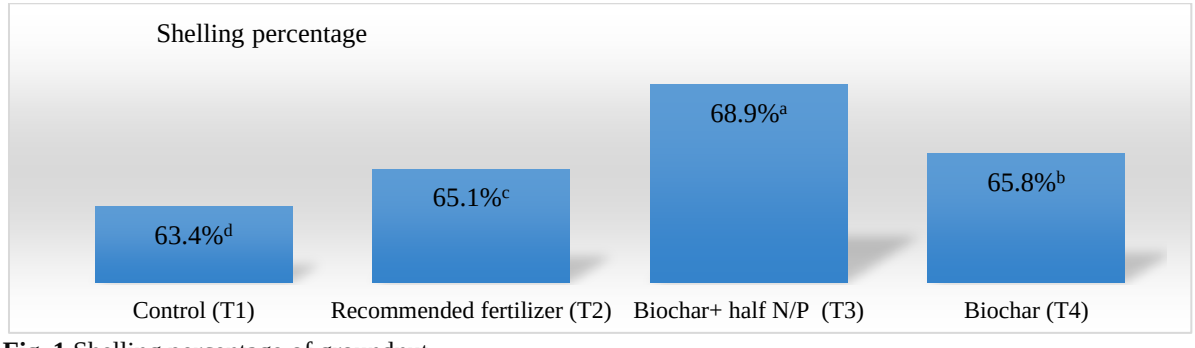

Fig. 1 Shelling percentage of groundnut

Growth data

For crop data parameters such as number of branches, plant height, root length, number of nodules on roots, and number of lateral roots were recorded. The data regarding these parameters is presented in Table 4.

Number of branches of groundnut

The number of branches per plant was counted after the harvesting. Table 4 shows the number of branches/plant of groundnut. As shown in table control treatment, T1 has an average of about 27 branches per plant. Treatment 2 (T2) involving recommended fertilizer has a mean of about 34 branches per plant. Treatment 3 (T3) involving application of biochar + half N/P has an average of 36 branches per plant. Whereas treatment 4 (T4) involving biochar has a mean of 32 branches per plant. This shows that the number of branches increases in treatment 3 (T3) that involves the application of biochar + half N/P.

Plant height

The plant height was measured by using the measuring scale. As shown in Table 4, the maximum height (21.2 inches or 54 cm) of Bari-2016 was obtained in treatment three (T3) that involves Biochar + half N/P application. Whereas the heights shown by other treatments one, two and four (T1, T2 and T4) were 15.4, 17.3 and 19.2 inches, respectively.

Root length

The root length was measured at the time of harvesting using the measuring scale and the data was recorded as shown in Table 4. Treatment one (T1) shows an average root length of about 7.2 inches, while treatment two (T2) shows an average root length of 8.2 inches. Treatment three (T3) shows a mean of 9.8 inches and treatment four (T4) shows a mean of 8.5 inches. The maximum root length (9.8 inches) was attained in treatment three (T3) that involves application of Biochar + half N/P.

Number of root nodules

The root nodules were counted and the results were recorded and shown in Table 4. Treatment one (T1) showed number of root nodules (65) while treatment two (T2) showed number of root nodules (81). Treatment three (T3) showed the number of root nodules (115). Treatment four (T4) showed the number of root nodules (97). The maximum no. of root nodules were attained in treatment three (T3) that involves application of Biochar + half N/P.

Number of lateral roots

Table 4 shows the number of lateral roots counted at the time of harvest. The number of lateral roots 76, 121, 142, and 82 were recorded in Treatment one, two, three and four respectively. The maximum number of lateral roots (142) was attained in treatment three (T3) that involves application of Biochar + half N/P.

Table 4 Number of branches, Plant height, Root length, number of root nodules and number of lateral roots of groundnut

Treatments	No. of Branches	Plant height (Inches)	Root length (Inches)	Root nodules	No. of lateral roots
Control (T1)	27^{b}	15.4^{d}	7.2^{d}	65^{d}	76^{d}
Recommended fertilizer NP 30-100 kg ha-1 (T2)	34^{a}	17.3^{c}	8.2^{c}	81^{c}	121^{b}
Biochar + half NP 15-50 kg ha-1 (T3)	36^{a}	21.2^{a}	9.8^{a}	115^{a}	142^{a}
Biochar (T4)	32^{ab}	19.2^{b}	8.5^{b}	97^{b}	82^{c}
Standard error	1.18	0.65	0.28	10	8.31

Note: For each parameter separate test was used i.e., one factor ANOVA (α=0.05)

Discussion

The early studies reported the use of N/P fertilizer and biochar and its effects on groundnut yield. Xu et al. (2015) reported that biomass of groundnut as well as pod yield has increased about two and three times on red ferrosol and redox hydrosol when biochar was mixed at 0.375 to 6.00% w/w. The combined application of N and P fertilizers (46 kg P_2O_5 ha^{-1} and 15 kg N ha^{-1}) enhanced the pod yield of groundnut by 85.4% (Tekulu et al., 2020). Kulkarni (1986) reported that when up to 50 kg ha^{-1} of phosphorus is applied it causes the rise in the number of pods per plant. Similarly biochar itself has a rich source of nutrients as discussed in early studies. Biochar residues that are present in the soil are likely to enhance yield potential of plants in comparison with soils without having biochar (Samira et al., 2012). Similarly, Kumar et al. (2014) revealed that treatment involving NPK fertilizers significantly produced a higher number of pods per plant, 100 seeds weight and yield of seeds.

Vala et al. (2017) revealed that when organic, inorganic and bio-fertilizers were applied together, it

significantly increased the pod yield of groundnut. The biomass of peanut as well as the pod yield of peanut was increased about two to three times in red hydrosol and red ferrosol when biochar was applied (Xu et al., 2015). Maturity is an unspecified trait that is managed by several gene sets and is extremely affected by different environmental factors such as temperature, light together with growing region latitude (Nigam & Aruna, 2007; Carter et al., 2017). Vala et al. (2017) revealed that when organic, inorganic and bio-fertilizers were applied together, it significantly increased the pod yield of groundnut. The biomass of peanut as well as the pod yield of peanut was increased about two to three times in red hydrosol and red ferrosol when biochar was applied (Xu et al., 2015). Maturity is an unspecified trait that is managed by several gene sets and is extremely affected by different environmental factors such as temperature, light together with growing region latitude (Nigam & Aruna, 2007; Carter et al., 2017).

Previous literature reported that more than 40 percent of pods of groundnut variety BARI-2016 have 3 to 4 seeded pods which is a distinguished trait of BARI-2016. This character allows it to differentiate from various previously approved varieties of groundnut (Hassan et al., 2022). Biochar residues that are present in the soil are likely to enhance yield potential of plants in comparison with soils without having biochar (Samira et al., 2012). The N and P fertilizer application increases the number of leaves (262) and the pod number (47.25) (Hasan et al., 2021). Previous studies supported our experiment. So, it indicates that in our experiment biochar based biofertilizers having rhizobium strains have ability to solubilize phosphorus and fix nitrogen which was easily available to groundnut crop to enhance its grain yield. Biochar and rhizobium both have a positive impact on plant growth and development along with its yield when half the ratio of N/P was used with biochar and rhizobium. It has an accumulative effect on growth as well as the yield of groundnut.

Some other studies reported that when a Combination of cow manure (20 t ha^{-1}) and rice husk biochar (10 t ha^{-1}) was given, the maximum yield on seed weight per plant was recorded (Yunilasari et al., 2020). The application of N and P fertilizer in the ratio (0.33 and 0.50) produced less dry pod weight per plant in comparison with higher N and P fertilizer ratio which produced the weight of about 15.82 g. The N and P fertilizer application is known to increase the pod weight of groundnut (22.8 g) (Hasan et al., 2021). Biochar application significantly affected the kernel yield as well as the shelling percentage of groundnut (Wang et al., 2021). The groundnut shelling percentage was considerably affected with the combined as well as the individual application of fertilizers (N and P) (Tekulu et al., 2020) Previous studies supported our experiment. So it indicates that in our experiment biochar based biofertilizers having rhizobium strains have ability to solubilize phosphorus and fix nitrogen which was easily available to groundnut crop to enhance its grain yield.

Previously it was reported that when cocopeat biochar and rice husk biochar residues were used then it has affected both the number of branches as well as the height of plant at 15, 30 and 45 Days after planting (Yunilasari et al., 2020). Both 15 kg N ha^{-1} as well as 30 kg N ha^{-1} application has the same effect on the branches number/plant of the groundnut (Tekulu et al., 2020). The biochar application resulted in improved growth of plant in early studies conducted by Haider et al. (2015). Similarly in another study when NP fertilizer was used then it also increases the plant height (Hasan et al., 2021). The biochar residues including both rice husk and cocopeat biochar residue can influence the growth of plants as well as the roots of plants (Blanco-Canqui & Lal, 2004).

Biochar application and Rhizobium inoculation on groundnut plants was known to enhance the number of effective nodules (Yusif et al., 2016). In case of Bambara groundnut when N and P fertilizers were applied (30 and 60 kg ha^{-1}), it significantly increased the yield, nodulation as well as the growth (Hasan et al., 2021). Previous studies also supported our experiment. It is indicated that in our experiment biochar based biofertilizers having rhizobium strains have ability to increase different crop parameters including number of branches, number of lateral roots, root length, plant height as well as number of root nodules.

Conclusion

The results indicated that the treatment three (T3) involving biochar + half NP showed better results in terms of yield, as there was an increase in pods number per plant (64), pods number per plot (663), filled pods (58), unfilled pods (1), mature pods (59), immature pods (6), pods having 1 seed (16), pods having 2 seeds (19), pods having 3 seed (24), fresh weight (66.5 g), dry weight (23.6 g), 100 seed weight (65.3), shelling percentage (68.9 %), plant height (21.2 inches or 54 cm), no. of branches (36), lateral roots (142), root length (25 cm) and number of root nodules (115) as compared to other treatments. These results indicated that groundnut yield has increased with combined application of biochar and half NP fertilizer. Grain yield as well as growth yield were significantly improved by application of this treatment. So, it was concluded that biochar had a positive impact on groundnut production when combined with half N/P fertilizer (15-30 kg ha^{-1}). This is because application of both NP fertilizer along with biochar (High carbon source) can significantly increase the pH of soil and maintain it in optimal range. In the presence of biochar, soil organic carbon content increases. Thus increase in soil organic carbon and total nitrogen content increases groundnut yield. Proper guidelines should be provided to farmers for the use of biochar based rhizobium biofertilizers. They should be kept aware about the benefits of using biochar as a carrier. This research will be helpful for farmers as they will get better bio-fertilizer which will be helpful in increasing the crop yield and soil fertility.

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