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Growth and yield of summer groundnut (*Arachis hypogaea* L.) under the influence of biochar and organics

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Abstract
A field experiment was carried out during summer season of 2019-20 on organic plot having black calcareous clayey soil at Junagadh (Gujarat) to study the effect of biochar on growth and yield of summer groundnut (*Arachis hypogaea* L.). The results indicated that the highest values of growth attributes *viz*., plant height, number of branches per plant, days to 50% flowering, number of root nodules and dry weight of root nodules and SPAD meter reading and yield attributes *viz*., peg to pod ratio, number of mature pods per plant, 100-pod weight and 100-kernel weight, pod weight per plant and shelling percentage along with the highest pod yield (2201 kg/ha) and haulm yield (4219 kg/ha) were recorded with application of enriched biochar 0.25 t/ha + vermicompost 1 t/ha, followed by microbial enriched biochar 0.25 t/ha + FYM 1.25 t/ha + vermicompost 0.5 t/ha.

Keywords: Biochar, *Arachis hypogaea*, FYM, vermicompost, microbial enriched biochar

Introduction
Groundnut (*Arachis hypogaea* L.) is considered as one of the most important oilseed crops and dominant annual crop widely cultivated in more than 120 countries. In India, Groundnut is second most important annual oilseed crop next to soybean. It is cultivated as commercial crop in Gujarat, Tamil Nadu, Andhra Pradesh, Rajasthan, Karnataka, Telangana and Maharashtra. In India, it occupies about 4.88 million ha with production of 9.25 million tonnes and an average productivity of 1893 kg/ha (Anon., 2018) [1].

Nutrient management has currently attained a special significance in crop production to address the sustainability problem and tremendous success has been achieved in several crops. Groundnut is called unpredictable legume, since its behaviour to nutrient application is always not optimistic. Organic nutrient management has an important role in maximizing the yield of groundnut. The optimization of the mineral nutrient has key role in optimization the production of groundnut because it has very high nutrient requirement. Thus, with the assurance of timely supply of organic nutrient sources for recycling, seems to be possible to produce organically a yield of groundnut, a premier oilseed crop (Bordoloi *et al*., 2007) [4]. Soil health is the foundation of vigorous crop productivity with higher opportunity for income and employment which in turn provides sustainable food system. Soil health management forms the basis for sustainable system of productive agriculture (Rani *et al*., 2018) [15] and crop residue burning has high impact on it. Crop residue management is one of the emerging problems in agriculture sector. 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 (McHenry, 2009) [12] 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. It is a fine-grained charcoal, high in organic carbon and largely resistant to decomposition. Biochar is the carbon rich product. Biochar application to soil have beneficial effect on crop productivity 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.

In the view of considering the importance of biochar influence on growth and yield on groundnut and taking note of the facts highlighted above, a field experiment was conducted on effect of biochar on growth and yield of summer groundnut.

Materials and Methods

The experiment was conducted on a medium black clayey soil at organic certified plot (since 10 years) of Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh during summer 2019. Geographically, Junagadh is situated at 21.5° N latitude and 70.5° E longitude with an altitude of 60 m above the mean sea level. The soil of the experimental plot was organically managed soil and slightly alkaline in reaction with pH 7.85 and EC 0.48 dS/m. The soil was medium in available nitrogen (247.78 kg/ha), available phosphorus (27.94 kg/ha) and high in potassium (276.47 kg/ha). The mean maximum and minimum temperature during the crop growth and development period ranged from 31.9 to 42.2 °C and 14.8 to 27.6 °C, respectively. During the crop period, the relative humidity was in the range of 17 to 90%. Bright sun shine hours, wind velocity and daily evaporation was 3.2 to 11.0 h/day, 4.0 to 12.7 km/h and 5.0 to 11.7 mm/day, respectively.

The experiment was laid out in randomized block design having ten treatments *viz*., T_1: RDF (50-25-25 kg N-P_2O_5-K_2O/ha, outside of organic plot), T_2: FYM 5 t/ha, T_3: Vermicompost 2 t/ha, T_4: FYM 2.5 t/ha + Vermicompost 1 t/ha, T_5: Biochar 1 t/ha, T_6: Biochar 0.5 t/ha + FYM 2.5 t/ha, T_7: Biochar 0.5 t/ha + Vermicompost 1 t/ha, T_8: Enriched biochar 0.25 t/ha + FYM 2.5 t/ha, T_9: Enriched biochar 0.25 t/ha + Vermicompost 1 t/ha and T_{10}: Enriched biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha with three replications.

As per the treatments, treatment T_1 (RDF) was kept outside the organic plot and crop was fertilized with nitrogen and phosphorous and potassium in the form of urea, di-ammonium phosphate and muriate of potash, respectively as a basal application just before sowing in outside the organic plot. Biochar was enriched with liquid formulation of Rhizobium (*Rhizobium leguminosarum*), Phosphorus Solubilizing Bacteria (*Bacillus subtilis*) and Potash Solubilizing Bacteria (*Frateuria aurantia*) and powder formulation of biocontrol agents *viz*., *Trichoderma harzianum*, *Pseudomonas fluorescence* and *Beauveria bassiana* were used for microbial enrichment of biochar with incubation period of 10 days before application. Rhizobium, PSB and KMB each @ 2 L/ha and biocontrol agents @ 2 kg/ha were applied to biochar and thoroughly incorporated in to biochar. The organic inputs like biochar, enriched biochar, FYM and vermicompost were applied as basal at each row in respective treatments just before sowing. Biochar was obtained from Greenfield Eco Solution Pvt. Ltd and manufactured through pyrolysis of woody biomass of *Prosopis juliflora* i.e. heating the biomass to 400-500 °C in a low oxygen environment. The biochar containing 715-725, 1.6-1.9, 1.9- 2.1 and 24-26 g/kg organic carbon, N, P and K respectively. Biochar was in coarse form. So, it was powdered to ease of application.

The groundnut variety Trombay Groundnut 37A (TG 37A) was sown on February 21, 2019 at row spacing of 30 cm using seed rate of 125 kg/ha. The area of experiment was 39.0 m x 12.8 m with gross and net plot size was 5 m x 1.8 m and 4 m x 1.2 m, respectively. Biochar at the rate of 0.5 and 1 t/ha along with FYM (1.25, 2.5 and 5.0 t/ha) and vermicompost (0.5, 1 and 2 t/ha) was applied just before sowing as per the treatments. Enriched biochar 0.25 t/ha was also applied as per treatments.

The crop was raised as per the recommended package of practices. The crop was harvested at physiological maturity on 21rd June, 2019. The harvesting was done by drawing harrow for easy uprooting of plants. The growth and yield attributes were recorded from the five tagged plants in each plot. The oil content of sample was determined by non-destructive method using Nuclear Magnetic Resonance Spectrophotometer against a standard reference sample (Model Oxford 4000 NMR analyzer) as suggest by Tiwari *et al*. (1974) [16]. Protein content in seed was determined by multiplying nitrogen content in seed (%) by a factor 6.25 (Gassi *et al*., 1973) [7].

Results and Discussion

Growth attributes

The results revealed that different treatments manifested significant influence on growth and yield of groundnut (Table 1). Significantly the highest plant height (36.31 cm), number of branches per plant (8.13), and earlier flowering (39.37 days) were observed with the treatment T_9 (Enriched biochar 0.25 t/ha + Vermicompost 1 t/ha), which remained statistically at par with the treatments T_{10} (Enriched biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha), T_7 (Biochar 0.5 t/ha + Vermicompost 1 t/ha) and T_8 (Enriched biochar 0.25 t/ha + FYM 2.5 t/ha). Similarly, number of root nodules (43.02), dry weights of nodules (0.879 g) and SPAD meter reading (37.23) were found higher under the treatment T_9 (Enriched biochar 0.25 t/ha + Vermicompost 1 t/ha), which remained statistically at par with the treatment T_{10} (Enriched biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha), T_7 (Biochar 0.5 t/ha + Vermicompost 1 t/ha) and T_8 (Enriched biochar 0.25 t/ha + FYM 2.5 t/ha), which might be due to enrichment of biochar in combination with organics might have favoured environment for soil microbia, which reflected in better growth and development of groundnut crop.

An application enriched biochar along with vermicompost in the treatment T_9 (Enriched biochar 0.25 t/ha + Vermicompost 1 t/ha) as well as combination of enriched biochar with organics under the treatment T_{10} (Enriched biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha) and T_8 (Enriched biochar 0.25 t/ha + FYM 2.5 t/ha) and combination vermicompost with biochar T_7 (Biochar 0.5 t/ha + Vermicompost 1 t/ha) resulted into adequate supply of N, P and K during the crop growth period through organics and improving the soil physical, chemical and biological properties of soil. Microbial enriched biochar along with vermicompost and FYM might have increased soil microbial population and enzymes in rhizosphere. Thus, enhanced availability of nutrients and water, which might have accelerated the photosynthetic rate, thereby increasing the supply of carbohydrates leading to increase in cell division, multiplication and elongation leading to increased growth. These findings are in agreement with results of Pandian *et al.* (2016) [13], Bahuguna (2018) [3], Asfaw *et al*. (2019) [2] and Jatav and Singh (2019) [10].

Yield attributes and yield

The data given in Table 2 showed that the treatment T_9 (Enriched biochar 0.25 t/ha + Vermicompost 1 t/ha) excelled in yield attributes *viz*., peg to pod ratio (1.22), number of mature pods per plant (19.70), pod weight per plant (12.01 g), 100-pod weight (76.03 g), 100-kernel weight (42.73 g) and

shelling percentage (73.33), which remained statistically at par with the treatments T_{10} (Enriched biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha), T_7 (Biochar 0.5 t/ha + Vermicompost 1 t/ha) and T_8 (Enriched biochar 0.25 t/ha + FYM 2.5 t/ha). A scrutiny of data (Table 2) further revealed that application of enriched biochar 0.25 t/ha + Vermicompost 1 t/ha (T_9) established its superiority by producing significantly the highest pod yield (2201 kg/ha), however it was found statistically at par with the treatments T_{10} (Enriched biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha), T_7 (Biochar 0.5 t/ha + vermicompost 1 t/ha) and T_8 (Enriched biochar 0.25 t/ha + FYM 2.5 t/ha). The magnitude of increase in pod yield with the treatments T_9, T_{10}, T_7 and T_8 was 21.87, 20.49, 14.45 and 11.41 per cent, respectively over the treatment T_1 (RDF).

Significantly the highest haulm yield (4219 kg/ha) was also registered under the treatment T_9 (Enriched biochar 0.25 t/ha + Vermicompost 1 t/ha), which remained statistically comparable to the treatments T_{10} (Enriched biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha), T_7 (Biochar 0.5 t/ha + Vermicompost 1 t/ha) and T_8 (Enriched biochar 0.25 t/ha + FYM 2.5 t/ha). On an average, the treatments T_9, T_{10}, T_7 and T_8 increased haulm yield to the extent of 23.54, 18.77, 18.18 and 14.23 per cent over the treatment T_1 (RDF), respectively. Higher yields under these treatments could ascribed to beneficial and combined effects of enriched biochar, vermicompost and FYM, which can enhance nutrient transformations in soil by improving physical, chemical and biological properties of soil. The increase in haulm yield was attributed to improvement in growth characters *viz*., plant height and number of branches with these treatments. These treatments help in sustaining the photosynthetic capacity of plants which ultimately contributes to higher yield. Positive response of groundnut crop in terms of yield attributes and yield to biochar, enriched biochar, FYM and vermicompost have also been reported by Coumaravel *et al*. (2011) [6], Budania and Yadav (2014) [5], Pandit *et al*. (2018) [14] and Gowthami *et al*. (2019) [9].

Table 1: Growth of summer groundnut under different treatments

Treatments	Plant height (cm)	Number of branches/ plants	Days to 50% flowering	Number of root nodules per plant	Dry weight of root nodules per plant (g)	SPAD meter reading
T_1: RDF	31.36	7.000	44.60	38.60	0.764	32.33
T_2: FYM 5 t/ha	29.30	6.590	46.83	34.22	0.684	30.03
T_3: Vermicompost 2 t/ha	31.27	6.987	44.90	37.03	0.754	31.50
T_4: FYM 2.5 t/ha + Vermicompost 1 t/ha	30.72	6.730	46.13	36.93	0.748	31.13
T_5: Biochar 1 t/ha	27.73	6.400	48.40	33.11	0.675	28.80
T_6: Biochar 0.5 t/ha + FYM 2.5 t/ha	30.62	6.660	46.70	36.54	0.723	30.70
T_7: Biochar 0.5 t/ha + Vermicompost 1 t/ha	34.17	7.980	42.20	40.97	0.845	33.90
T_8: EBC 0.25 t/ha + FYM 2.5 t/ha	33.40	7.690	42.20	39.15	0.829	33.13
T_9: EBC 0.25 t/ha + Vermicompost 1 t/ha	36.31	8.133	39.37	43.02	0.879	37.23
T_{10}: EBC 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha	35.04	8.060	41.53	41.67	0.867	34.57
S.Em.±	1.50	0.355	1.57	1.96	0.036	1.56
C.D. at 5%	4.46	1.056	4.69	5.82	0.108	4.63
C.V. %	8.13	8.52	6.17	8.89	8.08	8.35

RDF- Recommended Dose of Fertilizer, EBC- Enriched Biochar, FYM- Farmyard Manure

Table 2: Yield attributes and yield of summer groundnut under different treatments

Treatments	Peg to pod ratio	Number of mature pods per plant	Pod weight per plant (g)	100-pod weight (g)	100-kernel weight (g)	Shelling percentage	Pod yield (kg/ha)	Haulm yield (kg/ha)
T_1: RDF	1.42	16.64	9.94	72.74	37.49	65.17	1806	3415
T_2: FYM 5 t/ha	1.43	16.17	8.41	66.72	34.96	61.17	1692	3167
T_3: Vermicompost 2 t/ha	1.42	16.30	9.84	68.51	37.47	65.10	1801	3370
T_4: FYM 2.5 t/ha + Vermicompost 1 t/ha	1.43	16.24	9.77	68.46	37.24	65.16	1769	3240
T_5: Biochar 1 t/ha	1.54	15.30	9.02	63.28	34.62	61.99	1653	3004
T_6: Biochar 0.5 t/ha + FYM 2.5 t/ha	1.43	16.24	9.06	68.45	35.06	63.05	1742	3194
T_7: Biochar 0.5 t/ha + Vermicompost 1 t/ha	1.27	17.55	11.39	74.07	40.06	71.53	2067	4036
T_8: EBC 0.25 t/ha + FYM 2.5 t/ha	1.29	16.63	11.14	73.68	38.86	69.58	2012	3901
T_9: EBC 0.25 t/ha + Vermicompost 1 t/ha	1.22	19.70	12.01	76.03	42.73	73.33	2201	4219
T_{10}: EBC 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha	1.23	19.04	11.43	74.39	41.25	71.73	2176	4056
S.Em.±	0.06	0.75	0.69	2.53	1.70	2.72	122	256
C.D. at 5%	0.19	2.23	2.04	7.45	5.04	8.10	362	760
C.V. %	8.09	7.64	11.65	6.15	7.74	7.07	11.25	12.45

Table 3: Quality parameters of summer groundnut under different treatments

Treatment	Oil content (%)	Protein content (%)
T_1: RDF	44.79	18.58
T_2: FYM 5 t/ha	43.25	18.07
T_3: Vermicompost 2 t/ha	44.78	18.53
T_4: FYM 2.5 t/ha + Vermicompost 1 t/ha	44.75	18.42
T_5: Biochar 1 t/ha	43.14	17.58
T_6: Biochar 0.5 t/ha + FYM 2.5 t/ha	43.83	18.29
T_7: Biochar 0.5 t/ha + Vermicompost 1 t/ha	46.30	20.01
T_8: EBC 0.25 t/ha + FYM 2.5 t/ha	46.29	18.95
T_9: EBC 0.25 t/ha + Vermicompost 1 t/ha	46.38	21.14
T_{10}: EBC 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha	47.60	20.41
S.Em.±	0.94	0.68
C.D. at 5%	2.80	2.03
C.V. %	3.61	6.23

Quality parameters

Data (Table 3) clearly indicated that significantly the highest oil content (47.60%) was recorded under the treatment T_{10} (Enriched biochar 0.25 t/ha + FYM 1.25 t/ha + vermicompost 0.5 t/ha), which remained statistically at par with the treatments T_9 (Enriched biochar 0.25 t/ha + vermicompost 1 t/ha), T_7 (Biochar 0.5 t/ha + vermicompost 1 t/ha) and T_8 (Enriched biochar 0.25 t/ha + FYM 2.5 t/ha). While, significantly the highest protein content (21.14%) was found under the treatment T_9 (Enriched biochar 0.25 t/ha + vermicompost 1 t/ha), which remained statistically comparable with the treatments T_{10} (Enriched biochar 0.25 t/ha + FYM 1.25 t/ha + vermicompost 0.5 t/ha) and T_7 (Biochar 0.5 t/ha + vermicompost 1 t/ha). Improvement in quality parameters could be ascribed to combined effect of biochar with vermicompost and FYM, which increased the availability of nutrients in the soil and more absorption of nutrients by the crop. The finding was analogous with Gokila (2017) [8] and Maurya (2018) [11].

Based on the experimental results, it can be concluded that higher growth and yield along with quality from summer groundnut (Trombay Groundnut 37A) can be obtained by application of microbial consortia (*Rhizobium leguminosarum*, *Bacillus subtilis*, *Frateuria aurantia*, *Trichoderma harzianum*, *Pseudomonas fluorescence* and *Beauveria bassiana*) enriched biochar 0.25 t/ha + vermicompost 1 t/ha on medium black calcareous clayey soil under South Saurashtra Agro-Climatic Zone.

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