Influence of biochar on growth, yield and quality of summer organic sesame (Sesamum indicum L.) and soil properties

KV Hirapara, Dr. RK Mathukia, R Surya Prakash and HV Korat

DOI: https://doi.org/10.22271/chemi.2020.v8.i6f.10800

Abstract
A field experiment was conducted on organically managed medium black calcareous clayey soil at Junagadh (Gujarat) during summer season of 2019-20 to study the effect of biochar on growth, yield and quality of summer sesame (Sesamum indicum L.) and soil properties. The experimental results revealed that significantly higher values of growth parameters viz., plant height and number of branches per plant and yield attributes viz., number of capsules per plant, length of capsule, seed weight per plant and test weight along with higher seed yield (1741 kg/ha) and stover yield (2123 kg/ha) were recorded with application of enriched biochar 0.25 t/ha + vermicompost 1 t/ha. However, significantly higher nutrient uptake by plant, organic carbon, available N, P, K in soil after harvest along with higher net return (₹ 99142/ha) and B:C ratio (2.69) were also realized with the application of enriched biochar 0.25 t/ha + vermicompost 1 t/ha. Based on the results, it could be concluded that higher production and net returns from sesame along with improved soil fertility can be obtained by the application of microbial consortium enriched biochar 0.25 t/ha + vermicompost 1 t/ha.

Keywords: Sesamum indicum, sesame, biochar, microbial consortium enrichment, soil properties

Introduction
Sesame is one of the world’s oldest oil crop and has been cultivated in Asia from ancient times. India is the largest producer of sesame both in terms of area (19.50 lakh ha) and production (8.51 lakh tonnes) with an average productivity of 436 kg/ha. It is cultivated as commercial crop in Gujarat, West Bengal, Rajasthan, Tamil Nadu, Andhra Pradesh, Madhya Pradesh and Maharashtra. In Gujarat, sesame is the most important oilseed crop and cultivated in 1.23 lakh ha which produces 0.72 lakh tonnes with productivity of 586 kg/ha (Anon., 2018). The sesame seed has been considered as “Queen of Oilsseed” by virtue of its excellent quality of oil content, flavour, taste and traditionally categorised as a health food. Since sesame is low water requiring, remunerative and short duration crop, farmers of Saurashtra region are attracted towards its cultivation in summer season.

Agricultural waste is generally handled as a liability, often because the means to transform it into an asset is lacking. Crop residue management is one of the emerging problems in agriculture sector. Crop residues in fields can cause considerable crop management problems as they accumulate in surplus. Most of the farmers do crop residue burning and hence in addition to loss of valuable biomass and nutrients, burning also release of toxic gases like CO\(_2\), methane and nitrous oxide causing global warming. On the other hand, maintenance of a threshold level of organic matter in the soil is crucial for maintaining physical, chemical and biological integrity of the soil and also for the soil to perform its agricultural production. The low level of organic matter causes a strong reduction in soil fertility. Hence, conversion of organic waste to produce biochar using the pyrolysis process is one viable option that can enhance natural rates of carbon sequestration in the soil, reduce farm waste and improve the soil quality. The use of biochar as soil amendment is proposed as a new approach to mitigate man-induced climate change along with improving soil productivity.

The effect of biochar in increasing plant growth and soil quality has been well documented by many workers for many crops. Biochar may improve soil organic carbon, water holding capacity, cation exchange capacity, pH and nutrients availabilities. Compost can be enriched by N-fixing, P-solubilizing and K mobilizing cultures and biocontrol microbial cultures.
In addition to improving availability of plant nutrients, these additions help to reduce the composting time considerably and increase population of microorganisms. Taking note of the facts highlighted above, a field experiment was conducted to study the effect of integration of various organic amendments along with microbial enrichment on growth and yield of sesame and post-harvest soil fertility.

Materials and Methods
A field experiment was conducted on a medium black clayey soil at Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) in summer season of 2019-20. Geographically, Junagadh is situated at 21.50° N latitude and 70.50° E longitude with an altitude of 60 m above the mean sea level.

The experimental soil was organically managed (since 8 years) and slightly alkaline in reaction with pH 8.18 and EC 0.52 dS/m, low in available nitrogen (246 kg/ha), medium in available phosphorus (27 kg/ha) and high in available potash (254 kg/ha). The mean maximum and minimum temperature during the crop period ranged from 29.2 to 42.2 °C and 12.1 to 27.4 °C, respectively. During the crop period, the relative humidity was in the range of 38 to 78%. Bright sun shine hours, wind velocity and daily evaporation was 7.4 to 11 h/day, 4 to 9.5 km/h and 5.5 to 11.7 mm/day, respectively.

The experiment comprising 10 treatments viz., T1: RDF (50-25-0 kg N-P2O5-K2O/ha, outside of organic plot), T2: FYM 5 t/ha, T3: Vermicompost 2 t/ha, T4: FYM 2.5 t/ha + Vermicompost 1 t/ha, T5: Biochar 1 t/ha, T6: Biochar 0.5 t/ha + FYM 2.5 t/ha, T7: Biochar 0.5 t/ha + Vermicompost 1 t/ha, T8: Enriched Biochar 0.25 t/ha + FYM 2.5 t/ha, T9: Enriched Biochar 0.25 t/ha + Vermicompost 1 t/ha and T10: Enriched Biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha. The expenses incurred for all the cultivation operations from preparatory tillage to harvesting including the cost of inputs viz., seeds, manures, biochar, enrichment materials, irrigation, etc. applied to each treatment was calculated on the basis of prevailing local charges. The gross realization in terms of rupees per hectare was worked out taking into consideration the seed and stover yields from each treatment and local market prices. Net return of each treatment was calculated by deducting the total cost of cultivation from the gross returns. The benefit: cost ratio (B:C) was calculated by dividing gross return with cost of cultivation.

Results and Discussion
Growth and yield
The results revealed that different treatments manifested significant influence on growth and yield of sesame (Table 1). The treatment T9 (Enriched Biochar 0.25 t/ha + Vermicompost 1 t/ha) recorded significantly the highest plant height (70.00 cm) and number of branches per plant (3.10) at harvest, but it remained statistically equivalent to the treatments T10 (Enriched Biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha) and T7 (Biochar 0.5 t/ha + Vermicompost 1 t/ha). This might be due to adequate supply of nutrients in sufficient amount required by the plant throughout the growing season and improved soil physico-chemical and biological properties of soil through microbial enriched biochar along with vermicompost and FYM lead to improving root proliferation and promoting crop growth. These results are in conformity with the findings of Elangovan and Sekaran (2014) [6], Lal et al. (2018) [11] and Mansour et al. (2019) [12].

An appraisal of data (Table 1) indicated that significantly the most number of capsules per plant (58.00), length of capsule (2.86 cm), seed weight per plant (5.55 g) and test weight (4.22 g) were recorded with the treatment T9 (Enriched Biochar 0.25 t/ha + Vermicompost 1 t/ha), which remained statistically at par with the treatments T10 (Enriched Biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha) and T7 (Biochar 0.5 t/ha + Vermicompost 1 t/ha). A scrutiny of data (Table 1) further revealed that application of enriched biochar 0.25 t/ha + vermicompost 1 t/ha (T9) established its superiority by producing significantly the highest seed yield (1741 kg/ha), however it was found statistically at par with the treatments T10 (Enriched Biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha) and T7 (Biochar 0.5 t/ha + Vermicompost 1 t/ha). The magnitude of increase in seed yield with treatments T9, T10 and T7 was 58.90, 52.72 and 40.65 per cent, respectively over the treatment T1 (RDF).

Significantly the highest stover yield (2123 kg/ha) was registered under the treatment T9 (Enriched Biochar 0.25 t/ha + Vermicompost 1 t/ha), and it was found statistically comparable to the treatments T10 (Enriched Biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha) and T7 (Biochar 0.5 t/ha + Vermicompost 1 t/ha). The extent of increase in stover yield with the treatments T9, T10 and T7 was 47.34, 41.32 and 29.82 per cent, respectively over the treatment T1 (RDF). The beneficial effects of enriched biochar and manures on yield and yield attributes seems to be due to co-application of organics could have maintained high regime of soil fertility and moisture by means of better utilization of nutrients and moisture available in the soil by the crop leading to production of more photosynthates leads to higher plant growth and development, which ultimately depicted in increased yield attributes.
The increase in seed yield was attributed to remarkable improvement in almost all the growth and yield attributes under these treatments. Positive response of sesame crop in terms of yield attributes and yield to biochar, enriched biochar, FYM and vermicompost have also been reported by Bhattacharya et al. (2015) [9], Gokila (2017) [8] and Garamu (2019) [7].

**Nutrients uptake and post-harvest soil fertility**

The data given in Table 2 showed that application of enriched biochar 0.25 t/ha + vermicompost 1 t/ha (T5) recorded significantly the highest uptake of nitrogen (122.65 kg/ha), phosphorus (24.18 kg/ha) and potassium (35.26 kg/ha), but remained statistically at par with the treatment T6 (Enriched Biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha). Higher content of N, P and K in sesame with application of enriched biochar and other organics might be due to increased nutrients availability owing to better physical, chemical and biological properties of soil under these treatments. Furthermore, higher yield with these treatments ultimately resulted in higher uptake of nutrients. The present findings are within the close vicinity of those reported by Coumaravel et al. (2015) [4], Arunkumar et al. (2019) [2] and Jatav and Singh (2019) [10].

The data furnished in Table 2 indicated that significantly the highest organic carbon content (0.96%) was recorded under the treatment T6 (Enriched Biochar 0.25 t/ha + Vermicompost 1 t/ha), but it was statistically at par with the treatments T10 (Enriched Biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha), T7 (Biochar 0.5 t/ha + vermocompost 1 t/ha), T5 (Enriched Biochar 0.25 t/ha + FYM 2.5 t/ha) and T8 (Biochar 0.5 t/ha + FYM 2.5 t/ha). The treatment T1 (RDF) recorded significantly the lowest organic carbon content (0.72%). Ample supply organic matter through enriched biochar, FYM and vermicompost to the soil provides a favourable environment for mineralization of the carbon in organics by enriched microbial consortium this might have increased the organic carbon content. Similar findings were also reported by Pal (2019) [13-14] and Sindhu et al. (2019) [15]. Significantly the highest available N (248.42 kg/ha) was recorded under the treatment T9 (Enriched Biochar 0.25 t/ha + Vermicompost 1 t/ha), but it was statistically at par with treatments T10 (Enriched Biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha) and T7 (Biochar 0.5 t/ha + Vermicompost 1 t/ha). The treatment T9 (Biochar 1 t/ha) recorded significantly the lowest available N (202.20 kg/ha).

Significantly the highest available P2O5 (47.79 kg/ha) was noted with the treatment T9 (Enriched Biochar 0.25 t/ha + Vermicompost 1 t/ha), which was remained statistically comparable with the treatments T10 (Enriched Biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha) and T7 (Biochar 0.5 t/ha + Vermicompost 1 t/ha). While, the lowest available P2O5 (20.25 kg/ha) was analysed with the treatment T3 (Biochar 1 t/ha).

Application of enriched biochar 0.25 t/ha + vermicompost 1 t/ha (T5) resulted in significantly the highest available K2O (271.72 kg/ha) and it was found statistically similar to the treatments T10 (Enriched Biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha) and T7 (Biochar 0.5 t/ha + Vermicompost 1 t/ha). Conversely, the treatment T3 (Biochar 1 t/ha) registered significantly the lowest available K2O (236.95 kg/ha). Influence of biochar along with enrichment, FYM and vermicompost might have supplied the balanced nutrients timely and slowly for growth and development of plant. Enrichments of microbial consortia as supplements might have enhanced the nutrient availability by releasing or solubilizing the soil nutrients which are in fixed and unavailable forms. Hence, after harvest, higher amount of soil nutrients might have been observed due to rapid decomposition and mineralization of organics. These results are in conformity with those reported by Devi et al. (2018) [5], Palansooriya et al. (2019) [13-14] and Singh et al. (2019) [10].

**Table 1: Growth and yield of summer sesame under organic amendment treatments**

| Treatments | Plant height (cm) | Number of branches/plant | Number of capsules per plant | Length of capsule (cm) | Seed weight per plant (g) | Test weight (g) | Seed Yield (kg/ha) | Stover yield (kg/ha) |
|------------|------------------|--------------------------|------------------------------|------------------------|--------------------------|----------------|-------------------|-------------------|
| T1: RDF    | 60.0             | 2.13                     | 47.1                         | 2.45                   | 3.51                     | 3.67          | 1095              | 1441              |
| T2: FYM 5 t/ha | 58.1           | 1.70                     | 44.0                         | 2.39                   | 2.84                     | 3.51          | 885               | 1165              |
| T3: Vermicompost 2 t/ha | 58.6     | 1.75                     | 45.2                         | 2.41                   | 3.02                     | 3.56          | 951               | 1203              |
| T4: FYM 2.5 t/ha + Vermicompost 1 t/ha | 59.4   | 1.90                     | 46.4                         | 2.44                   | 3.44                     | 3.64          | 1074              | 1417              |
| T5: Biochar 1 t/ha | 55.4   | 1.33                     | 41.6                         | 2.29                   | 2.23                     | 3.00          | 682               | 889               |
| T6: Biochar 0.5 t/ha + FYM 2.5 t/ha | 57.7  | 1.53                     | 42.6                         | 2.34                   | 2.50                     | 3.27          | 792               | 994               |
| T7: Biochar 0.5 t/ha + Vermicompost 1 t/ha | 64.8  | 2.77                     | 51.7                         | 2.62                   | 4.87                     | 3.83          | 1541              | 1870              |
| T8: EBC 0.25 t/ha + FYM 2.5 t/ha | 61.2  | 2.40                     | 47.8                         | 2.50                   | 4.23                     | 3.70          | 1323              | 1642              |
| T9: EBC 0.25 t/ha + Vermicompost 1 t/ha | 70.0 | 3.10                     | 58.0                         | 2.86                   | 5.55                     | 4.22          | 1741              | 2123              |
| T10c: EBC 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha | 67.7 | 2.90                     | 55.3                         | 2.74                   | 5.27                     | 3.91          | 1673              | 2036              |
| S.Em.%    | 2.92             | 0.13                     | 3.06                         | 0.12                   | 0.27                     | 0.17          | 88                | 99                |
| C.D. at 5%| 8.69             | 0.38                     | 9.09                         | 0.34                   | 0.80                     | 0.51          | 261               | 293               |
| C.V. %    | 8.26             | 10.23                    | 11.05                        | 8.01                   | 12.47                    | 8.20          | 12.93             | 11.55             |

**Table 2: Nutrients uptake, post-harvest soil fertility and economics under organic amendment treatments**

| Treatments | N uptake (kg/ha) | P uptake (kg/ha) | K uptake (kg/ha) | OC (%) | Available N (kg/ha) | Available P (kg/ha) | Available K (kg/ha) | Net return (a/ha) | B:C ratio |
|------------|-----------------|-----------------|-----------------|--------|--------------------|--------------------|--------------------|-----------------|-----------|
| T1: RDF    | 69.01           | 13.14           | 20.44           | 0.72   | 220.65             | 27.85             | 251.45             | 61046           | 2.60      |
| T2: FYM 5 t/ha | 50.37           | 10.39           | 15.83           | 0.76   | 210.46             | 25.57             | 244.51             | 38721           | 1.93      |
| T3: Vermicompost 2 t/ha | 56.61     | 11.67           | 16.89           | 0.81   | 213.61             | 38.05             | 247.18             | 39023           | 1.83      |
| T4: FYM 2.5 t/ha + Vermicompost 1 t/ha | 66.69 | 12.88           | 19.85           | 0.78   | 219.27             | 29.17             | 250.14             | 53053           | 2.20      |
| T5: Biochar 1 t/ha | 29.67 | 6.59            | 11.37           | 0.79   | 202.20             | 20.25             | 236.95             | 3342            | 1.06      |
| T6: Biochar 0.5 t/ha + FYM 2.5 t/ha | 39.36 | 8.32            | 13.55           | 0.82   | 206.77             | 22.42             | 241.25             | 21776           | 1.44      |
The data on economics (Table 2) revealed that the maximum net returns of ₹ 99142/ha was realized with treatment T9 (Enriched Biochar 0.25 t/ha + Vermicompost 1 t/ha), followed by the treatments T10 (Enriched Biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha) and T7 (Biochar 0.5 t/ha + Vermicompost 1 t/ha) having net return of ₹ 94424/ha and ₹ 86805/ha, respectively. Whereas, the lowest net realization of Rs. 3342/ha was accrued under T5 (Biochar 1 t/ha). The data (Table 2) further indicated that the highest B:C ratio (2.69) was obtained with the treatment T2 (Biochar enriched Biochar 0.25 t/ha + Vermicompost 1 t/ha), followed by the treatments T9 (Enriched Biochar 0.25 t/ha + FYM 1.25 t/ha + Vermicompost 0.5 t/ha) with B:C ratio of 2.65, T7 (Biochar 0.5 t/ha + Vermicompost 1 t/ha) with B:C ratio of 2.64 and T1 (RDF) with B:C ratio of 2.60. While, the lowest B:C ratio (1.06) was accrued with the treatment T5 (Biochar 1 t/ha). The highest net return and B:C ratio gained in the treatment T5 is mainly due to increased seed and stover yield over other treatments.

Based on the experimental results, it seems quite logical to conclude that higher production along with improved soil fertility and higher net return from sesame (Gujarat Junagadh Tal 5) can be obtained by the application of microbial consortia enriched biochar 0.25 t/ha + vermicompost 1 t/ha on medium black calcareous clayey soil under South Saurashtra Agro-Climatic Zone.

Acknowledgments

The authors are grateful to the Director, College of Agriculture, Junagadh Agricultural University for providing necessary field and laboratory facilities during M.Sc. research work.

References

1. Anonymous. Ministry of Agriculture and Farmers Welfare. Government of India (ON1704) 2018. www.indiastat.com.
2. Arunkumar BR, Thippeshappa GN, Chiddanandappada HM Gurumurthy KT. Impact of biochar, FYM and NPK fertilizers integration on aerobic rice growth, yield and nutrient uptake under sandy loam soil. Crop Research 2019;54(5-6):111-117.
3. Bhattacharya S, Chandra R, Pareek N, Raverkar KP. Biochar and crop residue application to soil: Effect on soil biochemical properties, nutrient availability and yield of rice (Oryza sativa L.) and wheat (Triticum aestivum L.). Archives of Agronomy and Soil Science 2015;62(8):1095-1108.
4. Coumaravel K, Santhi R, Maragatham S. Effect of biochar on yield and nutrient uptake by hybrid maize and on soil fertility. Indian Journal of Agricultural Research 2015;49(2):185-188.
5. Devika OS, Prasad PR, Rani PP, Pathy RP. Nutrient status of soils influenced by the interaction of biochar and FYM with chemical Fertilizers. The Pharma Innovation Journal 2018;7(6):174-177.
6. Elangoval R, Sekaran NC. Effect of biochar application on growth, yield and soil fertility status in cotton. An Asian Journal of Soil Science 2014;9(1):41-49.
7. Garamu T. Effect of different source and rates of biochar application on the yield and yield components of mungbean on the acidic soil in western Ethiopia. Academic Research Journal of Agricultural Science and Research 2019;7(7):530-538.
8. Gokila B. Climate change impact on yield, quality and soil fertility of maize in sandy clay loam as influenced by biochar and inorganic nutrients in tptic haplustalf. International Journal of Current Microbiology and Applied Sciences 2017;6(11):3150-3159.
9. Jackson ML. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi 1974,327-350.
10. Jetav HS, Singh SK. Effect of biochar application in soil amended with sewage sludge on growth, yield and uptake of primary nutrients in rice (Oryza sativa L.). Journal of the Indian Society of Soil Science 2019;67(1):115-119.
11. Lal BP, Babu PR, Prasad PRK, Venkata, L.N. Influence of biochar derived from maize stover and maize cobs on growth and yield of sweet corn in sandy loam soils. The Andhra Agricultural Journal 2018;65(1):92-97.
12. Mansour W, Salim BBM, Hussin S, Rassoul M. Biochar as a strategy to enhance growth and yield of wheat plant exposed to drought conditions. 14th Scientific Conference for Agricultural Development and Research, Faculty of Agriculture, Ain Shams University 2019;27(1):51-59.
13. Palansooriya KN, Wong JTF, Hashimoto Y, Huang L, Rinklebe J, Scott XC et al. Response of microbial communities to biochar-amended soils: A critical review. Biochar 2019;1:3-22.
14. Pal R. Effects of soil application of biochar on soil health and productivity of rice-wheat cropping system in Rohtas district of Bihar. Journal of Krishi Vigyan 2019;8(1):109-112.
15. Sindhu YS, Prasad PR, Prasuna PR, Lakshimpathy R. Effect of different sources of biochar and microbial consortium on soil properties and performance of black gram. The Andhra Agricultural Journal 2019;66(1):84-90.
16. Singh R, Singh P, Singh H, Raghubanshi AS. Impact of sole and combined application of biochar, organic and chemical fertilizers on wheat crop yield and water productivity in a dry tropical agro-ecosystem. Biochar 2019;1:229-235.