Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(2): 1638-1642
Received: 16-01-2020
Accepted: 18-02-2020

Sanjay-Swami
School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University, Umiam (Barapani), Meghalaya, India

Chingak PW Konyak
School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University, Umiam (Barapani), Meghalaya, India

Corresponding Author:
Sanjay-Swami
School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University, Umiam (Barapani), Meghalaya, India

Soil dehydrogenase enzyme and microbial biomass carbon as influenced by integrated nutrient management under cabbage cultivation in acid Inceptisol of Meghalaya

Sanjay-Swami and Chingak PW Konyak

Abstract
To investigate the influence of integrated nutrient management on soil dehydrogenase enzyme activity and microbial biomass carbon in acid Inceptisol, a field experiment was conducted at School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences, Umiam, Meghalaya during *rabi* 2017-18. Cabbage (*Brassica oleracea* L. var. *capitata)* cv. Wonder Ball was raised as test crop with eight different combinations of doses of Farm Yard Manure (FYM), Vermicompost (VC) and recommended doses of NPK fertilizers (RDF). The treatment combination consists of control (T_1), 100% RDF (T_2), 100% N through FYM (T_3), 100% N through VC (T_4), 50% RDF + 50% N through FYM (T_5), 75% RDF + 25% N through FYM (T_6), 50% RDF + 50% N through VC (T_7) and 75% RDF + 25% N through VC (T_8). The experiment was laid out in RBD and replicated thrice. The experimental soil was having pH 4.87, SOC 1.24%, Alkaline $KMnO_4$- N 160 kg/ha, available P_2O_5 18.60 kg/ha and available K_2O 238.4 kg/ha. The experimental results revealed that treatment T_7 with 50% RDF + 50% N through VC produced highest cabbage yield (60.44 t/ha) which was statistically comparable with T_5 of 50% RDF + 50% N through FYM (54.33 t/ha). Significantly higher soil dehydrogenase enzyme activity (DHA) and soil microbial biomass carbon (SMBC) was observed under all organic manures treatments over the control and sole inorganic treatments. Among the organic treatments, T_3 (100% N through FYM) recorded highest DHA and SMBC. In both combined treatments, farm yard manure treated soils (T_5 and T_6) showed higher DHA and SMBC over vermicompost treated soils (T_7 and T_8) indicating superiority of FYM over VC in maintaining soil biological health after harvest of cabbage.

Keywords: Integrated nutrient management, cabbage, yield, soil enzyme, microbial biomass carbon, acid soil

Introduction
India has emerged as second largest vegetable producing country in the world, but the present level of production is not sufficient to make pace with the growing population. It is anticipated that the nation will require around 225 million tons vegetable by the year 2025 against the limitations of expansion of the cultivable land area. Cabbage is known to play predominant role in Indian meal as it possess high nutritive value supplying essential vitamins, proteins, carbohydrates and vital minerals amongst *Cruciferaceae*. However, productivity of cabbage in our country stands with just 22.6 t/ha which is far behind other developed countries, where as Meghalaya stands with just 21.57 t/ha (MoA, GoI, 2014) [1] due to existing acidity related stress (Sailo and Sanjay-Swami, 2019) [2].
Continuous use of inorganic fertilizers alone tends to reduce the crop yields over time by affecting the soil properties and depleting soil organic matter. Reduction of soil organic matter affects the water holding capacity, soil structure, water infiltration and increases soil compaction (Dutta *et al.*, 2003) [3]. Soil organic matter is a key component as it influences soil biological, physical and chemical properties that define soil quality (Doran and Parkin, 1994) [4] and acts as a reservoir of plant nutrients and serves as a substrate for soil micro-organisms (Dutta *et al.*, 2003) [5]. The energy crisis and high fertilizer costs have created considerable concern for use of organic materials as a source of plant nutrients (Sanjay-Swami and Singh, 2020) [6]. Integrated use of organic and inorganic fertilizers can improve crop productivity (Mal *et al.*, 2013) [7]. Use of chemical fertilizers in combination with organic manure is essentially required to improve soil health (Bajpai *et al*., 2006) [8].
Soil health is the most crucial factor in deciding the agricultural productivity in the Meghalaya (Lyngdoh and Sanjay-Swami, 2018) [9]. In Meghalaya, the acid soils are found under different acidic ranges, moderately acidic soils (1.19 million ha) and slightly acidic soils (1.05 million ha) (Yadav and Sanjay-Swami, 2019) [10].

There is an urgent need to develop nutrient management package involving use of renewable resources of plant nutrients available to the farmers of Meghalaya. Although FYM is commonly used organic manure but is not available in adequate quantity. The huge amounts of farm wastes can be recycled effectively by preparing vermicompost (Sanjay-Swami, 2012) [11]. Vermicompost application improves bulk density, water holding capacity, and humic substances of the soil (Sanjay-Swami and Bazaya, 2010) [12]. Its application also improves soil biology by increasing population of beneficial microbes and enzyme activities (Sharma and Garg, 2017) [13]. Soil enzymatic activities have been proposed as appropriate indicator because of their intimate relationship to soil biology and rapid response to changes in nutrient management. Microbial biomass carbon provides an insight into the composition and activity of micro-organisms and signifies the main source of soil enzymes. Therefore, the present investigation was carried out to study the influence of integrated nutrient management involving vermicompost and FYM in combination with inorganic fertilizers on cabbage yield, soil dehydrogenase enzyme activity and soil microbial biomass carbon in acid Inceptisol of Meghalaya.

Materials and Methods

The experiment was conducted at Research Farm of School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences, Umiam, Meghalaya during *rabi* 2017-18. The experimental soil was having pH 4.87, SOC 1.24%, Alkaline KMnO4- N 160 kg/ha, available P_2O_5 18.60 kg/ha and available K_2O 238.4 kg/ha. The recorded meteorological parameters during the crop growing season are presented in Figure 1.

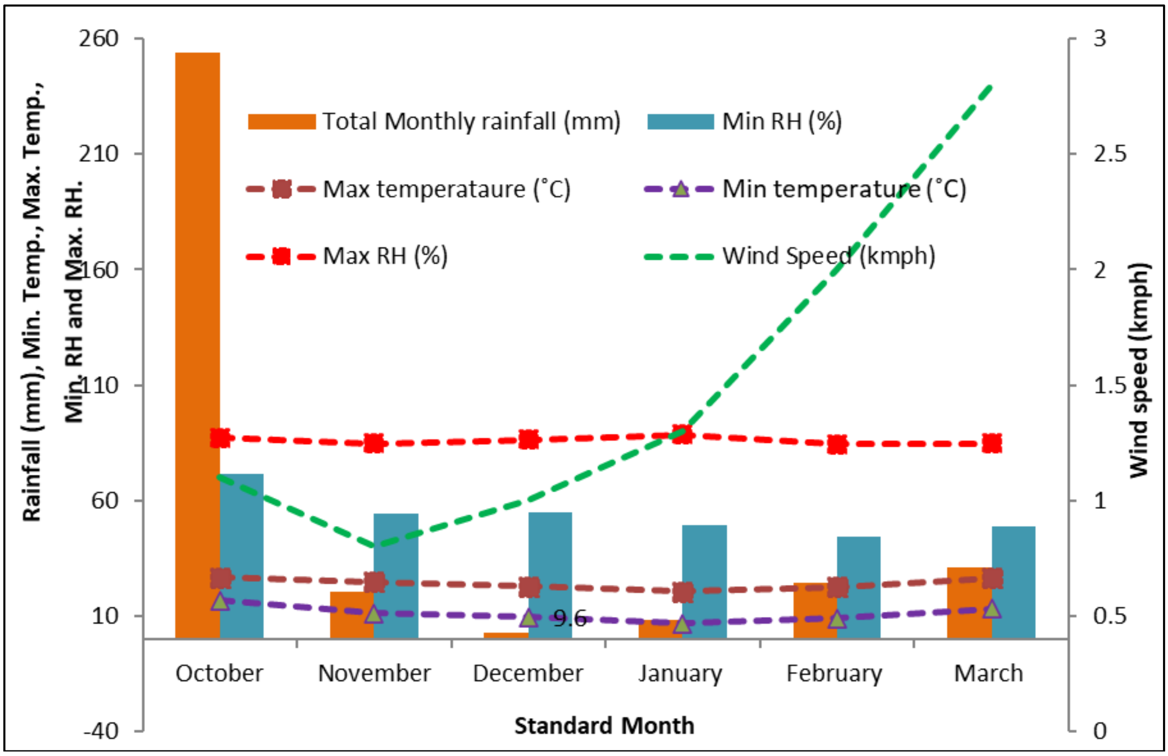

Fig 1: Monthly average values of metrological parameters during the crop growth period (October 2017 to March, 2018)

For raising cabbage nursery, the growing medium was prepared by thorough mixing of top soil, fine sand and well rotted FYM in a ratio 2:1:1 and transferred to plastic seedling tray of 50 cavities with each cavity of 38 mm depth with upper and lower diameter of 32 x 20 mm^2. The seeds of F_1 hybrid Wonder Ball were placed in each cavity. Light irrigation was given after sowing for easy and quick germination. Germination started after 4-5 days. Irrigation was provided regularly until the seedlings attained the age 30 days. The uniform cabbage seedlings were deported safely for transplanting in the experimental field. The trial was conducted in Randomized Block Design (RBD) with eight treatments *viz*., control (T_1), 100% RDF (T_2), 100% N through FYM (T_3), 100% N through VC (T_4), 50% RDF + 50% N through FYM (T_5), 75% RDF + 25% N through FYM (T_6), 50% RDF + 50% N through VC (T_7), 75% RDF + 25% N through VC (T_8) and replicated thrice. All the agronomic practices were followed through out the crop growing period. The N, P and K content in FYM on dry weight basis was 0.55, 0.24 and 0.34 percent while vermicompost was superior in N, P and K content with 2.10, 1.22 and 1.53 percent, respectively.

The plot-wise yield of cabbage head was recorded in kilograms and then converted into tonne per hectare and the mean values were statistically analysed. The soil samples were collected at the end of experimentation to determine soil organic carbon by Walkley and Black (1934) [14] method. For analysis of soil microbiological properties after harvest of cabbage, fresh soil samples were collected treatment wise from the plant rhizospheric region using a PVC pipe (1 inch inner diameter) and immediately stored in the refrigerator at 2 °C, until further analysis. Dehydrogenase activity was determined by Klein *et al.*, (1971) [15], and soil microbial biomass carbon (SMBC) by Jenkinson and Powlson (1976) [16]. The data recorded for various parameters were analysed statistically by following procedure of Gomez and Gomez (1984) [17].

Results and Discussion

Head yield of cabbage

The cabbage head yield data showed that maximum head yield of cabbage was found in treatment T_7 (50% RDF + 50% N through VC) as presented in Figure 2. The percent increase in T_7 over T_2 (100% RDF) was 12.02 percent. However, it was at par with other treatments *viz.*, T_3, T_4, T_5, T_6, T_7 and T_8. The integration of vermicompost and FYM increased head yield over RDF (120:60:60), reflecting their fertilizer use efficiency in terms of head yield. The higher yield in combined treatments (T_7, T_5, T_6 and T_8) might be due to favourable soil condition and synchronized release of nutrients throughout the crop growth period (Murali and Setty, 2004; Gupta *et al.*, 2019a&b) [18-20].

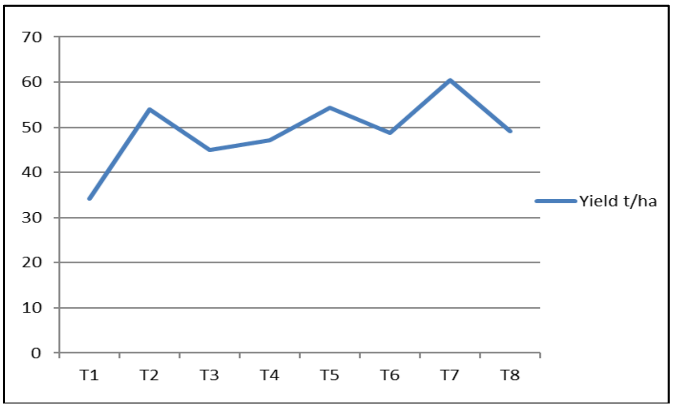

Fig 2: Effect of organic and inorganic nutrient sources on head yield of cabbage (*Brassica oleracea* L. var. *capitata)* in acid Inceptisol

T_1- Control; T_2-100% RDF; T_3-100% N through FYM; T_4-100% N through VC; T_5- 50% RDF + 50% N through FYM; T_6- 25% RDF + 75% N through FYM; T_7- 50% RDF + 50% N through VC; T_8- 25% RDF + 75% N through VC

*Recommended doses of fertilizers (RDF) = 120:60:60 :: N:P:K (kg/ha)

Soil organic carbon

Integrated nutrient management through farm yard manure (FYM) and vermicompost (VC) in both sole and combined treatment apparently affected the soil organic carbon (SOC) status of soil (Table 1). The SOC content varied between 1.44 per cent in T_1 (control) to 1.66 per cent in T_3 (100% N FYM). The per cent increase in T_3 over T_2 (100% RDF) was 41.88 per cent. Whereas, in T_2, increase in SOC over T_1 (control) was 2.63 per cent. The magnitude of increase in SOC over initial (1.24%) was higher in FYM treatment over VC treatment in both sole and combined treatments, respectively. The result also revealed that all the sole (T_3 and T_4) and combined (T_5, T_6, T_7 and T_8) treatments showed statistically higher organic carbon over T_1 (control).

The increase in SOC content in the manurial treatment combinations is attributed to direct addition of organic manure in the soil which stimulated the growth and activity of micro-organisms and also due to better root growth, resulting in the higher production of biomass, crop stubbles and residues (Moharana *et al.*, 2012) [21]. The subsequent decomposition of these materials might have resulted in the enhanced carbon content of soil. These results are in agreement with the findings of Majumdar *et al.* (2008) [22] and Nayak *et al.* (2012) [23]. Addition of organic nutrient source might have created environment conducive for formation of humic acid and stimulated the activity of soil micro-organism, resulting in an increase in the organic carbon content of the soil (Srilatha *et al.*, 2013; Gupta *et al.*, 2019a&b) [24-26].

Soil dehydrogenase enzyme activity (DHA)

Soil dehydrogenase enzyme is involved in oxidative phosphorylation, and is an important indicator of microbial activity in the soil which has been found to increase significantly in the soils applied in combination of organic and inorganic nutrient sources. The dehydrogenase enzyme activity (DHA) was observed significantly higher in T_3 (100% N through FYM) over T_2 (100% RDF) by 52.20 per cent. It was significantly lower in both sole inorganic treatment and control (T_2 and T_1) as compared to all other treatments. In both combined treatments, farm yard manure treatment (T_5 and T_6) showed higher DHA activity over vermicompost treatments (T_7 and T_8) as presented in Table 1.

The use of chemical fertilizer alone exhibited lower dehydrogenase activity compared with conjoined use of inorganic and organic nutrients sources. The inorganic source of nutrient simulated the activity of micro-organisms to utilize the native pool of organic carbon as a source of carbon, which acts as substrate for dehydrogenase activity. Secondly, the addition of nitrogen doses solely and partially through chemical fertilizers resulted in accumulation of nitrate in soil, thus inhibiting the activity of enzyme through interfering in the process of electron acceptors as reported by Goyal *et al.*, (1992) [27].

Between the organic sources, farm yard manure treatment in both sole and combined was found to be superior in maintaining higher DHA enzyme over vermicompost which might be due to higher content of organic matter in the FYM. Incorporation of bulky sources of potential beneficial microbes may provide microbial diversity and activity of micro-organisms accompanied by better DH activity. The higher dehydrogenase activity in soil treated with N supplied with manure treatment along with recommended P and K may be attributed to the increased SOC, total N and P status of soil. This may enhanced the microbial proliferation which led to increased activity. Further, the activity of soil dehydrogenase seems to be associated with microbial breakdown of organic matter. The addition of organic manures like FYM and vermicompost to cabbage for the supplementation of N along with P and K which might have stimulated the degradation and increased the microbial activity which, in turn, enhanced the metabolic activity as well as soil dehydrogenase activity. Rao (2007) [28] concluded the positive correlation of soil enzymes with crop residue and manure amended soil. Kumar *et al.*, (2017) [29] also observed maximum DH activity (136.90 µg TPF g^{-1} h^{-1}) under INM practice with 50% recommended dose of NPK + vermicompost @ 2 t ha^{-1} (mixed with microbial consortium) after okra cultivation. Similar relationship between SOC, microbial biomass, total N and soil dehydrogenase activity were reported by Gupta *et al.*, (2019a&b) [30, 31].

Soil microbial biomass carbon (SMBC)

Soil microbial biomass carbon (SMBC), the most active and dynamic pool of the soil organic matter, acts as transient nutrients sinks and is responsible for releasing nutrients from organic matter for use by plants. It plays a critical role in regulating the carbon and nitrogen biogeochemical processes in the soil. The size of microbial biomass carbon pool is strongly influenced by soil management practices. In the present study, soil microbial biomass carbon was observed significantly higher under all organic manures treatments over the control and sole inorganic treatments as presented in Table 1. Among the organic treatments, T_3 (100% N through FYM) was recorded highest with 509.63 µg/g soil which was followed by T_4 (100% N through VC) with 474.07 µg/g soil. The per cent increase in T_3 over sole inorganic treatment T_2 (100% RDF) was 59.99 whereas in T_2, the increase over T_1 (control) in SMBC was 7.49 per cent. Among the combined treatments, farm yard manure treated plots (T_5 and T_6) showed higher microbial biomass carbon content over vermicompost treated plots (T_7 and T_8), respectively.

The higher MBC in soils receiving organics is related to higher microbial population due to balanced supply of nutrients and carbon (Basak *et al.*, 2012) [32]. The good quality organic inputs in the soil have a potential to augment soil enzymatic activities and improve the microbial biomass carbon and organic carbon (Nath *et al.*, 2012) [33]. Between the organic sources, farm yard manure treatment in both sole and combined was found to be superior in maintaining higher SMBC over vermicompost which might be due to higher content of organic matter in the FYM. Increased organic carbon content of the soil due to application of various organic nutrients over the years served as a source of energy for biological activity, thereby enhancing the density of microbes (Moharana *et al.*, 2012) [34]. Further, most of the soil micro-organisms are chemo-autotrophs, which require organic source of carbon as food and oxidation of organic substances provides energy which might be the reason in improving microbial population in soils applied with organics (Ingle *et al.*, 2014; Kumar *et al.*, 2017; Gupta *et al.*, 2019a&b) [35-38].

Table 1: Effect of organic and inorganic nutrient sources on SOC (%), SMBC (µg/g soil) and DHA µg TPF/g soil/hr

Treatments	SOC	DHA	SMBC
T_1	1.14	5.43	296.30
T_2	1.17	5.90	318.52
T_3	1.66	8.98	509.63
T_4	1.63	8.27	474.07
T_5	1.53	7.75	414.81
T_6	1.59	7.94	438.52
T_7	1.44	7.06	391.11
T_8	1.49	7.78	402.96
$P \leq 0.05$	0.07	0.37	20.35
SEm±	0.20	1.13	61.73

T_1- Control; T_2-100% RDF; T_3-100% N through FYM; T_4-100% N through VC; T_5- 50% RDF + 50% N through FYM; T_6- 25% RDF + 75% N through FYM; T_7- 50% RDF + 50% N through VC; T_8- 25% RDF + 75% N through VC

*Recommended doses of fertilizers (RDF) = 120:60:60 :: N:P:K (kg/ha)

Conclusion

The present investigation demonstrated that application of 50 per cent nitrogen through vermicompost along with 50 per cent of the recommended dose of fertilizers (T_7) is the most effective combination for increasing yield of cabbage, whereas significantly higher soil organic carbon, soil dehydrogenase enzyme activity (DHA) and soil microbial biomass carbon (SMBC) was observed under all organic manures treatments over the control and sole inorganic treatments. Among the organic treatments, T_3 (100% N through FYM) recorded highest SOC, DHA and SMBC. In both combined treatments, farm yard manure treated soils (T_5 and T_6) showed higher SOC, DHA and SMBC over vermicompost treated soils (T_7 and T_8) indicating superiority of FYM over VC in maintaining soil biological health after harvest of cabbage in acid Inceptisol of Meghalaya

Acknowledgement

The laboratory facility provided by School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences, CAU, Umiam for carrying out soil and plant analysis is duly acknowledged.

References

1. MoA GoI. Indian Horticulture Database, Ministry of Agriculture, Government of India. 2014, 136-283.
2. Sailo V, Sanjay-Swami. Performance of pea (*Pisum sativum* L.) with residual phosphorus in phytoremediated heavy metal polluted soil of Jaintia hills, Meghalaya. International Journal of Chemical Studies, 2019; 7(3):3270-3273.
3. Dutta S, Pal R, Chakeraborty A, Chakrabarti K. Influence of integrated plant nutrient supply system on soil quality restoration in a red and laterite soil. Archive of Agronomy and Soil Science, 2003; 49:631-37.
4. Doran JW, Parkin TB. Defining and assessing soil quality. In: Defining Soil Quality for a Sustainable Environment, Doran J.W., Coleman, D.C., Bezdicek, D.F. and Stewart, B.A. (Eds.), SSSA Inc., Madison, Wisconsin, USA, 1994.
5. Dutta S, Pal R, Chakeraborty A, Chakrabarti K. Influence of integrated plant nutrient supply system on soil quality restoration in a red and laterite soil. Archive of Agronomy and Soil Science, 2003; 49:631-37.
6. Sanjay-Swami, Singh S. Effect of nitrogen application through urea and *Azolla* on yield, nutrient uptake of rice and soil acidity indices in acidic soil of Meghalaya. Journal of Environmental Biology. 2020; 41(1):139-146.
7. Mal B, Mahapatra P, Mohanty S, Mishra HN. Growth and yield parameters of okra (*Abelmoschus esculentus*) influenced by diazotrophs and chemical fertilizers. Journal of Crop and Weed, 2013; 9(2):109-112.
8. Bajpai RK, Chitale S, Upadhyay SK, Urkurkar JS. Long-term studies on soil physico-chemical properties and productivity of rice wheat system as influence by integrated nutrient management in Inceptisol of Chhattisgarh. Journal of Indian Society of Soil Science. 2006; 54:24-29.
9. Lyngdoh EAS, Sanjay-Swami. Phytoremediation effect on heavy metal polluted soils of Jaintia Hills in North Eastern Hill Region. International Journal of Current Microbiology and Applied Sciences. 2018; 7(11):1734-1743
10. Yadav OS, Sanjay-Swami. Performance of tomato (*Solanum lycopersicum* L.) in acid soil under integrated nutrient management with biochar as a component. International Journal of Current Microbiology and Applied Sciences. 2019; 8(05): 793-803.
11. Sanjay-Swami. Vermicomposting: Transforming garbage into gold, 2012. http://www.krishisewa.com/articles/organic-agriculture/6-vermicomposting.html.
12. Sanjay-Swami, Bazaya BR. Vermicompost technology. In: Quality Seed Production of Vegetable Crops: Technological Interventions, (ed.) Sharma, J.P., Kalyani Publishers, Ludhiana, Punjab, 2010, 344-356.
13. Sharma K, Garg VK. Vermi-modification of ruminant excreta using *Eisenia fetida*. Environmental Science and Pollution Research. 2017; 24(24):19938-19945.
14. Walkley A, Black CA. An examination of the Degtjareff method for determining soil organic matter and a

proposed modification of the chromic acid titration method. Soil Science, 1934; 37:29-38.
15. Klein DA, Loh TC, Goulding RL. A rapid procedure to evaluate the dehydrogenase activity of soils low in organic matter. Soil Biology and Biochemistry. 1971; 3(4): 385-387.
16. Jenkinson DS, Powlson DS. The effects of biocidal treatments on metabolism in soil V: A method for measuring soil biomass. Soil Biol. Biochem., 1976; 8(3):209-213.
17. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. John Wiley and Sons, New York, USA. 1984, 20-30.
18. Murali MK, Setty RA. Effect of fertilizer, vermicompost and triacontanol on growth and yield of scented rice. *Oryza*, 2004; 4:57-59.
19. Gupta R, Rai AP, Sanjay-Swami. Soil enzymes, microbial biomass carbon and microbial population as influenced by integrated nutrient management under onion cultivation in sub-tropical zone of Jammu. Journal of Pharmacognosy and Phytochemistry, 2019a; 8(3):194-199.
20. Gupta R, Sanjay-Swami, Rai AP. Impact of integrated application of vermicompost, farmyard manure and chemical fertilizers on okra (*Abelmoschus esculentus* L.) performance and soil biochemical properties. International Journal of Chemical Studies. 2019b; 7(2):1714-1718.
21. Moharana PC, Sharma BM, Biswas DR, Dwivedi BS, Singh RV. Long-term effect of nutrient management on soil fertility and soil organic carbon pools under a 6-year old pearlmillet–wheat cropping system in an Inceptisol of subtropical India. Field Crops Research. 2012; 136:32-41.
22. Majumdar B, Mandal B, Bandyopadhyay PK, Gangopadhyay A, Mani PK. Organic amendments influence soil organic carbon pools and rice-wheat productivity. Soil Science Society of America Journal, 2008; 72:775-785.
23. Nayak AK, Gangwar B, Shukla AK, Mazumdar SP, Kumar A. Long-term effect of different integrated nutrient management on soil organic carbon and its fractions and sustainability of rice–wheat system in Indo Gangetic Plains of India. Field Crops Research. 2012; 127:129-139.
24. Srilatha M, Rao PC, Sharma HK, Padmaja G. Physico-chemical characterization of humic substances under long-term application of fertilizers and manures in rice-rice cropping sequence in an Inceptisol. International Journal of Advanced Research, 2013; 10:343-348.
25. Gupta R, Rai AP, Sanjay-Swami. Soil enzymes, microbial biomass carbon and microbial population as influenced by integrated nutrient management under onion cultivation in sub-tropical zone of Jammu. Journal of Pharmacognosy and Phytochemistry. 2019a; 8(3):194-199.
26. Gupta R, Sanjay-Swami, Rai AP. Impact of integrated application of vermicompost, farmyard manure and chemical fertilizers on okra (*Abelmoschus esculentus* L.) performance and soil biochemical properties. International Journal of Chemical Studies. 2019b; 7(2):1714-1718.
27. Goyal S, Mishra MM, Hooda IS, Singh R. Organic matter-microbial biomass relationships in field experiments under tropical conditions: Effects of inorganic fertilization and organic amendments. Soil Biology and Biochemistry, 1992; 24(11):1081-1084. doi.org/10.1016/0038-0717(92)90056-4.
28. Rao DLN. Microbial diversity, soil health and sustainability. Journal of Indian Society of Soil Science, 2007; 55:392-403.
29. Kumar V, Saikia J, Barik N, Das T. Effect of integrated nutrient management on soil enzymes, microbial biomass carbon and microbial population under okra cultivation. International Journal of Biochemical Research and Review. 2017; 20(4):1-7. ISSN: 2231-086X.
30. Gupta R, Rai AP, Sanjay-Swami. Soil enzymes, microbial biomass carbon and microbial population as influenced by integrated nutrient management under onion cultivation in sub-tropical zone of Jammu. Journal of Pharmacognosy and Phytochemistry. 2019a; 8(3):194-199.
31. Gupta R, Sanjay-Swami, Rai AP. Impact of integrated application of vermicompost, farmyard manure and chemical fertilizers on okra (*Abelmoschus esculentus* L.) performance and soil biochemical properties. International Journal of Chemical Studies. 2019b; 7(2):1714-1718.
32. Basak BB, Biswas DR, Rattan RK. Comparative effectiveness of value added manures on crop productivity, soil mineral nitrogen and soil carbon pools under maize–wheat cropping system in an Inceptisol. Journal of Indian Society of Soil Science. 2012; 60(4):288-298.
33. Nath DJ, Ozah B, Baruah R, Barooah RC, Borah DK, Gupta M. Soil enzymes and microbial biomass carbon under rice–toria sequence as influenced by nutrient management. Journal of Indian Society of Soil Science, 2012; 60(1):20-24.
34. Moharana PC, Sharma BM, Biswas DR, Dwivedi BS, Singh RV. Long-term effect of nutrient management on soil fertility and soil organic carbon pools under a 6-year old pearlmillet–wheat cropping system in an Inceptisol of subtropical India. Field Crops Research. 2012; 136:32-41.
35. Ingle SS, Jadhao SD, Kharche VK, Sonune BA, Mali DV. Soil biological properties as influenced by long term manuring and fertilization under sorghum (*Sorghum bicolor*) - wheat (*Triticum aestivum*) sequence in Vertisols. Indian Journal of Agricultural Sciences, 2014; 84(4):452-457.
36. Kumar V, Saikia J, Barik N, Das T. Effect of integrated nutrient management on soil enzymes, microbial biomass carbon and microbial population under okra cultivation. International Journal of Biochemical Research and Review. 2017; 20(4):1-7. ISSN: 2231-086X.
37. Gupta R, Rai AP, Sanjay-Swami. Soil enzymes, microbial biomass carbon and microbial population as influenced by integrated nutrient management under onion cultivation in sub-tropical zone of Jammu. Journal of Pharmacognosy and Phytochemistry. 2019a; 8(3):194-199.
38. Gupta R, Sanjay-Swami, Rai AP. Impact of integrated application of vermicompost, farmyard manure and chemical fertilizers on okra (*Abelmoschus esculentus* L.) performance and soil biochemical properties. International Journal of Chemical Studies. 2019b; 7(2):1714-1718.