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Physico-chemical and microbiological properties of acid Inceptisol as influenced by INM practices under cabbage (*Brassica oleracea* L. var. capitata) production

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ABSTRACT

Aim: The aim of study was to evaluate the influence of various organic and inorganic nutrient sources on physico-chemical and microbiological properties of acid Inceptisol after cabbage (Brassica oleracea L. var. capitata) harvest.

Method and Materials: Eight different combinations of doses of Farm Yard Manure (FYM), Vermicompost (VC) and recommended doses of NPK fertilizers (RDF) such as 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) were tested 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.

Results: The results revealed that the 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.

Conclusion: The application of 50 per cent nitrogen through vermicompost along with 50 per cent of the recommended dose of fertilizers (T_7) found most effective combination.

Keywords: Acid Inceptisol, cabbage, integrated nutrient management and soil health.

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Introduction

India is the second largest producer of fruits and vegetables in the world and is the leader in several horticultural crops, namely mango, banana, papaya, cashew nut, areca nut, potato, and okra. Vegetables are rich and comparatively cheap sources of vitamins like β-carotene, folic acid, vitamin B, vitamin C, vitamin E, minerals like iron, calcium, magnesium, phosphorus and dietary fibers. Vegetables also supplies fair amount of carbohydrates, protein (4%) and energy (10%). The area under cultivation of vegetables stood at 10.45 million hectares and produced around 191 MTs of vegetables which accounts for nearly 14% of country's share in the world share. Cabbage is nutrient rich and a great source of vitamin C, vitamin K, fibre and folate. However, it is cultivated in 0.3 M ha with total production of 6.9 Mt and average productivity of 22.6 t ha^{-1} which is far behind other developed countries, whereas Meghalaya stands with just 21.57 t ha^{-1} (MoA, GoI, 2014) due to existing acidity related stress (Sailo and Sanjay-Swami, 2019). In Meghalaya, the acid soils are found under different acidic ranges like moderately acidic soils (1.19 million ha), and slightly acidic soils (1.05 million ha) (Yadav and Sanjay-Swami, 2019). Soil health or fertility is the most crucial factor in deciding the agricultural productivity in the region (Lyngdoh and Sanjay-Swami, 2018).

Due to continuous use of inorganic fertilizers alone reduces the crop yields over time by affecting the soil properties and depleting soil organic matter. Therefore, soil organic matter is a key component in defining soil quality (Doran and Parkin, 1994) and acts as a reservoir of plant nutrients and serves as a substrate for soil micro-organisms (Dutta *et al*., 2003). The use of chemical fertilizers in combination with organic manure is essentially required to improve soil health (Bajpai *et al*., 2006). Association of organic matter and nutrient availability has been confirmed by the high coefficients of correlation between the soil attributes (Sakal *et al*., 1996). 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 adequately available. The huge amounts of farm wastes can be recycled effectively by preparing vermicompost (Sanjay-Swami, 2012). Vermicompost application improves bulk density, water holding capacity, and humic substances of the soil (Sanjay-Swami and Bazaya, 2010). Its application also improves soil biology by increasing population of beneficial microbes and enzyme activities (Sharma and Garg, 2017). Therefore, the present investigation was carried out to study the influence of vermicompost and FYM in combination with inorganic fertilizers on improvement in the physico-chemical and microbiological properties of acid Inceptisol of Meghalaya.

Materials and Methods

The experiment was conducted at School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences, Umiam, Meghalaya during *rabi* 2017-18. 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 throughout the crop growing period. The physico-chemical properties of experimental soil and nutrient content in organic manures used in this investigation are presented (Table 1 and 2).

Table 1: Physico-chemical properties of experimental soil

S. No.	Particulars	Value	Method adopted	Inferences
1.	pH	4.87	pH meter with glass electrode	Piper (1966)
2.	Organic carbon (%)	1.24	Walkey and Blacks method of rapid titration	Walkley and Black (1934)
3.	Available nitrogen (kg ha^{-1})	160.00	Alkaline potassium permanganate method	Subbiah and Asijah (1956)
4.	Available phosphor us (kg ha^{-1})	18.60	Bray and Kurtz No. 1 method	Bray and Kurtz (1945)
5.	Available potassium (kg ha^{-1})	238.40	Neutral normal ammonium acetate method	Knudsen *et al*., (1982)

Table 2: Nutrient content in FYM and vermicompost (on dry weight basis) used in the investigation

S. No.	Particulars	FYM	Vermi-compost	Methods Adopted	Reference
1.	Total N (%)	0.55	2.10	Modified Micro Kjeldahl method	Jackson (1973)
2.	Total P (%)	0.24	1.22	Di-acid digestion and yellow colour development method	Jackson (1973)
3.	Total K (%)	0.34	1.53	Flame photometric method	Jackson (1973)

For analysis of soil physico-chemical and microbiological properties after harvest of cabbage, soil samples were collected treatment wise from the plant rhizospheric region using a PVC pipe (1 inch inner diameter). The soil samples were collected from 15 cm depth and processed for analysis of various soil physical and chemical properties. For analysing microbiological properties of soil, fresh soil samples were collected and immediately stored in the refrigerator at 2°C until further analysis. The data recorded for various parameters were analysed statistically by following procedure of Gomez and Gomez (1984).

Results and discussion

Soil bulk density

It is discernible from Fig. 1 that application of recommended doses of fertilizers alone (T_2) or with farm yard manure (T_3) and vermicompost (T_4), decreased the value of bulk density. Similarly, a small decreased in bulk density was also observed in combined treatments (T_5, T_6, T_7 and T_8) of organic and inorganic. However, the differences among the treatments were non-significant. The lower bulk density in surface soil was attributed to the higher SOC (Tripathi *et al.*, 2014). Higher SOM, better aggregation and increased root growth with balanced fertilization was also reported by Chalwade *et al.*, (2006); and Bandyopadhyay *et al.*, (2010).

Soil moisture

The perusal of Fig. 1 shows the effect of different treatments on soil moisture per cent. It indicates that highest (22.67 per cent water) soil moisture was found in treatment T_3 (100% N through FYM) and lowest in (19.06 per cent) under T_1 (control) treatment. The per cent increase in soil moisture per cent in T_3 over T_1 was 18.94 per cent. However, all treatments were found statistically at par with one another. Among the sole treatment of organic and inorganic, organic treatment showed higher soil moisture per cent. The treatment T_7 and T_5 with vermicompost were found more effective on soil moisture as compared to T_8 (25% RDF + 75% N through FYM) and T_6 (50% RDF + 50% N through FYM) with farm yard manure, respectively. The higher water retention may be due to better aggregation and higher SOC in surface soil (Thangasamy *et al.*, 2017). The amount of water retained at field capacity primarily depends on capillary effect, pore size distribution and soil structure (Hillel, 2004).

Soil pH

The effect of organic nutrient sources and inorganic nutrient sources on soil pH was very little between the treatments and was statistically non-significant. A slight increase in pH as compared to initial value was recorded in soil treated with organic sources in both sole (T_3 and T_4) and combined (T_5, T_6, T_7 and T_8) application whereas, slight decrease in soil pH as compared to initial value was found in sole application of inorganic source which is presented in Fig 2. The increase in pH might be due to decrease of Al^{3+} and release of basic cations during decomposition of manures, whereas application of nitrogenous fertilizers decreases the pH due to residual acidity of fertilizers. A similar result has been reported in the findings of Zhang *et al.* (2008); Yaduvanshi and Sharma (2016).

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 (Fig 2).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 treatment respectively. The result also revealed, all the sole (T_3 and T_4) and combined (T_5, T_6, T_7 and T_8) treatments showed statistically higher significant over T_1 (control).

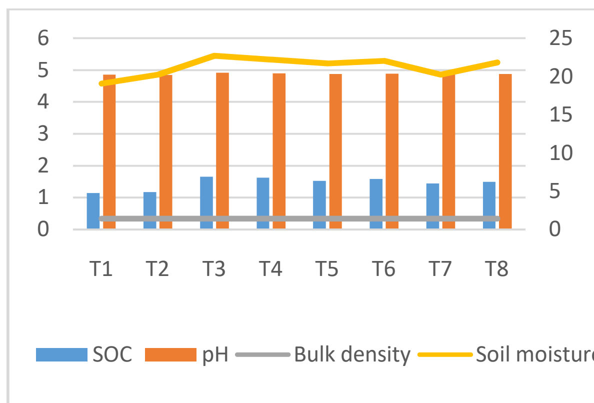

Fig. 1: Effect of integrated nutrient sources on SOC (percent), pH, bulk density (g/cm³) and soil moisture (percent)

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). 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). 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).

Soil available nitrogen

The soil available nitrogen content in all treatments (T_2 to T_8) was statistically significant over T_1 (control) as presented in Fig 2. The highest available nitrogen was recorded in T_7 (50% RDF + 50% N through VC) with 275.97 kg/ha which was followed by T_5 (50% RDF + 50% N through FYM) with 267.67 kg/ha. In general, application of sole manures (T_3 and T_4), inorganic fertilizers (T_2) and combined (T_5, T_6, T_7 and T_8) application improved the soil available nitrogen status of soil as compared to control treatment (T_1). The per cent increase in T_7 over T_2 (100% RDF) in soil available nitrogen was 6.45 per cent, whereas, increase in T_2 over T_1 for soil available nitrogen was 42.83 per cent. Among the sole treatment of organic and inorganic, inorganic treatment showed higher soil available nitrogen. However, the degree of response was of lower order as compared to sole inorganic treatment. The treatment T_7 and T_5 with vermicompost were found superior as compared to T_8 (25% RDF + 75% N through FYM) and T_6 (50% RDF + 50% N through FYM) with farm yard manure, respectively.

The higher soil available nitrogen in vermicompost treatments in both sole and combined treatments might be due to lower C: N ratio in vermicompost as compared to farm yard manure. While the higher soil available nitrogen in T_5 and T_7 as compared to T_6 and T_8 might be due to faster mineralization as compared to T_6 and T_8. The lower soil available nitrogen in sole application (T_3 and T_4) of organic manures as compared to sole application of inorganic fertilizer (T_2) might be due microbial demand of available nitrogen in the sole organic treatments. The lower content in untreated plots is a result of mining of available nitrogen with continuous cropping without fertilization during the crop period. These results are in line with the findings of Gupta *et al*. (2019a&b), who also observed that available nitrogen content in soil increased with the use of recommended dose of fertilizer in combination with manure.

Soil available phosphorus

The soil available phosphorus content in all treatments (T_2 to T_8) was statistically significant over T_1 (control) as presented in Fig 2. The highest soil available phosphorus was recorded in T_7 (50% RDF + 50% N through VC) with 28.16 kg/ha which was followed by T_5 (50% RDF + 50% N through FYM) with 27.09 kg/ha. In general, application of manures (T_3 and T_4), inorganic fertilizers (T_2) and combined (T_5, T_6, T_7 and T_8) application improved the soil available phosphorus status of soil as compared to control treatment. The per cent increase in T_7 over T_2 (100% RDF) in soil available phosphorus was 5.42 per cent, whereas, increase in T_2 over T_1 for soil available phosphorus was observed to be 64.36 per cent. Among the sole treatment of organic and inorganic, inorganic treatment showed higher soil available phosphorus. However, the degree of response was of lower order as compared to sole inorganic treatment. The treatment T_7 and T_5 with vermicompost were found superior as compared to T_8 (25% RDF + 75% N through FYM) and T_6 (50% RDF+50% N through FYM) with farm yard manure, respectively. The higher soil available phosphorus in vermicompost treatments in both sole and combined treatments might be due to lower C: N: P ratio in vermicompost and higher concentration (1.22% P in vermicompost and 0.24% P in farm yard manure) of as compared to farm yard manure. On the other hand, organic manures on decomposition solubilize insoluble organic P fractions through release of various organic acids, thus resulting into a significant improvement in available phosphorus status of the soil (Sanjay-Swami and Singh, 2019). The lower soil available phosphorus in sole application (T_3 and T_4) of organic manures as compared to sole application of inorganic fertilizer (T_2)might be due microbial demand of available phosphorus in the sole organic treatments. The lower content in untreated plots is a result of mining of available phosphorus with continuous cropping without fertilization during the crop period (Gupta *et al.,* 2019a&b).

Soil available potassium

The soil available potassium content in all treatments (T_1 to T_8) was statistically non-significant as presented in Fig 2. The highest soil available potassium was recorded in T_7 (50% RDF + 50% N through VC) with 208.89 kg/ha which was followed by T_5 (50% RDF + 50% FYM) with 202.95 kg/ha. In general, application of manures, inorganic fertilizers and combined application improved the soil available potassium status of soil as compared to control treatment. The per cent increase in T_7 over T_2 (100% RDF) in soil available potassium was 9.14 per cent. Whereas,T_2 increase over T_1 in soil available potassium was 11.78 per cent. Among the sole treatment of organic and inorganic, inorganic treatment (T_2) showed higher soil available potassium. However, the degree of response was of lower order as compared to sole inorganic treatment. The treatment T_7 and T_5 with vermicompost were found superior as compared to T_8 (25% RDF + 75% N through FYM) and T_6 (50% RDF + 50% N through FYM) with farm yard manure, respectively.

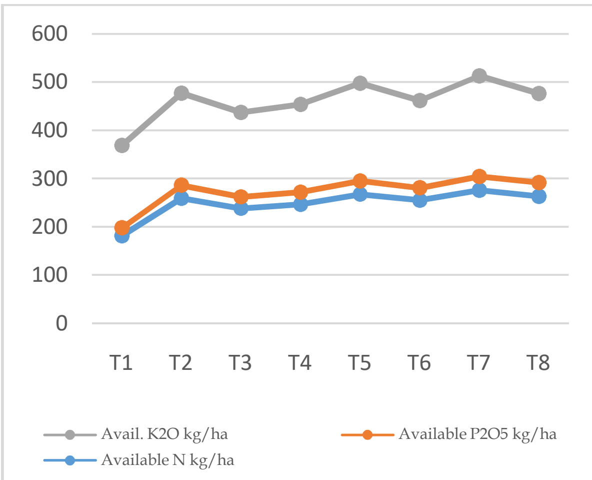

Fig. 2: Effect of organic and inorganic nutrient sources on soil available macronutrients

The higher soil available potassium in vermicompost treatments in both sole and combined treatments might be due to lower C: N: P: K ratio in vermicompost and higher concentration (1.53 % K in vermicompost and 0.34 % K in farm yard manure) as compared to farm yard manure. Application of organic manure may have caused reduction in potassium fixation and consequently increased potassium content due to interaction of organic matter with clay besides the direct addition to the available K pools of soil (Urkurkar *et al.*, 2010). Such increase in the content of available potassium with the integrated use of organics and chemical fertilizers has also been reported by Kumar and Singh (2010) and Gupta *et al.*, (2019a&b).

DTPA extractable micronutrients

The amount of available Fe, Mn, Cu and Zn (4.71, 43.73, 34.97 and 91.33 mg/kg respectively) was maximum with T_3 (100% N through FYM) treatment which was slightly followed by T_4 (100% N through VC) as presented in Fig 3. The effect of organic and inorganic sources on DTPA extractable Fe and Mn was found to be statistically non-significant while on DTPA extractable Cu and Zn, statistically significant higher in all organic source treatments (T_3, T_4, T_5, T_6, T_7 and T_8) over sole inorganic application (T_2) and control (T_1) were recorded. The per cent increase in T_3 over T_2 (100% RDF) was in Fe 10.30, Mn 21.23, Zn 74.39 and Cu 91.40 %, respectively.

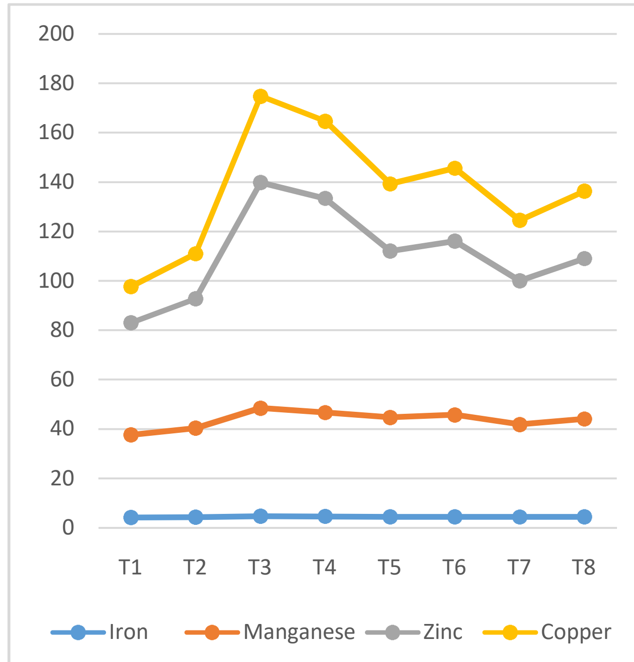

Fig. 3: Effect of organic and inorganic nutrient sources on DTPA extractable micronutrients (mg/kg)

Among the combined treatments of organic and inorganic, the plot receiving farm yard manure showed higher concentration of soil available Fe and Mn due to addition of organic manure in a larger quantity as compared to vermicomost. Higher availability of Fe and Mn in organic manure treated plots may be due to mineralization of organically bound forms of Fe and Mn in the organic manure and formation of organic chelates of higher stability which decreased their susceptibility to adsorption, fixation and precipitation resulting in their enhanced availability in soil (Kher, 1993). Organic sources *viz.* FYM and vermicompost which might have also contributed to its enhanced availability in soil. Behera and Singh (2009) found that the addition of organic matter to soil encouraged micro-organisms, which under certain conditions aided in the liberation of trace elements. Build-up of copper and zinc and was observed with the application of organic sources especially FYM and vermicompost which may be due to the fact that Cu and Zn forms Cu-humus complex and Zn-humus of relatively high stability with humus that decrease its susceptibility to fixation or precipitation in soil and increases its availability. These results were also found in consonance with Kumar *et al.* (2010).

Soil microbial biomass carbon (SMBC)

Soil microbial biomass carbon was significant higher under all organic manures treatments over the control and sole inorganic treatments as presented in Fig 4. 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 theT_2 increased over T_1 (control) in SMBC was 7.49 per cent. In both combined treatments, farm yard manure treatment (T_5 and T_6) showed higher microbial biomass carbon content over vermicompost treatments (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). 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). 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 concentration of organic matter in the soil. 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). 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; Gupta *et al.,* 2019a&b).

Soil dehydrogenase enzyme activity (DHA)

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 microbial biomass carbon content over vermicompost treatments (T_7 and T_8) as presented in Fig 4.

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 concentration of organic matter in the soil. 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) concluded the positive correlation of soil enzymes with crop residue and manure amended soil. Similar relationship between SOC, microbial biomass, total N and soil dehydrogenase activity were reported by Kumar *et al.* (2007) and Gupta *et al.,* (2019a&b).

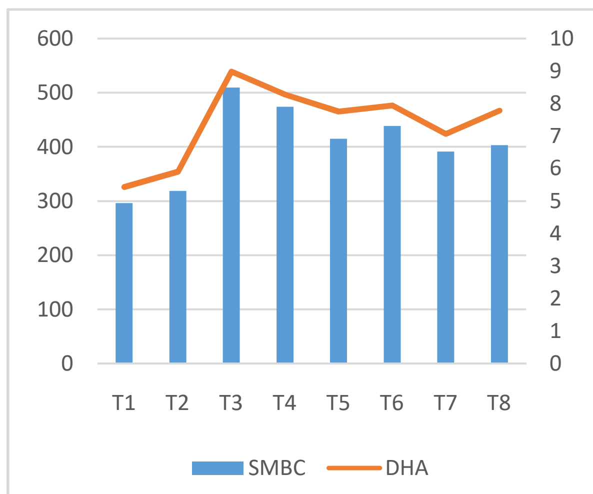

Fig. 5: Effect of organic and inorganic nutrient sources on SMBC (µg/g soil) and DHA µg TPF/g soil/24 hr

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 improving physico-chemical and microbiological properties of acid Inceptisol as compared to sole application of organic manure or inorganic fertilizers indicating the best suitable option for managing soil health of acid Inceptisol.

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