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Soil microbial, chemical properties and crop productivity as affected by organic manure application in popcorn (*Zea mays* L. var. *everta*)

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Soil microbial population, dehydrogenase activity and chemical properties of soil under different doses of farmyard manure (FYM), leaf compost and vericopmpost were examined at the research farm of the Indian Agriculture Research Institute (IARI), New Delhi, India during 2008-09 and 2009-10. Results indicated the higher value of microbial population, dehydrogenase activity, organic carbon, available nitrogen (N), phosphorus (P), potassium (K) and lower bulk density were observed in farmyard manure applied equivalent to 120 kg N ha^{-1} followed by vermicompost equivalent to 120 kg N ha^{-1}. Grain yield of popcorn was significantly higher in the treatments of recommended dose of fertilizers and vermicompost equivalent to 120 kg N ha^{-1}.

Key words: Dehydrogenase activity, farmyard manure (FYM), leaf compost, microbial population, vermicompost.

INTRODUCTION

Popcorn (*Zea mays* L. *var. everta*.) is the most important crop under irrigated conditions of north India. Due to its importance as food, feed and specialty corn, it is a versatile cereal crop for both domestic consumption and for export. popcorn requires huge amounts of nutrients for high productivity. The continued application of chemical fertilizer leads to deterioration of soil health with reduced organic carbon and increased multi-nutrients deficiencies (Swarup, 2002). Maintenance of soil quality is of utmost importance for enhancing productivity which leads to food and nutritional security. High aboveground biomass yield is accompanied by an active root system, which releases an array of organic compounds into the rhizosphere (Fließbach et al., 2007). For maintaining good soil health, nutrient schedules should be correctly followed, including organic manures viz., farmyard

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Table 1. Nutrient concentration in applied organic manures.

Source	N (%)	P (%)	K (%)
Vermicompost	1.60	0.50	1.52
Farm yard manure	0.48	0.28	0.51
Leaf compost	0.67	0.29	0.27

manure (FYM),vermicompost and leaf compost, as these sources have the potential to supply nutrients to crops as well as prevent soil deterioration (Kumar et al., 2005). Application of these organic manures not only helps in enhancing the productivity but also have the beneficial effect on soil properties (Pathak et al., 2005). Nutrients available in organic manures are released slowly, remain in the soil for longer time and are available to plants, thereby maintaining soil fertility and enhance the soil microbial population (Belay et al., 2001). Researchers reported that application of various organic manures stimulated the plant growth, activity of soil micro-organism, resulted in higher population of fungi, bacteria and actinomycetes and higher activity of soil enzymes (Krishnakumar et al., 2005; Sidhu et al., 2007; Alam et al., 2007; Knapp et al., 2010). Application of organic manures increased microbial respiration and resulted in increased carbon and plant nutrient mineralization rates in soil (Powon et al., 2005).

Microbial processes are dynamic, and therefore patterns of temporal fluctuation during crop growth are of great importance in relation to the nutrient supplying capacity of the ecosystem and the crop demand. Consequently, microbial association needs to be studied along with available plant nutrients in soil and crop growth. The information regarding microbial population, soil enzymes and chemical properties of soil in relation to organic manures is limited in crops like popcorn (Meena et al., 2013). Hence, the present study was carried out to evaluate the effect of organic manures on soil chemical, and biological properties as well as productivity in popcorn.

MATERIALS AND METHODS

Experimental location and climate

Field experiments were conducted during 2008-09 and 2009-10 at the research farm of Indian Agricultural Research Institute (IARI), New Delhi (latitude 28.40° N, longitude 77.12°E, 228.6 m above mean sea level). The climate of New Delhi is sub-tropical and semi-arid type with hot and dry summer and cold winter and falls under the Agro-climatic Zone ‘Trans-Gangetic Plains’. The mean annual rainfall is 650 mm and more than 80% generally occurs during the south-west monsoon (July-September) with mean annual evaporation of 850 mm. Minimum and maximum temperature ranged between 11.0 and 35.0°C and 10.9 and 37.9°C, with the rainfall of 582.7 and 502.7 mm during growth period of popcorn in 2008 and 2009, respectively.

Soil characteristics, layout and treatments

The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction (pH 7.7) with bulk density of 1.54 Mg m^{-3}, low in soil organic carbon (0.38%) and available nitrogen (159.4 kg ha_{-1}), medium in available phosphorus (12.6 kg ha_{-1}) and potassium (162.2 kg ha_{-1}), as analysed by Singh et al. (2005). The eight treatments (T1 = Control, T2 = RDF ($N_{120}P_{25}K_{35}$ kg ha_{-1}), T3 = Farmyard manure equivalent to 120 kg N ha_{-1}(FYM120), T4 = Leaf compost equivalent to 120 kg N ha_{-1} (LC 120), T5 = Vermicompost equivalent to 120 kg N ha_{-1} (VC 120), T6 = FYM equivalent to 90 kg N ha_{-1} (FYM 90), T7 = Leaf compost equivalent to 90 kg N ha_{-1} (LC 90), T8 = Vermicompost equivalent to 90 kg N ha_{-1} (VC 90)) were applied. The experiment was laid out in randomized block design (RBD) with three replicates.

Application of organic manures/fertilizers and crop management

The required quantity of organic manures was applied 10 days before sowing of the crop as per the treatments. The FYM, vermicompost and leaf compost samples were analyzed for total N using a Kjeldahl digestion method (Jackson, 1967), while total P and K were determined using a wet digestion (Di-acid digestion) method as described earlier (Prasad et al., 2006). Concentrations of different nutrients in organic manures are given in Table 1. Recommended dose of fertilizer ($N_{120}P_{25}K_{35}$ kg ha^{-1}) was applied through urea, single super phosphate and muriate of potash, respectively. Full dose of P and K, $^{1}/_{3}$ of N and 25 kg ha^{-1} zinc sulphate were applied as basal. The remaining N was applied in two equal splits at tasseling and grain formation stage. To ensure the optimum moisture for germination, pre-sowing irrigation was applied and afterwards irrigation was given to the crop at frequent intervals for better crop establishment. The field was prepared by two cross ploughings with disc plough and one ploughing with cultivator followed by planking. Thereafter, a ridge with a spacing of 60 cm for popcorn sowing was made with the help of tractor drawn ridger. The popcorn seed was dibbled at 3-4 cm seed depth on the side of the ridges at a spacing of 15-20 cm. The optimum plant population (83,000 plant ha^{-1}) was maintained by thinning of plants after one week of germination. For weed control, two manual weddings were done at 30 and 50 days after sowing and during second weeding the earthing up operation was also carried out.

Soil sampling, microbial population and dehydrogenase activity

Soil samples (0-15cm) were collected after harvest of the crop from each treatment for analysis. The samples were stored in plastic bags and taken to the laboratory, where soil was sieved (2 mm mesh size), homogenized and stored at 4°C. Organic carbon was determined by using wet digestion method (Walkley and Black, 1934), available N by alkaline permanganate (Subbiah and Asija, 1956), available P by Olsen’s et al. (1954) method, available K by Flame photometer method (Jackson, 1967), and bulk density was estimated by using the core sampler method (Bodman, 1942). The fungal, bacterial and actinomycetes population were estimated by standard plate count method using Marten’s for fungi (Martin, 1950), and nutrient agar medium for bacteria and actinomycetes (Allen, 1959). Microbial population was calculated and expressed as number of cells, $x10^{n}$/g soil. Dehydrogenase activity was determined by reduction of 2, 3, 5-triphenyltetrazolium chloride (TTC) (Casida et al., 1964). Individual character datasets were subjected to analysis of variance and means were separated by Duncan’s multiple range test (DMRT) at the 5% level of probability using SAS version 9.3.

Table 2. Effect of various treatments on microbial population in popcorn cultivated soil (pooled data).

Treatment	Bacteria ($cfu10^5$ g^{-1} soil)	Fungi ($cfu10^2$ g^{-1} soil)	Actinomyceties ($cfu10^2$ g^{-1} soil)
T1=Control	20.37^d	14.77^g	8.34^f
T2=RDF ($N_{120}P_{25}K_{35}$ kg ha^{-1})	23.18^c	16.58^f	9.58^e
T3=Farmyard manure equivalent to 120 kg N ha^{-1}	28.60^a	23.96^a	14.16^a
T4= Leaf compost equivalent to 120 kg N ha^{-1}	26.11^{ab}	21.13^d	11.61^{cd}
T5= Vermicompost equivalent to 120 kg N ha^{-1}	28.37^a	23.03^{ab}	13.49^{ab}
T6= FYM equivalent to 90 kg N ha^{-1}	27.12^{ab}	22.17^{bc}	12.92^b
T7=Leaf compost equivalent to 90 kg N ha^{-1}	24.74^{bc}	19.32^e	10.63^{de}
T8=Vermicompost equivalent to 90 kg N ha^{-1}	26.95^{ab}	21.21^{cd}	12.58^{bc}

Same letters (a, b and c) between the two treatments indicate a non-significant difference at $P \leq 0.05$ (DMRT-test).

RESULTS AND DISCUSSION

Microbial population of bacteria, fungi and actinomycetes

The pooled data of both the years are presented, as there was no significant difference observed among the years (Table 2). The microbial population viz., bacteria, fungi and actinomycetes significantly were affected with application of different organic N sources as compared to control. The application of 120 kg N ha^{-1} either through FYM (T3) or vermicompost (T5) resulted in maximum microbial population of bacteria (28.60 and 27.12 $cfu10^5$ g^{-1} soil), fungi (23.96 and 22.17 $cfu10^2$ g^{-1} soil) and actinomycetes (14.16 and 12.92 $cfu10^2$ g^{-1} soil), respectively (Table 2). The application of leaf compost equivalent to120 kg N ha^{-1} (T4) resulted in higher amount of microbial populations as compared to control and RDF (T2), although it was statistically at par with the application of 90 kg N ha^{-1} either through FYM (T6), vermicompost (T8) and leaf compost (T7). The increase in microbial population with the application of organic manure might be due to stimulated growth and activities of soil microorganism (Upadhyay et al., 2011). The crop plant secreted various types of organic acids from roots, which is an easily available source of food for soil microorganism (Dotaniya et al., 2013). The addition of organic inputs enhanced the microbial counts in soil, which might be due to carbon addition and changes in physico-chemical properties of soil. The recommended dose of fertilizer (RDF) resulted in lower values of microbial populations than organic manure treatments, but significantly higher than the control treatment. Microbial populations were more numerous in the application of 120 kg N ha^{-1} either through FYM (T3) or vermicompost (T5) probably due to the bioavailability of growth-promoting substances. Microbial population composition and density is an important attribute of soil organic matter quality, as it provides an indication of a soil's ability to store and recycle nutrients and energy. It also serves as a sensitive indicator of change and future trends in organic matter level. The increase in microbial biomass was proportional to the addition of nutrients and accelerated microbial activity (Masto et al., 2006).

Dehydrogenease activity in soil

Dehydrogenease activity increased significantly with application of organic manures (FYM, leaf compost and vermicompost) as compared to inorganic fertilizers and control (Figure 1). Farmyard manure equivalent to 120 kg N ha^{-1} (T3) resulted in significantly higher activity of dehydrogenase in soil (87 µg TPF g^{-1} soil 24 h^{-1}). Application of vermicompost equivalent to 120 kg N ha^{-1} (T5) also recorded higher values of dehydrogenase activity in soil, although it was statistically at par with the application of 90 kg N ha^{-1} either through FYM (T6) or vermicompost (T8). From these results, it can be inferred that dehydrogenase activity is influenced more by the quality than by the quantity of organic matter incorporated into soil. Thus, the stronger effects of FYM on dehydrogenase activity might be due to more easy decomposition of FYM on the metabolism of soil microorganisms (Pancholy and Rice, 1973). It has been shown before that dehydrogenase activity was positively influenced by the total porosity of soil and higher dehydrogenase activity was obtained in soil treated with organic manures (Marinari et al., 2000).

Available N, P and K contents in soil

Available N, P and K increased significantly with application of organic manures (FYM, leaf compost and vermicompost) as compared to RDF and control (Table 3). The application of FYM equivalent to 120 kg ha^{-1} (T3) resulted in the highest concentration of available N (175.8 kg ha^{-1}), P (14.8 kg ha^{-1}), and K (184.3 kg ha^{-1}) followed by vermicompost equivalent to 120 kg N ha^{-1} although it was statistically at par with 90 kg N ha^{-1} added as vermicompost or FYM or leaf compost at the equivalent

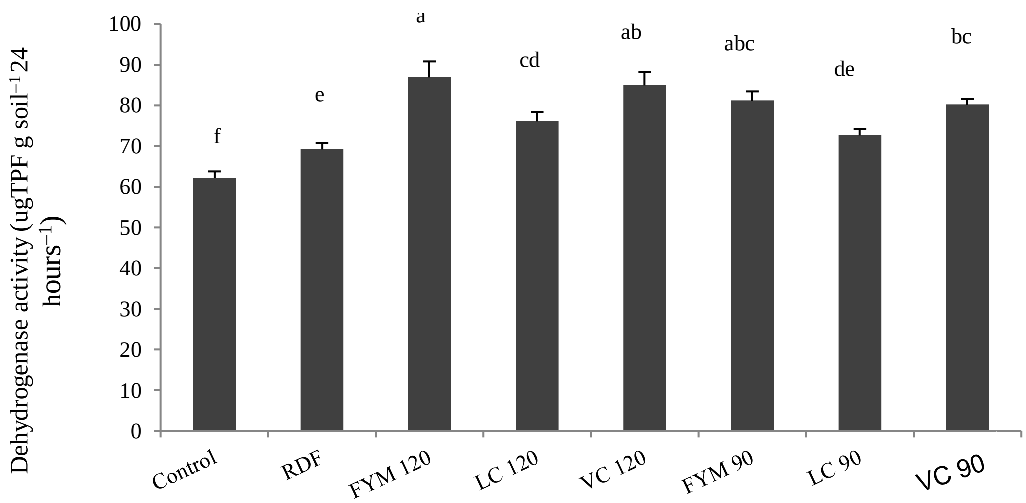

Figure 1. Effect of various treatments on dehydrogenase activity. Same letters (a, b and c) between the two treatments indicate a non-significant difference at $P \leq 0.05$ (DMRT-test).

Table 3. Effect of various treatments on available N, P, K, organic carbon and bulk density in popcorn cultivated soil (pooled data).

Treatment	Available N ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)	Available K ($kg\ ha^{-1}$)	Organic carbon (%)	Bulk density ($Mg\ m^{-3}$)
T1=Control	159.72^{e}	11.65^{f}	161.68^{d}	0.40^{f}	1.53^{a}
T2=RDF ($N_{120}P_{25}K_{35}$ kg ha^{-1})	167.28^{d}	12.78^{e}	170.65^{c}	0.44^{e}	1.51^{ab}
T3=Farmyard manure equivalent to 120 kg N ha^{-1}	175.83^{a}	14.80^{a}	184.31^{a}	0.52^{a}	1.42^{d}
T4= Leaf compost equivalent to 120 kg N ha^{-1}	172.65^{abc}	13.81^{cd}	181.08^{ab}	0.48^{cd}	1.45^{cd}
T5= Vermicompost equivalent to 120 kg N ha^{-1}	174.45^{ab}	14.60^{ab}	183.75^{a}	0.51^{ab}	1.43^{cd}
T6= FYM equivalent to 90 kg N ha^{-1}	172.15^{abc}	14.21^{bc}	178.00^{b}	0.50^{bc}	1.44^{cd}
T7=Leaf compost equivalent to 90 kg N ha^{-1}	169.84^{cd}	13.21^{e}	175.82^{bc}	0.47^{d}	1.46^{bc}
T8=Vermicompost equivalent to 90 kg N ha^{-1}	171.43^{bc}	13.72^{d}	177.15^{b}	0.49^{c}	1.44^{cd}

Same letters (a, b and c) between the two treatments indicate a non-significant difference at $P \leq 0.05$ (DMRT-test).

120 kg N ha^{-1}. The available N, P and K with farmyard manures equivalent to 120 kg N ha^{-1} (T3) was higher by 10, 22 and 14%, respectively, over control. All the organic sources of nutrients improved the available N, P and K status of the soil as compared to the inorganic sources of nutrients and control. Higher N, P, K under organic treatments may be due to continuous application of FYM and organic sources. These sources may enhance organic matter status in soil, which further improves soil physical as well as microbiological activities and increases the availability of plant nutrients (Kumar and Dhar, 2010; Meena et al., 2014). Singh et al. (2008) confirmed the role of organic manures in releasing N and improving N availability in soil. During decomposition of organic manures, various phenolic and aliphatic acids are produced which solubilize phosphatase and other phosphate bearing minerals and thereby lowers the phosphate fixation and increase its availability (Dotaniya et al., 2014a). Available K in soil increased with the application of organic manures which is due to solubilising action of organic acids produced during FYM decomposition and its higher capacity to hold K in available form (Vidyavathi et al., 2011).

Soil organic carbon

Soil organic carbon (SOC) concentration in soil is significantly influenced by different sources of nutrients whether organic or inorganic (Figure 2). In general, post-harvest soils of both years had more concentration of SOC (0.48%) than the samples taken before initiation of experiment (0.38%). The SOC contents of soil changes rapidly with addition of organic manures. The highest SOC concentration (0.52%) was observed with the application of FYM equivalent 120 kg N ha^{-1} (T3). The SOC was also higher with the application of 120 kg N ha^{-1} through FYM (T3) followed by application of vermicompost (T5, T6) during both years. The higher value of SOC content in soil with organic manures might be due to biological immobilization and continuous mineralization of FYM on surface soil layer (Ramesh et

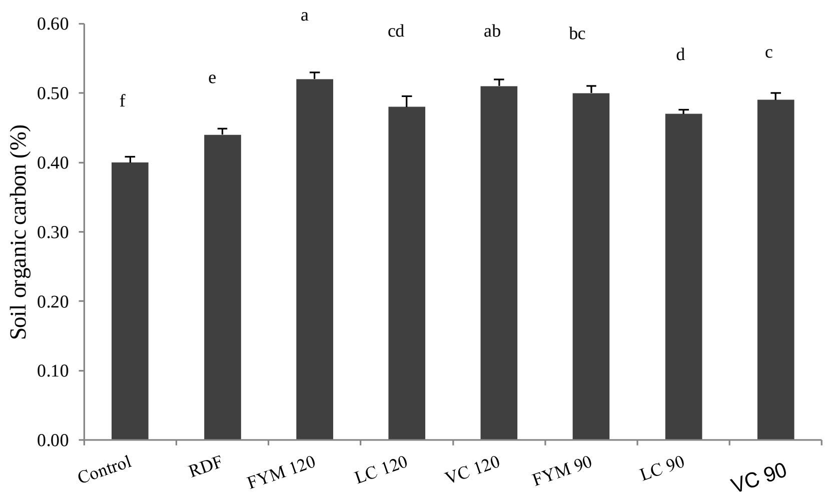

Figure 2. Effect of various treatments on soil organic carbon. Same letters (a, b and c) between the two treatments indicate a non-significant difference at P ≤ 0.05 (DMRT-test).

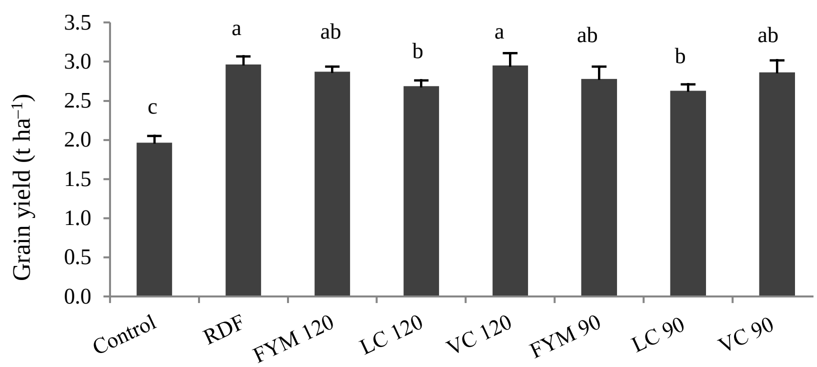

Figure 3. Effect of various treatments on grain yield of popcorn. Same letters (a, b and c) between the two treatments indicate a non-significant difference at P ≤ 0.05 (DMRT-test).

al., 2008). The SOC was also improved with the application of the RDF ($N_{120}P_{25}K_{35}$ kg ha^{-1}) as compared to control plots. The increase in SOC due to inorganic fertilization could be due to higher root biomass accumulation in fertilized treatment than in control as described previously (Masto et al., 2006).

Bulk density

Bulk density (0-15 cm layer) of the popcorn cultivated soil differed significantly due to various levels and sources of nutrients (Table 3). The values of bulk density were significantly lower (1.42-1.46 Mg m^{-3}) with the treatments consisting of organic sources of nutrients than the treatments with inorganic fertilizer (1.51 Mg m^{-3}) and control (1.53 Mg m^{-3}). This could be attributed to higher organic carbon content in these treatments which had better soil aggregate and larger macro pore space (Bellaki et al., 1998). Bulk density was significantly reduced with application of FYM equivalent to 120 kg N ha^{-1} (T3) as compared to RDF (T2) and control (T1), but it remained statistically at par with other organic sources of nutrients during both years. Organic manures (FYM, vermicompost and leaf compost) decreased the bulk density and improved the soil physical properties due to reduced mass per unit of soil (Das et al., 2002).

Popcorn grain yield

The highest grain yield of popcorn was recorded with the application of recommended dose of fertilizers and 120 kg N ha^{-1} applied through vermicompost (T5) during both years (Figure 3). The popcorn yield was 51.3 and 46.4% higher with the application of recommended dose of fertilizers and vermicompost, respectively. The higher yield under inorganic fertilizer is attributed to the increased nutrient availability, which significantly increase the yield parameters such as plant height, stem girth, number of leaves, leaf area, leaf area index and dry matter accumulation (Kolawole and Joyce, 2009).

Conclusions

Integrated use of organic manure and inorganic fertilizers improved the enzymatic activities as well as microbial population of bacterial, fungal and actinomycetes of soil used for growth of popcorn. Based on a two years study, it can be concluded that FYM and vermicompost equivalent to 120 kg N ha^{-1} have almost equally important effects with respect to soil chemical, and biological properties. Decomposition of organic matter and recycling of carbon have substantial effect on the activity of soil enzymes evolved in mineralization of crop plant nutrients. It improved the soil health and microbial population in soil. While, grain yield of popcorn was significantly associated with either recommended dose of fertilizers or vermicompost equivalent to 120 kg N ha^{-1}.

Conflict of interests

The authors did not declare any conflict of interest.

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