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Comparative assessment of conventional and organic nutrient management on crop growth and yield and soil fertility in tomato-sweet corn production system

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Abstract

Nutrient management plays a key role in improving crop yield with maintenance of soil fertility for sustainable production in intensive cropping. Field experiments were conducted to study the effect of organic and conventional fertilizer sources on growth, yield, and nitrogen use efficiency of tomato and sweet corn crop and on changes in chemical and biological properties in acid lateritic soil of eastern India. The tomato was grown during dry season (November – February) and sweet corn during wet season (May – July) in the cropping system during the years 2008 to 2010. The organic nutrient inputs were vermicompost (VC), vermiwash (VW), biofertilizer (BF) and crop residue (CR) and the conventional input was chemical fertilizer (CF). The treatments were CF at 100% recommended dose of N, P and K (CF_{100}), VC at 100% N recommendation (VC_{100}), VC_{50}+CF_{50}, CR, VC_{50}+CR, VC_{50}+VW+BF, and a control (no fertilizer application). The treatments with optimal dose of fertilizer application i.e. CF_{100}, VC_{100} and VC_{50} + CF_{50} were statistically at par and they were significantly superior to suboptimal dose of VC with other organic sources, in increasing yield of both tomato and sweet corn. Among the fertilized treatments, maximum N uptake was noted in CF_{100} treatment, but maximum N use efficiency in VC-based treatments. The VC-based treatments registered lower soil available macronutrients (N, P and K), but higher organic carbon and micronutrient (Fe, Mn, Zn and Cu) as compared to CF treatment at the end of two years cropping system. Inclusion of BF in VC-based treatment was more promising in increasing the microbial count by three fold as compared to the CF treatment. Organic fertilizer application, therefore exhibited potential in improving crop yield, N use efficiency and soil health in acid lateritic soil of the subtropical climate.

Keywords: Chemical fertilizer; Organic fertilizer; Crop yield; Soil fertility; Tomato; Sweet corn.
Abbreviations: BF_Biofertilizer, CF_Chemical fertilizer, CR_Crop residue, NUE_Nitrogen use efficiency,VC_Vermicompost, VW_Vermiwash.

Introduction

Sustainable development in agriculture and yield improvement of crops can be achieved through restoration and scientific management of land productivity. For yield maximization in intensive cropping, supply of appropriate source and amount of nutrients is indispensable. In conventional practice, improved cropping system involving high value crops rely on the use of chemical fertilizer due to its immediate availability of nutrients. Indiscriminate and continuous use of such chemical fertilizers leads to instability in yield and also poses a threat to soil health particularly due to micronutrients deficiency and fertilizer related environment pollution (Kalloo, 2003). With intensification of cropping and heavy use of chemical fertilizers, the supplementary and complementary roles of organic materials are being strongly felt for retaining soil productivity (Laudicina et al., 2011). Use of organic farming techniques to grow crops has gained popularity in recent years as a result of both an increase in consumer demand for organically grown produce and a genuine desire on the part of many growers to sustain or improve the soil health (Dimitri and Greene, 2002). Moreover, higher price of organically produce food than conventional produce (Oberholtzer et al., 2005) prompting producers to grow crops organically. The increased consumer demand appears to be driven primarily by the perception that organically grown produce is safer and more nutritious to eat than produce grown conventionally (Lester, 2006). The organic enrichment is most common through the application of composted materials, microbial biofertilizer or recycling of crop wastes. Vermicompost, a stable organic manure produced as vermicast by earthworm feeding on biological wastes materials is an important source of biofertilizer material. Vermicompost contains significant quantities of nutrients; a large beneficial microbial population; and biologically active metabolites; particularly gibberellins, cytokinins, auxins and group B vitamins which can be applied alone or in combination with organic or inorganic fertilizers, so as to get better yield and quality of diverse crops (Atiyeh et al., 2002; Arancon, 2006 and Jack et al., 2011).

Table 1. Effect of fertilizer sources on yield (kg ha^{-1}) of tomato and sweet corn.

	Tomato		Sweet corn	
Treatments	2008-09	2009-2010	2009	2010
Control	7983 c	10675 c	4250 c	4208 d
CF_{100}	54492 a	64075 a	14900 a	14878 a
VC_{100}	50617 a	61750 a	10308 ab	12165 ab
VC_{50} + CF_{50}	36900 b	56667 a	10892 ab	11713 ab
CR	5692 c	13133 c	6342 bc	6393 cd
VC_{50} + CR	29665 b	37100 b	9825 b	9498 bc
VC_{50} + VW + BF	34287 b	43875 b	10600 ab	9977 b

Means with the same letters among treatments don't differ significantly at P≤0.05. CF – Chemical fertilizer, VC – Vermicompost, VW –Vermiwash, CR – Crop residue, BF – Biofertilizer. The subscripts 100 and 50 represent their application at 100% and 50% of recommendation, respectively.

Table 2. Effect of fertilizer sources on nitrogen uptake (kg ha^{-1}) of tomato and sweet corn.

	Tomato		Sweet corn	
Treatments	2008-09	2009-2010	2009	2010
Control	1.59 f	3.48 f	14.90 e	16.10 e
CF_{100}	42.71 a	43.56 a	101.95 a	109.49 a
VC_{100}	25.21 c	28.16 c	71.89 b	75.79 b
VC_{50} + CF_{50}	33.53 b	37.29 b	99.27 a	107.50 a
CR	1.41 f	4.53 f	16.99 e	19.06 e
VC_{50} + CR	13.23 e	15.88 e	31.10 d	33.04 d
VC_{50} + VW + BF	18.00 d	21.24 d	42.09 c	43.78 c

Means with the same letters among treatments don't differ significantly at P≤0.05. CF – Chemical fertilizer, VC – Vermicompost, VW –Vermiwash, CR – Crop residue, BF – Biofertilizer. The subscripts 100 and 50 represent their application at 100% and 50% of recommendation, respectively.

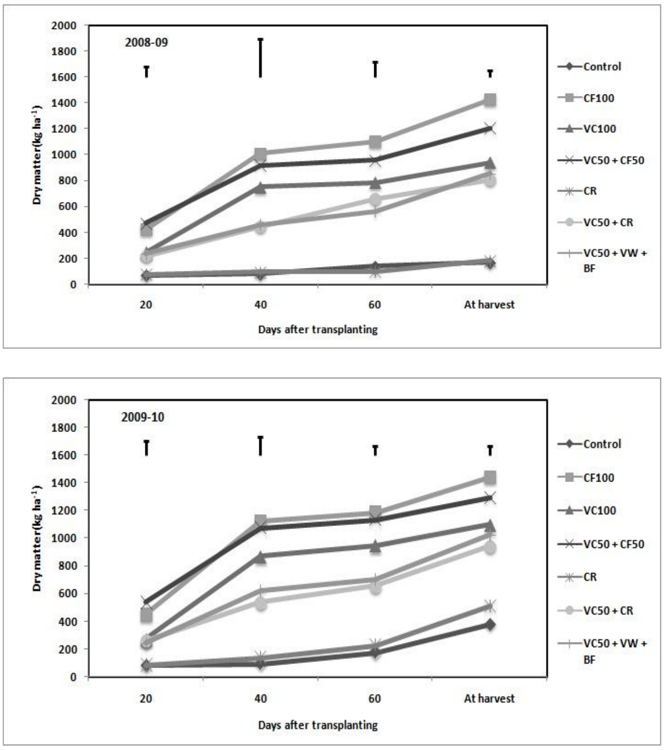

Fig 1. Effect of fertilizer sources on total above ground dry matter of tomato at 20, 40 and 60 days after transplanting and at harvest during 2008-09 and 2009-10 (the vertical lines indicate critical difference at p ≤ 0.05). CF - Chemical fertilizer, VC–Vermicompost, VW–Vermiwash, CR – Crop residue, BF–Biofertilizer. The subscripts 100 and 50 represent their application at 100% and 50% of recommendation, respectively.

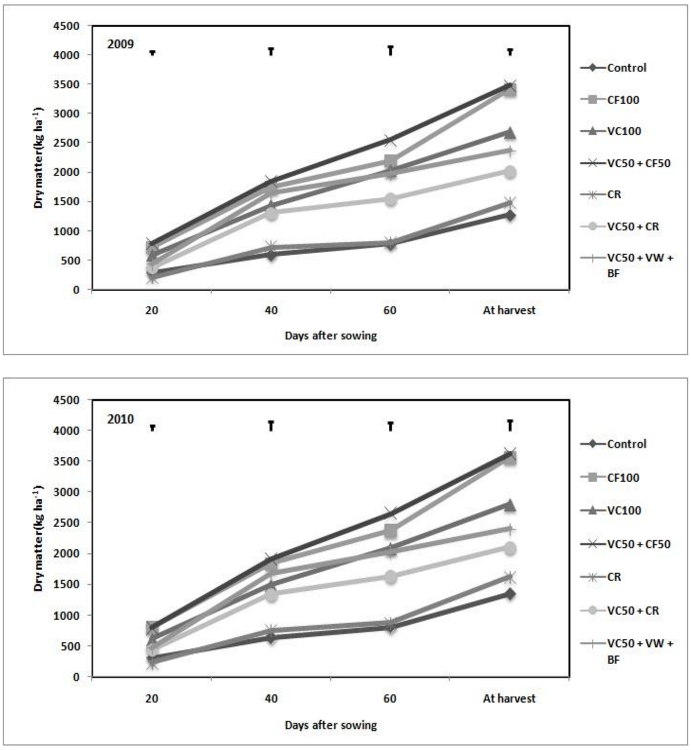

Fig 2. Effect of fertilizer sources on total above ground dry matter of sweet corn at 20, 40 and 60 days after sowing and at harvest during 2009 and 2010 (the vertical lines indicate critical difference at p ≤ 0.05). CF - Chemical fertilizer, VC – Vermicompost, VW–Vermiwash, CR–Crop residue, BF–Biofertilizer. The subscripts 100 and 50 represent their application at 100% and 50% of recommendation, respectively.

Other natural source of biofertilizer is free living N-fixer like *Azotobacter* which has tremendous potential in increasing soil fertility (Mahato et al., 2009). Besides this biofertilizer sources, recycling of crop wastes in a cropping system is a simplest approach to add organic matter in soil. These organic materials with varying C:N ratios and biochemical composition release nutrients at different pace (Azmal et al., 1996). Under dynamic multiple cropping systems, the choice of crops in sequence should be based on crop value as its quality and productivity, restoration of soil fertility and economics. In sub-tropical climate of eastern India, the high value crops, tomato (*Lycopersicon esculentum*) and sweet corn (*Zea mays* var. rugosa) can be successfully grown as dry and wet season crop, respectively, in a cropping sequence. Both the crops seem to be promising and gaining popularity with multiple advantages of meeting increasing demand of cereals and vegetables. Tomato requires nutrient elements such as N, P, K, Mg, Ca, Na and S for improved production. These nutrients are specific in function and must be supplied to the plant at the right time and in the right quantity (Shukla and Naik, 1993). Several studies have shown that organic production is comparable to conventional and low-input systems (Stamatiadis et al., 1999; Clark et al., 1999 and Delate et al., 2003), for example, the yield of carrots, lettuce, tomatoes (Eggert and Kahrmann, 1984), cabbage (Warman and Harvard, 1997) and peppers (Roe et al., 1997). In other study (Klonsky, 2000), when conventional growing did come ahead in terms of yield, organic and low-input systems had enhanced soil microbial biomass and activity, water-holding capacity, mobile humic acids, water infiltration rates, pools of phosphorous and potassium, and organic matter content. Paramanathan (2000) reported that integrated nutrient management by complementary use of chemical fertilizer and organic manure seems to be the best way to improve corn yield by improving the fertility status of the soil. Manure provides all necessary macro- and micro-nutrients in available forms, thereby improved the physical and chemical properties of the soil (Abou El-Magd et al., 2006). Higher levels of total organic C, total N, and soluble P were reported for organic soils (Poudel et al., 2002), whereas Mader et al. (2002) reported small differences for soil chemical parameters like organic C and P. Soil mineral N levels during the cropping season varied with crop, farming system and the amount and source of N fertilization (Poudel et al., 2002) while its availability was most important in limiting the yield in organic systems (Clark et al., 1999). Under integrated nutrient management, nitrogenous chemical fertilizer accelerate the pace of mineralization by lowering the wide C:N ratio of organic matter rich in carbon and low in nitrogen (Al-kaisi et al., 2008). Therefore, chemical fertilizer and organic matter have a complementary role in nutrient release in the soil and the release pattern is expected to vary with varying agro-climate. In the present investigation, we evaluated the effect of vermicompost as organic source of fertilizer applied alone or in combination of other organic sources and chemical fertilizer on growth and yield of tomato and sweet corn crop and on soil fertility in acid lateritic soil of subtropical climate in eastern India. Consequently, the objectives of this study were, to assess growth, yield and nutrient use efficiency of the crops and changes in soil fertility status under conventional and organic nutrient management practices.

Results

Crop growth and yield

Dry matter production of tomato and sweet corn was gradually increased with the crop age (Figs. 1 and 2). In case of tomato, maximum dry matter was recorded in CF_{100} treatment followed by VC_{50} + CF_{50} in both the years. Among the treatments of optimal dose of nutrients, the VC_{100} has shown significant reduction in dry matter as compared to CF_{100} or VC_{50} + CF_{50} treatment. However, it was significantly superior to suboptimal dose of nutrients i.e. VC_{50} + CR or VC_{50} + VW + BF treatments throughout the growth stages. Whereas in case of sweet corn, maximum dry matter was recoded in VC_{50} + CF_{50} treatments throughout the crop growth stages. At harvest, VC_{50} + CF_{50} was statistically at par with CF_{100} and they were significantly superior to rest treatments including VC_{100}, which noted significantly higher dry matter as compared to the treatments with sub-optimal dose of nutrients (VC_{50} + CR and VC_{50} + VW + BF) in both the years. At harvest, CR treatment has shown significant improvement in dry matter than control. Effect of different fertilizer treatments on fruit yield of tomato and cob yield of sweet corn is presented in Table1. For tomato, the yield was maximum in CF_{100} which was at par with VC_{100} in both the years. In case of VC_{50} + CF_{50} treatment, though there was significant reduction in tomato yield during 2008-09 as compared to former two treatments, in the following year the yield was observed at par. When vermicompost was applied at suboptimal dose (VC_{50}) along with other organic or biofertilizer sources, the yield was significantly reduced during both the years as compared to optimal nutrient application as in CF_{100} and VC_{100} treatments. In both the years, CR treatment was comparable with control and their yields were significantly lower as compared to fertilized treatments. In case of sweet corn, the maximum cob yield was noted in CF_{100} treatment, which was at par with VC_{100}, VC_{50} + CF_{50} and VC_{50} + VW + BF treatments during 2009 and with VC_{100} and VC_{50} + CF_{50} during 2010. It is noted that application of nutrient through suboptimal dose of VC with other organic and biofertilizer always produced lower yield than full dose of nutrients either through sole application of organic and inorganic or their integration.

Nitrogen uptake and use efficiency

Total nitrogen uptake by tomato and sweet corn crops is presented in Table 2. All the fertilizer treatments showed significant increase in uptake of N than control and CR treatments in both the crops. In general, full dose of fertilizer increased the N uptake which was considerably higher than the uptake at suboptimal dose of fertilizer. Among the fertilized treatments, maximum N uptake was observed in CF_{100} followed by VC_{50}+CF_{50} and VC_{100} and minimum in VC_{50}+CR treatment. The nitrogen use efficiency (NUE) of both tomato and sweet corn crop calculated in terms of kg fruit (tomato) or kg cob (sweet corn) yield per kg total N uptake by the crop is presented in Figure 3. All VC-based treatments had higher NUE as compared to chemical fertilizer in both the crops.

Soil fertility

Changes in chemical and biological properties of soil due to application of chemical and organic fertilizer sources were recorded at harvest of both the crops (Figs. 4 and 5).

Table 3. Effect of fertilizer sources on available Fe, Mn, Zn and Cu content (ppm) of soil at the end of two years tomato-sweet corn cropping system.

Treatments	Fe	Mn	Zn	Cu
Control	45.43 d	13.50 d	1.16 d	1.49 d
CF_{100}	44.17 e	12.03 e	1.10 d	1.35 e
VC_{100}	53.00 a	20.63 a	1.93 a	1.77 a
VC_{50} + CF_{50}	50.60 b	17.67 c	1.22 c	1.58 cd
CR	47.60 c	13.70 d	1.25 c	1.51 d
VC_{50} + CR	50.80 b	17.97 c	1.27 c	1.65 bc
VC_{50} + VW + BF	51.77 b	18.83 b	1.85 b	1.73 ab

Means with the same letters among treatments don't differ significantly at P≤0.05. CF – Chemical fertilizer, VC – Vermicompost, VW –Vermiwash, CR – Crop residue, BF – Biofertilizer, SEm – Standard error of mean. The subscripts 100 and 50 represent their application at 100% and 50% of recommendation, respectively.

The increase of organic carbon content was more pronounced in VC related treatments. The organic carbon content remained stagnant in the control treatment, where nothing was added. Whereas, there was considerable improvement in organic carbon content of the CR treatment. Maximum available nitrogen was recorded in CF_{100} treatment which was significantly superior to other fertilizer treatments. The treatment VC_{50} + CF_{50} was also found to be superior to VC_{100} treatment in improving the soil available N content. Application of suboptimal dose of fertilizer has shown significantly lower available N than full dose of fertilizer application. The available N in CR treatment was similar to control. Like N, maximum availability of P was recorded in CF_{100} treatment which was statistically at par with VC_{50} + CF_{50} treatments but superior to VC_{100} treatment. Suboptimal doses of fertilizer application have shown considerable less available P and were similar with control or CR treatments. The available P was lowest in case of CR and control treatments and they were at par. Maximum value of available K was noted in CF_{100} treatment which was significantly superior to other fertilizer treatments. The potassium level was significantly reduced when fertilizer was applied at suboptimal dose. After two years of crop cycle, the effect of fertilizer treatments on micronutrient (Fe, Mn, Zn and Cu) status of soil was studied (Table 3). All the VC-based treatments showed significant improvement in available micronutrient status as compared to CF_{100} treatment or control. Total microbial count and *Azotobacter* sp. count of soil was determined after harvest of each crop in different treatment in four seasons during the growing season 2008 to 2010 (Fig. 5). As compared to control, the total microbial count as well as the number of *Azotobacter* sp. was increased with time in all fertilizer treatments except in CF_{100} treatment. In CF_{100}, there was marginal improvement in microbial population count. The treatment VC_{50} + VW + BF was found to be most promising for increased microbial growth.

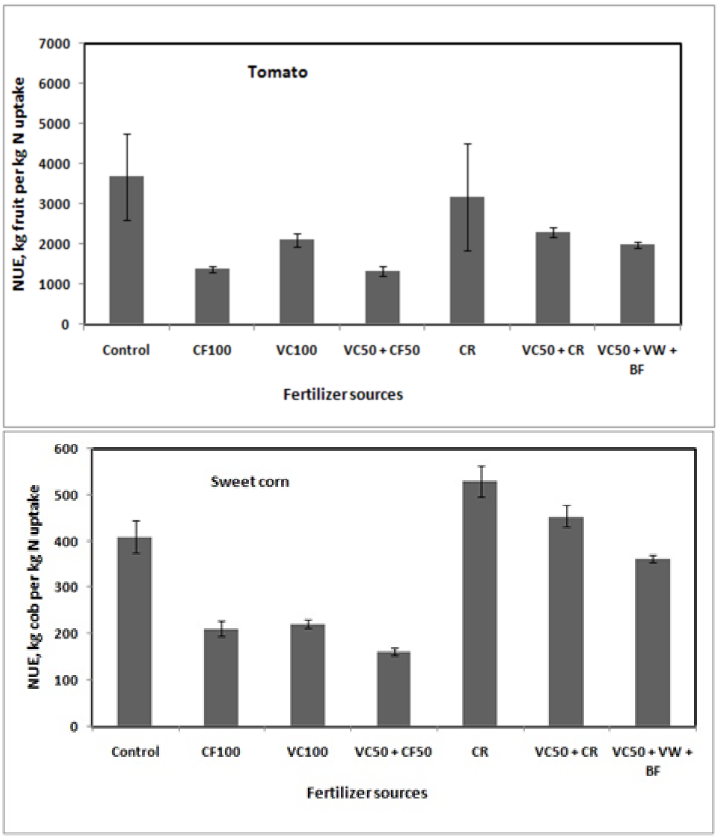

Fig 3. Effect of fertilizer sources on nitrogen use efficiency of tomato and sweet corn crop averaged over two seasons during 2008 to 2010 (the vertical lines indicate the standard error). CF - Chemical fertilizer, VC – Vermicompost, VW – Vermiwash, CR – Crop residue,BF – Biofertilizer. The subscripts 100 and 50 represent their application at 100% and 50% of recommendation, respectively.

Discussion

Crop growth, yield and nitrogen uptake

Application of full or suboptimal doses of fertilizers favored growth and yield of tomato as well as sweet corn crop. As compared to control, application of full and suboptimal dose of fertilizer through organic and/or chemical sources recorded the corresponding yield ratio of 6:1 and 4:1 for tomato during 2008-09 and 2009-10 and 3:1 and 2:1 for sweet corn during the year 2009 and 2010, respectively. Full dose of either chemical and organic fertilizers or their combined application were found superior in growth and yield of both the crops than application of vemicompost at suboptimal dose along with other organic and microbial biofertilizers. At full dose, both chemical and organic fertilizers or their combinations, increased nutrient supply and enhanced absorption of nutrients by both the crops. However, the rate of mineralization differed between chemical and organic fertilizers sources. In chemical fertilizers, mineralization process was faster and thereby has shown immediate release of nutrients elements N, P and K with their quick soil availability (Figure 4), resulting higher crop growth and yield. On the other hand, vermicompost mineralized the nutrients slowly and steadily. Unlike chemical fertilizer, vermicompost is an excellent fertilizer

Table 4. Chemical properties of experimental soil at 0-20 cm depth.

Particulars	Value	Method
Chemical properties		
pH (1: 2.5, soil: water)	5.20	Glass electrode pH meter (Jackson, 1973)
Organic carbon ,%	0.30	Walkley- Black method (Jackson, 1973)
Available N, ppm	72.7	Alkaline $KMnO_4$ (Subbaiah and Asija, 1956)
Available P, ppm	11.8	NH_4F-extraction (Jackson, 1973)
Available K, ppm	46.9	NH_4OAc-extraction (Jackson, 1973)
Available Fe, ppm	50.12	DTPA extraction (Lindsay and Norvell, 1978)
Available Mn, ppm	12.5	DTPA extraction (Lindsay and Norvell, 1978)
Available Zn, ppm	1.25	DTPA extraction (Lindsay and Norvell, 1978)
Available Cu, ppm	1.55	DTPA extraction (Lindsay and Norvell, 1978)

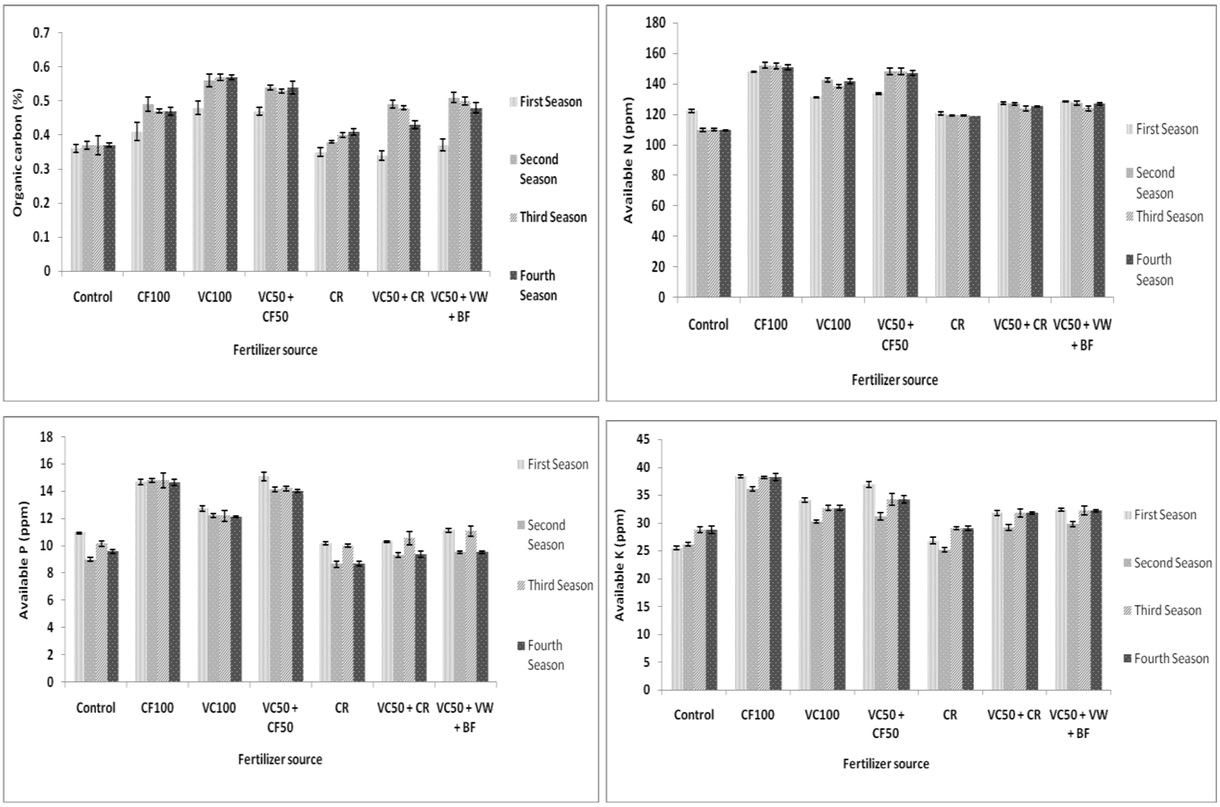

Fig 4. Effect of fertilizer sources on organic carbon, available N, P and K of soil at harvest of tomato (first and third season) and sweet corn (second and fourth season) grown in sequence during 2008 to 2010 in four seasons (the vertical lines indicate the standard error). CF – Chemical fertilizer, VC – Vermicompost, VW –Vermiwash, CR – Crop residue, BF – Biofertilizer. The subscripts 100 and 50 represent their application at 100% and 50% of recommendation, respectively.

source containing higher level of both macro and micro nutrients in available forms (N, P, K, Ca, Mg, Fe, Mn, Zn and Cu). During the experimental period covering four cropping seasons in tomato and sweet corn cropping systems, a total of 33.2 ton ha^{-1} of vermicompost was added in full dose which supplied adequate quantity of macro and micronutrients in the soil. The addition of macronutrients; N, P, K, Ca, Mg, and S were 498, 325.4, 365.2, 91.6, 136.1, and 19.9 kg ha^{-1}, respectively and micronutrients; Fe, Mn, Zn and Cu were 371.8, 42.8, 5.9 and 1.3 kg ha^{-1}, respectively through full dose of vermicompost in soil. Besides supplying plant nutrients, vermicompost contains plant growth regulators and humic acid which probable have additive effect on plant growth (Tomati et al., 1988). Thus, the yield advantage on application of vermicompost was due to its capability to supply both essential plant nutrients as well as growth promoting substances for improvement of growth and yield of crops. The increased N uptake under full dose of fertilized treatment applied either through inorganic sources or in combination of organic and inorganic is associated with their increased soil availability (Figure 4) and thereby uptake through increased biomass and yield of the crops in the respective treatments. The types of fertilizers used and the N form available for plant uptake play a major role in plant development (Heeb et al., 2005; Toor et al., 2006). Increased N availability from N fertilization might have increased fruit yield and N uptake as also observed by several researchers (Melton and Dufault, 1991; Korsaeth and Eltun, 2000; Eltun et al., 2002). The VC-based treatments had higher NUE as compared to chemical fertilizer in both the crops. This is because of slow and steady release of N in VC-based treatments and thereby its lower soil availability and low crop uptake. Further, higher yield advantage on application of VC due to availability of other essential macro- and micro-nutrients and plant growth regulators, resulted in increased nitrogen use efficiency. Improved nutrient-use efficiency on organic farms can occur through reduced nutrient losses due to lower stocking rates and fertilization levels. Furthermore,

Table 5. The nutrient composition of Vermicompost (VC) and vermiwash (VW) used in the experiment.

Nutrients elements	Vermicompost	Vermiwash
pH	6.9	6.8
Organic carbon (%)	14.1	-
N (%)	1.5	0.005
P (%)	0.98	0.0025
K (%)	1.1	0.063
Ca (mg/kg)	2760	786
Mg (mg/kg)	4100	328
S (mg/kg)	600	-
Fe (mg/kg)	11200	0.151
Mn (mg/kg)	1290	213
Zn (mg/kg)	180	0.132
Cu (mg/kg)	38	0.117

lower nitrogen losses on organic farms from soils occur due to the incorporation of straw, manure and other compost which bind nitrogen in the soil (Kasperczyk and Knickel, 2006).

Soil chemical and biological properties

Application of chemical fertilizer and vermicompost in the field led to build up in organic carbon content as well as nutrient status of the soil. Many researchers have reported about increase in organic carbon content in soil with application of vermicompost (Mascicandaro et al., 1997; Mitchell et al., 2007; Carey et al., 2009). Organic carbon status of soil after harvest of each crop showed gradual increase with addition of vermicompost (Fig. 4). In VC_{100} treatment, a total of 33.2 t ha^{-1} of vermicompost was applied in soil, that supplemented 4680 kg of organic carbon, which was responsible for increase organic carbon status in soil. At suboptimal dose, low loading (16.6 t ha^{-1}) of vermicompost has shown lower status of organic carbon in soil than that of full dose. In CR treatment, total dry matter of 7.68 t ha^{-1} was added of which tomato and sweet corn contributed 20.8 and 79.2% respectively. The addition of organic carbon through the crop residue was 576 kg per hectare during the study period, which resulted marginal increase of organic carbon in soil. Kong et al. (2005) studied the recycling of crop residues in a maize tomato cropping sequence. They observed higher level of organic carbon content in recyclable crop waste under organic farming system than conventional one. The data showed that there was significant gain in available N in soil due to the use of either organic or chemical sources of fertilizers. However, such increase of N level in soil was gradual in case of VC related treatments which was due to slow mineralization process of organic matter and hence release of the nutrients. Vermicompost has been demonstrated to act as valuable soil amendments that offer a balanced nutritional release pattern to plants, providing nutrients such as available N, soluble K, exchangeable Ca, Mg, and P that can be taken up readily by plants (Edwards, 1998; Edwards and Fletcher, 1988) besides being a source of several micronutrients. Available P and K in soil showed a similar trend of increase during the study period (Figure 4). Savant and De Dutta (1982) reported that reserved nutrients were observed because of fixation and accumulation of organic nutrient elements, which are promoted by application of organic materials. In the present study, it is apparent that vermicompost application is favorable for improving reserved nutrient status in soil due to cumulative gain during the experiment period. Vermicompost possesses all essential plants nutrients in readily available form for plant uptake (Edwards 1998; Edwards and Fletcher, 1988). In the present study a total addition of 33.2 t ha^{-1} of vermicompost has

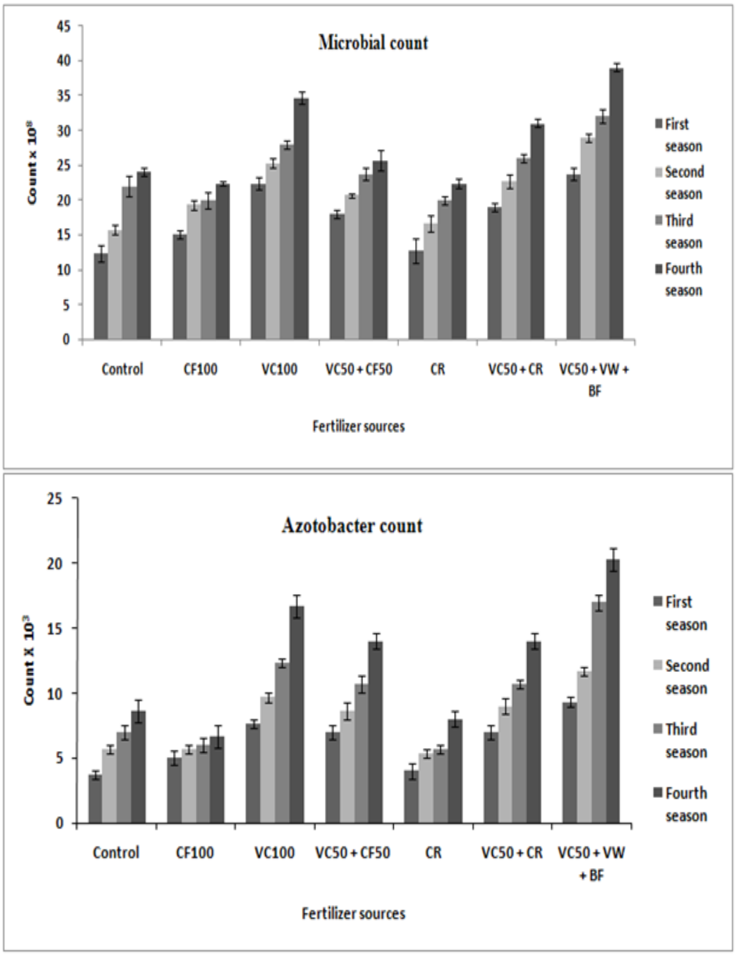

Fig 5. Effect of fertilizer sources on Microbial and Azotobacter sp. count per gram of soil at harvest of tomato and sweet corn crops grown in sequence during 2008 to 2010 (the vertical lines indicate the standard error). CF - Chemical fertilizer, VC – Vermicompost, VW –Vermiwash, CR – Crop residue, BF – Biofertilizer. The subscripts 100 and 50 represent their application at 100% and 50% of recommendation, respectively.

added considerable amount of macro and micronutrients in soil as explained earlier which has improved the nutritional status of soil by increasing availability of secondary and micronutrients. Shankar et al. (2012) also reported significant influence of organic manures application on soil micronutrient status as compared to conventional fertilizers application. Gigliotti et al. (1996) in a 6-year field study demonstrated that compared to untreated soils, amended soils

Table 6. Chemical composition of Nutrient agar and Jensen's agar media.

Chemicals	Amount per Litre solution
Nutrient agar	
Beef extract	3.0 g
Peptone	5.0 g
Agar	20.0 g
Dist. Water	1000 ml
pH	7.0 -7.2
Jensen's agar	
Sucrose	20.0 g
K_2HPO_4	1.0 g
$MgSO_4$, $7H_2O$	0.5 g
Na_2MoO_4	0.001g
$FeSO_4$, 7 H_2O	0.01g
$CaCO_3$	2.0 g
Agar	18.0g
Dist. Water	1000 ml
pH	7.0 -7.2

with urban waste compost showed a significant increase in Cu and Zn concentrations in the last 2 years. Higher microbial population was due to incorporation of *Azotobacter* as biofertilizer along with vermicompost. In chemical fertilizer treatment, ammonia releasing fertilizers like urea inhibit the activity of many of the soil flora and fauna, including nitrifying bacteria and earthworms. Moreover, higher concentration of exchangeable and soluble Al^{3+} ion under the chemical fertilizer treatment might have created a deleterious impact of soil acidity on microorganisms, which in turn reduced the microbial population under the chemical fertilizer treatment (Brady and Weil, 2002). On the other hand, vermicompost, the earthworm-processed organic wastes are finely divided peat-like materials with high porosity, aeration, drainage, and water holding capacity (Edwards and Burrows, 1988) harbor the microbial organisms. At the end of experiment it was evident that the *Azotobacter* sp. population in the VC_{50} + VW + BF treatment was three times higher than in the chemical fertilizer treatment. van Diepeningen et al. (2006) compared organically and conventionally managed soil and found a higher microbial population and microbial biomass in the former than the latter soil.

Materials and methods

Plant materials

The cultivar S-22 of tomato (*Lycopersicon esculentum*) crop and the cultivar Sugar-75 of sweet corn (*Zea mays*) crop were used as test crop. The duration of tomato was 90-110 days and of sweet corn was 75-80 days.

Study site

The experiment was conducted at experimental farm of Agricultural and Food Engineering Department, Indian Institute of Technology Kharagpur, (22° 19' N and 87° 19' E). The annual rainfall ranges from 1300 to 1500 mm, of which 85% is received during June-October from south west monsoon. During the experimental period (2008-2010), the annual rainfall received was in the range 1110 to1961 mm. The soil of the experimental field is acid laterite (type – Haplustalf) and sandy loam in texture. It is low in organic C and available N content, medium to low in available P and low in available K content. The detailed chemical properties of the soil of experimental field and the analytical methods are presented in Table 4.

Experimental details

Field experiments were conducted to study the effect of chemical and organic input management on growth, yield, N uptake and use efficiency of tomato and sweet corn grown in acid lateritic soil. Effect of the nutrient management on chemical and biological properties of soil was also evaluated. The experiment with tomato-sweet corn cropping system was conducted during the years 2008 to 2010. Tomato was grown during dry seasons (November to February) of the year 2008-09 and 2009-10 and sweet corn during wet season (May-July) of the years 2009 and 2010.

Treatments

The experiment included six treatments of organic and inorganic input management and one control where nothing was added. The organic inputs were vermicompost (VC), vermiwash (VW), biofertilizer (BF) and crop residue (CR) of previous crop and the conventional input was chemical fertilizer (CF). The treatments of organic and inorganic inputs were: CF at 100% recommended dose of N, P and K (CF_{100}), Vermicompost at 100% N recommendation (VC_{100}), VC_{50} + CF_{50}, CR, VC_{50} + CR and VC_{50} + VW + BF. The recommended dose of CF as N: P_2O_5:K_2O were 100:80:60 kg ha^{-1} for tomato and 150:50:50 kg ha^{-1} for sweet corn, supplied through urea, single super phosphate (SSP) and murate of potash (MOP) respectively. For the treatment VC_{100}, the dose of vermicompost was 6.6 t ha^{-1} for tomato and 10.0 t ha^{-1} for sweet corn, which was calculated on 100% recommended N equivalent basis i.e. 100 kg N ha^{-1} for tomato and 150 kg N ha^{-1} for sweet corn considering N content in vermicompost as 1.5 %. In the integrated treatment of VC_{50} +CF_{50}, half dose of VC and half dose of CF was applied, where the VC dose was 3.3 t ha^{-1} for tomato and 5.0 t ha^{-1} for sweet corn and the CF doses were 50:40:30 and 75:25:25 kg ha^{-1} of N: P_2O_5:K_2O for tomato and sweet corn, respectively. In CR treatment, the total crop residues of tomato and sweet corn were added after harvest of each crop. The quantity of tomato and sweet corn residue were 0.8 and 3.04 t ha^{-1}, respectively. In VC_{50} + CR treatments, VC was applied at 3.3 t ha^{-1} with addition of full crop residue after harvest of each crop. In VC_{50} + VW + BF, the vermicompost, vermibed wash and microbial bio-fertilizer were added in an integrated manner. In this treatment, the application of VC was at half of the recommended dose, vermiwash (VW) at 650 L ha^{-1} which supplied 3.25 kg N ha^{-1} besides addition of other nutrients element and microbial bio-fertilizer (BF) was applied through *Azotobacter* at 3.5 kg ha^{-1}.

Experimental design

The experiment with the seven treatment combinations was laid in a Randomized Complete Block Design (RCBD), where each treatment had three replications. In total, there were 21 plots and each plot had dimension of 5 m × 4 m.

Treatment application and crop management

Well-composted vermicompost and vermiwash were collected from local farm. The chemical composition of both vermicompost and vermiwash is given in Table 5. For the treatments with CF, half dose of N and full dose of P_2O_5 and K_2O were applied as basal at planting/sowing time and remaining half nitrogen was top dressed at 30 days after planting (DAP) in case of tomato and 35 days after sowing (DAS) in case of sweet corn. The solid VC was applied as basal before plantation of tomato/sweet corn. The *Azotobacter* was applied as basal by mixing with vermicompost of the same treatment. The fertilizer as per the treatment was applied in the crop row and well mixed with soil. Tomato seedlings (cv. S-22) of 21 days old earlier raised in nursery bed, were transplanted at spacing of 50 cm between rows and 30 cm between plants on 15 November in 2008 and 2009. In case of sweet corn, the seeds (cv. Sugar-75) were sown manually by dibbling at about 2 cm depth in soil maintaining a spacing of 50 cm between rows and 15 cm between seeds in the rows on 5 May in 2009 and 8 May in 2010. The duration of tomato was 90-110 days and of sweet corn was 75-80 days. The total volume of VW was sprayed on the crop canopy by mixing with water at 1:5 ratio in seven equal splits starting at 35 days after sowing/planting of crop and thereafter at one week interval. The control plot received no fertilizer, however the soil preparation was similar to those of fertilized treatments. Weeding was done manually at 20 and 50 DAS to keep the plot weed free. The weeds removed from different plots were incorporated in the same plots. No plant protection measure was taken as there was no incidence of major pest and diseases. The tomato crop grown in dry season received supplementary irrigation as per the crop requirement. The sweet corn was grown in wet season as rainfed crop without any supplementary irrigation.

Crop observation

Representative plant samples were selected from each plot for growth assessment. The data on dry matter production was recorded at 20, 40, 60 DAP/DAS and at harvest for both tomato and sweet corn form the collected plant samples. The tomato crop was harvested at maturity when the fruits attained 70% reddish colour. Thus, periodically harvesting was done by number of pickings. Harvesting was done on net plot area basis considering an area of 2 m^2 in each plot and the yield was determined. In case of sweet corn, the harvesting of cob was done when the silk started turning into brown colour. The harvesting was done on net plot area basis as that followed in tomato and the cob yield was recorded after removal of husk. Plant samples at harvest were collected for dry matter accumulation and were analysed for N content by Modified Kjeldhal method (Chapman and Pratt, 1961). Total N uptake and N use efficiency (NUE) of tomato and sweet corn was calculated (Huang, 2008) as follows:

$$Nitrogen\ uptake (kg\ ha^{-1}) = \frac{N\ content(\%) \times weight\ of\ total\ dry\ matter(kg\ ha^{-1})}{100}$$

$$NUE\ (kg\ economic\ yield\ per\ kg\ N\ uptake) = \frac{Crop\ yield\ (kg\ ha^{-1})}{Total\ N\ uptake(kg\ ha^{-1})}$$

Soil analysis

Soil samples were collected from the rhizophere region (0-20 cm soil depth) of both tomato and sweet corn after each season harvest. The harvest of tomato in 2008-09 and 2009-10 were considered as first and third season and of sweet corn in 2009 and 2010 in the cropping system as second and fourth season. In each plot, the samples were collected from five randomly selected spots and were thoroughly mixed to prepare a homogenous sample. A part of the soil was used for bacterial count which was stored at 4^oC in freeze for microbial analysis. The remaining part was dried under shade and ground in pestle and mortar and passed through 2 mm sieve for the analysis of chemical properties.

Chemical properties

The chemical properties of soil samples analyzed are organic carbon content and available N, P, K and micronutrients content (Fe, Mn, Zn, and Cu) following standard analytical procedure as given in Table 4. The macronutrient (N, P, and K) content was analyzed after each season harvest soil and the micronutrients at the end of the two years cropping.

Microbial enumeration

Five grams of fresh soil was put in 45 ml of sterile distilled water and serial dilution was prepared. Thereafter, 1 ml of each dilution was placed in petriplates containing Nutrient Agar media for total population count. For enumeration of *Azotobacter*, modified Jensen's agar media (Sharma, 2003) were used as the culture media. The chemical composition of the media is presented in Table 6.

Statistical analysis

The data of the experiment involving seven treatments of nutrient management and three replications conducted in a randomized completely block design were statistically analyzed using standard procedures as described by Gomez and Gomez (1984). To determine the significance of the treatment effect, Analysis of Variance (ANOVA) tables were prepared for the data on crop growth and yield, nutrient uptake and soil fertility using a statistical package 'MSTATC'. Duncan's Multiple Range Test (DMRT) was performed for analyzing the significance of treatment effects at $P \leq 0.05$.

Conclusions

In intensive cropping systems, nutrient management plays a major role for enhanced crop yield with maintenance soil health for sustainable production. In this experiment, application of full dose of fertilizer through organic or chemical sources or their combination resulted higher growth and yield of tomato and sweet corn crop grown in sequence as compared to sub-optimal dose of nutrient application through the organic source. The effectiveness of chemical fertilizer was better pronounced in increasing crop growth and yield, but of vermicompost in improving crop N use efficiency in addition to comparable yield improvement. Use of organic sources of fertilizers improved the soil chemical properties through increasing the content of macro- and micro-nutrients and organic carbon in the subtropical climate of India. The biological property of soil with regard to microbial count was strengthened when *Azotobacter* was applied along with vemicompost.

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