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ASSESSING SOIL CHARACTERISTICS AND GUAVA ORCHARD PRODUCTIVITY AS INFLUENCED BY ORGANIC AND INORGANIC SUBSTRATES

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ABSTRACT

Guava cultivation in subtropical region of India is mainly confined to marginal lands under rainfed conditions resulting in low productivity and poor fruit quality. Restoration of the soil quality of such guava orchards with low soil fertility is one of the important aspects for enhancing orchard productivity and sustainability as millions of farmers are engaged in guava production for their livelihood and nutritional security. Keeping this in view, effects of organic and inorganic substrates on soil characteristic and guava orchard productivity were studied through field experimentations during 2007-12. Different combinations of organic (FYM, vermicompost, mulching, *Azotobacter*, PSM and *Trichoderma harzianum*) and inorganic (N, P, K) substrates were applied each year within the tree basin under subtropical environmental condition. At the end of the study, soils fertilized with vermicompost, biofertilizers and organic mulching showed improvement in yield as compared to NPK+ FYM application. Higher soil moisture retention, soil fertility and organic carbon build up and better soil temperature regulation was observed under mulching treatment. Microbial population and dehydrogenase activity were significantly higher in plots treated with vermicompost, microbial inoculants and mulching as compared to NPK+FYM application. The highest pooled data of dehydrogenase activity ($3.1\mu gTPFg^{-1}h^{-1}$) was recorded in the treatment receiving 10 kg vermicompost which was superior over application of 5 kg FYM + 5 kg vermicompost or 10 kg FYM. The correlation studies revealed positive and significant relationship among the soil factors and yield. Highest correlation was observed between yield and microbial populations ($r = 0.93^{*}$ to 0.97^{**}). Dehydrogenase activity was also positively correlated with the soil organic carbon content ($r = 0.99^{**}$), soil moisture ($r = 0.99^{**}$), soil temperature ($r = 0.95^{*}$) and soil nutrients ($r = 0.91^{*}$ to 0.97^{**}).

Key words: Vermicompost, biofertilizers, soil processes, yield, correlation analysis, Guava.

INTRODUCTION

Orchard soils under semiarid/arid subtropical regions have low organic carbon content and inherent low soil fertility status. Restoration of the soils are important if tree crops are planted from view point of orchard sustainability and productivity as millions of farmers are engaged in fruit production, sustaining their livelihood and nutritional security (Kumar *et al*., 2011). Guava (*Psidium guajava* L.) is an important commercial fruit crop in India and has gained considerable credit because of its high nutritive value, rich in vitamin C, pectin and availability at affordable price. Uttar Pradesh is one of the important states wherein the fruit crop has vastly been grown. The contiguous belts of guava orchards of the region are often planted in low-fertility soils. The rainfed orchards comprise most of the total harvested area. The low precipitation along with impaired nutrient management systems during the rainy and winter season is the main limiting factor for orchard productivity (Adak *et al*., 2012). Hence, nutrient management options found to be of paramount importance in maintaining soil productivity and are becoming the constraints of the orchard productivity system (Kumar *et al*., 2012).

The indiscriminate and excessive use of mineral fertilizers in intensive agricultural or horticultural system has reduced the soil organic matter in most of the semiarid tropical and/or subtropical soil leadings to an increase of soil erosion risk and fertility losses. The quality of soil determines the sustainability and productivity of any land use system (Schjonning *et al*., 2002; Manna *et al*., 2005; Dwivedi and Dwivedi, 2007; Kumar, 2012). The use of organic amendments, such as FYM, vermicompost, microbial consortia, organic mulching are effective means for enhancing soil fertility, increasing microbial diversity and populations, microbial activity, improving the soil physical properties particularly moisture-holding capacity of soils and increasing crop yields (Adak *et al*., 2013). Integration of organic substrates with inorganic one, when applied to the low fertility soils, is primarily responsible for their contributions to nutrient supplies and soil fertility. However, they can also have significant effects on the soil physico-chemical and microbiological properties of the soil, which are indirectly responsible for supporting crop growth. Keeping this in view, the present study was undertaken to evaluate the influence of organic and inorganic sources of nutrition on soil characteristics and yield of guava grown in low fertile soil.

MATERIALS AND METHODS

Site description: The effect of organic and inorganic substrates on guava fruit productivity and associated orchard soil properties was studied in the experimental research farm of Central Institute for Sub-tropical Horticulture, Rehmankhera, Lucknow (26.54^{0}N Latitude, 80.45^{0}E Longitude and 127 m above mean sea level), Uttar Pradesh, India. The climate is semi-arid, with a dry hot summer and cold winters in subtropical Indian situation. May and June are the hottest months, with mean daily maximum temperature varying from 36 to 39°C, while January is the coldest month with mean daily minimum temperature ranging from 6.6 to 7.9°C. The mean annual rainfall is around 1000 mm, of which 80% is received during the southwest monsoon from July to September; the rest is received through the 'Western Disturbances' from December to February. Mean daily pan evaporation (mm/day) ranges from 1.8 during January to 8.75 during May, mean wind velocity varies from 2.71 km/h in December to 9.08 km/h in June. The soil of the experimental site is mixed hyperthermic *Typic Ustocrepts* and belongs to the major group of Indo-Gangetic alluvium with sandy loam texture and well drained.

Experimental design: The experiment was laid out in a randomized block design with four replications on newly planted guava cv Shewta at a spacing of 5 × 5 m. during 2007. The treatments consisted of T_1- 10 kg FYM + 120, 60, 50 g N, P and K / tree /year of age, T_2-10 kg FYM + 120, 60, 50 g N, P and K / tree /year of age + *Azotobacter* + PSM + *Trichoderma harzianum* + Organic mulching (10 cm thick), T_3- 10 kg Vermicompost + 120, 60, 50 g N, P and K / tree /year of age + *Azotobacter* + PSM + *Trichoderma harzianum* + Organic mulching (10 cm thick), T_4- 5 kg FYM + 5 kg Vermicompost + 120, 60, 50 g N, P and K / tree /year of age + *Azotobacter* + PSM + *Trichoderma harzianum* + Organic mulching (10 cm thick) and T_5- 120, 60, 50 g N, P and K / tree /year of age + *Azotobacter* + PSM + *Trichoderma harzianum* + Organic mulching (10 cm thick). Organic mulching consists of leaf litter. The experimental soil was sandy loam, with pH and electrical conductivity ranging from 6.60 to 7.75 (mean 7.22) and 0.07 to 0.16 dS/m (mean 0.12 dS/m) respectively. DTPA extractable Fe, Mn, Zn and Cu content ranged from 1.87-2.92, 2.56-13.06, 0.097-0.518 and 0.154-0.724 ppm respectively. Initial soil organic carbon, available N, P and K were low. The initial fungal count ranged from 8.6×10^3 to 1.0×10^6, while the bacterial count ranged between 1.8×10^6 and 1.0×10^8 cfu/g soil. All trees were fertilized with urea, DAP and MOP per tree basis based on required dose in each year. Orchard soils were thoroughly ploughed by tractor in August-September to control weeds and pests and pathogen. The treatments were applied in the tree basin and appropriate intercultural practices were followed. Irrigation was given to the crop in the basin only during stress period. Total four irrigations one each during third week of April, first and fourth week of May and last week of December were given based on 60 per cent open pan evaporation replenishment.

Observations: Soil samples were collected from the tree basin with vertical depth of 0-30 cm from all the treatments before fertilization each year. Samples were air dried at room temperature and processed through a 2 mm sieve and homogenated. Soil organic carbon was estimated using standard wet digestion method. Soil pH and electrical conductivity (EC) were determined in a 1:2.5 soils: water extract. Sand, silt and clay percentage were determined as per the standard methodology using Hydrometer. The available Zn, Cu, Mn and Fe contents (DTPA extractable) were estimated by 'Chemito' AA203D model of atomic absorption spectrophotometer as per the standard procedure. Available N was estimated in auto-N analyzer as potassium permanganate ($KMnO_4$)-oxidizable N, Available P of soil was estimated by the Olsen method using spectrophotometer and available K of soil was estimated by extraction with 1 N ammonium acetate at pH 7.0 by AAS. Microbial population like bacteria, fungi and actinomycetes were counted as per standard plate count method. Dehydrogenase activity was estimated using 2, 3, 5 triphenyal tetrazolium chloride using 1 g of air-dried soil (<2 mm) and expressed as µg of triphenylformazan (TPF) formed per gram of soil per 24 hours (Casida *et al.*, 1964). This enzyme activity was assayed using appropriate control. Root zone (0-30 cm soil depth) volumetric soil moisture and soil temperature was recorded during fruit harvesting period using WET sensor. Fruits were harvested from each treatment and yield was reported per tree basis.

Statistical analysis: For all parameters, data were analyzed by analysis of variance (ANOVA) procedure for a randomized block design. Comparison of means was performed by the Duncan multiple range test at 95% level of probability. The correlation between nutrients and yield was assessed by means of Pearson's correlation coefficient. All statistical analysis was performed using SPSS version 12.0. Required graphs were generated using MS Excel software.

RESULTS AND DISCUSSION

Soil characteristics: Soil pH did not change significantly among the different treatments. However, a marginal increase in Vermicompost + biofertilizers + mulching treated soils was observed over NPK+ FYM treated soil. Mechanical analysis showed that the soil was sandy in nature having clay content in the range of <5% which indicated low nutrient and water retention capacity (Table 1). Furthermore, it was observed that the soil treated with organic sources (T_2 to T_5) had higher moisture content than their absence (Table 2). Moreover, plots receiving microbial inoculants and mulching had significantly improved the moisture retention over those treated with NPK+FYM (T_1). The soil temperature varied between 16.5 to 19.9^{0}C across different treatments in different replications. The plots receiving mulching as a component had higher soil temperature as compared to addition of NPK+FYM. Thus, the role of mulching in conserving soil moisture and regulating soil temperature was evident. Similar results were also reported by Singh *et al*., (2009) from the subtropical mango orchards in Lucknow situation wherein alleviated soil moisture conservation and soil temperature regulation in mulched trees was observed as compared with the non-mulched ones. Even in mandarin orchards under Nagpur, Maharashtra agro-ecological zone, drip irrigation with mulching had improved soil moisture retention in clay loam soil (Panigrahi *et al*., 2008).

There was significant increase in microbial population and enzymatic activity in plots receiving vermicompost, microbial inoculants and mulching (T_2 to T_5) over with receiving NPK+FYM (T_1). The highest pooled dehydrogenase activity (3.1µgTPFg^{-1}h^{-1}) was recorded in the treatment T_3 receiving 10 kg vermicompost (Table 3). This treatment was superior to that of 5 kg FYM + 5 kg vermicompost or 10 kg FYM. The lowest dehydrogenase activity (0.71µgTPFg^{-1}h^{-1}) was observed in FYM + NPK. Microbial population (bacteria, fungi and Actinomycetes) varied significantly among various treatments. Highest and lowest bacterial count being the 9.37×10^7 and 4.37×10^7 cfu/g; fungal population as 9.73×10^4 and 3.80×10^4 cfu/g and actinomycetes as 4.2 $\times10^5$ and 10×10^5 cfu/g. Significantly higher microbial population was recorded in the treatment where NPK was with the vermicompost + biofertilizers + mulching. The results thus, indicated that vermicompost, biofertilizers and mulching in combination were superior to FYM application in restoring the fertility of soils in respect of different soil microbial processes. Application of 10 kg vermicompost was found to be superior over 10 kg FYM or 5 kg FYM + 5 kg Vermicompost.

The organic carbon, available N, P and K content and DTPA-extractable micronutrients were recorded higher in organic and inorganic substrate treated soil than addition of chemical fertilizers +FYM only (Fig. 1 and 2). The treatment T_3 that received 10 kg vermicompost had higher nutrient build up than the soils treated with10 kg FYM (T_2) and 5 kg FYM + 5 kg vermicompost (T_4).

Management regimes and plant species have been viewed as an important production strategy to influence soil physical, chemical and biological properties (Lipiec *et al*., 2005; Masto *et al*., 2006; Verma *et al*., 2011). The impacts are also conditioned by the composition of amendment, the rate of application and the soil type as they are going to impact existing soil conditions (Zaman and Chang, 2004; Tejada *et al*., 2006). The improved retention of soil moisture and regulation of soil temperature in the present study, may primarily because of the application of organic mulching coupled with vermicompost and microbial consortia enhance the soil's water holding capacity and thermal properties. The marginal increases of pH values in organic amended soils are related with addition of basic cations in the organic materials. However, this study showed that inorganic or organic amendments in a semiarid system during 5 years had only a little effect on pH values may be due to the strong buffering capacity of these soils.

The application of vermicompost to soil is considered as a good management practice in any agricultural production system because of the stimulation of soil microbial growth and activity, subsequent mineralization of plant nutrients, and increased soil fertility and quality (Arancon *et al*., 2006; Ferreras *et al*., 2006). However, the influence of vermicompost on soil properties depends on amount, type, and size of the added organic materials. Also, the influence of vermicompost on environmental quality maintenance depends of the substrates used during the vermicomposting process. It had higher efficient role over FYM in sustaining soil health of any agroecology. In our study, addition of 10 kg vermicompost had higher impacts on yield and quality attributes of soil and leaf nutrient properties than its absence and/or application of 10 kg FYM. Inclusion of vermicompost as soil amendment had positive role even in a greenhouse container media wherein germination, seedling growth, flowering of ornamentals and growth and yield of vegetables even at low substitution rates were observed (Atiyeh *et al*., 2000). This may be because of the availability of plant growth-influencing materials, such as plant growth regulators and humic acids, produced by the greatly increased microbial populations resulting from earthworm activity. Tejada and González (2009) based on three years of experimentation on an *Aquic Xerofluvent* soil, reported that application of vermicompost significantly enhanced soil biological properties (soil microbial biomass, soil respiration and soil enzymatic activities), soil humus-enzymes complexes, nutrition (N, P, and K plant contents, pigments, and leaf soluble carbohydrate concentrations), and improved yield and quality parameters of rice.

The fate of different soil factors like microbial populations, enzymatic activity and nutrients in both the soil and leaf would have been influenced by the interactions of organic and inorganic sources. In the present experiment, all plots, those received vermicompost treatments, had significantly more dehydrogenase activity ($p\leq 0.05$) than plots with less FYM. This was true in case of microbial inoculants and mulching also. Microbial inoculants and vermicompost, normally enhanced the microbial populations and enzymatic activities in soil and thus improved soil health parameters. These microorganisms can produce plant growth promoting materials such as gibberellins, auxins, cytokinins, abscisic acid that promoted plant growth, yield as well as secretion of several acids that enhance nutrient availability by way of conversation of insoluble nutrients into soluble form, chelating to avoid leaching loss. Due to low initial fertility status of the experimental soil application of vermicompost and microbial inoculants were found to be fruitful as it releases phosphate ions from soil ion exchange sites and increases their concentration in soil solution. A number of organic acids especially oxalic acid produced facilitate the solubilization of bound phosphorus and potassium in soil. Higher protease and acid phosphate activity in vermicompost treated soils might be responsible for higher nitrogen and phosphorus content in soil. Pramanik *et al*., (2010) reported that application of vermicompost, prepared from different organic wastes, significantly increase organic carbon, mineralizable nitrogen and available phosphorus in lateritic soil so is the case of dehydrogenase activity.

Orchard productivity: Yield is the most important component of any production system. We have recorded pooled highest yield (kg/tree) as 45.4 kg $tree^{-1}$. Guava yield was more ($p \leq 0.05$) in plots treated with vermicompost than from those plants grown in plot that received NPK+FYM. Moreover, the yields were significantly higher in the soils amended with microbial inoculants and mulching as compared to their absence. Guava yield is highly complex and dependent on genetics, biotic and abiotic factors and applied cultivation technology. The highest yield in our study, per tree, was obtained with the treatment consisting of 10 kg vermicompost + microbial inoculants and organic mulching + NPK fertilizer (Fig. 3). This yield was statistically superior over only NPK+FYM application as well as the treatment T_2 and T_5 where no vermicompost was applied. This emphasized the positive role of vermicompost as an important soil organic amendment for fruit tree based orchard soils. The guava cultivar was equally treated and affected by identical biotic and abiotic factors, the improvement in physical attributes and quality parameters was therefore achieved in the T_3 treatment may be due to the combined effect of organic sources and composite NPK mineral fertilizer on the soil chemical composition and improved soil water, air and temperature regimes in the root zone area**.** The mineral organic sources in presence of inorganic one, enhances the efficacy of applied fertilizers, ensuring better vegetative growth of tree and hence higher yields and quality parameters. Even, they can improve the situation in case of a newly planted apple orchard to cause significant increase in apple yields (Milosevic and Milosevic, 2009).

Table 1. Soil reaction, sand, silt and clay per cent in guava grown soil (mean value) treated with organic and inorganic substrates

Treatment	pH	Sand	Silt	clay
T1	6.97	59.3	39.1	1.6
T2	7.06	57.4	39.8	2.8
T3	7.54	60.5	40.9	1.6
T4	7.23	59.8	37.1	3.1
T5	7.18	57.5	37.9	1.6
Mean	7.20	58.9	39.0	2.1

Table 2. Volumetric soil moisture content (%) and soil temperature (^{0}C) in guava orchard soils

Treatment	Mean ± Standard error of mean	Mean ± Standard error of mean
	Soil moisture content	Soil temperature
T1	8.3 ± 0.1	16.5 ± 0.01
T2	12.1 ± 0.1	18.6 ± 0.4
T3	16.7 ± 0.1	19.9 ± 0.1
T4	12.7 ± 0.4	19.1 ± 0.5
T5	11.6 ± 0.4	17.9 ± 0.1

Correlations: The correlation studies have revealed significant relationship among the soil and plant factors. Yield and quality parameters like TSS, acidity, total sugar and vitamin C content were positively and significantly correlated with the dehydrogenase activity, leaf and soil nutrients (Table 4). Highest correlation was observed between yield and Microbial populations ($r = 0.93^*$ to 0.97^{**}) and dehydrogenase activity was also positively correlated with the SOC content (r = 0.99**), soil moisture (r = 0.99**), soil temperature (r = 0.95*) and soil nutrients (r = 0.91* to 0.97**). Thus the positive effect of soil factors on yield in guava was established as it has been observed that the performance of the tree crop was influenced in a characteristics way by the soil environment. Henceforth, integrated production systems needs to be prioritized and implemented effectively so that farmers can get reasonable yield for their livelihood and economic benefit. Judicious nutrient management strategy based on soil fertility should be followed to optimize the productivity level in such orchards.

Table 3. Dehydrogenase activity (μg TPF g^{-1} h^{-1}) (Mean ± Standard error of mean) in guava orchard soils

Treatment	Soil depth (cm)			Pooled
	0-10	10-20	20-30	
T1	1.50 ± 0.25	0.53 ± 0.06	0.10 ± 0.001	0.71 ± 0.07
T2	3.47 ± 0.48	1.60 ± 0.47	0.19 ± 0.001	1.75 ± 0.05
T3	6.02 ± 0.61	2.25 ± 0.21	1.00 ± 0.05	3.09 ± 0.17
T4	3.17 ± 0.22	1.92 ± 0.48	0.93 ± 0.01	2.00 ± 0.04
T5	3.42 ± 0.38	1.60 ± 0.47	0.21 ± 0.001	1.74 ± 0.07
CD (P = 0.05)	0.82	0.37	0.28	0.37

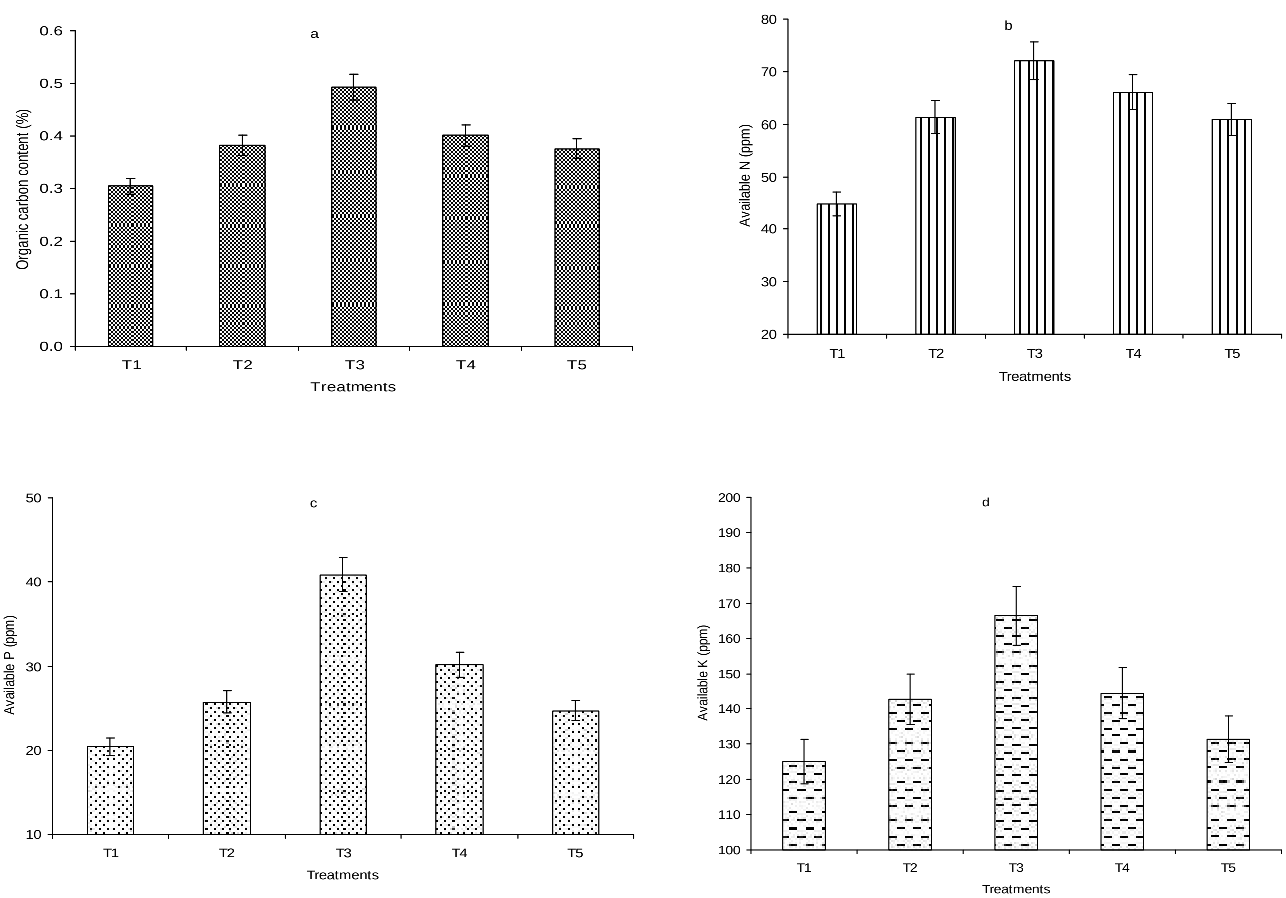

Fig. 1. Organic carbon content, available N, P and K status in soils. a, b, c and d stands for organic carbon, available N, P and K content respectively. All plots receiving vermicompost, microbial inoculants and organic mulching as organic sources had significantly higher quality enhancement as compared to plots that received FYM + inorganic fertilizers. The statistical significance was drawn using SPSS version 12.0 at LSD (p = 0.05).

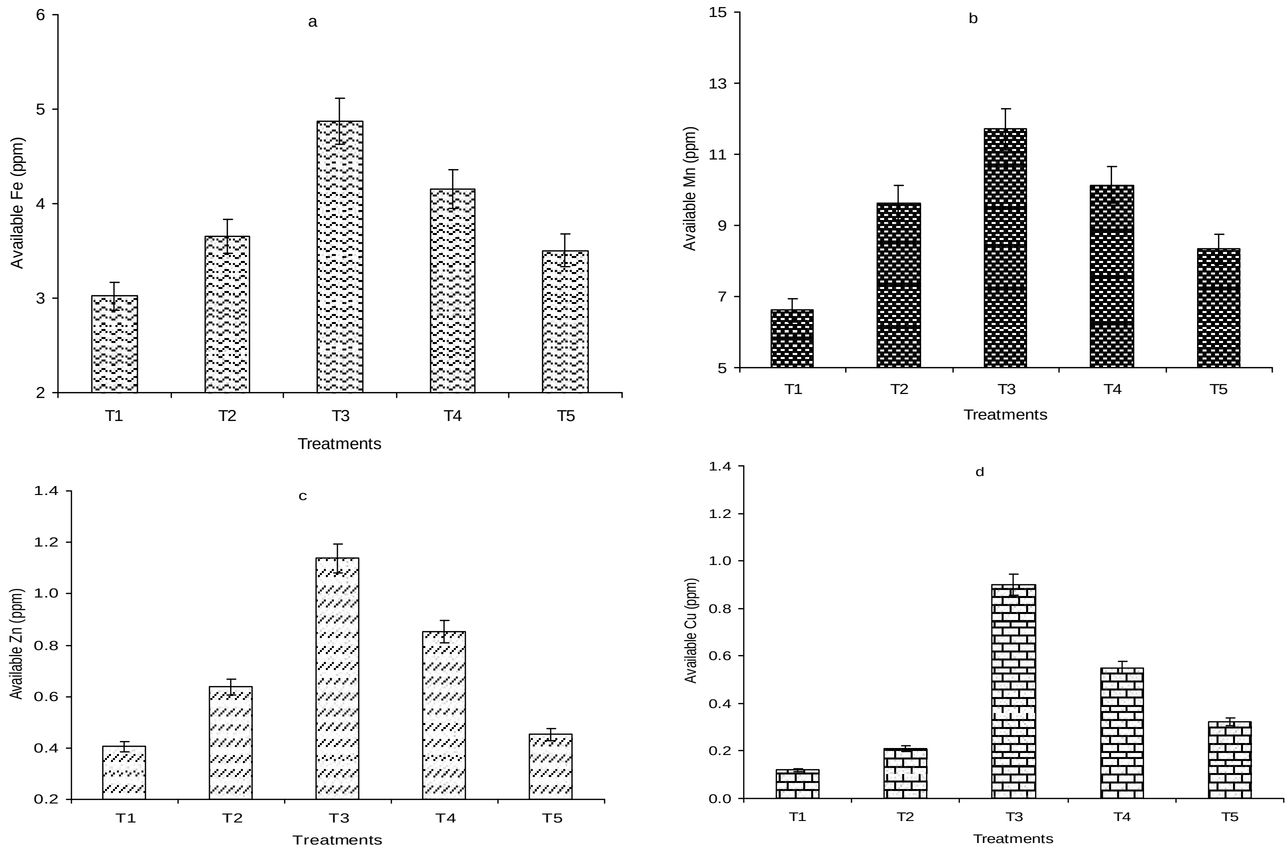

Fig. 2. Available micronutrients status in soils. a, b, c and d stands for Fe, Mn, Zn and Cu content. All plots receiving vermicompost, microbial inoculants and organic mulching as organic sources had significantly higher quality enhancement as compared to plots that treated with FYM + NPK. The statistical significance was drawn using SPSS version 12.0 at LSD (p = 0.05).

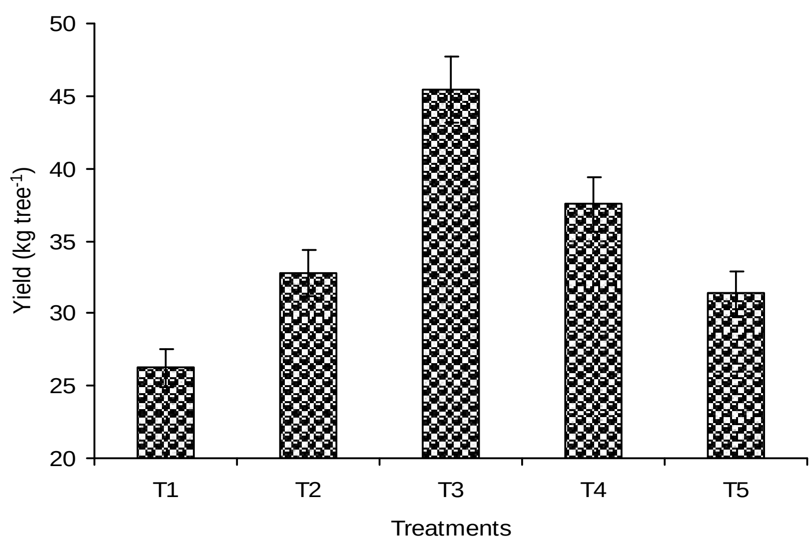

Fig. 3. Yield (kg/tree) of guava fruit. All plots receiving vermicompost as an organic sources had significantly higher physical attributes than plots that received inorganic fertilizers +FYM. The statistical significance was drawn using SPSS version 12.0 at LSD (p = 0.05).

Table 4. Statistical significance and Person's correlation coefficient between soil factors with yield in guava

	DHA	Bacteria	Fungi	Actinomycetes	Moisture (%)	Temp. (ºC)	SOC (%)	Avail. N (%)	Avail. P (%)	Avail. K (%)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Yield (kg Tree^{-1})
DHA	1	0.97**	0.91*	0.95*	0.99**	0.95*	0.99**	0.96*	0.96**	0.95*	0.97**	0.96*	0.91*	0.92*	0.93*
Bacteria		1	0.95*	0.95*	0.98**	0.97**	0.97**	0.94*	0.92*	0.96**	0.94*	0.98**	0.90*	0.84*	0.93*
Fungi			1	0.96*	0.92*	0.97**	0.92*	0.91*	0.91*	0.96**	0.94*	0.99**	0.95*	0.82*	0.97**
Actinomycetes				1	0.96*	0.93*	0.96**	0.88*	0.99**	0.99**	0.98**	0.96**	0.99**	0.94*	0.93*
Moisture (%)					1	0.96*	0.99**	0.95*	0.96**	0.96**	0.97**	0.96**	0.92*	0.92*	0.93*
Temp. (ºC)						1	0.95*	0.98**	0.90*	0.93*	0.95*	0.99**	0.91*	0.82*	0.99**
SOC (%)							1	0.94*	0.98**	0.97**	0.98**	0.96**	0.92*	0.94*	0.93*
Avail. N								1	0.88**	0.87**	0.92*	0.96*	0.85*	0.81*	0.96**
Avail. P									1	0.97**	0.99**	0.93*	0.97**	0.98**	0.91*
Avail. K										1	0.97**	0.96**	0.97**	0.92*	0.92*
Fe (mg/kg)											1	0.96**	0.98**	0.95*	0.96**
Mn (mg/kg)												1	0.94*	0.85*	0.98**
Zn (mg/kg)													1	0.93*	0.94*
Cu (mg/kg)														1	0.84*
Yield (kg Tree^{-1})															1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Conclusions: The soil rejuvenation with organic sources are essentially required in subtropical regions with low organic matter content and inherent low fertility, in order to improve the soil fertility and sustainability of guava orchards. Application of 10 kg vermicompost should be considered for integration in the nutrient management strategy.

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