IJAFLS

International Journal of
Agriculture, Forestry and Life Science, 2 (2) 2018, 145-153

e-ISSN: 2602-4381 Received: 20.06.2018 Accepted: 03.12.2018 Published (online): 03.12.2018

ORIGINAL PAPER

EFFECT OF VERMICOMPOSTAMENDMENTAND NITROGEN LEVELS ON SOIL CHARACTERISTICS AND GROWTH AND YIELD OF TOMATO (*Solanum lycopersicum* cv. Diamante max)

Jessie SABIJON[1], Michael Adonis SUDARIA[2*]

[1] Department of Agriculture and Related Programs, Northwest Samar State University, San Jorge Campus, Samar/Philippines
[2]College of Arts and Sciences, Northwest Samar State University main campus, Samar/Philippines

*Corresponding author email: michaelsudaria@gmail.com

Abstract

A 3 x 3 factorial pot experiment was conducted to determine the effects of different kinds of vermicompost on soil chemical properties of an acid soil and its influence on the growth and yield of tomato var. Diamante max.There were nine treatment combinations from three types of amendments: (A_1=Urea, A_2=Vermicompost 1, A_3=Vermicompost 2) and three levels of nitrogen: (B_1 = 0 kg ha$^{-1,}$$B_2$ = 45 kg ha^{-1}, B_3 = 90 kg ha^{-1}) which were laid out in Randomized Complete Block Design (RCBD) with three replications. Results of the study showed that addition of two different kinds of vermicompost at a rate of 45 and 90 kg ha^{-1}significantly ($P \leq 0.05$) increased the chemical properties acid soil such as soil organic matter, total N, extractable P, exchangeable K and Mg compared to soils in untreated pots. However, the addition of two types of vermicompost resulted in the decrease on soil pH. Growth and yield of tomato were also significantly increased with application of vermicompostsat rates of 45 and 90 kg ha^{-1}.In addition, application of 45 and 90 kg ha^{-1} urea also increased some of the chemical properties of acid soil and the growth and yield of tomato. The result of the experiment revealed that addition of vermicomposts had positive effects on the soil chemical properties and on the growth and yield of tomato.

Keywords: Nitrogen levels, soil characteristics, solanaceous, tomato, vermicomposts.

INTRODUCTION

Tomato (*Solanum lycopersicum*) locally known as “kamatis” is one of the most popular and most consumed vegetable in the world and in the Philippines (Gutierrez-Miceli et al, 2007). It is a solanaceous crop that can be eaten fresh which is tasty and easily digestible and its bright color stimulates appetite. It is consumed as salad with other leafy vegetables in sandwiches, and as stewed, fried, and baked singly or in combination with other vegetables (PCAARD, 1980). At the same time, essential ingredient for pizza, pasta, hamburger, hot dogs, and other foods. It is also rich in nutrients and calories and good source of Fe and vitamin A, B, C. Most importantly, itis extensively cultivated in Claveria, Misamis Oriental, which is considered as the “tomato bowl” of Northern Mindanao (Mercado et al., 2010).

One of the cultural management practices employed in increasing the yield of vegetable crop is the use of fertilizer. Fertilizer application is considered the most common and conventional farm practices of augmenting and overcoming the limitation of infertile soil to supply the adequate nutrients for the growth and development of the plants (Zamora, 2007). It has been known that the mineral nutrition of tomato from the application of organic fertilizers and manures can increase tomato yield and nutrient uptake by several folds compared with no fertilization (Azarmi et al, 2008). However, tomato plants prefer soil that has a neutral pH which is generally between 6.4 and 7.0. Hence, several studies stated that application of organic fertilizer can bring the soil to the pH within the optimal range so that the plants can uptake nutrients appropriately. The use of organic fertilizer such as thermophilic composts has been recognized generally as an effective means for improving soil aggregation, structure and fertility, increasing microbial diversity and populations, improving the moisture holding capacity of soils, increasing the soil cation exchange capacity (CEC) and increasing crop yields (Zink and Allen, 1998). Furthermore, the long term benefits of using compost include improved soil structure, soil organic matter, increased water use efficiency and crop yield (Chan et al. 2008).

Vermicompost is a good example, which is any organic material subjected to earthworm (vermi) and its cast (vermicast) that ingests organic matter, fragmenting, grinding into finely divided peatlike material under aerobic and mesophilic condition (Recycled Organic Units, 2000). It is a rich natural fertilizer that can be used as a soil conditioner and containing N, P, K and several micronutrients essential for plant growth (Ball et al., 1992). Moreover, several experiments have demonstrated that vermicompost can suppress *Pythium*, *Rhizoctonia* and *Verticillium* plant diseases (Chaoui et al., 2002) and plant parasitic nematodes (Arancon et al., 2002).Previous studies also showed that vermicompost application resulted to improved growth and increased nitrogen and phosphorus uptake and yield of crops (Arancon et al., 2004). On the other hand, one experiment demonstrated that addition of 5,10 and 15 t ha^{-1}vermicompost in soil had significant positive effects on uptake of element nutrients such as P,K, Fe and Zn (Azarmi et al., 2008).Greenhouse experiments also have shown that vermicompost contains plant growth hormones which may be responsible in part for germination, growth and yield of plants (Atiyeh et al., 2002).In the study of Arancon et al. (2006) demonstrated that vermicompost contain plant growth hormones and humic acids, which are probably responsible for most of the increase germination, growth and yield of plants in response to application and substitution independent of the nutrients it contain. Differently, Gutierrez–Miceli et al (2007) reported that tomatoes grown in soil mixed with sheep manure, vermicompost revealed to be ideal for juice production because of soluble solids greater than 4.5 ºBrix and pH less than 4.4. In addition, Atiyeh et al. (2000) reported also increasing rates of germination, growth and yield of tomato plants, grown in a range of concentrations of soilless commercial container media MetroMix360 that was substituted with a corresponding range of concentration of pig waste vermicompost. Therefore, the study aims to determine the effects of different kinds of vermicompost on soil chemical properties of an acid soil planted with tomato and at the same time evaluate the influence of vermicompost on the growth and yield of tomato.

MATERIALS AND METHODS

Site description, soil sample collection and analysis

The soil samples were collected from the Claveria, Misamis Oriental, Philippines (8˚38'39"N, 124˚55'49") which is located at 980 meters above mean sea level (amsl). The soils in the area are primarily derived from pyroclastic materials (Mounts Mat-I, Balatukan, Sumagaya) that are deep and well drained (Mercado et al., 2010). Claveria soils represent most of acid uplands in Southeast Asia physically (Mercado, 2007) and socio-economically (Bertumeu, 2005). At the soil series level, they are classified as Adtuyon clay containing 71% clay, 23% silt and 6% sand.

Soil samples from 0 – 20 cm layer were collected from a field grown to corn and previously planted with tomato. The soil has a pH of 5.84 categorized as moderately acidic.Soil samples wereair – dried, pulverized, mixed and passed through a 10 mm wire screen to remove small stones, gravel and other fragments. For the analysis, about 1 kg composite soil sample was set aside from the bulk sample. It was air-dried, pulverized and passed through a 2 mm mesh sieve. This served as the initial composite sample analyzed for soil pH following the potentiometric method using 1: 2.5 soil-water ratios (PCARRD, 1980),organic matter (%) using the modified Walkley-Black method (Nelson and Sommers, 1982), total nitrogen following the Kjeldahl method (USDA, 2004), extractable P and exchangeable bases using 1 N NH_4OAc neutralized to pH 7 (USDA-NRCS, 1996); and then exchangeable bases (K, Ca, Na, and Mg)were quantified by atomic absorption spectrophotometer (AAS) (Westerman, 1990).

Production and chemical analysis of vermicompost

Two types of vermicompost substrates were done with a ratio of 50:50 (Corn cobs and cow manure) and 70:30 (sunflower and cow manure) in weight basis. The cow manures and corn cobs were collected from a farm at Claveria, Misamis Oriental, at the same time the wild sunflower (*Tithonia diversifolia*) plants were collected at nearby roadside as these growing luxuriantly in Claveria. These substrates were shredded by a mechanical chopper to which has a suitable size for vermicomposting processes. The fresh substrates of about 500 kg were placed in a 1.5m x 12 x 0.3m plot with wooden driver under the shed and watering was allowed regularly to achieve at 80% moisture content. Throughout vermicomposting processes, observation and monitoring was done to avoid disturbance and to facilitate cast formation. After 1 to 1.5 months, vermicasts were harvested by scrapping the surface and mixed them thoroughly. Samples were taken and set aside used for amendments and chemical analysis.

For the vermicompost analysis, subsamples were air – dried and set aside for pH, OM and total N, P, exchangeable K, Mg and Ca content determination. The pH, OM and total N were determined with the same methods of soil analysis. Extractable P and exchangeable K, Mg and Ca were determined by dry ashing 0.5g (ODW) of vermicomposts in a muffle furnace set at 550^0C. The ash was soaked overnight in 3 ml concentrated

HCl to solubilize the inorganic P in vermicomposts and allowed to stand overnight. The acid treated ash was transferred to 100 ml volumetric flask made to volume to 100 ml with 0.1 N HCl. The solution was passed through a Whatman no. 42 filter paper. Total P was measured using ascorbic acid method by Murphy and Riley (1962). For exchangeable K, Mg and Ca analysis, the extract was submitted to Central Analytical Service Laboratory (CASL) at the Philippine Rootcrops Research and Training Center(PhilRootcrops) for quantification using Atomic Absorption Spectrophotometer (AAS).

Experimental design and layout

A 3 x 3 factorial experiment was laid out in a randomized complete block design (RCBD) with three replications. There were nine treatment combinations from three types of amendments and three levels of nitrogen application, making a total of 27 pots. Two sets of 27 pots and each were prepared for the whole study. The first set of 27 pots was the source of the soil data. Growth and yield parameters were collected from the other set of 27 pots. The pots were placed in an open field at PhilRootcrops Experimental Area to expose the plants under natural environmental condition.

The treatments are as follows;

Factor A = Amendments
A_1 = Urea
A_2 = Vermicompost 1 (50% Sunflower + 50% Cow manure)
A_3 = Vermicompost 2 (70% Corn cobs + 30% Cow manure)

Factor B = Levels of nitrogen
B_1 = 0 kg N ha^{-1}
B_2 = 45 kg N ha^{-1}
B_3 = 90 kg N ha^{-1}

Seed germination

Tomato seeds (var. Diamante max) were sown in a seed box filled with previously sterilized mixture of 1/3 rice hull, 1/3 garden soil and 1/3 compost. It was placed in a shaded area to facilitate care, acquire favorable condition and to avoid unnecessary disturbance. Irrigation of seedlings was done after sowing and throughout the growth of the seedlings. One week before transplanting, the seedlings were hardened by exposing them to sunlight and by gradual water withdrawal.

Potting of soil medium

The experiment was conducted using clay pots with a diameter of 20 cm and 25 cm height. Each pot was filled up with 5 kg soil on oven dry weight basis. Before potting, a representative sample was taken and air-dried to determine the moisture content.

Fertilizer calculation and application

The amount of urea as a source of nitrogen as well as in solophos and muriate of potash was calculated based from the fertilizer recommendation for tomato which is 90 kg N ha^{-1}, 120 kg $P_2O_5ha^{-1}$ and 60 kg K_2O ha^{-1} (PCARRD, 1975).On the other hand, the amount of vermicomposts was also calculated base from the organic fertilizer recommendation of about 15 tons ha^{-1}. The result of the analysis, about 0.5g of urea, 0.12g of vermicompost 1 and 0.28g of vermicompost 2 (for the 90kg N ha^{-1}) at the same time 0.25g, 0.06g, 0.14g of urea, vermicompost1 and vermicompost 2 (for the 45kg N ha^{-1}) respectively was applied basally to the soil prior to planting. Moreover, a blanket application also of 1.5g Solophos and 0.25g Muriate of potash in all treatments were thoroughly done prior to planting.

Transplanting

Three weeks after emergence with the first true leaf having emerged; one healthy seedling from the seedling tray was transplanted to each pot. Watering of the seedlings was done right after transplanting.

Soil analysis after harvest

Right after the termination of the study, subsamples from each pot was collected, air dried, sieved and analyzed for pH, OM, N, P and exchangeable bases using the previously described methods. The analyses of pH, OM, N and P were done at the Soil Research Testing and Plant Analysis Laboratory (SRTPAL) of the Department of Agronomy and Soil Science, Visayas State University, Baybay, Leyte. Exchangeable bases on the other hand, were analyzed at the PhilRootcrops Central Analytical Laboratory using Atomic Absorption Spectrometry (AAS).

Statistical Analysis

Data were subjected to Analysis of Variance with the use of Crop Stat program. Interaction effects found significant, trend analysis was done for the nitrogen levels in each amendment or source of organic fertilizer. However, if only the source of organic fertilizer is found significant, the Least Significant Difference (LSD) was used to compare the means.

Meteorological Data

Data on daily rainfall (mm) and weekly average temperature (^oC) throughout the conduct of the study was taken from the records of the Philippine Atmospheric Geophysical Astronomical Services Administration (PAGASA) Agro-meteorological station at the Visayas State University, Visca, Baybay, City, Leyte.

Data gathered for Tomato

a. Horticultural characteristics

1. *Plant height (cm).* This was obtained by measuring the plants in each pot from the ground level up to the tip of the longest leaf.
2. *Dry matter yield (g plant^{-1}).*This was obtained by taking the dry weight of the shoots and roots after oven drying in a forced draft oven set at 70^oC for four days until the weight was constant.

b. Yield and Yield Components

1. *Total number of fruits per plant*. This was determined by counting the total number of fruits harvested per plant.
2. *Number and weight of marketable and non-marketable fruits per plant*. This was recorded by counting and weighing all the marketable and non-marketable fruits per plant.
3. *Fruit yield (kg plant^{-1}*). All harvested fruits (marketable and non-marketable) per treatment from the first harvest only was weighed and expressed in kg plant^{-1}.

RESULTS AND DISCUSSION

The total weekly rainfall and average daily temperature ^0C (minimum and maximum) were recorded during the conduct of the study. The average weekly rainfall ranges from 2.2 to 323.6 mm while the average daily temperature ^0C (minimum and maximum) ranges from 22.11 to 30.57 ^0C. The climatic condition at two weeks after transplanting probably affects the growth performance of tomato. However, a mixture of strong wind and heavy rain was documented with the occurrence of typhoon. The plants were also tending to fall down with destroyed branches and root exposure. The growth performance recovery was started at three weeks after transplanting in which the climatic condition was already favorable for the temperature requirement of tomato.

Effects of vermicompost on soil chemical properties

Fertilizer source and levels had varying effects as observed in the study. The addition of vermicomposts in the soil changed the soil pH (Table 3). The decrease in pH content in this study was observed in soils treated with vermicompost at increasing rates ranging from 45 kg ha^{-1} to 90 kg ha^{-1}. In relation with other studies, Atiyeh et al. (2001) reported that the increase of vermicompostrate in the soil resulted in the decrease in soil pH. The result explains that the production of NH_4^+, CO_2 and organic acids during microbial metabolism in vermicompost may contribute to the decrease in soil pH (Albanell et al., 1988).

Soil organic matter is one of the important component of the soil. It affects many chemical, physical and biological properties of the soil (Agriscope, 1988). Likewise, there was significant increase in organic matter (OM $\leq$ 0.05) after application of 45 to 90 kg ha^{-1}vermicompost in Vermi1 and Vermi2 as compared to control pots (Table 3.). These findings revealed that there was continuous decomposition of organic matter which could be attributed to the addition of vermicomposts. Pascual et al. (1997) reported also that the addition of organic materials to the soil could increase biomass C, basal respiration, biomass ratio of C to total organic C, and metabolic quotients indicating the activity of soil microorganisms. In addition, the increase in soil organic matter resulted in decrease K fixation and subsequently increases K availability in the soil (Olk and Cassman, 1993).

Table 1. Chemical analysis of soil and vermicompost before planting.

Chemical properties	Soil	Vermicompost 1	Vermicompost 2
pH	5.84	6.95	6.81
Organic matter (%)	3.38	4.54	3.48
Total nitrogen (%)	0.14	1.84	0.78
Extractable P ($mg\ kg^{-1}$)	20.8	31.3	210
Exchangeable K ($mg\ kg^{-1}$)	36	0.856	0.387
Exchangeable Mg ($mg\ kg^{-1}$)	25	0.55	0.21
Exchangeable Ca ($mg\ kg^{-1}$)	673.8	995.5	294

Table 2. Amount of fertilizer material applied per plant

N levels ($kg\ ha^{-1}$)	Fertilizer material ($g\ pot^{-1}$)				
	Urea	Vermicompost 1	Vermicompost 2	Solophos	Muriate of potash
0	0	0	0	1.5	0.25
45	0.25	0.06	0.14	1.5	0.25
90	0.50	0.12	0.29	1.5	0.25

Table 3. Effects of inorganic and organic amendments on pH, OM, total N, extractable P, and exchangeable bases (K, Mg, and Ca) of the soil after harvest.

Treatments	Levels	pH	OM (%)	Total N (%)	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)
Urea	0	5.62a	3.48a	0.14b	22.51b	78.67a	30.63a	894.77a
	45	5.71a	3.46a	0.19b	69.99 b	68.07a	35.17a	959.27a
	90	5.79a	3.48a	0.32a	243.62 a	61.53a	41.17a	985.00a
Vermi 1	0	5.42a	3.41c	0.12b	170.04b	78.57b	29.80b	964.86a
	45	5.57a	3.94b	0.15b	252.47a	100.87a	36.60b	867.10a
	90	5.55a	4.25a	0.23a	283.73a	104.93a	70.00a	915.60a
Vermi 2	0	5.56a	3.50c	0.13b	7.62b	80.77b	24.47b	767.03a
	45	5.49a	4.01b	0.19a	261.36a	87.17b	32.23b	584.37a
	90	5.57a	4.27a	0.20a	298.69a	117.90a	50.30a	964.70a
CV (%)		0.37	0.10	0.06	81.96	21.94	8.16	205.56

Means with similar letters are not significantly different at 5% LSD.

Results showed that total N concentration in soil was significantly ($P \leq 0.05$) affected by the two different types of vermicompost (Table 3.). The soils treated with Vermi 1 andVermi 2 at the rate of 45 to 90 kg ha^{-1} had more total N compared to soils with no application of vermicompost.Vermicompost might have produced more residual N in soil than those in control pots.This result was similar with the findings of Nethra et al (1999), which indicated that addition of vermicompost increased the nitrogen content of the soil. The marked decrease in total N in soils without vermicompost application in comparison with vermicompost treated soils may have been due to larger amounts of total C and N that could have provided a larger source of N for mineralization (Arancon et al., 2006).

In contribution, soils treated with Vermi1 and Vermi2 at the rate of 45 to 90 kg ha^{-1} have more P ($P \leq 0.05$) content as compared to control pots (Table 3). This implied that the continuous inputs of P to the soil were probably due to the slow release of P from vermicomposts which was facilitated by the activity of soil microorganisms (Arancon et al., 2006). Marinari et al. (2000) reported a similar increase in soil P after application of organic amendments. The soil available K was also increased significantly ($P \leq 0.05$) with increasing the levels of vermicompost (Table 3). Application of two different types of vermicompost at a rate of 45 and 90 kg ha^{-1} increased available K respectively in comparison to control pots. This is attributed also from the selective feeding of earthworm on organically rich substances which breakdown during passage through thegun, biological grinding, together with enzymatic influence on finer soil particles, were likely responsible for increasing the different forms of K (Rao et al., 1996). Orozco et al. (1996) stated that vermicompost contains most nutrients in plant available forms such as phosphates, exchangeable calcium and soluble which could also contribute relative information to the increase in potassium content. On the other hand, there was also significant increase in the Mg content of the soils treated with two different types of vermicompost at 45 to 90 kg ha^{-1} in comparison to control pots (Table 3).

Horticultural Characteristics of Tomato

Highly significant effects of organic amendments (Vermi 1 and Vermi 2) and urea application were observed onthe plant height of tomato at three to eight weeks after transplanting (Fig.1). However, Vasanthi et al. (1999) reported that application of vermicompost is a good source of nutrient for plant growth and development, thus reducing the need of chemical fertilizer. The plant height was greatly affected by the treatments at different growth period. It was observed that the plants applied with vermicompost 1 and 2 have faster growth from fifth to eight weeks after transplanting compared to plants treated with urea. The result might due to the slow availability of nutrients in vermicompost, in spite of this, significant increasein the plant height of tomato was still evident with increasing time.

Application of 45 to 90 kg urea significantly increases the fruit yield of tomato.The increase was observed with application of vermicompost1 and 2.Similar results were noted by Maynard (1995) reported that tomato yields in field soils amended with compost were significantly greater than those in the untreated plots.

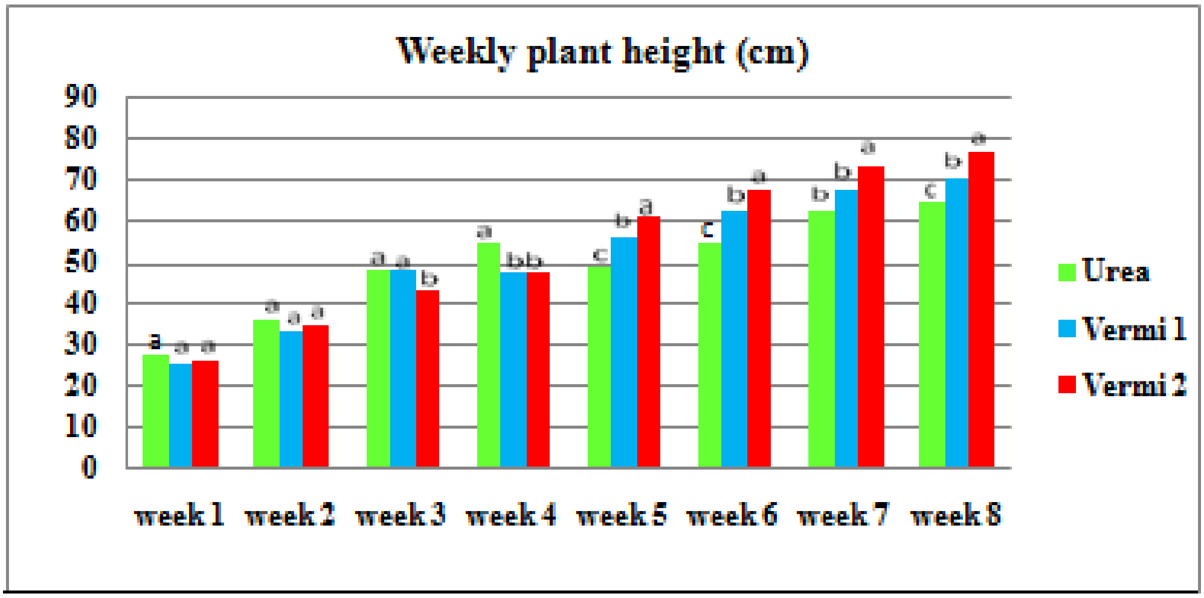

Figure 1. Weekly plant height of tomato as affected by inorganic and organic. (Urea, Vermicompost 1 (50% Sunflower + 50% Cow manure) and Vermicompost 2 (70% Corn cobs + 30% Cow manure). *Treatment means with common letters are not significantly different at 5% LSD*

Figure 3. Tomato fruit yield applied with varying levels of vermicompost 1(50% Sunflower + 50% Cow manure)

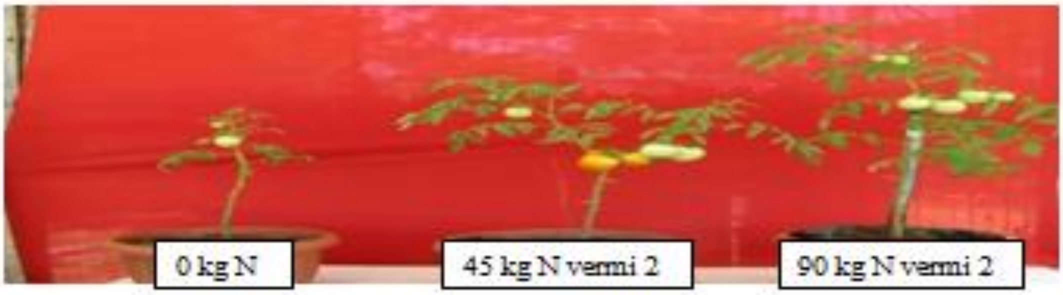

Figure 4. Tomato fruit yield applied with varying levels of vermicompost 2 (70% Corn cobs + 30% Cow manure)

Figure 2. Tomato fruit yield applied with varying levels of N (0 kg N ha^{-1}, 45 kg N ha^{-1} and 90 kg N ha^{-1}).

Yield and yield components of Tomato

The yield of vermicompost treated plants was found to be 132.99 g plant $^{-1}$in Vermi 1 and 115.23 g plant $^{-1}$in Vermi2. The results in Vermi 1 was 75% more than the plants in control pots and was near to inorganic fertilizer treated plants (urea) as shown in Table 4. This finding was supported by the study of Arancon et al (2003) wherein addition of different types of vermicompost increased tomato yields. Likewise, the results of this study seemed to reveal that amendment of organic fertilizer was suitable because of its significant effect on the growth and yield of tomato.

Table 4. Effects of inorganic and organic amendments and N levels on the yield of tomato.

N levels (kg/ha)	Total fruit yield of tomato (g plant^{-1})		
	Urea	Vermi 1	Vermi 2
0	19.53c	17.21b	17.56b
45	194.07b	108.55ab	104.34ab
90	242.48a	132.99a	115.23a

Means with similar letters are not significantly different at 5% LSD.

CONCLUSIONS

Two types of vermicompost (Vermi1 and Vermi2) significantly increased the different soil chemical properties of upland acid soil such as percent OM, total N, extractable P and exchangeable K and Mg. Application of two types of vermicompost also significantly increased the growth and yield of tomato.

REFERENCES

Agriscope, 1988. Organic Fertilizer: Nature's Gift to Farmers. The Nation's Agribusiness Magazines: 2(5):17-21.

Albanell E, Plaixats J, Cabrero T (1988). Chemical changes during vermicomposting (*Eisenia Andrei*) of sheep manure mixed with cotton industrial wastes. Boil.Fertil. Soil, 6:266-269.

Arancon, N.Q., C.L. Edwards and P. Bierman C. Welch, T. D. Metzger. 2004. Influence of vermicompost on field strawberries; Effects on growth and yields. Bioresource technology. 93:145-153.

Arancon, N.Q., Edwards, C.A., Yardim, E., Lee, S. (2002). Management of plant parasitic nematodes by applications of vermicompost. The Brighton Crop Portection Conference-Pest and Diseases 2002. Brighton, London. 8B-2, 705-716.

Arancon NQ, Edwards CL, Bierman P (2006). Influences of vermicompost on field strawberries: 2. Effects on soil microbiological and chemical properties. Bioresour. Technol., 97: 831 – 840.

Arancon, N.Q., Lee, S., Edwards, C.A., Atiyeh, R.M. 2003. Effects of humic acids and aqueous extracts derived from cattle, food and paper waste vermicompost on growth of greenhouse plants. Pedobiologia 47:741-744.

Atiyeh, R.M., Edwards, C.A., Metzger, J.D., Lee, S., Arancon, N.Q. (2002). The influence of humic acids derived from earthworm-processed organic wastes on plant growth. Bioresource Technology 84:7-14.

Atiyeh RM, LEE Edward CA, Sulbar S, Metzger T (2001). Pig manurevermicompost as a component of a horticultural bedding plantmedium. Effects on physiochemical properties and plant growth.Bioresour. Technol., 78:11-20.

Atiyeh, R.M., Subler, S., Edwards, C.A., Metzger, J., (2000). Growth of tomato plants in horticultural potting media amended withvermicompost. Pedobiologia 43:724-728.

Azarmi R, Sharifi P, Satari MR (2008). Effect of vermicompost on growth, yield and nutrition status of tomato (*Lycopersicumesculentum*) In Press.

Ball, J. and R. Kourik, 1992. Easy Composting Ortho Books Publication. P. 56-59.

Bertomeu, M. 2005. Smallholder Timber Production on Sloping Lands in the Philippines: A System Approach. World Agro forestry Centre: Los Baños, Laguna.

Chan, K.Y., Dorahy, C., Wells, T., Donovan, N., Fahey, D., Saleh, F. and Barchia, I. 2008. Use of garden organic compost in vegetable production under contrasting soil P status. *Aust. J Agric. Res., 59:374-382.*

Chaoui, H., Edwards, C.A., Brickner, A., Lee, S., Arancon, N.Q. (2002). The BCPC Conference-Pest and Diseases 2002. Brighton, London. 8B-3,711-716.

Gutierrez-Miceli, F.A., J. Santiago – Boraz, J.A. Molina, C.C. Nafate, M. Abud-Archila, M.A. O. Llaven, R. Rincon-Rosales and L. Dendooven, 2007. Vermicompost as a soil supplement to improve growth, yield and fruit quality of tomato (*Lycopersiconesculentum*). Bioresour. Tecnol., 98:2781-2786.

Marinari S, Masciandro G, Ceccanti B, Grego S (2000). Influence of organic and mineral fertilizers on soil biological and physical properties, Bioresour. Technol. 72:9-17.

Maynard, A.A., 1995. Cumulative effect of annual additions of MSW compost on the field grown tomatoes. Compost Sci. Util., 3: 47 – 54.

Mercado, A.R. JR. 2007. Potential of Timber Based Hedgerow Intercropping for Smallholder on Degraded Soils in Humid Tropics of Southeast Asia. World Agroforestry Centre: Los Baños, Laguna

Mercado A JR, Tulin, A.B and Dorahy C. 2010. Soil management and crop nutrition for tomato in acid soil of Claveria, Philippines. In Gilkes, RG, Prakongkep N, editors. Proceedings of the 19th World Congress of Soil Science; Soil Solutions for a Changing World; ISBN 978-0-646-53783-2; Published on DVD; http://www.iuss.org; Symposium 3.3.1; Integrated nutrient management; 2010 Aug 1-6. Brisbane, Australia: IUSS; 2010, pp. 271-273.

Murphy, J. and J. Riley. 1962. A modified single solution method for determination of phosphate in natural waters. Ana. Chem. Acta 27:1409-1416.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic and organic matter. In: A. L. Page, R. H. Miller and D. R. Reeney (eds.). Methods of soil analysis part 2: Chemical and microbiological properties. American Society of Agronomy, Inc. Madison, Wisconsin, USA. Pp 593 – 597.

Nethra N.N, Jayaprasad K.V, Kale R.D (1999). China aster (*Callistephus chinensis*L.) cultivation using vermicompost as organic amendment, Crop Res. Hisar. 17(2): 209-215.

Olk DC, Cassman KG (1993). Reduction of potassium fixation by organic matter in vermiculitic soils. Soil organic matter dynamics and sustainability of tropical agriculture, pp. 307-315.

Olsen, S.R., and L.E. Sommers. 1982. Phosphorus. In: D. R. Buxton, (ed.) Method of Soil Analysis. American Society of Agronomy, Inc., Madison, Wisconsin USA. pp 403-430.

Orozco FH, Cegarra J, Trujillo LM, Roig A (1996). Vermicomposting of coffee pulp using the earthworm Eiseniafetida: effects on C and N contents and the availability of nutrients. Biol. Fert. Soils 22:162-166.

PCARRD. (Philippine Council for Agriculture and Resources Research Development.) 1975. The Philippine Recommends for vegetable crops. p. 113.

PCARRD, 1980. Standard methods of analysis for soil, plant tissue, water and fertilizer. Farm and systems Res. Div. Philippine Council for Agriculture and Resource, Los Baños. 164 p.

Rao S, Subba Rao, Takkar PN (1996). Changes in different forms of K under earthworm activity. National Seminar on Organic Farming and Sustainable Agriculture, India, pp. 9-11.

Recycled Organic Units, 2000. Guide to developing a process control system for a composting facility. Printed by the Recycled Organic Units, the university of New South Walls, Sydney Australia.

Tisdale, S. L. and W. AL. Nelson. 1985. Soil fertility and fertilizers. 3rd ed. McMillan publ. Co., Inc., New York. 694 pp.

United States Department of Agriculture, Natural Resource Conservation Service. 2004. Soil Survey Laboratory Methods Manual (R. Burt., ed.) USDA, NRCS Lincoln, Nebraska.

USDA-NRCS. 1996. Soil survey laboratory methods manual. Soil Survey Investigation Report No. 42, Version 3.0. USDA-Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

Vasanthi, D. AND Kumaraswamy, K. 1999. Efficacy of vermicompost to improve soil fertility and rice yield. Journal of the Indian Society of Soil Science.

Westerman, R.L. (ed.). 1990. Soil Testing and Plant Analysis. 3rd ed. SSSA, Madison, WI.

Zamora, R. F. 2007. Fertilizer and water management for lowland rice production Undergrad Thesis ViSCA, Baybay, Leyte. Pp. 51.

Zink TA, Allen MF (1998). The effects of organic amendments on the restoration of disturbed coastal sage scrub habitat. Restor. Ecol. 6: 52-58.