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Effects of chicken manure and earthworm fertilizer on growth and fruit quality of greenhouse tomato

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ABSTRACT

Production of organic food is not allowed to use chemical fertilizers. This study evaluated two organic fertilizers including chicken manure and earthworm fertilizer on growth and fruit quality of greenhouse tomato (*Lycopersicum esculentum*). A tomato variety, Tep Pratarn, was planted in a completely randomized design with three replications in greenhouse. Five treatments consisted of untreated control, chicken manure at the rate of 12.5 tons ha^{-1}, chicken manure at the rate of 25 tons ha^{-1}, earthworm fertilizer at the rate of 12.5 tons ha^{-1} and earthworm fertilizer at the rate of 25 tons ha^{-1}. Application of earthworm fertilizer at the rate of 25 tons ha^{-1} had the highest stem diameter, leaf size, flower number, fruit number and fruit size. Application of organic fertilizers for production of tomato in greenhouse is discussed.

Keywords: bamboo soil, chicken manure, earthworm fertilizer

INTRODUCTION

Production of greenhouse tomato (*Lycopersicum esculentum*) is generally practiced when the price is incentive because of inappropriate growing environments such as too low temperature and heavy rain. Application of organic fertilizers to greenhouse crops for building nutrient-rich soil in greenhouse takes more extra time and effort, but results in long run is worth attempting (Dodson *et al*., 2002). Nutrient supply and crop yield with organic fertilizers were maintained at similar levels to those obtained with inorganic fertilizer. The effects of the organic amendments were observed even when they involved a small portion of the total amount of nutrients supplied; thereby confirming that some of the beneficial effects of integrated fertilizer strategies may occur in the short term (Lazcano *et al*., 2013). According to Wikipedia (2019), organic farming is defined by the use of fertilizers of organic origin such as compost manure, green manure, and bone meal and places emphasis on techniques such as crop rotation and companion planting.

Tomato is one of the most valuable and popular vegetables worldwide, and each cultivar differs in fruit size, shape, taste, color, skin and flesh firmness. In Thailand, "See Da" tomato is a special type of tomato that is suitable for use as an ingredient of papaya salad. Papaya salad is a popular dish with a wide variation that is consumed in all parts of the country and the dish is also popular among the foreigners. Tomato is therefore a cash crop in the country and greenhouse technology may increase the production efficiency and generate more income to the growers.

However, the effects of organic fertilizer types and appropriate rates are still ambiguous because the organic fertilizers from different types and sources have different qualities (Chang *et al*., 2008). For poultry manure, the variations would be because of animal types (broilers and layers), farm management (organic farm and normal production house), litter used, moisture and manure types

(compost or fresh manure) (Bolan *et al*., 2010). Earthworm fertilizer also had variation in its quality due to different worm species and materials used in production of the compost (agricultural waste and industrial waste) (Saranraj and Stella, 2012). Earthworm fertilizer is a nutritive organic fertilizer rich in humus, NPK, micronutrients, beneficial soil microbes; nitrogen-fixing, phosphate solubilizing bacteria, actinomycets and growth hormones including auxins, gibberlins and cytokinins (Adhikary, 2012). The use of chicken manure and vermicompost for production of greenhouse tomato has an advantage if the manure is available near the farms at low-cost and the farmers can produce vermicompost by themselves. Moreover, organic fertilizers also have residual effect on succeeding crops (Isitekhale *et al*., 2013).

Organic fertilizers are known to have low nutrients and, in most cases, it is recommended to add some chemical fertilizers to increase nutrients (Lazcano *et al*., 2013; Liu *et al*., 2014). However, one of the advantages of organic fertilizers is that they provide their nutrients especially the principal nutrients (NPK) to growing plants over a long period of time in a slow release process (Purnomo *et al*., 2017). In cease of organic farming, the supplement of chemical fertilizers is not allowed and it is necessary to apply inorganic fertilizers at higher rates (Wikipedia, 2019). According to Isitekhale *et al*. (2013), applications of poultry manure at the rate of 6 tons ha^{-1} alone or with chemical fertilizers significantly increased plant height and leaf area of tomato and the residual effect on the succeeding tomato crop was also significant.

Application of vermicompost at the rate of 11.25 tons ha^{-1} plus nitrogen and phosphorus (NP) fertilizer at the rate of 75% of recommended rate had the highest values for the various growth, yield and quality attributing parameters and the treatment also increased residual soil status followed by application at the rate of 7.5 tons ha^{-1} plus NP at the rate of 50% of recommended rate (Mengistu *et al*., 2017). In tomato, application of cattle manure vermicompost at the rate of 20 tons ha^{-1} increased dry weight of shoot of 52 folds and root of 115 folds, number of fruit(s)/plant of 6 folds and mean fruit weight of 29 folds (Kashem *et al*., 2015). The experiment in Vietnam, however, the highest yield was obtained at 35 tons ha^{-1} vermicompost (in autumn-winter season 2013) and at 30 tons ha^{-1} vermicompost (in autumnwinter season 2012, but the difference was not significant as compared to level 35 tons ha^{-1}) (Thuy *et al*., 2017). The highest ratio of soil and vermicompost used in tomato was 1:1, which also had the highest fruit yield (Abduli *et al*., 2013).

The maximum rates of earthworm fertilizer and chicken manure reported so far would be as high as 50% of the soil. These rates were either used as single fertilizers or in combination with chemical fertilizers. The main factors for the varying rates would be due to nutrient compositions and organic carbon of the fertilizers. The hypothesis underlying the research project is that how tomato responds to the rates of the organic fertilizers at high rate and recommended rate when they are used as single fertilizers. The objective of this study was to evaluate the effects of organic fertilizers in the forms of chicken manure and earthworm fertilizer on growth and fruit quality of greenhouse tomato. The information obtained in this study is important to make a guideline for tomato growers especially for the most widely used fertilizers such as chicken manure and earthworm fertilizers.

MATERIALS AND METHODS

Experimental design :

The experiment was carried out in a completely randomized design with three replications at the Faculty of Agriculture Technology, Valaya Alongkorn Rajabhat University during January to April 2019. Five treatments consisted of unfertilized control, chicken manure at the rate of 33.7 g/pot (12.5 tons ha^{-1}), chicken manure at the rate of 67.4 g/pot (25 tons ha^{-1}), earthworm fertilizer at the rate of 33.7 g/pot (12.5 tons ha^{-1}) and earthworm fertilizer at the rate of 67.4 g/pot (25 tons ha^{-1}). The experimental unit had 5 pots or plants, and there were 75 pots or plants totally.

Crop management :

A tomato F_1 hybrid, Tep Pratarn, was used in this study. This variety has medium-sized fruits with pink color, and it is used mainly for making papaya salad, which is a popular dish in Thailand. Other uses of this variety are similar to other varieties except that it is not suitable for processed tomato. The seeds were planted in plug trays in a greenhouse with 50% shading for two weeks, and the seedlings were then available for transplanting.

Tomato seedlings were planted in plastic containers with 12 inches in diameter. Prior to transplanting, the bamboo soil of 4 kg (the soil under bamboo shade) was loaded into the containers, and the fertilizers were mixed into the soil according to the treatments mentioned above. The crop was maintained in a greenhouse. Water was supplied to the crop daily in the morning and the evening until flowering, and the crop was then transferred to open environment for insect pollination.

Data collection :

At 55 days after transplanting (DAT), data were recorded for stem diameter, leaf size and number of flowers. Stem diameter was recorded at 30 cm above soil surface. Leaf size was recorded form leaf sample of five randomly chosen leaves in each plant and leaf size was averaged from five plants in the plot. Flower number averaged from five times at five-day intervals was recorded from the first day of flowering (55 DAT) until the end of the experiment (91 DAT). Number of fruits averaged from five times at five days intervals was recorded at 65 DAT (ten days after pollination) until the end of the experiment.

At 91 DAT, data were recorded for plant height, fruit size by fresh weight, fruit diameters, fruit firmness and fruit color parameters. Plant height was recorded from the soil surface to the highest point of the stem. Fruit fresh weight of five fruits was recorded for five times with five-day intervals from five fruits of the plant for each time, and, then, the averaged value across five times was reported. Fruit diameter was recorded at ripening stage at vertical and horizontal directions. Fruit firmness was recorded at ripe stage using a texture analyzer model TA.XT plus (stable Micro Systems, UK). The P/2 compressor head was used for the analysis. Color parameters were recorded for L*, a* and b* on ripe fruits at two points in the middle of the fruits using a Color reader model CR-10 (Minolta, Japan).

Data analysis :

Analysis of Variance (ANOVA) was performed for all parameters according to a completely randomized design. Treatment means were compared by Duncan's Multiple Range Test (DMRT) at 0.05 probability level.

RESULTS AND DISCUSSION :

Growth parameters and fruit size :

Fertilizer treatments including unfertilized control and organic fertilizers were significantly different ($P \leq 0.05$) for stem diameter, leaf size and number of flowers, but they were not significantly different for plant height and number of fruits (Table 01). The treatments among organic fertilizers were also similar for stem diameter (1.62-2.25 cm) but only earthworm fertilizer at the rate of 25 tons ha^{-1} (2.25 cm) was significantly different from untreated control (1.33 cm). The treatments among organic fertilizers were significantly different for leaf size in which earthworm fertilizer at the rate of 25 tons ha^{-1} had the highest leaf size (and 8.99 cm^2) and it was significantly different from untreated control (5.90 cm^2). Unfertilized control was not significantly different from chicken manure at two rates and earthworm fertilizer at the rate of 12.5 tons ha^{-1}.

Table 01. Means for plant height, stem diameter, leaf size, number of flowers (averaged from five times of counting) and number of tomato fruits (averaged from five times of counting) of tomato treated with different types and rates of organic fertilizers.

Fertilizer	Plant height (cm)	Stem diameter (cm)	Leaf size (cm^2)	Number of flowers	Number of fruits
Control	73.80	1.33b	5.90b	17.80ab	7.53
Chicken manure[1]	78.47	1.87ab	5.86b	19.73ab	7.26
Chicken manure[2]	73.00	1.62ab	4.50b	14.46bc	5.73
Earthworm fertilizer[1]	79.26	2.04ab	6.26b	11.46c	9.73
Earthworm fertilizer[1]	91.33	2.25a	8.99a	22.00a	12.46
Means	6.41	1.82	6.36	17.09	8.54

Means in the same column followed by the same letter(s) are not significantly different by DMRT at 0.05 probability level.

[1]at the rate of 12.5 tons ha^{-1}

[2]at the rate of 25 tons ha^{-1}

Earthworm fertilizer at the rate of 25 tons ha^{-1} had the highest number of flowers (22.09 flowers). Earthworm fertilizer at the rate of 12.5 tons ha^{-1} was lowest for this trait (11.46 flowers) and it was

significantly lower than control (17.80 flowers), whereas chicken manures at two rates (19.73 flowers for 12.5 tons ha^{-1} and 14.40 flowers for 25 tons ha^{-1}) were not significantly different from untreated control.

Unfortunately, the authors did not analyze the fertilizers for chemical properties prior to experiment. However, the authors provided the information on the fertilizers from other sources in the literature (Abernethy, 2017; Kalbani *et al*., 2016; Ogundare *et al*., 2015; Thakur *et al*., 2011). Based on the literature review, variations in chemical properties of vermicompost and chicken manure were rather high. According to the recommendations of the supplier, vermicompost can be used at the rate of 5 tons ha^{-1} by spreading on raised beds. It is highly recommended that users should use the organic fertilizers based on nutrient analysis for each batch of organic fertilizer production.

Application of earthworm fertilizer at the rate of 25 tons ha^{-1} resulted in the highest stem diameter, leaf size, flower number and fruit size by weight. According to Wang *et al*. (2017), applications of earthworm fertilizer at the rate of 30 tons ha^{-1} and chicken manure at the rate of 19 tons ha^{-1} had higher stem diameter than application of urea at the rate of 900 kg nitrogen ha^{-1} and unfertilized control. The authors also reported that application of earthworm fertilizer also had the highest tomato yield followed by chicken manure, urea and untreated control, respectively.

Fruit quality :

Fruit quality parameters including fruit size (five fruit weight), fruit firmness and fruit diameters measured both vertical and horizontal directions are presented in Table 02. Fertilizer treatments including untreated control and organic fertilizers were significantly different ($P \leq 0.05$) for fruit size, fruit firmness and fruit diameter at vertical direction, but they were not significantly different for fruit diameter at horizontal direction.

Table 02. Means for fruit size, fruit firmness, fruit diameter (vertical) and fruit diameter (Horizontal) of tomato fruits treated with different types and rates of organic fertilizers.

Fertilizer	Fruit size (g/5 fruits)	Fruit firmness (N/cm^2)	Vertical fruit diameter (cm)	horizontal fruit diameter (cm)
Control	73.06b	445.15a	3.00ab	2.30
Chicken manure[1]	85.71ab	275.42bc	3.37a	2.62
Chicken manure[2]	65.07b	239.04c	2.36b	1.98
Earthworm fertilizer[1]	89.40ab	249.00bc	3.39a	2.69
Earthworm fertilizer[1]	107.08a	285.34b	3.45a	2.74
Means	84.06	298.79	3.11	2.47

Means in the same column followed by the same letter(s) are not significantly different by DMRT at 0.05 probability level.

[1]at the rate of 12.5 tons ha^{-1}
[2]at the rate of 25 tons ha^{-1}

Fruit sizes among the treatments ranged from 65.07 g for chicken manure at the rate of 12.5 tons ha^{-1} to 107.08 g for earthworm fertilizer at the rate of 25 tons ha^{-1}. Among organic fertilizer treatments, only earthworm fertilizer at the rate of 25 tons ha^{-1} was significantly higher than untreated control but other organic treatments were similar to untreated control.

Mean for fruit firmness across the treatments was 298.79 N/cm^2, and the range of this parameter was from 239.04 N/cm^2 for chicken manure at the rate of 12.5 tons ha^{-1} to 445.14 for untreated control. All organic treatments had significantly lower fruit firmness than untreated control. It was likely that application of organic fertilizers reduced firmness.

Vertical diameter (3.74 cm) was larger than horizontal diameter (3.11 cm). Application of fertilizers did not significantly affect horizontal diameter, but it did affect vertical diameter although the effect was small. All organic fertilizer treatments were similar to untreated control for vertical fruit diameter, whereas chicken manure at the rate of 25 tons ha^{-1} was significantly lower than other organic treatments.

Application of earthworm manure could improve fruit quality of tomato such as increase in sugar/acid ratio and reduction in nitrate (Wang *et al*., 2017). Earthworm fertilizer is also known as vermicompost and it is used widely in a variety of crop species especially for making soilless potting media by mixing with other materials such as burnt rice husk, coconut dusk and others (Ahirwar and Hussain, 2015). According to Hashemimajd *et al*. (2004), potting mixtures consisting of compost or vermicompost produced significantly higher biomass than the control (soil + sand) and raw daily manure, and potting media consisting for vermicompost and other materials such as rice husk, tobacco residue, yard leaf and sewage sludge could increase shoot and root dry matters, whereas the rate of compost in potting mixture did not generally affect dry matter. The authors also found the reduction in dry matter in the potting media consisting of sewage sludge+ yard leaf and yard leaf + tobacco residue.

In this study, application of chicken manure at the rate of 25 tons ha^{-1} had detrimental effects on plant height, leaf size, number of fruits, fruit size by weight and fruit firmness. These effects would be possibly due to excess application of the fertilizer because chicken manure had higher nutrients and organic carbon than earthworm fertilizer (Table 03). According to Nakhro and Dkhar (2010), organic carbon was positively associated with soil fungal and bacterial populations. Application of organic fertilizers increased soil organic carbon and, thereby, increased microorganism populations. The competition between soil microorganism and plant for nutrients may be the cause of reduction in crop performance under excessive doses of organic fertilizers.

Table 03. The selected properties of chicken manure and earthworm fertilizer.

Property	Chicken manure [1/]	Chicken manure [2/]	Earthworm fertilizer [3/]	Earthworm fertilizer [4/]
Moisture	15%	ND	ND	ND
C/N ratio	17:1	10.6:1	10.5:1	ND
Sodium chloride	1%	ND	1.91 (me/100g)	ND
Total nitrogen	2.5%	3.6%	1.17%	450.26 (kg ha^{-1})
Phosphorus	1%	1.34%	6,100 (mg/kg)	560 (kg ha^{-1})
Potassium	2%	3.12%	5.9 (me/100g)	96.63 (kg ha^{-1})
Trace elements	7,000 PPM	ND	ND	47.60 (Meq/100gm)
Organic matter	50%	38.36%	12.2%*	15.4%
pH	7	ND	7.4	7.0
EC	9m.mhos/cm3	ND	ND	1.85 m.mhos/cm3

ND= Not determined

* Reported as total carbon

[1/] Kalbani *et al*. (2016)

[2/] Ogundaren *et al*. (2015)

[3/] Abernethy (2017)

The advantages of organic fertilizers over chemical fertilizers are that if the fertilizers are used in the form of compost, they are used at varying rates without detrimental effects on the crops and environments and they are slowly-released fertilizers that have beneficial effects on the succeeding crops. However, the experiment was limited to one season in pot experiment. Further investigations on the varying rates and types of organic fertilizers are required. The experiment on raised beds with bee keeping is also necessary to obtain the complete information for tomato production in greenhouse.

Fruit color :

CIELab scale was used to identify the differences among fertilizer treatments for fruit color. In this study, fertilizer treatments were not significantly different for the color parameters L*, a* and b* (Table 04). L* is the lightness effect (0 is black, 100 is white). a* is a red-green axis (positive is red, neutral is 0, negative is green), and b* is blue-yellow axis (positive is yellow, neutral is 0, negative is blue). Although visual perception of fruit color may be similar, the measurements with instrument may be different. The results indicated that fruits of tomato treated with different organic fertilizers both types and rates were uniform for color.

Table 04. Means for fruit color parameters (L*, a* and b*) of tomato fruits treated with different types and rates of organic fertilizers.

Fertilizer	L*	a*	b*
Control	44.09	16.35	16.24
Chicken manure[1]	47.73	20.91	20.52
Chicken manure[2]	34.94	15.94	14.26
Earthworm fertilizer[1]	46.69	22.05	19.49
Earthworm fertilizer[1]	42.04	20.95	17.25
Means	43.10	19.24	17.55

Means in the same column followed by the same letter(s) are not significantly different by DMRT at 0.05 probability level.

[1]at the rate of 12.5 tons ha^{-1}

[2]at the rate of 25 tons ha^{-1}

CONCLUSIONS :

The consumers are currently aware of health problems caused by inappropriate consumption of food. Organic food, therefore, serves their need as consumption of organic food with good agricultural practices is safer than consumption of ordinary food. In this study, organic tomatoes were different from ordinary tomato for many growth characters, tomato yield and fruit quality characters. However, they were not significantly different for plant height and the trait may not be suitable for evaluation of tomato growth. Stem diameter and leaf size were good parameter to differentiate the effects of fertilizers on tomato. Vertical fruit diameter seemed to be good for evaluation fruit quality of tomato. Application of earthworm fertilizer at the rate of 25 tons ha^{-1} was better than other treatments for many traits such as stem diameter, leaf size, flower number fruit number and fruit weight. Application of organic fertilizers at all rates reduced fruit firmness of tomato. Applications of organic fertilizers for both types and both rates did not significantly affect fruit color. Care must be taken to apply chicken fertilizer to tomato at high rate as it can be toxic to the crop. The information obtained in this study is useful for the development of production guidelines for greenhouse tomato.

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