Organic and chemical fertilizers have varied effects on tomato growth in a sandy soil

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ABSTRACT: This study was aimed at evaluating effects of unconventional organic fertilizers, vermicompost (VC) and VC in combination with rice husk charcoal (RHC) at an optimum rate in comparison to conventional chemical (CF) and organic (cow manure, CM) fertilizers at recommended rates on plant growth. Five treatments of a greenhouse pot experiment were: (i) unamended (control, CT), (ii) CF, (iii) CM, (iv) VC, and VC+RHC. Tomato was planted for 80 days as a test plant. The VC treatment produced significantly higher dry weight (g/plant) (4.1) than CT (0.5) and CF (1.4) treatments. The VC+RHC treatment brought about significantly higher shoot dry weight (6.8) than VC alone. However, shoot dry weight between CT and CM (0.9) treatments were not significantly different. Mechanisms pertaining to effects of unconventional organic fertilizers on plant growth were discussed. Re-evaluation of the low recommended rate (10 t/ha or approximately 2t/rai) of the conventional cow manure is suggested.

Keywords: Biochar, Cow manure, Inorganic fertilizer, Recommended rates, Vermicompost

Introduction

Increasing crop productivity in cultivated lands to meet rising global demand and consumption of agricultural crops for food, animal feed, and fuel is a focus of much research at the present time (Edgerton, 2009). However, this goal is difficult to achieve in the tropics, where soils are highly weathered and with low fertility (Uehara and Gillman, 1981). This includes Northeast Thailand where soils are mostly degraded (Vityakon, 2011). Tomato is an important cash crop in the Northeast which is grown after rice largely in Sakon Nakhon for industrial foods (Kutrasaeng et al., 2017) and in Khon Kaen under contracts to seed companies (Rambo, 2017). An increase in tomato yield via soil fertility improvement is therefore significant for higher earnings of farmers.

There have been many approaches proposed to enhance crop productivity. Conventional strategies for soil improvement are through both inorganic and organic means, such as amending soils with chemical fertilizers and cattle manures, respectively (Chouichom and Yamao, 2011). In 1989, Hervas et al. (1989) and

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Saiz-Jimenez et al. (1989) proposed a material derived from earthworm cast as an organic fertilizer, namely vermicompost. Interests in its benefits as soil amendments have been increasing since then (Scopus Analysis, 2018). The beneficial roles of vermicompost which have been reported are their high contents of plant nutrients, humus, and plant growth hormones, their enhancement of beneficial soil microorganisms, and increases in soil porosity (Adhikary, 2012). Based on the authors' interview with the producers, there are many advantages of utilizing vermicompost as an organic fertilizer nevertheless production of vermicompost is time consuming and laborious. As for users, vermicompost cost is high as the on-site sale is about $0.9/kg or ฿30/kg. Combined use of vermicompost with other organic materials can reduce the cost. Charcoal has been shown tobe promising in improving crop growth when used in combination with vermicompost (Sohi et al., 2010).

In the past two decades, charcoal use as a soil amendment, termed biochar, has been a focus for research (Butnan et al., 2015). Positive effects of charcoals on soil and crop improvement were already found by Sohi et al. (2010),Lehmann et al. (2011), and Gurwick et al. (2013).Among various charcoals, rice husk charcoal is produced in large amounts in Northeast Thailand due to high quantities of rice production. Recently, rice husk charcoals were reported to increase crop growth such as lentil (*Lens cullinaris*) (Abrishamkesh et al., 2015), and rice (*Oryza sativa*) (Pratiwi and Shinogi, 2016).

Regarding amounts of various soil amendments used to improve soil fertility and crop yield, there have been some established rates used by growers. For more conventional fertilizers, such as chemical fertilizers and cattle manure, the rates are mostly recommended by government agencies, Departments of Agriculture, and Agriculture Extension. Meanwhile, newer, unconventional organic fertilizers are currently under research and some optimum rates have been published, such as vermicomposts (Chakatrakarn and Jala, 2015) and biochars (Butnan et al., 2015).

Therefore, the objective of this study is to evaluate effects of vermicompost alone and that in combination with rice husk charcoal at optimum published rates in comparison to the conventional chemical and organic (cow manure) fertilizers at recommended rates on plant growth.

Materials and methods

The soil used was sandy textured of the Yang Talat series (isohyperthermic Typic Oxyaquic Kandiustults), which was collected at the Field Research Facilities of the Plant Science Section, Sakon Nakhon Rajabhat University (17° 11' 9.7" N; 104° 05' 18.8" E) from 0 – 15 cm-depth. It was air-dried and sieved to pass through a 2-mm sieve. Cow manure was from a local dairy farm. It was stored for approximately a month before using in the experiment. Vermicompost was that of the African night crawler (*Eudrilus eugeniae*) which was fed solely with dairy cow manure soaked in water overnight. Rice (*Oryza sativa*) husk charcoal was commercially available in stores in Sakon Nakhon province.

A greenhouse pot experiment was conducted at the Field Research Facilities of the Plant Science Section, Sakon Nakhon Rajabhat University during September to November 2017. There were 5 treatments of soil amendments including: (i) unamended (control, CT), (ii) chemical fertilizer (CF), (iii) cow manure (CM), (iv) vermicompost (VC), and (v) VC in combination with rice husk charcoal (VC+RHC). The experiment was arranged in randomized complete block design with five blocks. Two kg soil per pot was mixed thoroughly with an amendment according to its respective treatment. The rates of various amendments used were based on either government agencies' recommended rates or published optimum rates for plant growth. In the CF treatment, chemical fertilizergrades 46-0-0 and 15-15-15 each of which was applied at rate 312.5 kg/ha (or 50 kg/rai) as recommended by the Department of Agriculture Extension (Konkayan, 2008) was used. As for CM treatment, the recommended rate (10 t/ha or 1.6 t/rai) following Chakraborty and Kundu (2015) was employed. This rate is comparable to that recommended by Department of Agriculture's 2 t/rai (Department of Agriculture, 2006). Meanwhile, VC rate was applied at 50% v/v following the published optimum rate for high biomass of Chinese cabbage test plant of Chakatrakarn and Jala (2015).RHC was applied at the rate 2% w/w based on a published optimum charcoal rate for sandy soils (Butnan et al., 2015). Cow manure and vermicompost in the CM and VC treatments were incubated with soil for 15 days. Fifteen-day-tomato seedlings were transplanted to a pot. CF was split applied twice at 15 and 34 days after planting (DAP) at half of the total rate at each application (Konkayan, 2008).Tomato shoot biomass was harvested at 80 DAP and fresh weight determined. Dry biomass was determined by oven-dry at 65°C until constant weight. Data collection of height, branch number, and leaf number was performed at 42, 46, 50, 54, 58, 62, 70, and 80 DAP.

Analysis of variance based on the randomized complete block design was performed to determine effects of treatments on tomato growth, i.e., shoot fresh- and dry-biomass, height, branch number, and leaf number. The statistical analyses were performed by SAS software version 9.1 (SAS Institute Inc., Cary, NC, USA). Significant differences were at $P \leq 0.05$.

Results and discussion

The VC treatments brought about significantly higher shoot fresh biomass (23.1 g/plant) (Figure 1a) and shoot dry biomass (4.1 g/plant) (Figure 1b) as well as height (Figure 2a) of tomato during 42 – 80 DAP than CT (2.7 g/plant for fresh biomass; 0.5 g/plant for dry biomass) and CF (8.9 g/plant for fresh biomass; 1.4 g/plant for dry biomass) (Figure 1). The VC also significantly increased number of branches relative to CT during 42 – 70 DAP (Figure 2b) but not at 80 DAP, which suggested that the VC effects on tomato depended on times after planting as confirmed by treatment x time interaction($P \leq 0.05$) (data not shown). In addition, VC had significantly higher leaf number during 42 – 80 DAP (Figure 2c) than CT and CF. Adhikary (2012) suggested that beneficial effects of VC in enhancing plant growth was due to its high contents of: (i) plant nutrients, i.e., N, P, K, and micronutrients, (ii) plant growth hormones in particular auxins, cytokinins, and gibberellins, and (iii) humic substances. In addition, VC had (iv) beneficial microorganisms including nitrogen fixing bacteria, phosphate solubilizing bacteria, mycorrhiza, actinomycetes, *Azotobacter* spp., and *Nitrobacter* spp. These aforementioned characteristics of VC resulted in (v) soil structure improvement.

Rice husk charcoal (RHC) could supplement VC in improving tomato growth. This was seen in significantly greater shoot fresh biomass (37.0 g/plant for VC+RHC vs 23.1 g/plant under VC alone) (**Figure 1a**), dry shoot biomass (6.8 g/plant for VC+RHC vs 4.1 g/plant under VC alone) (**Figure 1b**), height (**Figure 2b**), and leaf number (**Figure 2c**) in VC+RHC than VC alone. This was due primarily to effect of high ash content of RHC on the acid soil (pH 5.6) (Somchai Butnan, unpublished data) used in this study. Ash of charcoals contains a number of elements essential to plant growth, e.g., P, K, Ca, and Mg (Butnan et al., 2015). In addition, an increase in soil pH due to effect of metal oxides in ash, e.g., CaO, K_2O, MgO, and SiO_2 (Butnan et al., 2016), may bring about increases in plant nutrient availability (Mengel and Kirkby, 2001). Furthermore, RHC may alleviate toxicity of certain elements, such as Al and Mn (Berek et al., 2011; Butnan et al., 2015) which was reported to be a problem of tropical sandy soils(Vityakon and Seripong, 1989; Hue, 2011).

Cow manure (CM) and CT did not show significant differencesin shoot biomass (**Figure 1a and 1b**) which suggested that the recommended rate of CM (10 t/ha or approx. 2 t/rai) could not significantly enhance tomato growth. This result was different from previous findings that cow manure at the rates20 t/ha (3.2 t/rai) (Vityakon et al., 1988)and 360 t/ha (57.6 t/rai) (Shakoor et al., 2015) significantly increased corn growth. The significant positive effects of cow manures on plant growth as cited above were possible at high application rates. This result points to a re-evaluation of an effective cow manure application rates that can enhance crop growth and yield.

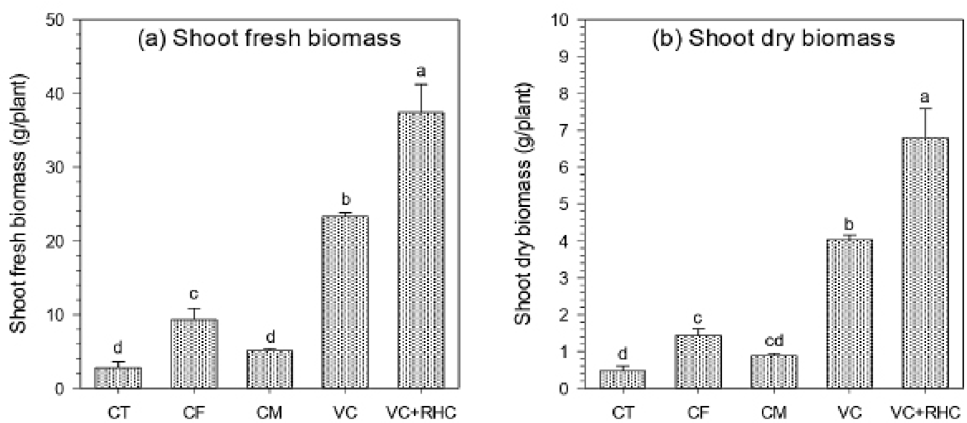
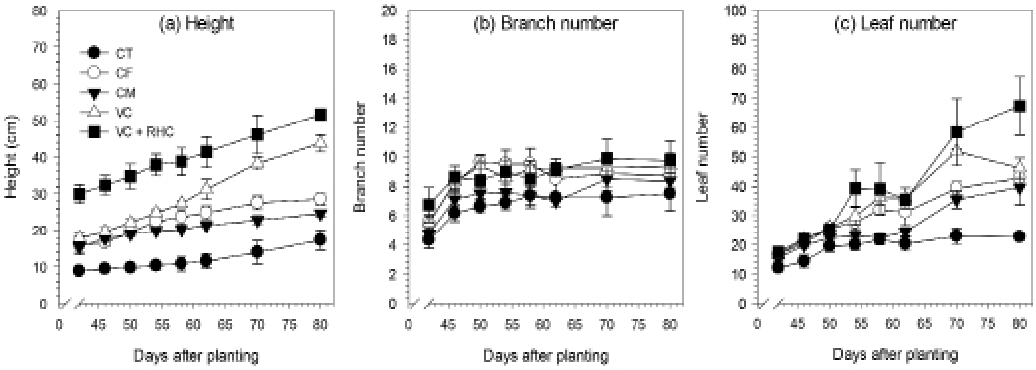


Figure 1 Effects of different fertilizers including unamended (control, CT), chemical fertilizer (CF), cow manure (CM), vermicompost (VC), and combination of VC with rice husk charcoal (VC+RHC) on: (a) shoot fresh biomass, and (b) shoot dry biomass of tomato. Bars with similar letters are not significantly different ($P \geq 0.05$; Tukey's Student range test). Error bars are standard deviation



Amendment	Days after planting							
	42	46	50	54	58	62	70	80
CT	d	d	d	d	d	d	d	e
CF	c	c	c	c	c	c	c	c
CM	c	c	c	c	c	c	c	d
VC	b	b	b	b	b	b	b	b
VC + RHC	a	a	a	a	a	a	a	a

Amendment	Days after planting							
	42	46	50	54	58	62	70	80
CT	c	b	d	c	b	b	b	ns
CF	bc	a	a	a	a	a	a	ns
CM	bc	b	c	bc	b	b	ab	ns
VC	ab	a	ab	ab	a	a	a	ns
VC + RHC	a	a	bc	a	ab	a	a	ns

Amendment	Days after planting							
	42	46	50	54	58	62	70	80
CT	c	b	c	c	b	b	c	c
CF	ab	a	ab	b	a	a	b	b
CM	b	a	bc	c	b	b	b	b
VC	ab	a	a	b	a	a	a	b
VC + RHC	a	a	ab	a	a	a	a	a

Figure 2 Effects of different fertilizers including unamended (control, CT), chemical fertilizer (CF), cow manure (CM), vermicompost (VC), and combination of VC with rice husk charcoal (VC+RHC) on: (a) height, (b) branch number, and (c) leaf number. The accompanied tables show comparison among treatments within a time interval or a period of days after tomato planting (DAP). Similar letters within a DAPare not significantly different ($P \geq 0.05$; Tukey's Student range test). Vertical bars are standard deviation

Conclusions

Results of this study showed clearly that the use of an unconventional organic fertilizer, i.e., vermicompost, could substitute for chemical fertilizer in improving tomato growth in a sandy soil provided that its application is adequately high (58 t/rai or 363 t/ha). Beneficial effect of vermicompost could be enhanced through its combination with rice husk charcoal. Meanwhile, it is necessary to re-evaluate the rate of a conventional fertilizer, cow manure of10 t/ha because this low rate could not improve tomato growth in this study.

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