Agricultural Water Management 160 (2015) 98–105

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Effects of vermicomposts on tomato yield and quality and soil fertility in greenhouse under different soil water regimes

Lijuan Yang[a], Fengyan Zhao[a], Qing Chang[a], Tianlai Li[b], Fusheng Li[c,*]

[a] Land and Environmental College, Shenyang Agricultural University, Shenyang, Liaoning 110866, China
[b] Horticutural College, Shenyang Agricultural University, Shenyang, Liaoning 110866, China
[c] College of Agriculture, Guangxi University, Nanning, Guangxi 530005, China

ARTICLE INFO

Article history:
Received 18 October 2014
Received in revised form 3 July 2015
Accepted 6 July 2015
Available online 20 July 2015

Keywords:
Greenhouse
Irrigation level
Soil fertility
Tomato
Vermicompost

ABSTRACT

Vermicompost has great commercial potential in the horticultural industry and its effectiveness is affected by soil water regimes. The effects of vermicompost (VM) on tomato yield and quality and soil fertility were compared with chick compost (CM), horse compost (HM) and chemical fertilizer (CF) in a greenhouse under the three soil water regimes (50–60, 60–70 and 70–80%θ_f, θ_f is field capacity). Additionally a control treatment (CK, no fertilization) was included. Under 60–70%θ_f, VM increased the yield by 16.3, 9.6, 52.0 and 69.3%, and the vitamin C (V_C) content by 8.2, 59.2, 15.2 and 80.3% when compared to CM, HM, CF and CK, respectively. However, VM decreased the soluble solids and total acidity under three soil water regimes. Total acidity in VM was 17.8, 4.8, 26.4 and 9.1% lower than that in CM, HM, CF and CK, respectively, and the sugar/acid ratio (the ratio of soluble solids to total acidity) in VM was also lower than the other two composts, but higher than CF and CK. VM had the highest sugar/acid ratio under 50–60%θ_f. The sugar/acid ratio in VM decreased with the increase of soil water content. VM had lower soil organic matter content than CM and HM, but higher than CF and CK under the three soil water regimes. The soil organic matter content in VM was 17.0 and 12.7% lower than that in CM and HM, but 12.9 and 10.1% higher than that in CF and CK. VM had higher available N and P contents in soil than the other treatments under 70–80%θ_f. VM increased the activities of acid phosphatase, catalase and urease in soil compared to the other treatments under the three soil water regimes. Thus vermicompost increased tomato yield and V_C under 60–70% of field capacity and the effects of vermicompost on soil fertility varied with soil water regime.

1. Introduction

Vermicompost is a kind of natural eco-manure, which is the product of organic matter degradation through the interaction between earthworms and microorganisms (Hu et al., 2004). It contains nutrients that are readily taken up by the plants, such as nitrate, available phosphorus, potassium, calcium and magnesium. Vermicompost is an excellent soil amendment or conditioner because of high porosity, aeration, drainage, water-holding capacity and microbial activity (Edwards and Burrows, 1988; Orozco et al., 1996). Arancon (2006) reported that greater contents of NH_4-N, NO_3-N and orthophosphates and higher dehydrogenase activity are recorded in vermicompost-treated soils than in the controls on the harvest date. Vermicompost can improve soil fertility in continuous cropping (Zhang et al., 2010). Vermicompost amendment has been shown to increase N uptake (Tomati et al., 1994), dry mass (Edwards, 1995; Liu et al., 1991) and yield in greenhouse crops (Atiyeh et al., 2000a,b, 2001; Buckerfield et al., 1999; Edwards et al., 2004; Edwards and Arancon, 2004). Atiyeh et al. (2000a) reported that the largest marketable yield of tomato is the treatment in the substitution of Metro-Mix 360 with 20% of vermicompost. Similar results were obtained by Arancon et al. (2004) where pepper plants grown in potting mixtures containing 40% of food waste vermicompost and 60% of Metro-Mix 360 increased fruit weights by 45% and mean number of fruits by 17% if compared to those grown in Metro-Mix 360 only. Bai et al. (2011) reported that higher sugar content is detected for the melons using 70 and 90% of vermicompost than that cultivated in other substrates. Zhao et al. (2010) indicated that cucumber yield with vermicompost and vermicompost organic-inorganic mixed fertilizer is close to

* Corresponding author. Fax +86 771 3235314 802.
E-mail address: lpfu6@163.com (F. Li).

http://dx.doi.org/10.1016/j.agwat.2015.07.002
0378-3774/

those with chicken manure and inorganic mixed fertilizer, but the overall quality of cucumber is improved by applying vermicompost and vermicompost organic-inorganic mixed fertilizer in the greenhouse.

Irrigation amount significantly affects the crop growth, yield and irrigation water productivity. Water consumption for tomato plant is estimated at 0.5–0.9 m^3/m^2 per year (Papadopoulos, 1991). Another study conducted by Soria and Cuartero (1998) revealed that water consumption of a tomato plant ranges from 0.19 to 1.03 L/d at different water salinities. Increasing the irrigation rate up to 120% of pan evaporation increases crop yield, but decreases total soluble solids (Tűzel et al., 1994). Drip irrigation at 75% of reference evapotranspiration has the maximum crop yield and irrigation water productivity (Harmanto et al., 2005).

There are lots of studies about the interactive effect of water and chemical fertilizer on the productivity of vegetable plants and soil fertility, but fewer studies about the interactive effect of water and organic manure. The hypothesis of this study was that the effects of vermicompost on tomato yield and quality and soil fertility in the greenhouse are controlled by soil water regime, so a pot experiment was conducted to investigate this hypothesis with five fertilizer treatments including vermicompost and three irrigation levels.

2. Materials and methods

2.1. Experimental site and materials

Pot experiment was conducted in a greenhouse in Shenyang Agricultural University, Liaoning, northeast China (latitude 41°31′N, longitude 123°24′E, altitude 51.6 m.a.s.l.). The experimental crop was tomato (*Lycopersicon esculentum* P. Miller var. LFZ-3). The experimental soil was meadow brown earth soil (Mollic Gleysols, FAO-UNESCO system). Soil bulk density was 1.31 g/cm^3, soil porosity was 50.0% and field capacity (θ_f) was 21.6% (mass basis). Soil pH was 7.20 and organic matter content was 18.26 g/kg. The contents of total nitrogen (N), phosphorus (P) and potassium (K), and available N, P and K were 1.06, 0.66 and 11.03 g/kg, and 63.10, 102.09 and 159.42 mg/kg, respectively.

2.2. Experimental method

There were three irrigation levels and five fertilizer treatments in this study, totally 15 treatments (i.e. 3×5), and each treatment was replicated four times. Three irrigation levels included low irrigation (L, 50–60%θ_f), medium irrigation (M, 60–70%θ_f) and high irrigation (H, 70–80%θ_f). Five fertilizer treatments included vermicompost (VM), chicken compost (CM), horse compost (HM), chemical fertilizer (CF) and no fertilizer (CK). Warmcast, chicken manure and horse manure were respectively composted with crushed maize straw and rice chaff at the ratio of 1:1:1 to be completely decomposed as vermicompost (VM), chicken-compost (CM) and horse-compost (HM). The nutrient contents in various manures/fertilizers were shown in Table 1. All treatments were applied with 0.64 g N /kg soil, the amount of compost used according to their N content in Table 1 was 91.43, 54.23 and 53.33 g/kg soil for VM, CM and HM, respectively. No other fertilizers were applied in the three compost treatments. For chemical fertilizers treatment (CF), N 0.64, P_2O_5 0.46 and K_2O 1.0 g /kg soil were supplied as urea, diammonium phosphate ($(NH_4)_2HPO_4$) and potassium sulfate (K_2SO_4), respectively. All chemical fertilizers were supplied with analytical regents. All three composts, and half of N, P and K fertilizers were added as basal fertilizer and evenly mixed into the soil at the beginning of the experiment, and the other half of N, P and K fertilizers was added on 9 June (60 days after transplanting (DAT), i.e. 60DAT).

One seedling (40 days old) was transplanted in each pot (33 cm in diameter, 25 cm in depth) filled with 12.5 kg of air-dried soil per pot on 9 April 2011. After transplanting, all seedlings were immediately watered to 100% of field capacity. Controlling soil moisture started at 7DAT (16 April). Weighing the pots and irrigating with tap water during the experimental period was used to soil water regime (Yang et al., 2012). Plants were harvested on 11 August 2011, i.e. 122DAT.

2.3. Soil and plant sampling and measurement

Tomato fruits were harvested from 28 June (79DAT) to 11 August (122DAT) when approximately 80% of the fruits were red or orange. Fruits were weighed after sorting into mature, green and rotten sub-groups for commercial evaluation (Yang et al.,2008). From the mature fruits subset harvested on 28 June, a sample was taken and passed through a 0.8 mm mesh sieve to separate seeds and epidermis from the juice.

Soluble solids, total acidity and vitamin C (V_C) were measured using the homogenized juice (Niu, 1990). Soluble solids, total acidity and V_C were determined using Abbe refractometer, neutralization titration method and 2, 4-dinitrophenylhydrazine colorimetry, respectively (Niu, 1990). Sugar/acid ratio was defined as the ratio of soluble solids to total acidity.

Soil samples at 0–20 cm layer were collected on 11 May (32DAT, fruit enlarging stage), 15 June (67DAT, fruit maturity stage) and 20 July (102DAT, later fruit harvesting stage), respectively.

Soil organic matter was analyzed using potassium dichromate volumetric method (external heating method). Soil available N content was determined using 1 mol/L NaOH solution diffusion method. Available P content was extracted using 0.5 mol/L $NaHCO_3$ (pH 8.5) and determined according to the method of Olsen and Sommers (1982). Other soil properties were determined according to the methods of Lu (1999).

Total N and P contents in the organic manure were determined by digesting samples with concentrated H_2SO_4 and H_2O_2 and measuring N using distillation method, P using the colorimetric method (Murphy and Riley, 1962).

Parts of fresh soil samples collected on 20 July (102DAT, later fruit harvesting stage) were used to determine soil microbial population. Soil microbial population was enumerated by soil dilution plate method (Wollum, 1982). The following culture media were used to enumerate the microorganisms: 10% tryptic soy agar (TSA; Difco) for bacteria (Lawley et al., 1983), actinomycete isolation agar (Difco) for actinomycetes and Martin's rose bengal for fungi (Martin, 1950). Plates were incubated at 28 °C in the dark, and bacteria and fungi were counted after 4 to 7 days of incubation and actinomycetes were counted after 10 to 14 days.

Three enzymatic activities in soil at the later fruit harvesting stage (102DAT) were analyzed using air-dried soil according to Guan et al. (1986). Acid phosphatase activity was analyzed with para-nitrophenol phosphate di-sodium and expressed as μg pNP/(g h). Catalase activity was determined by back-titrating residual H_2O_2 with $KMnO_4$ and expressed as 0.1 mol/L $KMnO_4$ ml/g. Urease activity was measured using phenol-sodium hypochlorite colorimetry and expressed as μg NH_3-N/(g h). The detailed procedure is referred to Li et al. (2010).

2.4. Data analysis

Analysis of variance (ANOVA) was performed with the SPSS19.0 for Windows software package (SPSS, Chicago, USA), and mean comparisons were done using the least significant difference (LSD) test at $P < 0.05$.