Scientia Horticulturae 160 (2013) 148–154

Contents lists available at SciVerse ScienceDirect

Scientia Horticulturae

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

Interactions between compost, vermicompost and earthworms influence plant growth and yield: A one-year greenhouse experiment

Thuy Thu Doan[a,b], Phuong Thi Ngo[c,d], Cornelia Rumpel[c], Bo Van Nguyen[e], Pascal Jouquet[b,*]

[a] Soils and Fertilizers Research Institute, Dong Ngac, Hanoi, Viet Nam
[b] Institute of Research for Development (IRD), UMR 211 BIOEMCO, Centre IRD Bondy, Bondy, France
[c] CNRS, UMR 7618 BIOEMCO, Campus AgroParisTech, Thiverval-Grignon, France
[d] Institute of Environmental Technology (VAST), Hanoi, Viet Nam
[e] Viet Nam Academy of Agricultural Science (VAAS), Hanoi, Viet Nam

ARTICLE INFO

Article history:
Received 7 September 2012
Received in revised form 17 April 2013
Accepted 29 May 2013

Keywords:
Compost
Vermicompost
Earthworms
Soil fertility
Tropical soil

ABSTRACT

The aim of the present study was to examine the interactions between an endogeic earthworm species, *Metaphire posthuma*, and purely mineral (control) or mineral plus organic (compost vs. vermicompost) amendments in terms of soil chemical properties and plant growth and yield. A one-year experiment was carried out in a greenhouse with a maize–tomato–maize cycle. Compost and vermicompost modified soil chemical properties leading to higher C and N, higher pH and CEC, and lower available P, NH_4^+ and NO_3^- than in the control. Although no significant difference in plant growth was observed for the first maize planting, tomato and maize growth were then highest for the mineral and vermicompost treatments and lowest for compost. Overall plant yields were always highest in mineral fertilizer alone and lowest for the compost treatments. The application of vermicompost led to a similar yield as the control treatment for the first maize planting. However, its beneficial influence decreased during the experiment until it was similar to that of the compost treatment. The presence of earthworms reduced the C content in soil mixed with compost and vermicompost but only influenced plant growth and yield in the compost treatment. The effect of earthworms was initially null (i.e. for the first maize crop), positive (i.e. for tomato planting) and finally negative (i.e. for the second maize planting), thereby underpinning the complexity of the interactions between the quality of organic matter in soil, earthworm activity and plant growth.

1. Introduction

In recent years, the effect of exogenous organic amendments on soil properties has received renewed attention (Birkhofer et al., 2008; Herencia et al., 2008). Although the utilization of mineral fertilizers could be viewed as the best solution in terms of plant productivity, this approach is often inefficient in the long-term in tropical ecosystems due to the limited ability of low-activity clay soils to retain nutrients (Lal, 2006). Intensive use of agrochemicals in agricultural systems is also known to have irreversible effects on soil and water resources, such as a reduction of soil organic matter (SOM) stocks (Kimetu et al., 2008) and pollution of surface and ground water resources (Townsend et al., 2008). In this context, restoring and maintaining SOM contents are thus essential for the long-term chemical quality of the soil and crop productivity in the tropics. Numerous studies have shown the beneficial effects of OM amendments, such as crop residues and compost, on soil fertility, crop yield and ecosystem services (i.e. Herencia et al., 2008; Gomerio et al., 2008). Decomposing organic amendments slowly release nutrients which may be taken up by plants (Lal, 2006; McLauchlan, 2006) and thus result in improved agroecosystem productivity. The utilization of exogenous OM improves ecological functions such as the water and nutrient storage capacity, resistance to compaction and erosion, infiltration and aeration, and resistance to infection of roots by soil borne pathogens (Whalen et al., 2003). OM amendments are also favorable for the development of soil macrofauna which play a key role in improving soil quality and providing ecosystem services (Birkhofer et al., 2008).

Among soil organisms favored by organic fertilization, earthworms have been identified as a key functional group and are considered as soil engineers due to their influence on soil biological, physical and chemical properties (Jouquet et al., 2006). They greatly affect soil structure, microbial activity and diversity, and soil OM dynamics in temperate (Jongmans et al., 2001; Pulleman et al., 2005) and tropical ecosystems (Jouquet et al., 2007; Bottinelli et al., 2010; Bernard et al., 2011). Earthworm activity is also an important

* Corresponding author.
E-mail address: pascal.jouquet@ird.fr (P. Jouquet).

0304-4238/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.scienta.2013.05.042

factor controlling vegetation dynamics and diversity and several studies have reported their positive influence on plant growth (Laossi et al., 2010).

Earthworm activity is also used for the management of organic waste and the production of high-quality compost, known as 'vermicompost' (Edwards et al., 2004). This substrate has been shown to improve the germination, growth, and yield of plants, due to faster release of nutrients than traditional composts, and the production of plant growth hormones (Arancon et al., 2008). Vermicompost has been extensively studied as a plant growth media and soil amendment (Edwards and Arancon, 2004; Tejada et al., 2009) but its utilization in interaction with endogeic earthworms has only been addressed in a few studies (Jouquet et al., 2010; Ngo et al., 2012). Furthermore, few studies have been made on vermicompost produced from buffalo manure, which is the main source of OM for many farmers in Asia, especially in Northern Vietnam.

The aim of this study was to investigate the impact of compost and vermicompost produced from buffalo manure on plant growth in the presence or absence of earthworms. We used a common agricultural soil from the red river delta in Northern Vietnam and an endogeic earthworm species *Metaphire posthuma* found in the same area. A one-year experiment was carried out in a greenhouse where a maize–tomato–maize cycle was planted in containers with and without earthworms. Our hypotheses were that (i) vermicompost amendments lead to increased plant growth compared to the application of compost and chemical fertilization and that this effect is constant over time (Edwards et al., 2004), (ii) earthworm development is higher with compost than vermicompost, due to the chemical stabilization of vermicompost (Lazcano et al., 2008), and (iii) earthworm activity will improve plant growth and yield (Laossi et al., 2010).

2. Materials and methods

2.1. Soil properties and organic amendments

The soil was sampled in the 0–10 cm layer of a fallow in the red river delta (Dong Ngac commune, Ha Noi, Vietnam) where *M. posthuma* is naturally observed. The soil was air-dried and sieved at 2 mm to discard stones and litter residues. It is described as Eutric Fluvial (FAO, 1988) with low OM content and low nutrient content and is mainly sandy loam (61.0% sand, 28.7% silt and 10.3% clay). Compost and vermicompost were produced in a farm in Dong Cao Village from domestic buffalo manure after three months of maturation in two different and separated units, as reported by Jouquet et al. (2010). They were air-dried for one week and sieved at 1 cm. The earthworm species used to produce the vermicompost was *Eisenia andrei*. Chemical properties of the soil and organic amendments are given in Table 1.

Table 1
Chemical properties of the soil (soil T_0), compost and vermicompost substrates (average values from the three applications): pH, C and N content (%), total P and K (%), NH_4^+ and NO_3^- (mg kg^{-1}), CEC (cmol(+) kg^{-1}). Standard errors are in parentheses, $n = 3$.

Chemical properties	Treatments		
	Soil T_0	Compost	Vermicompost
pH	7.99 (0.01)	8.5 (0.3)	7.5 (0.2)
C	0.97 (0.05)	18.23 (0.20)	16.88 (0.7)
N	0.09 (0.01)	1.37 (0.13)	1.62 (0.17)
P	0.18 (0.01)	1.40 (0.30)	1.42 (0.40)
K	1.13 (0.04)	1.05 (0.09)	1.24 (0.08)
NH_4^+	0.51 (0.04)	15.69 (3.98)	10.31 (2.14)
NO_3^-	0.84 (0.12)	6.93 (1.28)	10.32 (1.71)
CEC	5.17 (0.11)	29.16 (2.55)	38.65 (8.02)

2.2. Greenhouse experiment

The experiment was carried out for one year in a greenhouse at the Soil and Fertilizer Research Institute (SFRI), in Hanoi, Vietnam. The air humidity was always high, between 75 and 100% and the average daily temperature varied from 15 to 25 °C throughout the year. The experiment was set up in 10 L baked clay pots with holes in the bottom for drainage. A 5 cm layer of white sand and stones was placed in the bottom of the pots followed by 5 kg of soil mixed thoroughly with compost, vermicompost or the same amount of nutrients as in the compost and vermicompost but in their chemical forms. These amendments were repeated three times during the experiment after each vegetative period. The amount of compost and vermicompost was calculated to be equivalent to applying 20 t ha^{-1} of organic substrate (90.5 g pot^{-1}), as recommended by the Soils and Fertilizers Research Institute (SFRI). Mineral fertilizers were urea (CH_4N_2O, %N = 46.3%), potash (K_2O, %K = 60%) and phosphate (P_2O_5, %P = 16%). Before each experiment, the amount of N, P and K in the compost and vermicompost was analyzed and the same amount of mineral nutrients was applied to the control soil. When differences occurred between compost and vermicompost, additional nutrients were also applied to these organic substrates. This protocol allowed us to compare the influence of substrates which had exactly the same nutrient content. We then planted common agricultural crops: maize (June–September 2008, variety LNS 222), tomato (November 2008 to April 2009, variety HT14), and maize (June–September 2009, variety LNS 222). For the three dates, only one plant was grown per pot. Pots were watered once or twice a week, depending on the season, and the same quantity of water was applied for all the treatments.

The influence of earthworms on plant growth and soil properties was investigated by adding two adults of the endogeic species *M. posthuma* per pot (0.61 g ind^{-1} in average) before each cultivation (before the two maize and tomato plantings). This species was found in the garden of the SFRI institute. *M. posthuma* is a medium size endogeic geophagous earthworm (~12 cm in length, and 5 mm diameter on average at the adult stage) which produces approximately 5–10-fold its own weight in casts per day (Bottinelli et al., 2010; Jouquet et al., 2011, 2012). Its casts range from 1 to 3 mm and are mainly found belowground. Earthworm survival and development were assessed by measuring earthworm abundance after each crop harvest. Earthworm activity was also assessed at the end of the one-year experiment by measuring the dry weight of earthworm casts (40 °C during 48 h). Earthworm casts were easily distinguished from the bulk soil by their rounded shape and size (Bottinelli et al., 2010; Jouquet et al., 2011). They were carefully collected with a spatula in three soil clods (~125 cm^3) per plot.

2.3. Plant development

Leaf chlorophyll content was measured with a SPAD-502 Chlorophyll meter (Minolta Osaka Co., Ltd., Japan, 1989) from four fully expanded leaves at the top of the plants, as described by Dwyer et al. (1994). The chlorophyll measurement is based on the difference in light attenuation at 650 and 940 nm. The chlorophyll meter provides a SPAD value with a higher number corresponding to greener leaves, and thus a higher plant N status and chlorophyll content (Pedro et al., 2012). It reaches its maximum during flowering (Karele, 2002). Measurements were made after 35 days for maize when plants had 10 leaves, which correspond to the transition from vegetative growth to floral differentiation, and 28 days for tomato plants, which corresponds to the first flowering stage.

Above-ground plant biomass was harvested at the end of each cultivation cycle and weighed after incubation at 50 °C for 10 days. The yield of maize was estimated as the total dry weight of grains