Scientia Horticulturae 175 (2014) 269–277

Contents lists available at ScienceDirect

Scientia Horticulturae

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

Short-term compost application increases rhizosphere soil carbon mineralization and stimulates root growth in long-term continuously cropped cucumber

Xueyan Zhang[a,1], Yune Cao[a,1], Yongqiang Tian[b], Jianshe Li[a,*]

[a] College of Agriculture, Ningxia University, 489 Helanshan Xilu, Yinchuan 750021, China
[b] Beijing Key Laboratory of Growth and Developmental Regulation for Protected Vegetable Crops, Department of Vegetable Science, China Agricultural University, 2 Yuanmingyuan Xilu, Beijing 100193, China

ARTICLE INFO

Article history:
Received 9 January 2014
Received in revised form 4 June 2014
Accepted 20 June 2014
Available online 11 July 2014

Keywords:
Continuously cropped cucumber
Compost
Rhizosphere soil
Carbon mineralization
Plant growth

ABSTRACT

Continuous cropping, a common agricultural practice in the world, often results in soil degradation and eventually lead to crop yield decline over time. Composts application has several advantages such as improving soil quality and increasing crop yields. However, little information is available regarding the effect of compost application on crop growth in continuous cropping systems. In this study, we investigated three long-term (>15 years) continuously cropped cucumber soils to examine the effect of compost application on carbon mineralization of rhizosphere soils and plant growth. All three soils were treated with/without compost, *Bacillus subtilis* and their combination. In general, the amounts of cumulative carbon mineralization in soils treated with compost were larger than those in untreated soils. The initial carbon mineralization rate, m_0, was significant higher in soils treated with compost than in untreated soils. Soil microbial biomass carbon (MBC) and root growth was significantly ($P < 0.05$) increased by the compost addition, but was not statistically ($P > 0.05$) affected by the bacterial inoculation in all soils. In compost-treated soils, there was a higher faction of thin roots (<0.5 mm diameter) and a smaller fraction of thicker roots (>0.5 mm diameter) compared with untreated soils. Cucumber fruit yield was significantly positively correlated with the CCM and MBC values. Our results suggested that short-term compost application increases rhizosphere soil carbon mineralization and stimulates root growth in long-term continuously cropped cucumber.

1. Introduction

In conventional agriculture, there is a trend word-wide to grow crops in monoculture, i.e. continuous cropping system. This trend was driven by several factors, such as mechanization, economic market trends, government policies and chemical inputs (Bennett et al., 2012). However, continuous cropping generally can result in soil degradation, such as soil hardening, acidification, nutrient enrichment and unbalance, and eventually lead to crop yield decline (Yao et al., 2006; Tian et al., 2009; Guo et al., 2010). Several previous studies have indicated that yield decline in monoculture is related to the change of soil microbial ecology, such as deleterious microorganisms (Bennett et al., 2012), microbial imbalance (Tian et al., 2009, 2011b, 2013) and nutrient unbalance mediated by microorganisms (Tian et al., 2010, 2011a).

Soil microbial communities, widely recognized as integrative components of soil quality, play important roles in many biogeochemical and ecological processes (Huang et al., 2005). For instance, empirical studies have demonstrated that soil microbial communities influence soil nutrient cycling (Leininger et al., 2006; Petersen et al., 2012), energy flow and organic matter turnover (Zhang et al., 2010; Pratscher et al., 2011; Petersen et al., 2012). In addition, it has been well demonstrated that soil microorganisms are important player in plant–soil systems because of their strong influence on plant growth (Buée et al., 2009; Bennett et al., 2012). For example, soil microorganisms can beneficially promote plant growth (Belimov et al., 2009) or detrimentally cause plant disease (Barrett et al., 2009).

Among microbe-mediated ecologic processes, carbon (C) cycling is of great importance in agricultural systems partly because the C mineralization provides most of the inorganic nutrients necessary for plant growth (Schmidt et al., 2011). Moreover, there

* Corresponding author. Tel.: +86 951 2061619.
E-mail addresses: jslinxcn@163.com, 553268311@qq.com (J. Li).
[1] These authors contributed equally to this work.

http://dx.doi.org/10.1016/j.scienta.2014.06.025

are close links between the C cycle and other elemental cycles (Manzoni and Proporato, 2009). Soil microorganisms influence soil C cycling not only through the decomposition of soil organic matter (SOM) but also via the production of microbial biomass C, which is the important component of SOM (Manzoni and Proporato, 2009; Schmidt et al., 2011). In general, SOM turnover is determined by the balance between organic matter input and carbon dioxides output (Bertrand et al., 2007). As a result, agricultural practices can influence soil C cycling through affecting microbial activity and community structure. For example, microbial activity and community structure shifts following plant residue inputs can have strong effects on soil C mineralization (Tian et al., 2011a, 2013).

Since the important roles played by soil microorganisms in plant–soil system, many studies have been conducted by scientists to seek the useful and efficient soil amendment methods which can enhance crop growth in continuous cropping (Yao et al., 2006; Tian et al., 2009; Bennett et al., 2012), based on exploring the potential relationship between soil microorganisms and plant growth (Bennett et al., 2012). Among soil amendment methods, composts application has several advantages: improving soil physical and chemical properties (Mylavarapu and Zinati, 2009), enhancing soil water balance (Movahedi Naeini and Cook, 2000), and increasing nutrient availability to crops (Zinati et al., 2004) and crop yields (Mylavarapu and Zinati, 2009). Evidence from previous studies indicates that the advantages of compost application are related to the changes of soil microbial properties and the improvement of soil microbial environment of crops in particular (Abbasi et al., 2002).

In plant–soil system, growing root-induced changes in soils generally provide additional niches for rhizosphere microorganisms. To the best of our knowledge, however, less study has been conducted to investigate the effects of soil amendment treatments on microbial properties in rhizosphere soils of continuously cropped plants, especially in long-term continuously cropping systems.

Cucumber is one of the most economically significant vegetable crops in the world. In China, continuous cropping is a common practice in tomato production, especially in protected vegetable production systems. In this study, we studied the effects of short-term compost application on carbon mineralization in rhizosphere soils, root development and biomass accumulation of long-term (>15 years) continuously cropped cucumber. The objectives of this study were to (1) examine the effects of compost application on carbon mineralization mediated by microorganism, microbial populations and biomass in rhizosphere soils and root growth of long-term continuously cropped cucumber grown in alkaline, neutral and acid soils, and (2) to test whether the plant growth of long-term continuously cropped cucumber can be enhanced by short-term compost application.

2. Materials and methods

2.1. Site description and experiment design

The study was conducted in three long-term (15, 18 and 20 years) continuously cropped cucumber farming sites in north China in January 2012. These farming sites were selected to cover acid (pH 6.28), neutral (pH 7.09) and alkaline (pH 7.51) soils. The selected characteristics of the soils are listed in Table 1. The experiment was conducted from late January 2012 to early February 2013 with four treatments using a randomized block design. The treatments include (i) the untreated soil (Control), (ii) soil amended with 6% straw compost (C), (iii) soil amended with 10^9 spores of *Bacillus subtilis* l^{-1} soil (I), and (iv) soil amended with 6% straw compost supplemented with 10^9 spores of *Bacillus subtilis* l^{-1} soil (CI). Each treatment was conducted with four replicates.

Table 1
The selected characteristics of long-term continuously cropped cucumber soils used in this study. The same letter in the same column denotes no significant difference (P = 0.05) by Tukey's multiple range test. Values are means ± SD (n = 3).

Soil codes	Land use history	Organic matter (g kg^{-1})	Total N (g kg^{-1})	NH_4^+-N (mg kg^{-1})	NO_3^--N (mg kg^{-1})	Inorganic-N (mg kg^{-1})	Olsen-P (mg kg^{-1})	NH_4OAc-K (mg kg^{-1})	pH	EC (mS cm^{-1})
Acid soil	Cucumber, 18 years	20.8 ± 0.9	1.27 ± 0.11	12.8 ± 2.4	241 ± 13	254 ± 17	341 ± 32	293 ± 22	6.28 ± 0.11	1.75 ± 0.12
Neutral soil	Cucumber, 20 years	25.6 ± 1.3	1.57 ± 0.12	6.63 ± 0.23	50.8 ± 5.6	57.4 ± 4.5	144 ± 12	599 ± 56	7.09 ± 0.04	0.50 ± 0.05
Alkaline soil	Cucumber, 15 years	11.8 ± 0.8	0.76 ± 0.08	10.4 ± 1.5	143 ± 11	153 ± 21	131 ± 8	239 ± 18	7.51 ± 0.08	0.76 ± 0.11

Soil codes	**Ca (g kg^{-1})**	**Mg (g kg^{-1})**	**S (g kg^{-1})**	**B (mg kg^{-1})**	**Cu (mg kg^{-1})**	**Fe (mg kg^{-1})**	**Mn (mg kg^{-1})**	**Zn (mg kg^{-1})**	**Mo (mg kg^{-1})**
Acid soil	0.64 ± 0.08	0.75 ± 0.05	0.14 ± 0.03	1.43 ± 0.03	5.52 ± 0.06	5413 ± 251	121 ± 13	0.72 ± 0.08	24.3 ± 2.8
Neutral soil	0.74 ± 0.11	0.63 ± 0.10	0.13 ± 0.04	1.52 ± 0.07	6.75 ± 0.13	4423 ± 143	90.5 ± 12.6	0.63 ± 0.21	27.8 ± 5.6
Alkaline soil	0.87 ± 0.05	0.75 ± 0.07	0.12 ± 0.04	1.33 ± 0.12	7.88 ± 0.16	4643 ± 324	98.2 ± 8.4	0.74 ± 0.18	24.6 ± 4.6