Journal of Integrative Agriculture 2017, 16(8): 1819–1831

Available online at www.sciencedirect.com

ScienceDirect

RESEARCH ARTICLE

Impacts of chemical fertilizer reduction and organic amendments supplementation on soil nutrient, enzyme activity and heavy metal content

NING Chuan-chuan, GAO Peng-dong, WANG Bing-qing, LIN Wei-peng, JIANG Ni-hao, CAI Kun-zheng

Key Laboratory of Tropical Agro-environment, Ministry of Agriculture/South China Agricultural University, Guangzhou 510642, P.R.China

Abstract

Excessive use of agro-chemicals (such as mineral fertilizers) poses potential risks to soil quality. Application of organic amendments and reduction of inorganic fertilizer are economically feasible and environmentally sound approaches to develop sustainable agriculture. This study investigated and evaluated the effects of mineral fertilizer reduction and partial substitution of organic amendment on soil fertility and heavy metal content in a 10-season continually planted vegetable field during 2009–2012. The experiment included four treatments: 100% chemical fertilizer (CF100), 80% chemical fertilizer (CF80), 60% chemical fertilizer and 20% organic fertilizer (CF60+OM20), and 40% chemical fertilizer and 40% organic fertilizer (CF40+OM40). Soil nutrients, enzyme activity and heavy metal content were determined. The results showed that single chemical fertilizer reduction (CF80) had no significant effect on soil organic matter content, soil catalase activity and soil heavy metal content, but slightly reduced soil available N, P, K, and soil urease activity, and significantly reduced soil acid phosphatase activity. Compared with CF100, 40 or 60% reduction of chemical fertilizer supplemented with organic fertilizer (CF60+OM20, CF40+OM40) significantly increased soil organic matter, soil catalase activity and urease activity especially in last several seasons, but reduced soil available P, K, and soil acid phosphatase activity. In addition, continuous application of organic fertilizer resulted in higher accumulation of Zn, Cd, and Cr in soil in the late stage of experiment, which may induce adverse effects on soil health and food safety.

Keywords: chemical fertilizer, organic amendments, soil fertility, vegetable, soil health, heavy metal

1. Introduction

Chemical fertilizer plays an important role in increasing soil fertility and crop productivity (Hera 1996). However, long-term excessive use of chemical fertilizers has contributed to reduce soil organic matter (SOM) content, with a consequent decline in the agricultural soil quality, and even an increase in soil acidification and environment pollution (Roelcke *et al.* 2004; Dinesh *et al.* 2010; Guo *et al.* 2010), which has become a major concern (Chaudhry *et al.* 2009).

At present, there is an increasing requirement for agricultural production not only to meet high standards of quality but also to be produced by environmentally sound practices. Previous studies have indicated that application of organic fertilizer fulfills the requirements of sustainable

Received 9 March, 2016 Accepted 29 August, 2016
Correspondence CAI Kun-zheng, E-mail: kzcai@scau.edu.cn

doi: 10.1016/S2095-3119(16)61476-4

agriculture, and organic fertilizer has apparent advantages over chemical fertilizer in many aspects. For example, organic fertilizer has higher organic matter content and richer nutrient elements; it can enhance soil physical properties mainly by improving aggregate stability and decreasing soil bulk density; it can also improve soil biological and biochemical properties and optimize soil microbial community structure (Zhang *et al.* 2009b; Diacono and Montemurro 2010). However, exclusive use of organic fertilizer may not meet the nutrient requirement for crops as it releases nutrients slowly, and only a fraction of the N and other nutrients become available for plants in the first year after application (Hartl *et al.* 2003).

Taking into account the advantages and disadvantages of organic and inorganic fertilizer, combined application of organic amendments and mineral fertilizers has become an effective approach of nutrient management. Numerous studies have shown that balanced application of inorganic and organic amendments can increase SOM and maintain soil productivity (Arancon *et al.* 2004; Blair *et al.* 2006; Gong *et al.* 2009). A short-term field experiment by Lazcano *et al.* (2013) showed that partial replacement of inorganic fertilizer by vermicompost or manure had a significant positive impact on soil microbial activity, and maintained nutrient supply and crop yield at similar levels with inorganic fertilizer. Herencia *et al.* (2007) found that use of straw compost could reserve soil nutrient stability and maintain competitive yield. Through a 15-year field experiment, Zhang *et al.* (2009a) also showed that a suitable combined application of chemical fertilizer and straw or cow manure could increase crop yield, as well as maintain soil fertility and soil buffering capacity. Furthermore, incorporation of organic fertilizer can improve chemical fertilizer utilization efficiency. For example, incorporating straw compost can reduce adsorption of phosphate through humus wrap Fe, Al, and Ca oxides, which greatly improves the effectiveness of inorganic phosphate (Lee *et al.* 2004).

Conversely, organic fertilizer can also be a source of environmental pollution and has a risk for human health, due to the presence of heavy metals, residual additives, and even microbial pathogens, particularly when they are improperly used (Hao and Chang 2003; Kumpiene *et al.* 2008). Several studies have reported that the concentration of heavy metals in organic fertilizers is generally higher than the normal concentration in soil; thus, heavy metal accumulation in soil may exist when organic fertilizer is repeatedly applied (Zhao *et al.* 2006; Kumpiene *et al.* 2008). More specifically, excess organic fertilizer may lead to soil salinization (Hao and Chang 2003) and increase the risk of heavy metal accumulation by crops. In addition, organic fertilizers may also produce more greenhouse gases (e.g., CO_2, CH_4) when applied into soil, accelerating greenhouse effects (Iqbal *et al.* 2009).

Many effects, such as nutrient release, carbon sequestration, and possible build-up of toxic elements in the soil, evolve slowly and thus need long-term investigation (Diacono and Montemurro 2010). A number of studies have shown that long-term effects of organic fertilizer are usually more evident than its short-term effects (Udom *et al.* 2004; Herencia *et al.* 2008; Liu *et al.* 2013). However, responses of soil biological and biochemical properties to changes of soil environment and fertilizer management are sensitive and rapid enough (Gil-Sotres *et al.* 2005). For example, short-term increases in microbial biomass have been reported previously and attributed to the supply of organic C substrates (Arancon *et al.* 2006; Dinesh *et al.* 2010). Whether it is feasible or not, sustainable application of organic fertilizer in agriculture depends on the characteristics of organic fertilizer (nutrient and toxic element contents, availability, transportation costs, and environmental regulations), as well as application rates and amount, which is well reviewed in detail by Westerman and Bicudo (2005).

In the present study, field trials of inorganic fertilizer reduction and incorporation of partial organic fertilizer were conducted in continuous 10-season vegetable cultivation to investigate the effects of mineral fertilizer reduction and supplementation with organic amendments on soil fertility and microbial activity, and assess the risk of heavy metals in soil under different fertilization regimes.

2. Materials and methods

2.1. Study site

The site of field trial was an intensive vegetable farm located in Yisha Village (22°44´40´´N, 113°29´51´´E), Nansha District, Guangzhou, Guangdong Province, China. This area has a subtropical monsoon climate, and the annual average temperature and rainfall are 21.9°C and 1 647.5 mm, respectively. The rainfall and average temperature per month during experimental years are shown in Fig. 1. The basic physical and chemical properties of the soil are shown in Table 1.

2.2. Experimental fertilizers

Chemical fertilizer in this experiment was a kind of chemical compound fertilizer (N:P:K, 15%:15%:15%; YARA International Company, Norway). Organic fertilizer was produced by Guangzhou Liangtian Fertilizer Company, its main raw material was pigeon droppings. Its basic physical and chemical properties are shown in Table 1.