Applied Soil Ecology 120 (2017) 229–238

Contents lists available at ScienceDirect

Applied Soil Ecology

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

Influence of a six-year organic and inorganic fertilization on the diversity of the soil culturable microrgansims in the Indian mid-Himalayas

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ARTICLE INFO

Keywords:
Poultry manure
Soil cracking
Soil culturable microbial diversity index
Soil temperature moderation
Vermicompost

ABSTRACT

Industrial agriculture inputs can diminish soil microbial biodiversity. The use of organic soil amendments may foster beneficial microorganisms. Organic production systems have increased in recent years, but we know little about the effect of these production practices on soil culturable microbial diversity compared to inorganic fertilization. Therefore, the objective of our research was to evaluate the effect of two levels (high and low) of three organic amendments (poultry manure, vermicompost and cattle manure) versus inorganic fertilization (IF) on soil culturable microorganism diversity and selected soil properties after six years under a gardenpea (*Pisum sativum* var. *hortense* L.)-french bean (*Phaseolus vulgaris* L.) system in a sub-temperate soil of the mid-Himalayas. There was at least 31% greater population of beneficial microorganisms with application of high level (6 Mg ha^{-1}) of poultry manure (PM_6) than IF in the surface soil layer (0–15 cm depth). The highest soil culturable microbial diversity index was recorded with PM_6 (0.562). Application of high level (6 Mg ha^{-1}) of vermicompost (VC_6) yielded the highest *Trichoderma* species count, and PM_6 plots had similar values to VC_6. The morning and afternoon surface soil temperature moderation during the coldest and hottest weeks with PM_6 amendment was 0.50 and 1.73 °C higher over IF, respectively. The soil cracking surface area under PM_6 was 112% less than IF (0.311 m^2 m^{-2} area). Application of PM_6 provided 38 and 29% higher gardenpea and french bean pod yields than IF, respectively. The soil organic carbon under PM_6 in the surface layer was about 9% greater than IF. Soil organic carbon markedly influenced soil culturable microbial diversity, moderation of soil temperature and other soil properties. Thus, application at 6 Mg ha^{-1} poultry manure for each crop is recommended over inorganic fertilizer for higher soil culturable microbial diversity under gardenpea-french bean system in this region and similar agro-ecologies.

1. Introduction

It is well known that inorganic fertilizers and pesticides degrade the environment and soil biodiversity. Food and environmental safety are often-cited reasons for popularity of organically produced foods (Bulluck et al., 2002). Hence, demand for organically produced food has increased manifold. The world organic market size reached $80 billion US dolar in 2014 from $15.2 billion US dolar in 1999 (Willer and Lernoud, 2016). Indian organic farming industry is estimated at $78 million US dolar and is almost entirely export oriented (Willer and Lernoud, 2015). A premium for organic production of 10–100% in India (Chadha and Choudhary, 2007; Mahanta et al., 2015) and 12–60% in different countries of world (Bulluck et al., 2002; Lohr, 1998) is often obtained.

Most of the arable lands in the Indian Himalayas have not yet been exposed to inorganic fertilizer and pesticide application. Hence, these

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http://dx.doi.org/10.1016/j.apsoil.2017.08.012
Received 25 April 2016; Received in revised form 6 June 2017; Accepted 22 August 2017
Available online 06 September 2017
0929-1393/

lands are organic by default (Saha et al., 2007). The livestock population per household in this region is higher than India's average (Mahanta et al., 2013). These livestock and poultry are the main sources of biological wastes. The biological wastes will contribute substantial amounts of greenhouse gases. Hence, utilization of these wastes as organic manures is a better option. The biological wastes produced in this region are sufficient to fulfill the manure requirement of the organic growers. Since the organic food markets are also expanding rapidly in many countries, including India, it makes the Himalayan farmers to emerge as major suppliers of organic products with high price premiums. In addition, the use of organic soil amendments can foster beneficial microorganisms and improve soil properties. Furthermore, the amounts of soil nitrogen in plots under inorganic fertilizer have been negatively correlated with soil microbial population (Bulluck et al., 2002).

In this study, three different organic amendments, i.e. cattle manure (CM), vermicompost (VC) and poultry manure (PM), were compared with inorganic fertilizers (IF) in a vegetable production system. Out of these three manures, CM is mostly used for vegetable cultivation. However, VC and PM are less frequently used, but slowly gaining importance in the sub-temperate Himalayas. Recently, the Himalayan states of India are providing subsidy for vermicomposting to popularize its use in organic farming (Anonymous, 2014; Venkatachalam et al., 2012). Despite an increase in organic production systems in recent years, little is known about the soil culturable microbial communities and their diversity in organic fields compared to inorganic fertilizer. Information on the impacts of organic production practices on crop productivity and soil properties are limited. Inadequate studies have been conducted to assess the impacts of soil amendments on soil organic matter (SOM), culturable soil microorganism population and crop yield in actual organic and conventional production systems in the field (Bulluck et al., 2002).

Soil organic matter has a definite effect on strength and structural characteristics of soils and it can determine how soils respond to different management practices (Bhattacharyya et al., 2012a, 2012b). Certain soil physical factions (like soil cracking, soil temperature and bulk density) and SOM can influence the population of culturable microorganisms in soils. The development of new methodologies, such as the estimation of the culturable soil microbial diversity index may give us better insight into many of the soil biological processes (Murphy, 2014). Due to the complexity of soil function and origin of microbes, different microbes and their groups may respond to different sources and levels of nutrients. Hence, a single numerical value, i.e. soil culturable microbial diversity index, is thought to be useful to condense all the information. Many studies have assessed the impact of organic amendments on soil culturable microbial count and biomass (Prakash et al., 2007; Saha et al., 2008). However, few studies have observed the impact on functional groups or classes of soil culturable micro-organisms and their diversity index in the Himalayas.

With the increasing organic vegetable production in the Indian mid-Himalayas, it is pertinent to think about if the organic amendments (CM, VC and PM) versus IF will affect the soil culturable microbial diversity index and other soil properties. Gardenpea and french bean are two important leguminous vegetables cultivated in the mid-Himalayas (Mahanta et al., 2013). Hence, it was hypothesized that different organic soil amendments would provide higher soil culturable microbial diversity index and better soil properties than inorganic fertilizers under a gardenpea-french bean system. To address that hypothesis, the objective was to determine the effects of organic amendments and inorganic fertilizers on soil culturable microbial population count, diversity index and selected soil properties under a gardenpea-french bean system in the sub-temperate mid-Himalayas.

2. Material and methods

2.1. Site

The field experiment was conducted during 2002 to 2008 at the research farm of ICAR-*Vivekananda Parvatiya Krishi Anusandhan Sansthan*, Almora. The farm is at Hawalbagh (29°36′N and 79°40′E and 1250 m above mean sea level) in the Indian Himalayan region in Uttarakhand state, India. The soil was a silty clay loam (Typic Haplaquept) with the following characteristics in 0–15 cm soil depth: pH 6.1 (1:2.5 soil:water suspension), soil organic C 11.3 g kg^{-1}, available N 179.9 mg kg^{-1}, 0.5 M $NaHCO_3$ extractable P 6.79 mg kg^{-1} and 1.0 N NH_4OAc exchangeable K 80.4 mg kg^{-1} soil.

2.2. Experimental details

The experiment was conducted for six years with two leguminous vegetable crops- gardenpea and french bean. A factorial randomized complete block design (RCBD) with three replications and eight nutrient management practices was used. Two levels (low and high) of three organic amendments (poultry manure (PM), vermicompost (VC) and cattle manure (CM)) were evaluated with two additional treatments- inorganic fertilizer (IF – recommended NPK) and absolute control (Con) in a fixed plot. The low levels for PM, VC and CM were 3 Mg ha^{-1} (PM_3), 3 Mg ha^{-1} (VC_3) and 5 Mg ha^{-1} (CM_5) and high levels were 6 Mg ha^{-1} (PM_6), 6 Mg ha^{-1} (VC_6) and 10 Mg ha^{-1} (CM_{10}), respectively. The high levels of organic amendments were commonly used in this region. The low levels were included in the test as a consideration of the resource available to poor marginal farmers. The low and high levels of CM were relatively higher than other organic amendments (PM and VC) because of the lower nutrient status present in CM (Table 1). All organic amendments were added on a dry-weight basis. The recommended inorganic fertilizers rates for gardenpea and french bean under IF treatment were 20-26.2-33.3 and 50-30.6-41.7 kg ha^{-1} N-P-K, respectively, and were applied during sowing. The sources for N, P and K were urea, single superphosphate and muriate of potash, respectively.

Gardenpea was sown (80 kg seeds ha^{-1}) in the last week of October each year. The seeds were manually sown in row interval of 30 cm apart at about 5 cm depth. Pods were harvested manually. The last picking of pods was completed in the last week of April or first week of May in different years. After gardenpea harvest, french bean was sown in the fourth week of May. French bean was sown by hand (75 kg seeds ha^{-1}) in row spacing of 40 cm apart to a depth of about 5 cm. French bean pods were harvested by picking and last picking was completed in the fourth week of August. Both crops were cultivated under irrigated conditions and hand weeding was also done for both crops for weed control. Maize-wheat system was cultivated in the land before the experiment on gardenpea-french bean system was conducted.

2.3. Organic amendment preparation from biological waste

Poultry manure (PM) was collected from a nearby poultry farmhouse. The basic materials used for preparation of PM are poultry excreta, the spilled poultry feed and material used as bedding in poultry operations. Vermicompost (VC) and cattle manure (CM) were produced at the experimental farm. The details of the CM and vermicompost preparation are given by Mahanta et al. (2015) and Saha et al. (2008). All manures were applied manually 15 days before crop sowing. Each organic amendment was analyzed before application for different properties (Table 1).

2.4. Yield and economics

Marketable green pods of gardenpea and french bean were harvested in different phases during harvesting period for pod yield