Catena 140 (2016) 1–8

Contents lists available at ScienceDirect

Catena

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

# Changes in biological and chemical properties of saline soil amended with municipal solid waste compost and chemical fertilizers in a mustard–pearl millet cropping system

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ARTICLE INFO

*Article history:*
Received 4 July 2015
Received in revised form 14 December 2015
Accepted 8 January 2016
Available online 21 January 2016

*Keywords:*
Municipal solid waste compost
Chemical fertilizers
Microbial activities
Nutrient cycling
Rice straw compost
Salinity

ABSTRACT

The restoration of microbial activities is a basic step in the reclamation of saline soil. For this reason, the ability of municipal solid waste compost (MSWC) to accelerate the microbiological and chemical properties of soil was evaluated in a field experiment. The aim of this study was to evaluate the efficiency of combined use of organic amendments viz. MSWC, gypsum enriched compost (GEC), rice straw compost (RSC) and chemical fertilizers as reclamation agents for improving biological and chemical properties of saline soil in a mustard–pearl millet cropping system. Integrated use of 25% recommended dose of fertilizer (RDF) along with organic amendments (RSC@3.5 t $ha^{-1}$ + GEC@3.5 t $ha^{-1}$ + MSWC@4 t $ha^{-1}$) resulted significantly higher amount of microbial activities, Walkley and Black Organic Carbon (WBC) as well as available $KMnO_4$-N, Olsen-P and $NH_4$ OAc-K over unfertilized control plot after mustard and pearl millet harvest. Combined use of organic amendments along with 25% RDF increased by 50 and 56% higher microbial biomass carbon (MBC) over unfertilized control plot after harvest of mustard and pearl millet respectively. Treatment receiving 100% RDF improved dehydrogenase activity (DHA), alkaline phosphatase activity (APA) and urease activity by 39, 26 and 23%, respectively over unfertilized control plot after harvest of pearl millet crop. Balanced use of organic amendments plus 25% RDF maintained 9, 42 and 16% higher amount of available $KMnO_4$-N, Olsen-P and $NH_4OAc$-K, respectively over the alone use of 100% RDF after mustard harvest. After harvest of pearl millet soil EC (1:2) was significantly lower under treatment receiving organic amendments along with 25% RDF than other treatments.



## 1. Introduction

Salt accumulation in the soil is a major contributing factor to land degradation and decreases agricultural production, particularly in arid and semiarid regions (Rengasamy, 2008). Salinity inhibits plant growth due to low osmotic potential of the soil solution, ion toxicity and ion imbalance which further reduce nutrient uptake (Marschner, 2012). Salinity also reduces microbial activity and biomass and thus organic matter turn over (Pathak and Rao, 1998). Salinity susceptible microorganisms are more vulnerable to saline ecosystem and leads to imbalances in microbial community structure due to microbial genotypes differ in tolerance to osmotic stress. Microorganisms play a pivotal role in soil nutrient cycling and plant growth. Many studies showed that salinity reduces microbial activity and microbial biomass (Batra and Manna, 1997; Pathak and Rao, 1998; Chowdhury et al., 2011; Andronov et al., 2012; Yan and Marschner, 2012). Soil microbial properties (biomass, counts and enzymes) provide an indicator of land use effects on soil quality (Singh et al., 2013). In irrigated soils, salinity varies with the quality of the irrigation water. The salt concentration in the soil solution also varies with soil water content, and increases as the water content decreases because the salt is concentrated in the remaining soil solution.

Managing municipal solid waste is a pervasive urban problem globally. While several strategies have been applied for efficient municipal solid waste management in developing countries particular to India, their performance level has not been critically investigated (Aliu et al., 2014). The primary goals of sustainable waste management are to protect human health and the environment and to conserve resources. In addition goals include prevention of the export of waste related problems into the future (Brunner, 2013) and socially well acceptable waste management practices (Wilson et al., 2007). A key precondition of affordable waste management should be costs effective.

Attention has been focused on municipal solid waste compost (MSWC), in order to reduce the volumes to be disposed in landfill and to provide a new organic amendment to compensate for costly chemical fertilizers as well as reclamation of saline soil. Moreover, the application of MSWC with chemical fertilizers was shown to increase soil microbial

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http://dx.doi.org/10.1016/j.catena.2016.01.009

properties and crop production (Soumare et al., 2003; Oue'draogo et al., 2006). The amendment of saline soil with compost enhances their subsequent mineralization with microflora with a concomitant increase in $CO_2$ release and consequently soil aeration (Muhammad et al., 2007) presumably owing to their enzymatic activities stimulus. However, few preliminary studies have to be conducted to assess the impact of MSWC application as an organic amendment and to define the best fertilizer rates. Repeated application of MSWC consistently increased SOC content and soil C:N ratio to levels greater than those of unamended soil (Crecchio et al., 2004; Walter et al., 2006). The farmyard manure which was usually used in agriculture in order to restore the SOC is becoming more and more rare and expensive. However, municipal solid waste compost presents an interesting alternative; indeed, it constitutes an important organic mass for the formation of steady humus (Tidsell and Breslin, 1995) and contributes to the improvement of the fertility of soils (He et al., 1992; Perez et al., 2007).

Recycling of agricultural wastes for crop production especially rice straw is gaining significant importance as it has limited use as an animal feed because of its high silica content. According to FAO (2013), over the past ten years, the global paddy rice output on an average was about 664.3 million tonnes (Mt). Direct incorporation of the rice straw into the soil is also limited as it may cause certain agronomic problems such as temporary immobilization of nutrients and associated crop yield reduction (Yadvinder-Singh et al., 2005). As a result, a large amount of produced straw is left unutilized, which is mostly burnt on-farm (Gadde et al., 2009), although burning of the straw *in situ* is the most discouraged option as it emits air pollutions (Gadde et al., 2009), and causes considerable loss of both organic C and nutrients, and there is environmental pollution from the emissions of toxic and greenhouse gases. Attempts were made to produce compost from rice straw and bioinoculant with *Trichoderma viride* which may serve as a supplement source of plant nutrients (Meena and Biswas, 2013). Hence, research priorities have been directed toward how to recycle the huge amount of agricultural as well as municipal solid waste, the best and environmentally convenient way is composting.

The aim of this study was to investigate the changes in soil biological and chemical properties amended with MSWC and chemical fertilizers in saline soil under mustard–pearl millet cropping system.

## 2. Methods and materials

### 2.1. Compost preparation

Municipal solid waste compost was collected from Municipal Corporation of Delhi, New Delhi, India. Rice straw and gypsum were used to prepare rice straw compost (Rice straw alone + *T. viride*) and gypsum enriched compost (Rice straw + Gypsum @ 25 kg per 100 kg rice straw + *T. Viride*). For composting chopped rice straw (5–6 cm size), soaked in water for 24 h, was mixed thoroughly on a polythene sheet with required quantities of gypsum as per the above composition of compost. A uniform dose of urea solution @ 0.25 kg N per 100 kg of rice straw (air dry weight basis, 30 ± 1 °C) was added to reduce the C:N ratio, while fresh cow dung @ 10 kg per 100 kg of rice straw was made into slurry and added to compost mass as natural inoculant. A uniform dose of *T. Viride* @ 50 g fresh mycelia per 100 kg of rice straw was added to compost mass in order to hasten the composting rate. Whole of the composting mass was mixed thoroughly and put in the cemented pits of 100 L capacity each. Manual turning was performed after 30, 60 and 90 days of composting to provide adequate aeration. Moisture was maintained to 60% of water holding capacity throughout the composting period (120 days).

### 2.2. Chemical characterization of compost

At maturity (after 120 days), representative sample was drawn from each pit in triplicate. Compost samples first air-dried (30 ± 1 °C) and then oven-dried (65 ± 1 °C) for 24 h, crushed to pass through a 2-mm sieve, thoroughly mixed and were used for the analysis of total carbon (C), nitrogen (N), phosphorus (P) and potassium (K). Total C, P and K was determined as per the standard procedure (Jackson, 1973). Total N was determined by Bremner and Mulvaney (1982). Micronutrient cations (Fe, Mn, Cu and Zn) and heavy metals (Ni, Pb and Cd) were determined by an atomic absorption spectrophotometer (Ayten, 2004). The cation exchange capacity (CEC) was determined as per the procedure of Jackson (1973).

### 2.3. Experimental site and soil

The present field experiment on mustard–pearl millet cropping system was carried out during 2012–2013 at the research farm Nain, Panipat of ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal, India. The soil of the experimental site is sandy loam and the climate is semi-arid subtropical with hot summers (May–June) and cold winters (December–January). Initial soil samples were collected at surface soil (0–15 cm depth) from the experimental site. Some of the physicochemical and biological properties of the experimental soil are given in Table 1.

### 2.4. Experimental design and treatments details

Performances of MSWC, GEC *vis-à-vis* RSC and mineral fertilizers were evaluated in mustard and pearl millet crop for improving nutrient supplying capacity and reducing soil salinity. Following nine treatments were used for conducting the present field experiment. $T_1$: Control; $T_2$: Recommended dose of NPK fertilizers (100% RDF); $T_3$: Rice straw compost @ 14 t $ha^{-1}$; $T_4$: Gypsum enriched compost @ 14 t $ha^{-1}$; $T_5$: Municipal solid waste compost @ 16 t $ha^{-1}$; $T_6$: 50% RDF + Rice straw compost @ 7 t $ha^{-1}$; $T_7$: 50% RDF + Gypsum enriched compost @ 7 t $ha^{-1}$; $T_8$: 50% RDF + Municipal solid waste compost @ 8 t $ha^{-1}$; $T_9$: 25% RDF + RSC @ 3.5 t $ha^{-1}$ + GEC @ 3.5 t $ha^{-1}$ + MSWC @ 4 t $ha^{-1}$. The field experiment was laid out in a randomized block design with three replications having a plot size of 5.0 m × 5.0 m. Mustard and pearl millet were grown as test crops in winter and rainy season respectively. Recommended dose of fertilizers applied to mustard and pearl millet was: 60:30:30 kg N, $P_2O_5$ and $K_2O$, respectively. Fertilizer materials used were urea, diammonium phosphate (DAP) and muriate of potash (MOP). Half quantity of N and full quantities of composts, P and K were applied as basal in both crops by broadcasting followed by mixing by disc plow. The remaining half of N was applied at 35–40 days after sowing of mustard and 20–25 days after sowing of pearl millet. Mustard (*Brassica juncea*) variety CS-52 was sown on

**Table 1**
Physicochemical and biological properties of experimental soil.

| Parameters | Values | Reference |
|---|---|---|
| Mechanical analysis | | Bouyoucos (1962) |
| Sand (%) | 56.4 | |
| Silt (%) | 25.0 | |
| Clay (%) | 18.6 | |
| Texture | Sandy loam | |
| CEC [cmol $_{(p+)}$ $kg^{-1}$ soil] | 11.68 | Jackson (1973) |
| pH | 8.4 | Jackson (1973) |
| $EC_e$ ($dSm^{-1}$) | 7.2 | Jackson (1973) |
| Available N (kg $ha^{-1}$) | 108 | Subbiah and Asija (1956) |
| Available P (0.5 *M* $NaHCO_3$, pH 8.5) (kg $ha^{-1}$) | 18.1 | Olsen et al. (1954) |
| Available K (1 *N* $NH_4OAc$) (kg $ha^{-1}$) | 203 | Hanway and Heidel (1952) |
| Organic C (g $kg^{-1}$) | 1.9 | Walkley and Black (1934) |
| Microbial biomass C (mg $kg^{-1}$) | 176.1 | Jenkinson and Powlson (1976) |
| Dehydrogenase (μg TPF $g^{-1}$ soil 24 $h^{-1}$) | 43.2 | Klein et al. (1971) |
| Alkaline phosphatase (μg PNP $g^{-1}$ $h^{-1}$) | 3.3 | Tabatabai and Bremner (1969) |
| Urease ($NH_4$ mg $kg^{-1}$ $h^{-1}$) | 64 | Tabatabai and Bremner (1969) |