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RESEARCH ARTICLE

Buried straw layer and plastic mulching increase microflora diversity in salinized soil

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Abstract

Salt stress has been increasingly constraining crop productivity in arid lands of the world. In our recent study, salt stress was alleviated and crop productivity was improved remarkably by straw layer burial plus plastic film mulching in a saline soil. However, its impact on the microflora diversity is not well documented. Field micro-plot experiments were conducted from 2010 to 2011 using four tillage methods: (i) deep tillage with plastic film mulching (CK), (ii) straw layer burial at 40 cm (S), (iii) straw layer burial plus surface soil mulching with straw material (S+S), and (iv) plastic film mulching plus buried straw layer (P+S). Culturable microbes and predominant bacterial communities were studied; based on 16S rDNA, bacterial community structure and abundance were characterized using denaturing gradient gel electrophoresis (DGGE) and polymerase chain reaction (PCR). Results showed that P+S was the most favorable for culturable bacteria, actinomyces and fungi and induced the most diverse genera of bacteria compared to other tillage methods. Soil temperature had significant positive correlations with the number of bacteria, actinomyces and fungi ($P<0.01$). However, soil water was poorly correlated with any of the microbes. Salt content had a significant negative correlation with the number of microbers, especially for bacteria and fungi ($P<0.01$). DGGE analysis showed that the P+S exhibited the highest diversity of bacteria with 20 visible bands followed by S+S, S and CK. Moreover, P+S had the highest similarity (68%) of bacterial communities with CK. The major bacterial genera in all soil samples were *Firmicutes*, *Proteobacteria* and *Actinobacteria*. Given the considerable increase in microbial growth, the combined use of straw layer burial and plastic film mulching could be a practical option for alleviating salt stress effects on soil microbial community and thereby improving crop production in arid saline soils.

Keywords: buried straw layer, plastic mulch, soil microflora changes, PCR-DGGE, microflora diversity, salinized soil

1. Introduction

Soil salinization is a worldwide land degradation problem. According to FAO (2008) survey, it is expected that over 800 million ha will be affected by salinity in the near future, making it a major constraint to food production for a steadily increasing population. Salinity occurs mainly in arid and semi-arid regions, where evapotranspiration exceeds annual precipitation and irrigation is the essential means for crop

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production. Currently, at least 20% of the world's irrigated land is salt-affected and/or irrigated with water containing elevated salt levels (Qadir *et al*. 2008). In salinized soils, physico-chemical and biological problems arising from a lack of organic matter are usually evident, e.g., reduced water and nutrient holding capacity, poor soil aggregation, low cation exchange capacity, and reduced microbial activity (Qadir *et al*. 2000, 2008; Liang *et al*. 2003; Tejada *et al*. 2006). In contrast to soil physical and chemical properties, soil microbiological aspects related to saline environments have been less intensively studied (Yuan *et al*. 2007). The effects of salinity on soil microorganisms and microbially mediated processes have been increasingly investigated in the past decade (Batra and Manna 1997; Rietz and Haynes 2003; Sardinha *et al*. 2003; Tripathi *et al*. 2006, 2007; Wu *et al*. 2015), and they all clearly revealed the adverse effects of salinization on the soil microbial biomass. However, some authors have reported that microbial activity and biomass were not related to soil salinity or high pH (Sarig and Steinberger 1994; Beltrán-Hernández *et al*. 1999; Luna-Guido *et al*. 2000). These contradictory observations might be due to differences in quality of the added organic amendments or differences in soil properties, especially the levels of salinity, anion composition, soil pH, texture, and organic matter level (Li *et al*. 2006; Muhammad *et al*. 2007).

Microorganisms are the most vibrant part of the soil eco-system; they regulate the quality of soil by influencing the physical, chemical and biological properties and their dynamics (Zelles 1999). Microorganisms reflect soil conditions through their species, quantity and distribution. They are sensitive to soil microclimate as well as physical and chemical (nutrient) compositions (Kandeler *et al*. 1998). Traditional laboratory culturing and assay methods address less than 1% of the total quantity of microbial species (Ward *et al*. 1990); therefore, using traditional approaches to classify and culture microorganisms for determining microflora composition in the soil risks losing a lot of information on microbial diversity. The 16S rDNA molecular biotechnology removed the constraints of traditional culture-based technology, being capable of obtaining vast amounts of information about culturable and uncultured microorganisms in the soil in a fast and convenient way. It has now been widely applied to studies on the hereditary diversity of soil microorganisms (Saleena *et al*. 2002; Arcate *et al*. 2006). For example, Crecchio *et al*. (2004) examined the impact of different tillage methods on soil microbial diversity. Bossio *et al*. (2005) studied the impact of different land use regimes on the same. Using denaturing gradient gel electrophoresis (DGGE), Dilly *et al*. (2004) explored the changes in soil microbial diversity during straw decomposition, and found that as straws decomposed further, both the quantity of microorganisms and the number of species increased. Wakelin *et al*. (2007) found that returning straws to the field could significantly change the microbial composition in soil. Specifically, by sequencing the DGGE band they found that the bacterial composition in the β-Proteobacteria group had changed. Lu *et al*. (2015) also analyzed the DGGE profile of bacterial community structure in a saline soil and found that bacterial gene abundance was significantly increased in both bulk and rhizosphere samples with biochar products.

Soil salinization is a major obstacle to sustainable agriculture in Hetao irrigation area of Inner Mongolia, China. It affects 394 000 ha or 68.65% of the total arable land of the area (Lei *et al*. 2001). Salinization impairs seedling establishment and causes severe yield losses in this region. Currently, plastic film mulching has been widely used to increase crop yield in saline soils. Burying a straw layer in soil has potential positive effects on soil water and salt management (Sembiring *et al*. 1995; Tumarbay *et al*. 2006). Recently, in a three-year field trial (2011–2013), we proved that combining straw layer burial at a depth of 40 cm with plastic film mulching significantly reduced evaporation from phreatic water, increased soil moisture (especially at the seedling stage), reduced soil salinity, and hence achieved a significant improvement in crop yield (Zhao *et al*. 2016). However, little is known of the microflora composition, predominant population and the interaction between microorganisms and soil physico-chemical factors during remediation.

In this study, we hypothesized that the salt stress effects on soil microbial community may be alleviated and thus microbial growth and activity improved by straw layer burial and plastic film mulching. This is now tested by characterizing the changes in (i) culturable microflora and predominant bacterial communities using the coating dilution plate count method and (ii) microbial diversity and major nonculturable bacterial species using molecular biological assay. Our goal was to explore ways of improving microflora diversity and positively altering the biological features of salinized soil for better crop productivity through straw layer burial and plastic film mulching.

2. Materials and methods

2.1. Site description

This experiment was conducted from October 2010 to September 2011 at the Yichang Experimental Station (41°04´N, 108°00´E, 1 022 m a.s.l.) in Wuyuan County, Inner Mongolia, China. The study area has a typical arid continental climate that is very cold in winter with little snowfall and very dry in summer with little rainfall. Mean monthly precipitation and pan evaporation in the experimental years and previous 10 years (2001–2010) are presented in Fig. 1. The total precipitation during the experimental period (27 May to 24