Pedosphere **24**(2): 167–177, 2014
ISSN 1002-0160/CN 32-1315/P

Published by Elsevier B.V. and Science Press

PEDOSPHERE

www.elsevier.com/locate/pedosphere

Carbon Mineralization and Microbial Attributes in Straw-Amended Soils as Affected by Moisture Levels*1

CHEN Lin[1,2], ZHANG Jia-Bao[1,3,*2], ZHAO Bing-Zi[1], XIN Xiu-Li[1], ZHOU Gui-Xiang[1], TAN Jin-Fang[3] and ZHAO Jin-Hua[3]

[1] *State Key Laboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences, Nanjing 210008 (China)*
[2] *University of Chinese Academy of Sciences, Beijing 100049 (China)*
[3] *Collaborative Innovation Center of Food Crops in Henan, Henan Agriculture University, Zhengzhou 450002 (China)*

(Received August 28, 2013; revised January 10, 2014)

ABSTRACT

An 80-d incubation experiment was conducted to investigate straw decomposition, the priming effect and microbial characteristics in a non-fertilized soil (soil 1) and a long-term organic manure-fertilized soil (soil 2) with and without ^{13}C-labeled maize straw amendment under different moisture levels. The soil 2 showed a markedly higher priming effect, microbial biomass C (C_{mic}), and β-glucosidase activity, and more abundant populations of bacteria and fungi than the soil 1. Also, soil CO_2 emission, C_{mic}, β-glucosidase activity, and bacterial and fungal population sizes were substantially enhanced by straw amendment. In the presence of straw, the amount of straw mineralization and assimilation by microbes in the soil at 55% of water holding capacity (WHC) were significantly higher by 31% and 17%, respectively, compared to those at 25% of WHC. In contrast, β-glucosidase activity and fungal population size were both enhanced as the moisture content decreased. C_{mic} decreased as straw availability decreased, which was mainly attributed to the reduction of straw-derived C_{mic}. Amended soils, except the amended soil 2 at 25% of WHC, had a more abundant fungal population as straw availability decreased, indicating that fungal decomposability of added straw was independent of straw availability. Non-metric multidimensional scaling analysis based on fungal denatured gradient gel electrophoresis band patterns showed that shifts in the fungal community structure occurred as water and straw availability varied. The results indirectly suggest that soil fungi are able to adjust their degradation activity to water and straw availability by regulating their community structure.

Key Words: bacteria, decomposition, fungi, maize straw, organic manure

Citation: Chen, L., Zhang, J. B., Zhao, B. Z., Xin, X. L., Zhou, G. X., Tan, J. F. and Zhao, J. H. 2014. Carbon mineralization and microbial attributes in straw-amended soils as affected by moisture levels. *Pedosphere*. **24**(2): 167–177.

Returning crop straw into fields is a common practice to resolve an oversupply of straw and improve soil organic matter (SOM) levels. Returned straw is a carbon, energy and nutrient source substrate for soil microbes. Microbial decomposition of added crop straw is affected by many factors including soil salinity (Muhammad *et al.*, 2006), soil-straw contact (Henriksen and Breland, 2002), straw location (Jacobs *et al.*, 2011), straw quality and size (Bending and Turner, 1999), and growing plants (Jannoura *et al.*, 2012). These factors have the potential to affect the accessibility of straw to soil microorganisms, and thus alter rates of colonization and patterns of decomposition and mineralization. Among these factors, soil moisture content is an important property in relation to microbial decomposition of added crop straw. Water availability is a major determinant of soil microbial activity and community composition (Drenovsky *et al.*, 2004; Geisseler *et al.*, 2011; Chen *et al.*, 2012), and thus influences straw decomposition. Also, with the addition of straw, microbial characteristics in moist soil are distinctly different from those in dry soil. Geisseler *et al.* (2011) found that respiration and microbial biomass in a dry soil amended with oats-legume straw were reduced while protease, β-glucosidase, β-glucosaminidase and exocellulase activities were increased compared to an amended soil with a higher moisture potential.

It is commonly predicted that the intensity of straw amendment and soil carbon content are positively linked. Paradoxically, some long-term field investigations show that although crop straw is incorporated into soil in large quantities, soil carbon content is not necessarily increased (Campbell *et al.*, 1991; Ko-

*1Supported by the National Basic Research Program (973 Program) of China (No. 2011CB100506), the Knowledge Innovation Program of Chinese Academy of Sciences (No. CXJQ120111), and China Agriculture Research System—Wheat.
*2Corresponding author. E-mail: jbzhang@issas.ac.cn.

rner and Arnone, 1992; Gill *et al.*, 2002). In fact, soil microbes have the ability to decompose old recalcitrant SOM by using fresh straw carbon as a source of energy, *i.e.*, the phenomenon called the priming effect (PE) (Kuzyakov *et al.*, 2000). Actually, soil carbon losses increase when soil microbes are nutrient limited (Fontaine *et al.*, 2004a). A bank mechanism was advanced by Fontaine *et al.* (2011), who suggested that the PE is low when nutrient availability is high, allowing sequestration of nutrients and carbon; in contrast, microbes release nutrients from SOM when nutrient availability is low.

Intensive agricultural cultivation typically results in depletion of soil carbon and reduced productivity. The application of organic manure is therefore a management technique which has the potential to increase the soil carbon content and improve soil fertility. Previous studies have dealt with the effect of long-term organic manure management on soil nutritional properties and microbial characteristics. For example, Ghosh *et al.* (2012) demonstrated that microbial biomass carbon and mineralizable carbon both increase following the addition of organic inputs. Also, the application of organic manure can enhance many soil enzyme activities and alter microbial community structure and function (Chu *et al.*, 2007; Islam *et al.*, 2011; Liu *et al.*, 2013). To date, the effects of long-term organic manure-fertilized soil amended with crop straw on straw decomposition, the priming effect and microbial characteristics as affected by moisture levels are poorly understood. Therefore, an incubation experiment was conducted in this study to investigate straw decomposition, the priming effect and microbial characteristics in a non-fertilized soil and a long-term organic manure-fertilized soil with and without ^{13}C-labeled maize straw amendment under different moisture levels.

MATERIALS AND METHODS

Site and soils

Soil samples were collected from the long-term fertility experiment site located at the Fengqiu Agro-Ecological Experimental Station of Chinese Academy of Sciences, Fengqiu County, Henan Province, China (35°00′ N, 114°24′ E). Organic manure has been applied to the site since 1989. The organic manure is a composted mixture of wheat straw, oil cake and cotton cake in a weight ratio of 100:40:45. These materials were ground to 3–5 mm, mixed completely with limited water, and were composted for 2 months. The oil cake and cotton cake were the machine-dried residues of oil-harvested rapeseeds and cottonseeds, respectively. Organic manure is regularly applied to winter wheat (*Triticum aestivum* L.) and summer maize (*Zea mays* L.) with the amount of application being equivalent to 150 kg N ha^{-1} calculated from the N content of the organic manure. Some soils have received no application of mineral or organic fertilizer for each crop since 1989 as control.

Soil samples were taken from the tilled layer (0–20 cm) in October 2012 after the harvest of summer maize. The soil (456 g kg^{-1} sand, 407 g kg^{-1} silt, and 137 g kg^{-1} clay) has developed from alluvial sediments of the Yellow River. It is an Aquic Inceptisol according to the USDA classification system. The non-fertilized soil (soil 1) and long-term organic manure-fertilized soil (soil 2) were homogenized, air-dried, and passed through a 0.25-mm mesh sieve. Basic soil properties were measured and are shown in Table I.

^{13}C-labeled maize straw

Maize plants were grown in pots under greenhouse conditions, and were watered to approximately 80% of field capacity every other day. ^{13}C-labeling was performed when the plants reached the shooting stage. Briefly, plants were air-tightly packed with transparent plastic film (300 cm × 220 cm × 170 cm). Fifty milliliters of 100% ^{13}C-enriched CO_2 (SRICI, Shanghai, China) were infused into the plastic film. Photosynthesis was maintained for 10 h of daylight with a fan keeping good ventilation, and the film was uncovered in the evening. ^{13}C labeling was repeated by the same procedure for 6 d. Maize plants were harvested

TABLE I

Some basic properties[a)] of the non-fertilized soil (soil 1) and long-term organic manure-fertilized soil (soil 2) collected from the long-term fertility experiment site in Fengqiu County, Henan Province, China

Studied soil	pH (H_2O)	Organic C	δ^{13}C	Total N	δ^{15}N	Total P	Total K
		mg g^{-1}	‰ V-PDB[b)]	mg g^{-1}	‰ air	mg g^{-1}	
Soil 1	8.3±0.0[c)]	3.3±0.3	−22.89±0.12	0.48±0.01	32.42±3.42	0.41±0.02	18.1±0.5
Soil 2	8.0±0.0	9.3±0.4	−25.36±0.11	1.26±0.08	13.83±0.63	0.64±0.03	17.5±0.5

[a)]δ^{13}C is the ^{13}C abundance and δ^{13}N is the ^{13}N abundance; [b)]Vienna-Pee Dee Belemnite; [c)]Means±standard errors (n = 3).