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ScienceDirect
Journal of Integrative Agriculture
2014, 13(12): 2758-2767
December 2014
RESEARCH ARTICLE

Response of Soil Organic Carbon and Its Aggregate Fractions to Long-Term Fertilization in Irrigated Desert Soil of China

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Abstract

Irrigated desert soil samples in the Hexi Corridor of China were collected over a period of 23 years from a site where different fertilization methods had been used. Changes of soil organic carbon (SOC) and its water stable aggregate (WSA) size fractions were studied. The effects of various fertilization methods on the distribution of added organic carbon (OC) in different WSA size fractions were also analyzed. The results showed that the applied fertilizations for 23 years improved SOC concentrations and OC concentrations in all WSA size fractions compared to the non-fertilized treatment (CK). In addition, fertilization obviously increased the OC stocks of <2 mm WSA size fractions compared to the CK. The average OC stock of <0.053 mm WSA fraction was 1.7, 1.6 and 3.2 times higher than those of >2 mm, 0.25-2 mm and 0.053-0.25 mm WSA fractions, respectively. A significant positive correlation was found between soil C gains and OC inputs (r=0.92, P<0.05), indicating that SOC may have not reached the saturation point yet at the site. The C sequestration rate was estimated by 14.02% at the site. The OC stocks in all of the <2 mm WSA fractions increased with the increase of OC input amounts; and the conversion rate of the input fresh OC to the OC stock of <0.053 mm WSA fraction was 1.2 and 2.6 times higher than those of the 0.25-2 mm and 0.053-0.25 mm WSA fractions, respectively. Therefore, the <0.053 mm WSA fraction was the most important component for soil C sequestration in the irrigated desert soil.

Key words: aggregate, irrigated desert soil, long-term fertilization, organic carbon

INTRODUCTION

Soil is the largest carbon (C) cycle stock in the terrestrial ecosystems, and sequesters approximately 1 550 gigatons (Gt) of organic carbon (OC) at a global scale (Eswaran *et al*. 2000). The soil organic carbon (SOC) stock is 2.0 and 2.8 times those of the atmospheric (760 Gt) and biotic (560 Gt) stocks, respectively (Lal 2004). The SOC stock of farmland occupies an important share in the total SOC stocks and plays a pivotal role in sequestering carbon and in reducing discharge around the globe. Therefore, an in-depth study on the SOC stock and its distribution in farmland is important during the evaluation of the C cycle in the global terrestrial ecosystems. Changes in the SOC stock are balanced between C inputs and outputs. The soil organic matter (SOM) in farmland mainly comes from crop residues (straws, stubble, roots, and rhizodeposition exudates) and organic

Received 15 August, 2013 Accepted 5 November, 2013
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doi: 10.1016/S2095-3119(13)60681-4

manures which are intentionally amended into soils (Six *et al*. 2004; Bronick and Lal 2005). Increasing organic matter (OM) input is an effective way to improve SOC stocks. The SOC content is closely related to water stable aggregate (WSA) fractions and also influences the number and size distribution of WSA fractions. De Gryze *et al*. (2008) reported that the presence of macro-WSA fractions (>0.25 mm) are usually and positively associated with OC contents. Moreover, the role of the formation of WSA fractions is an important mechanism for C sequestration in soils, and is especially important in the physically protected mechanisms involved in the WSA fractions for OC sequestration (Pan *et al*. 2007). Previous studies showed that the accumulated amount of SOC in paddy fields of the Taihu lake region, in a red-soil dry land, and in the Jianghuai hilly area were closely correlated with the OC content of the 0.25-2 mm WSA fraction (Li *et al*. 2000; Wang *et al*. 2009). Dou *et al*. (1991) reported that the 0.01-0.05 and 0.05-0.25 mm WSA size fractions were the dominant and sub-dominant fractions of microaggregates in black soils, respectively, and they played an important role in soil C sequestration. Therefore, different soil types had the different mechanisms for soil C sequestration.

The irrigated desert soil is a typically cultivated soil of arid inland regions. The soil is distributed in inland river basin and the Yellow River Basin of the desert border region, which occupies more than half of the total land area in China (Guo and Tan 1998) and is also widely distributed around the world. The soils of the Hexi Corridor represent a typical irrigated desert soil region in China, and they have great viscosity and are rich in phosphorus, potassium and calcium carbonate. Therefore, studies on the mechanism of C sequestration in the irrigated desert soil under conventional fertilization modes in China is of important directive significance to the researches of C sequestration in the irrigated desert soil worldwide. In this study, we analyzed the results from a long-term fertilization experiment carried out in a single field located in China's Hexi Corridor for such a purpose. This study aims at (1) determining the OC concentrations and OC stocks of different WSA size fractions under different fertilization treatments; (2) examing the relationship between the input fresh OC and OC stocks in different WSA size fractions; and (3) evaluating the mechanisms for soil C sequestration in the irrigated desert soil.

RESULTS

Basic soil properties

The experimental soils were measured in January 2012. The soils were alkaline calcareous soils with pH values ranging from 8.5 to 8.6, sand contents from 30.0 to 31.8%, silt contents from 25.3 to 29.2%, clay contents from 22.6 to 24.7%, and bulk densities from 1.20 to 1.31 g cm^{-3} (Table 1).

In comparison with the treatment without fertilizer (CK), the application of chemical N fertilizer alone increased the soil bulk density, while the combined application of organic manures with chemical N fertilizer decreased the soil bulk densities (Table 1). Compared with the CK, the application of chemical N fertilizer alone had no significant effect on SOC and total soil N (TSN). However, the combined application of organic manures with chemical N fertilizer significantly increased SOC and TSN by 7.0-73.1% and 24.0-68.6% compared with the CK for the various treatments, respectively.

Table 1 Analysis of physical and chemical properties of soils

Treatments[1)]	pH (H_2O)	Sand (%)	Silt (%)	Clay (%)	BD (g cm^{-3})[2)]	SOC (g kg^{-1})[3)]	TSN (g kg^{-1})[4)]
CK	8.6±0.0 a	31.8±0.9 a	28.3±0.7 a	23.1±0.1 b	1.29±0.00 ab	9.98±0.32 d	1.25±0.11 b
N	8.5±0.0 a	31.7±0.4 a	27.2±1.1 a	23.6±0.2 ab	1.32±0.00 a	10.68±0.12 cd	1.24±0.08 b
MN	8.5±0.0 a	31.3±1.5 a	25.3±1.5 a	24.7±0.8 a	1.21±0.00 b	15.39±1.21 a	1.70±0.06 a
GN	8.5±0.1 a	31.2±0.6 a	28.5±0.5 a	22.6±0.4 b	1.22±0.10 b	13.67±0.30 b	1.73±0.07 a
SN	8.5±0.1 a	30.0±2.4 a	27.3±1.2 a	23.4±0.6 b	1.27±0.10 ab	11.80±0.21 c	1.63±0.06 a

[1)] CK, treatment without fertilizer; N, the chemical nitrogen fertilizer treatment; MN, the manure plus chemical nitrogen fertilizer treatment; GN, the green manure plus chemical nitrogen fertilizer treatment; SN, the straw plus chemical nitrogen fertilizer treatment. The same as below.

[2)] BD, bulk density.

[3)] SOC, soil organic carbon.

[4)] TSN, total soil nitrogen.

Values are means±SD (n=3). Different letters show significant differences at $P<0.05$. The same as below.