Journal of Integrative Agriculture 2016, 15(3): 658–666

Available online at www.sciencedirect.com

ScienceDirect

RESEARCH ARTICLE

Effect of chemical and organic fertilization on soil carbon and nitrogen accumulation in a newly cultivated farmland

YANG Rong[1], SU Yong-zhong[1], WANG Tao[2], YANG Qin[3]

[1] *Linze Inland River Basin Research Station, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 73000, P.R.China*

[2] *Lanzhou Branch, Chinese Academy of Sciences, Lanzhou 730000, P.R.China*

[3] *Institute of Vegetables, Gansu Academy of Agricultural Sciences, Lanzhou 73000, P.R.China*

Abstract

Increased food demand from the rapidly growing human population has caused intensive land transition from desert to farmland in arid regions of northwest China. In this developing ecosystem, the optimized fertilization strategies are becoming an urgent need for sustainable crop productivity, efficient resources use, together with the delivery of ecosystems services including soil carbon (C) and nitrogen (N) accumulation. Through a 7-year field experiment with 9 fertilization treatments in a newly cultivated farmland, we tested whether different fertilizations had significant influences on soil C and N accumulation in this developing ecosystem, and also investigated possible mechanisms for this influence. The results showed that applying organic manure in cultivated farmland significantly increased the soil C and N accumulation rates; this influence was greater when it was combined with chemical fertilizer, accumulating 2.01 t C and 0.11 t N ha^{-1} yr^{-1} in the most successful fertilization treatment. These high rates of C and N accumulation were found associated with increased input of C and N, although the relationship between the N accumulation rate and N input was not significant. The improved soil physical properties was observed under only organic manure and integrated fertilization treatments, and the significant relationship between soil C or N and soil physical properties were also found in this study. The results suggest that in newly cultivated farmland, long term organic manure and integrated fertilization can yield significant benefits for soil C and N accumulation, and deliver additional influence on physical properties.

Keywords: C and N accumulation, sandy farmland, chemical fertilizer, manure, soil physical property

1. Introduction

Globally, soils are the largest terrestrial carbon (C) and nitrogen (N) reservoir, but there is compelling evidence that over the last few decades large amounts of C and N have been lost from soil of natural and agricultural ecosystems through erosion, leaching and accelerated soil respiration (Di and Cameron 2002; Bellamy *et al.* 2005; Quinton *et al.* 2010). To help mitigate rising atmospheric CO_2 levels and improve farmland soil nutrient status and sustainability, the management of ecosystems to deliver ecosystem services such as C and N storage has recently become an important aim of agri-environment schemes in many regions (Stewart *et al.* 2007; Yan *et al.* 2007; Sainju *et al.* 2008). Commonly

Received 22 January, 2015 Accepted 15 May, 2015
Correspondence YANG Rong, Tel: +86-13893328490, E-mail: yangrong@lzb.ac.cn

doi: 10.1016/S2095-3119(15)61107-8

recommended management practices to increase and maintain the soil C and N stocks in farmland ecosystems include soil tillage, nutrient and fertilizer management, cover crops, efficient irrigation, and agroforestry practices (Lal 2004), among them, the balanced fertilization has been shown to be an efficient practice (Tong *et al.* 2009; Zhou *et al.* 2013).

The rational fertilization can improve the soil nutrient status and maintain high crop productivity which can directly alter the amount and quality of C and N input from crop residues (Dersch and Böhm 2001; Holeplass *et al.* 2004). The fertilization also influence soil C and N accumulation through change on soil structure, soil organic C and N component (Hai *et al.* 2010), and soil aggregation (Su 2007). Soil C and N accumulation in soils of different textures could have different responses to fertilization, because the different saturation and initial soil C and N levels could limit the soil C and N sequestration capacity (Six *et al.* 2002; Kong *et al.* 2005). Compared with the studies in other soil texture (Rudrappa *et al.* 2006; Tong *et al.* 2009; Zhou *et al.* 2013), the study about the effects of fertilization on soil C and N accumulation in sandy texture farmland developed from desert are much more limited.

Desert soil is widely distributed in the inland arid regions of northwest China, which cover about one-fifth of China's land surface (Ogle *et al.* 2012). Over the past several decades, increasing population and food demands have caused intensive land exploitation in these arid regions (Luo *et al.* 2003; Huang *et al.* 2007; Li *et al.* 2009), which led to frequent land transition from desert to farmland (Su *et al.* 2010). To maintain environmental stability and the sustainable productivity through rational agricultural practice is becoming an important issue in this developing ecosystem. However, local farming practices tend to adopt an unbalance fertilization practice, in which excessive chemical fertilizer is applied, but no organic manure, which result in some ecological problems, such as excessive resource consumption, soil nutrient leaching. Thus, the optimized fertilization strategies in here are becoming a need for sustainable crop productivity and efficient resources use, and the delivery of ecosystems services including soil C and N accumulation. In this paper, we quantified the influence of long-term fertilization on soil C and N stock and their accumulation rate in such a developing ecosystem by using a 7-year field experiment. We also estimated treatment effects on the C and N input, N output, soil physical properties; and their relationship with soil C and N to explore the mechanisms underlying the influence.

2. Results

2.1. C, N input, and N output rates under different treatments

Fertilizer C input rates ranged from 0 to 2 401 kg ha^{-1} yr^{-1} (Table 1) with maximum values under high organic manure (M3), low chemical N, phosphorus (P) levels combined with high organic manure level (NP1M3), and low chemical N, P, potassium (K) levels combined with high organic manure level (NPK1M3) treatments, and minimum values under high chemical N and P levels (NP3, CK), low chemical N, P, and K (NPK1), medium chemical N, P, and K levels (NPK2), and high chemical N, P, and K levels (NPK3) treatments. Fertilizer N input rates ranged from 120 to 311 kg ha^{-1} yr^{-1} with maximum values under the high chemical N, P, and K levels combined with low organic manure level (NPK3M1) treatment and minimum values under the NPK1 treatment. Average crop C input rate of 756 kg ha^{-1} yr^{-1}, with maximum values under the high chemical N, P, and K levels combined with low organic manure level (NPK2M2) treatment and minimum values under the M3 treatment, was 40% of average C input rate (1 891 kg ha^{-1} yr^{-1}). Average crop N input rate of 25 kg ha^{-1} yr^{-1}, with maximum values under the NPK1M3

Table 1 Estimated average annual C and N input and N output under different treatments

Treatments[1)]	Fertilizer input (kg ha^{-1})		Crop input (kg ha^{-1})		Crop output (kg ha^{-1})	
	C	N	C	N	C	N
M3	2401	134	641	17	−	177
NP3 (CK)	0	244	739	23	−	248
NPK1	0	120	713	21	−	241
NPK2	0	182	768	24	−	266
NPK3	0	244	754	24	−	266
NP1M3	2401	254	736	21	−	252
NPK1M3	2401	254	778	46	−	264
NPK2M2	1801	283	858	25	−	294
NPK3M1	1201	311	813	25	−	282

[1)] M3, high organic manure level; NP3, high chemical N and P levels (CK, which represented the local fertilization practice); NPK1, low chemical N, P, and K levels; NPK2, medium chemical N, P, K levels; NPK3, high chemical N, P, K levels; NP1M3, low chemical N, P levels combined with high organic manure level; NPK1M3, low chemical N, P, K levels combined with high organic manure level; NPK2M2, medium chemical N, P, K levels combined with medium organic manure level; NPK3M1, high chemical N, P, K levels combined with low organic manure level. The same as below.