Soil & Tillage Research 152 (2015) 94–103

Contents lists available at ScienceDirect

Soil & Tillage Research

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

Impacts of long-term chemical and organic fertilization on soil puddlability in subtropical China

Lidong Bi [a,1], Shuihong Yao [b,1], Bin Zhang [b,*]

[a] Key Laboratory of Efficient Irrigation-Drainage and Agricultural Soil-Water Environment in Southern China, Hohai University, Ministry of Education, Nanjing 210098, China

[b] Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China

ARTICLE INFO

Article history:
Received 12 November 2014
Received in revised form 8 April 2015
Accepted 9 April 2015

Keywords:
Puddling tillage
Sinkage resistance
Soil clods
Long-term fertilization
Rice

ABSTRACT

Soil puddlability measures the susceptibility of a soil to puddling, and can influence transplantation and the growth of rice plants. The effects of chemical fertilizers and organic amendments on soil puddlability of paddy soils are poorly understood. This study used two 26-year field experiments (1) to compare the effects of chemical and organic fertilization on soil puddlability by measuring sinkage resistance and hard clod content after puddling, (2) to characterize physical properties of hard clods and (3) to explain the change in soil puddlability. Each of the two experiments consisted of nine treatments of chemical fertilizers alone or in combination with organic amendments. The sinkage resistance and the content of hard clods were higher in the treatments with chemical fertilization alone than in the treatments with organic amendments. The sinkage resistance was positively correlated with the content of hard clods and negatively correlated to content of soil organic C (SOC) and mean weight diameter (MWD). The bulk density, water sorptivity and apparent porosity were similar among individual hard clods from different treatments, suggesting that the hard clods were formed under the same processes. The formation of hard clods was likely attributed to the breakdown of the compacted topsoil by puddling tillage, which formed due to clogging pores by fine particles produced during previous puddling tillage and due to shrinkage upon drying during rice growth period. Compared with the organic amendment treatments, the chemical fertilization treatments contained more and larger hard clods, indicating that the compacted topsoil was thicker due to higher soil dispersibility due to N fertilization and lower SOC content in the chemical fertilization treatments than in the organic amendment treatments. The study also suggests that continuous input of organic C at an annual rate of >2.5 Mg ha^{-1} is needed to maintain SOC content and soil structure under chemical fertilization in the study region.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

Soil structure plays a critical role in providing mechanical support for plants against lodging, controlling the availability of water, nutrients and aeration necessary for plant growth, and affecting the microbial habitats and activities involving in nutrient cycling in terrestrial ecosystems (Elliott, 1986; Dexter, 1988). The maintenance of an optimum soil structure is critical to realize potential crop yields and sustain soil fertility (Kirchhof et al., 2000; Mandal et al., 2013). One of the most dramatic forms of soil structure changes is puddling tillage in rice fields. Puddling tillage involves several rounds of agitating soil under the submerged condition, aiming to soften and flatten the surface soil to ease transplanting of rice seedlings, to control weeds, to mix fertilizers and crop residues into soil and to reduce water leakage (Sharma and De Datta, 1985; Yoshida and Adachi, 2001). Intensive puddling in water disperses soil into microaggregates and primary particles (Chen et al., 1984) and destroys soil macropores (Eickhorst and Tippkotter, 2009), which benefits rice crop transplantation and establishment. However, upon drying, the muddy soil becomes consolidated, with large cracks developing due to shrinkage (Lennartz et al., 2009). Soil strength and saturated hydraulic conductivity quickly change in the puddled soil layer, and possibly in the plow pan (Yoshida and Adachi, 2001; Mohanty et al., 2004). These changes in soil physical properties can have negative

---

* Corresponding author. Tel.: +86 10 82106719; fax: +86 10 82106225.
E-mail addresses: zhangbin01@caas.cn, bzhang@caas.ac.cn (B. Zhang).

[1] These authors contributed equally to this work.

http://dx.doi.org/10.1016/j.still.2015.04.005
0167-1987/© 2015 Elsevier B.V. All rights reserved.

impacts on yields of rice and the following crops, depend on puddling intensity and soil type (Kirchhof et al., 2000; Mohanty et al., 2004; Lennartz et al., 2009).

Soil puddlability as a measure of susceptibility of soil to puddling was defined as the change in apparent specific volume of soil per unit work extended in causing such change. Soil puddlability reflects not only the requirement of force and energy for puddling tillage, but also the quality of puddling that influences transplantation and growth of rice crops. Because it is difficult to define the work in the field, soil puddlability is often measured after puddling tillage as the amount of dispersed aggregates and clay particles (Sharma and De Datta, 1985; Sharma and Bhushan, 2003; Deng et al., 2013) and the sinkage resistance (Kirchhof et al., 2000). The sinkage resistance, originally termed as sinkage capacity by Kirchhof et al. (2000), was measured using an apparatus identical to a penetrometer in which the cone is replaced with a plate to simulate the resistance to rice plant transplantation. In general, soil puddlability depends on moisture content, soil type, tillage implement and cultivation practices (Singh et al., 2001). The proportion of dispersed clay particles or un-dispersed aggregates after puddling depends also on clay type (Sharma and De Datta, 1985), puddling intensity (Deng et al., 2013) and soil organic C (SOC) content (Sharma and Bhushan, 2003; Deng et al., 2013). Kirchhof et al. (2000) reported that the sinkage resistance varied with puddling intensity, and its influences on rice yields or post-rice crop yields depended on soil texture.

Long-term application of organic manure or crop residues has been shown to improve soil puddlability as indicated by the formation of water-stable aggregates with macropores (Sharma and Bhushan, 2003; Deng et al., 2013) and the decrease in sinkage resistance (Yao et al., 2014). In contrast, the paddy soils under chemical fertilization have large shrinkage capacity, resulting in high bulk density or compacted structure due to loss of structural macropores upon drying (Deng et al., 2013). Morphological studies in tilled uplands demonstrated that there were hard clods remaining in the plow layer after plowing (Richard et al., 1999; Boizard et al., 2002; Roger-Estrade et al., 2004). The hard clods termed as Δ clods had few structural macro-pores and were low in hydraulic conductivity. The formation of Δ clods was attributed to soil compaction and is proportional to the severity of compaction (Boizard et al., 2002; Roger-Estrade et al., 2004). These results imply the negative effects of long-term chemical fertilization on soil structure, porosity, hydraulic conductivity and the sinkage resistance after puddling tillage.

In China, intensive puddling has been criticized as an important obstacle to increasing rice yields in the Yangtze Delta region since 1980s when chemical fertilizers started to replace organic amendments although the practice has been used in paddy fields for centuries in (Cheng et al., 1979; Zhao et al., 1981; Chen et al., 1984). However, it is unclear whether the changes in chemical and organic fertilization influence the quality of puddling tillage and the regeneration of physical structure during the rice growth period. Understanding these effects is critical for sustainable management of paddy fields.

Two long-term field experiments were established in 1981 to compare the effects of chemical fertilization and organic amendments to substitute chemical fertilization on rice yield and soil fertility (Bi et al., 2009). This present study used these experiments to determine the effects of long-term organic amendment and chemical fertilization on soil puddlability. The specific objectives of the study were (1) to determine the effects of field treatments on soil puddlability by measuring sinkage resistance and hard clod content after puddling, (2) to characterize physical properties of hard clods in comparison with normal aggregates and (3) to explain the changes in soil puddlability. It was hypothesized that long-term chemical fertilization caused the formation of hard clods that had few structural pores and low hydraulic conductivity, but were higher in sinkage resistance compared with organic amendments.

2. Materials and methods

2.1. Site description

The long-term fertilization experiments were located at the Jiangxi Institute of Red Soil, Jiangxi Province, China (28°37′N, 116°26′E and 26 m above the sea level). The local climate is a typically subtropical climate with an annual mean temperature of 18.1 °C and annual rainfall of 1727 mm (1981–2006). The fields were terraced for rice cropping more than 100 years before the experiment was started. The soils in the region are Stagnic Anthrosols (IUSS Working Group WRB, 2006) or anthric saturated Typic Epiaquept (Soil Survey Staff, 2010). The paddy soil has a silty loam texture (26.0% clay) with dominant kaolintic minerals and iron oxides. The parent material was quaternary red clay. The soil profile constitutes four horizons such as A (0–15 cm), P (15–24 cm), W1 (24–38 cm) and W2 (38–90 cm). The soil in A (plowed layer) horizon before the experiment contained 16.2 g kg^{-1} soil organic carbon, 1.6 g kg^{-1} total nitrogen, 0.5 g kg^{-1} total phosphorus, 143.7 mg kg^{-1} available nitrogen (hydrolizable), 10.3 mg kg^{-1} available P (Olsen-P), 38.2 mg kg^{-1} available K and pH (H_2O) of 5.7.

The two experiments were established in April 1981 to investigate the effects of chemical and organic fertilization on soil productivity and fertility. The two experiments were 200 m apart from each other and located on either side of one road, resulting in one higher than another on the terraced land. The cropping system was the same as double-rice cropping followed by winter fallow. The first rice crop was transplanted on 29th April and harvested around on 20th July. The second rice crop was transplanted around on 28th July and harvested around on 1st November. Rice cultivar changed every five years during the period from 1985 to 1995 and one cultivar was used for less than five years after 1995 to avoid yield decline due to continuous use. The name and used period of each cultivar were recorded.

Each experiment included nine treatments (Table 1). Both the experiments were arranged in a randomized complete block design with three replications. Plots were separated from each other with cement plates to avoid the cross contamination. The plot size was $7.1 \times 6.6\,m^2$ in the chemical fertilization experiment and $12 \times 5\,m^2$ in the organic amendment experiment. In the chemical fertilization experiment, the treatments included no fertilization control (CK-C), N, P and K fertilizers alone, and N plus P and N plus K (N-C, P-C, K-C, NP-C, NK-C), recommended chemical fertilization with all N, P and K (NPK-C), intensified fertilization with double amounts of NPK (2NPK-C) and chemical plus organic amendments (NPKOM-C). In NPKOM, green manure (GM, *Astragalus sinicus* L.) from other fields were incorporated into the plow layer (0–0.20 m) during the field preparations for the early/first rice and pig farmyard manure (FYM) for the late/second rice.

In the organic amendment experiment, the treatments included no-fertilizer control (CK-O), recommended chemical fertilization (NPK-O) and reduced application of chemical fertilization in combination with rice straw (straw), GM or FYM. In the treatments with organic amendments, the chemical fertilization rates were reduced by up to 56% in N, 60% in P and 72% in K (Bi et al., 2009). The green manure was grown during the winter fallow from November to April, and incorporated into the plow layer only for the first rice crop. The pig farmyard manure was applied and incorporated into the plow layer either for the first rice crop or the second rice crop. Rice straw was incorporated into soil for the second rice or used as mulching materials during the winter fallow.

For both experiments, the chemical fertilizers were applied urea, fused calcium magnesium phosphate (7.0% P) and KCl. These

Download English Version:

https://daneshyari.com/en/article/305545

Download Persian Version:

https://daneshyari.com/article/305545

Daneshyari.com