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Long-term effects of organic amendments on the rice yields for double rice cropping systems in subtropical China

Lidong Bi [a], Bin Zhang [a,*], Guangrong Liu [b], Zuzhang Li [b], Yiren Liu [b], Chuan Ye [c], Xichu Yu [c], Tao Lai [c], Jiguang Zhang [a], Jianmin Yin [d], Yin Liang [a,*]

[a] State KeyLaboratory of Soil and Sustainable Agriculture, Institute of Soil Science, Chinese Academy of Sciences, Nanjing 210008, China
[b] Institute of Soil and Fertilizer, Jiangxi Academy of Agricultural Sciences, Nanchang 330200, Jiangxi Province, China
[c] Jiangxi Institute of Red Soil, Jinxian 331700, Jiangxi Province, China
[d] Jiangxi Institute of Meteorological Science, Nanchang 330046, Jiangxi Province, China

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ABSTRACT

Organic amendment (OA) has positive effects on rice yield in literature, but few studies have reported positive effects on rice yield trend in a region, which need to be distinguished for the development of sustainable agriculture in terms of management of organic resources available in agroecosystems. The objectives of the present study were to examine the long-term effects of OA on rice yield, yield trends and soil fertility change under the same double rice cropping system at three experimental sites established in 1980s in subtropical China. Organic amendments at the sites covered different strategies in use of locally available green manure, rice straw and farmyard manure to partially substitute inorganic fertilizers at different doses of recommended N, P and K in combination at Jinxian, Jiangxi Province, to partially substitute inorganic N at rates of 30%, 50% and 70% of the recommended rate at Nanchang, Jiangxi Province, and to fully substitute single element of inorganic N, P and K at Qiyang, Hunan Province. The actual rice yield showed no significant time trends at Jinxian and Nanchang and negative trends in the treatments with low N application rates at Qiyang. Analysis of the relative yield trends showed significant positive effects of OA on the yield trends for either first or second rice crop in the treatments except for those without sufficient nutrient supply. The positive effects can be attributed mainly to the increased soil organic carbon and soil nutrient capacity due to the long-term application of OA. The results suggest that the organic amendments strategies should be encouraged as partial substitution of inorganic fertilizers for the consideration long-term yield trends and soil fertility.

1. Introduction

Sustainable increases in crop yields are needed for food security in China as well as in the world. Rice (*Oryza sativa* L.) is the main staple food for more than 60% of the total population in China and national rice production must increase by 1.21% annually to meet the demand of ever-increasing population (Wu and Li, 2002). Rice yield in China increased at an average rate of 3.37% per year from 1970 to 1990 (FAO, 2008) mainly due to the introduction of high yielding varieties and the increasing consumption of chemical fertilizers (China Agricultural Year Book, 1980–1990; Yuan, 1996; Tong et al., 2003). However, the average rate of yield growth dropped to 0.60% per year from 1990 to 2006 (FAO, 2008). Keeping this increasing rate may be further challenged due to the scarcity of water resources (Van Nguyen and Ferrero, 2006) and global climate change (Lobell and Asner, 2003; Peng et al., 2004). Meanwhile, the increasing use of chemical fertilizers is contributing to air and water pollution in China (Zhu and Chen, 2002).

Organic amendments (OAs) have sustained rice production for several thousand years before the introduction of inorganic fertilizers. But recently, farmers in Asia seek to increase the use of inorganic fertilizers and decrease the use of organic materials due to increased labor cost and advent of mechanized harvesting. For example, the average application rate of organic manure to rice field in Yangtze Delta was around 50 kg N ha^{-1}, accounting for 30% of total N applied in 1986, and it reduced to 20 kg N ha^{-1}, accounting for 6.7% of total N applied in 1997 (Zhu and Chen, 2002). Burning crop residues is a common practice in the field to lessen the interference with tillage and seeding operations for the next crop. Such disposal of crop residues by burning and reduced return of enough organic carbon into soil has been blamed for the loss of plant nutrients and causing atmospheric pollution (Nguyen et al., 1994). Therefore, recycling use of organic resources becomes

* Corresponding authors. Tel.: +86 25 86881198.
E-mail addresses: bzhang@issas.ac.cn (B. Zhang), yliang@issas.ac.cn (Y. Liang).

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an increasingly important aspect of sustainable agriculture to minimize such environmental problems (Pathak et al., 2006).

Farmers may recycle crop residues or actively apply organic materials only if there is no yield loss in the short term and there are long-term benefits such as increased crop yields, reduced production inputs or both. Although OA have reportedly positive effect on rice yield (Regmi et al., 2002; Aulakh et al., 2001; Ghosh et al., 2004), few studies have reported the positive effects on yield trend (Dawe et al., 2003). Yadav et al. (2000) have showed a positive effect of OA on rice and wheat yield trends in the Indo-Gangetic Plain region, which has, however, not been confirmed by the study in intensive rice cropping systems across a wide range of environmental conditions in Asian countries (Dawe et al., 2003). Possible reasons for this discrepancy can be attributed to the inherent design limitations of existing experiments and the differences in statistical methods used, which fail to distinguish the effects of OA from the effects of weather and rice cultivar on yield trends (Dawe et al., 2003).

Three experimental sites established in the early 1980s in subtropical China were used in this study because they had the same double rice cropping system, but represented different use strategies of organic resources available for paddy fields such as external farmyard manure (FYM), green manure (GM) and rice straw (Straw). The objectives of the present study were to examine the long-term effect of such OA on rice yield, yield trends and soil properties.

Table 1
Treatments used in the double rice long-term experiments in subtropical China.

Treatments	First rice	Second rice
Jinxian site[a]		
Control	Control (no fertilizer)	Control (no fertilizer)
NPK	100% NPK	100%NPK
T_3	Reduced NPK + GM	Reduced NPK
T_4	Reduced NPK + 2GM	Reduced NPK
T_5	Reduced NPK + GM + PM	Reduced NPK
T_6	Reduced NPK + GM	Reduced NPK + PM
T_7	Reduced NPK + GM + Straw	Reduced NPK + PM
T_8	Reduced NPK + GM + Straw	Reduced NPK
T_9	Reduced NPK + GM	Reduced NPK + Straw
Nanchang site[a]		
Control	Control (no fertilizer)	Control (no fertilizer)
NPK	100% N_1 + PK	100% N_2 + PK
7CF + 3OF	70% N_1 + PK + GM_1	70% N_2 + PK + PM_1
5CF + 5OF	50% N_1 + PK + GM_2	50% N_2 + PK + PM_2
3CF + 7OF	30% N_1 + PK + GM_3	30% N_2 + PK + PM_3
Qiyang site		
NPK	NPK	NPK
OM	Cattle manure	Cattle manure
PK + OM	PK + cattle manure	PK + cattle manure
NK + OM	NK + cattle manure	NK + cattle manure
NP + OM	NP + cattle manure	NP + cattle manure
NPK + OM	NPK + cattle manure	NPK + cattle manure

[a] GM green manure; PM pig manure.

2. Materials and methods

2.1. Site description

The three long-term experimental sites were located in Jinxian County (116°10′E, 28°21′N) and Nanchang County (115°56′E, 28°34′N), Jiangxi Province, and Qiyang County (111°52′E, 26°45′N), Hunan Province (Fig. 1). The climate is typical subtropics. Annual rainfall was the highest at Jinxian (1727 mm), followed by Nanchang (1632 mm) and the lowest at Qiyang (1290 mm), and the annual mean temperature was not largely different (18.1 °C at Jinxian, 18.4 °C at Nanchang, 17.8 °C at Qiyang). The experiments were established in 1981 at Jinxian, in 1984 at Nanchang and in 1982 at Qiyang. The soils were used for rice cropping for more than 100 years before the starting the experiments and were classified as Stagnic Anthrosols (IUSS Working Group, WRB, 2006). The rice yield with a water content of 13% was recorded every year from whole plots. The rice yield data of Jinxian are reported for the first time here and the yield data of other two sites are mostly available in the reports by Li et al. (2006) and Gao et al. (2008) with no attempt to analyze the yield trend.

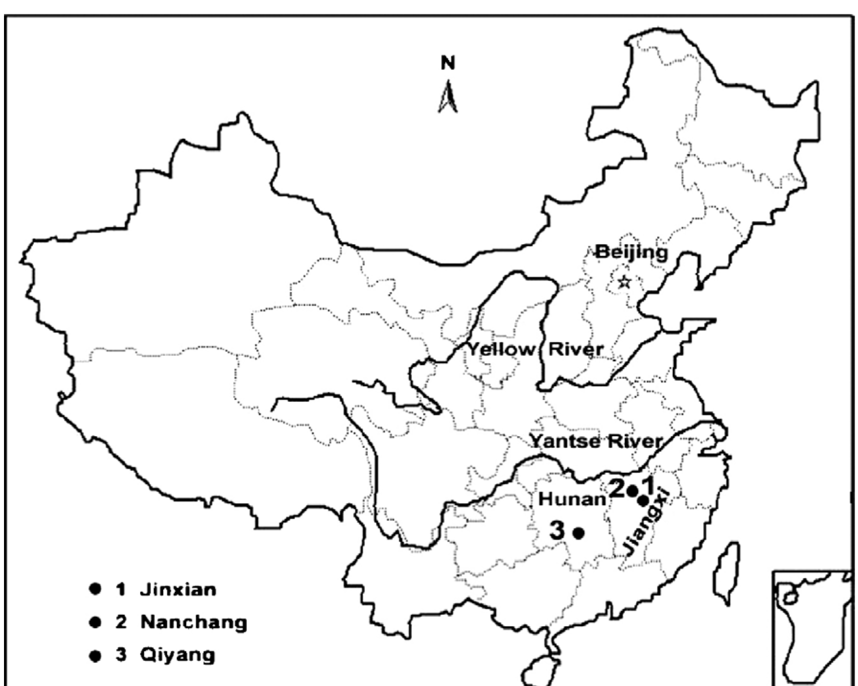

Fig. 1. Sketch map showing the locations of the long-term experimental sites in subtropical China.