The Changes in Guilin Paddy Soil Organic Matter and Rice Yield under Long-Term Fertilization

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Abstract Rational fertilization is an important measure to increase crop yield and soil fertility. Through analysis, this paper aims to master the change characteristics of soil organic matter and rice yield under different fertilizer treatments, in order to provide an important reference for the sustainable use of soil and effective fertilization. Long-term (19 years) rice crop rotation experiments in waterloggogenic paddy soil were conducted to investigate the change trend of crop grain yield and soil organic matter with time, reveal the dynamic characteristics and relationship between main fertility factors and crop yields using comparative analysis at three sites with conventional fertilization and non-fertilization in Guilin. The results showed that compared with previous years, the rice yield increased by 53% under the fertilization treatment and degreased by 66% under the control. Over the years, the average soil organic matter (SOM) content under fertilization treatment was 23% higher than under CK treatment. This indicates that chemical fertilizer and organic manure application can increase the rice yield and soil organic matter, and high rice yield can be attributed to the SOM increase.

Key words Long-term fertilization, Waterloggogenic paddy soil, Soil organic matter (SOM), Yield change

1 Introduction

The long-term continuous located fertilization is a reliable method to study the inherent laws of soil and crop under different fertilization modes, and research soil fertility and productivity trends as well as the connection with environment. It is far better than the short-term experiment[1-3]. Fertilization is the most direct factor of evolution for soil fertility, and soil organic matter is an important material basis of soil fertility. The content and character have a very important impact on crop yields[4-6]. Thus, the soil organic matter content is positively correlated with soil fertility and crop nutrients, and also closely related to crop yields[7]. Studies suggest that the single application of chemical fertilizers leads to declining soil organic matter content, while the combined application of organic fertilizer and chemical fertilizer can increase soil organic matter content[7]. Studies have shown that the combined application of organic fertilizer and chemical fertilizer or single application of organic fertilizer plays a greater role than single application of chemical fertilizer or non-fertilization treatment in accumulation of active soil organic matter[8]. Zhang *et al.*[9] point out that the combination of organic and inorganic fertilizer can continuously provide effective crop nutrients and optimize the physical properties of the soil, so that the cultivated crops grow well. With the widespread attention to sustainable agricultural production, the researchers are not satisfied with the research results of one-season or two-season crops, and they start to pay attention to monitoring of long-term effect, and study the long-term effects of different fertilization on soil fertility and yield. Xin Jingshu *et al.* study the evolution of China's arable land quality. Xu Minggang *et al.*[3] expound the trend of Chinese soil fertility on the basis of long-term fertilization experiment site. Although the combined application of organic and inorganic fertilizer can significantly increase soil fertility and crop yields and it has been confirmed, the effect is quite different in the north and south[2, 11, 12]. Therefore, it is necessary to understand fully the trends of fertilization on different soils in different geographic regions in order to achieve precise management[12]. Paddy soil is the primary farming soil in Guangxi, and it is formed under long-term human hydroponic conditions. There is continuing redox reaction. In this study, we take waterloggogenic paddy soil in Northern Guangxi for example. According to the long-term monitoring tests of rice fields in Guilin, we analyze the impact of combined application of organic and inorganic fertilizer and single application of chemical fertilizer on the double cropping rice yield and soil organic matter, objectively evaluate the role of combined application of organic and inorganic fertilizer in increasing rice yield and improving soil fertility, and propose suitable fertilization management mode for the waterloggogenic paddy soil in Guilin.

2 Materials and methods

2.1 Overview of the experimental field The soil for experiment is waterloggogenic paddy soil, and the experiment site (25° 19′N, 110°17′E) is located in Guilin City, Guangxi Zhuang Autonomous Region, featuring a subtropical humid monsoon climate. It has annual average temperature of 19.3℃, annual rainfall of 1900mm and frost-free period of 309 d. The experiment was carried out from 1987 to 2005, and the same early and late rice crop

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rotation was maintained during the experiment. The replication is not set for field fertilizer experiment. The soil is the waterloggogenic paddy soil from the piled limestone slope. The application rate of pure N, P_2O_5 and K_2O is 346.6 ± 11.7, 132.9 ± 6.4 and 268.0 ± 10.9 kg/hm^2. The nutrients provided by organic fertilizer account for 16.4%.

2.2 Sampling and determination methods From 1987 to 2005, after the late rice harvest, the 0 – 20cm topsoil samples were collected using S-shaped random mixing method, and the samples were dried and sifted over 0.25mm sieve. During 1987 – 1996 and 2002 – 2003, the single application of organic fertilizer was conducted for early rice while the organic fertilizer was not applied for late rice; during 1997 – 2001 and 2004 – 2005, there was no application of organic fertilizer. The chemical fertilizer was applied for double cropping rice during the experiment. As for the control group (CK), no fertilizer was used. Soil nutrients were measured by conventional analytical methods and organic matter was measured by $H_2SO_4 - K_2CrO_7$ external heating method. Experimental data are analyzed using Excel2003 and SPSS software.

3 Results and analysis

3.1 Effect of long-term fertilization on waterloggogenic paddy soil organic matter With the extension of fertilization year, the soil organic matter content shows a slight increasing trend, but it does not reach significant levels, and fluctuates around 50 – 60 g/kg (Fig. 1). Under long-term fertilization, the soil organic matter content is relatively stable, but the soil organic matter content is greatly affected by climate and soil moisture. Therefore, the soil organic matter content in 1994 and 2004 was significantly higher than in other years under fertilization. During 1997 – 2001, the organic fertilizer was not applied, and in order to ensure that the soil organic matter was at the same level, the application of chemical fertilizer increased year by year, from 600 kg/ha to 990 kg/ha. However, the soil organic matter in 2001 was significantly lower than in other years, because the long-term single application of chemical fertilizer and few crop stubble residues led to a decline in the soil organic matter content. In 2002, the organic fertilizer was applied, and the soil organic matter increased significantly by 23%. The reason is that organic fertilizer is the main source of soil organic matter, and it not only directly provides nutrients for the crop, but also provides energy for microbes, thus indirectly enhancing the accumulation and supply capacity of soil organic matter. The long-term considerable application of chemical fertilizer causes some problems such as increased toxic elements, decreased microbial activity, nutrient imbalance and increased acidification, while the humic acid in organic fertilizer, as soil modifying agent, can loosen the soil and improve soil physical and chemical properties. The results show that the rice yield will be higher if there is higher content of organic matter, because organic matter is one of the main sources of plant nutrition, and it contains a variety of nutrients needed for plant growth. Therefore, improving the paddy soil organic matter content is an important way to improve rice yields.

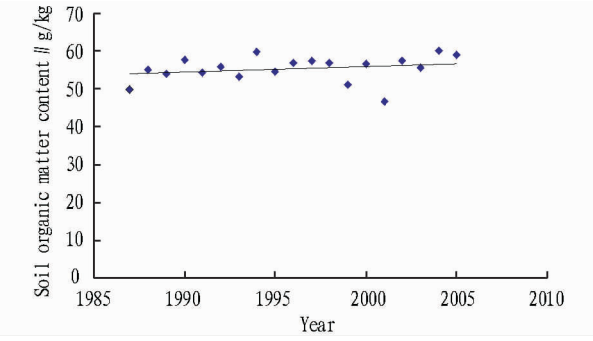

Fig. 1 Soil organic matter content during 1987 – 2005

3.2 Effect of long-term fertilization on rice yield The rice grain, stem and leaf yield under CK is significantly lower than under combined application of organic and inorganic fertilizer (Fig. 2). As can be seen from Fig. 2 (a), the total rice yield in the first year is higher than in other years, because the remaining fertility in paddy soil before experiment provides nutrients to rice, and the rice yield in the late period of experiment is 66% lower than in the early period of experiment. Soil fertility is affected by natural and climatic conditions, as well as some human factors such as different crops, tillage management, irrigation and fertilization, and over time, the rice yield fluctuates around 400 – 3000 kg/ha, because under continuous cropping conditions, the natural productivity of rice is difficult to remain at a certain level for a long time. Under conventional fertilization conditions, rice yield is rising, and the yield in the late period is 53% higher than in the early period. By comparing Fig. 2 (a) and (b), it is found that the long-term combined application of organic and inorganic fertilizer can significantly increase rice grain, stem and leaf yield (6000 – 14000 kg/ha) when compared with non-fertilization treatment (CK). In the experiment during 1997 – 2001 and 2004 – 2005, the organic fertilizer was not applied, and the rice yield did not fall but significantly increased. The reason is that after putting organic fertilizer into soil, the microbial decomposition is relatively slow, and it can release a steady stream of nutrients needed for growth of various crops within a certain time. Thus, the single application of organic fertilizer, or the combined application of organic fertilizer and chemical fertilizer, can significantly promote the accumulation of organic matter in the topsoil, and improve the quality of soil organic matter. Obviously, the combined application can significantly increase rice yield.

4 Discussions

4.1 Soil organic matter The study results of Zhang *et al.* [9] show that under the long-term single application of chemical fertilizer, the soil organic matter content shows a decreasing trend, and the results of this study show that under conventional fertilization, the soil organic matter content is stable, with no significant rise or fall. At present, there is controversy over whether the chemical fertilizer can increase the soil organic matter content. Studies suggest that the application of chemical fertilizer can increase biologi-

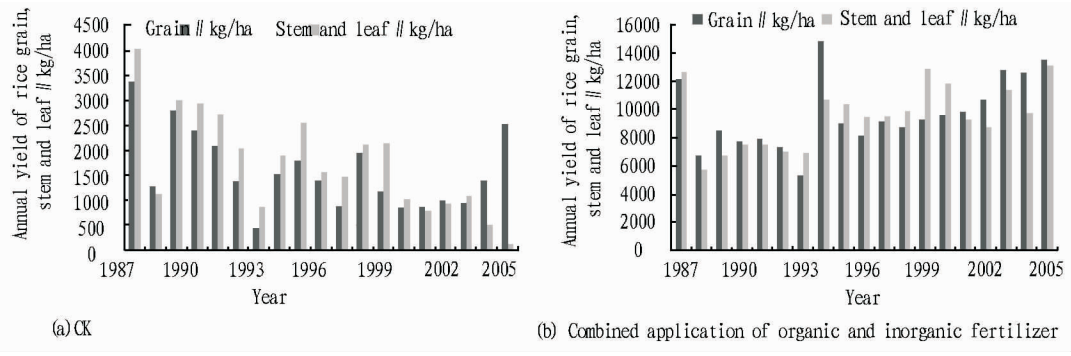

Fig. 2 Rice grain, stem and leaf yield from 1987 to 2005

cal yields of crops, thereby increasing the input to soil organic matter (roots, stubble, leaves, etc.)[10, 13]. Studies of Liu Yiren *et al.*[14] have shown that under chemical fertilizer treatment, the soil organic matter content is maintained at the original level, with no significant growth trend, which may be due to difference in soil texture and climate. Long-term combined application of organic and inorganic fertilizer has a significant impact on the accumulation rate of soil organic matter content, but it is closely related to the soil parent material, fertilization amount and farming methods. This study shows that the long-term combined application of chemical fertilizer and organic fertilizer can significantly increase the soil organic matter content. This is consistent with the findings of Sun *et al.*[15]. To sum up, the long-term combined application of chemical fertilizer and organic fertilizer can not only increase soil organic matter content and improve soil fertility, but also save the amount of fertilizer and improve fertilizer use efficiency. Animals and plants, microbial residues and the organic fertilizers are the major sources of soil organic matter[13]. Studies have shown that the organic matter directly affects many properties of soil to some extent, and is the source of N, P, S and other nutrients for plants[16]. Soil organic matter content is closely related to soil fertility, and has a great impact on soil properties, crop growth and application of chemical fertilizers. Studies show that the combination of chemical fertilizer and organic fertilizer, on the one hand, directly increases the soil nutrients in paddy system through organic fertilizer, and on the other hand, provides balanced mineral nutrition for all stages of rice growth by adjusting the release strength and speed of soil and fertilizer nutrient, thereby increasing the rice yield[5-6]. Therefore, improving the paddy soil organic matter content is an important way to increase rice yields. This study shows that the higher soil organic matter content will lead to higher rice yield, which is consistent with the above findings.

4.2 Rice yield China's traditional agriculture has long used farm organic fertilizer to improve soil fertility and increase productivity[9]. The combined application of organic and inorganic fertilizer can result in sustained high crop yield, because organic fertilizer can not only provide a lot of organic fertilizer nutrients needed for growth of the crop, but also be a good source of trace elements in crops[14-15]. The test results indicate that under the long-term combined application of organic and inorganic fertilizer, the rice yield is significantly improved, which is consistent with many studies. Long-term experimental study of returning straw to farmland suggests that the combined application of organic and inorganic fertilizer can more effectively improve soil fertility and increase crop yield than the single application of straw fertilizer or chemical fertilizer[4, 7]. Studies of Hou Hongqian *et al.*[17] have shown that under combined application of organic and inorganic fertilizer, the rice yield is highest for the early rice or late rice. The reason is that N utilization rate is improved under the combined application of organic fertilizer and chemical fertilizer, and organic matter promotes the accumulation of soil organic matter and improves the supply of nutrients, thereby increasing rice yield. This experiment is based on the data of a experimental site, and there are some limitations, so there is a need to take appropriate fertilization measures for the waterloggogenic paddy soil with different parent materials.

5 Conclusions

Through analysis, this paper aims to master the change characteristics of soil organic matter and rice yield under different fertilizer treatments, in order to provide an important reference for the sustainable use of soil and effective fertilization. Long-term (19 years) rice crop rotation experiments in waterloggogenic paddy soil were conducted to investigate the change trend of crop grain yield and soil organic matter with time, reveal the dynamic characteristics and relationship between main fertility factors and crop yields using comparative analysis at three sites with conventional fertilization and non-fertilization in Guilin. The results showed that compared with previous years, the rice yield increased by 53% under the fertilization treatment and degreased by 66% under the control. Over the years, the average soil organic matter (SOM) content under fertilization treatment was 23% higher than under CK treatment. This indicates that chemical fertilizer and organic manure application can increase the rice yield and soil organic matter, and high rice yield can be attributed to the SOM increase. Long-term combined application of organic and inorganic fertilizer (organic fertilizer occupying 16.4% of total nutrients) is an ideal fertilization method for farming on the waterloggogenic paddy soil in North Guangxi.

References

[1] CONG RH, WANG XJ, XU MG, *et al*. Dynamics of soil carbon to nitrogen ratio changes under long-term fertilizer addition in wheat-corn double cropping systems of China[J]. European Journal of Soil Science, 2012, 63(3): 341 – 350.

[2] CAO ZH, ZHOU JM. Soil quality of China[M]. Beijing: Science Press, 2008. (in Chinese).

[3] XU MG, LIANG GQ, ZHANG FD. China's evolution of soil fertility[M]. Beijing: China Agricultural Science and Technology Press, 2006. (in Chinese).

[4] ZHANG XB, XU MG, SUN N, *et al*. How do environmental factors and different fertilizer strategies affect soil CO2 emission and carbon sequestration in the upland soils of southern China? [J]. Applied Soil Ecology, 2013, 72:109 – 118.

[5] XU M, LI D, LI J, *et al*. Polyolefin-coated urea decreases ammonia volatilization in a double rice system of Southern China[J]. Agronomy Journal, 2013, 105(1):277 – 284.

[6] LI ZF, XU MG, ZHANG HM, *et al*. Yield trends of double-cropping rice under long-term fertilizations in southern China[J]. Acta Agronomica Sinica, 2013,39(5):943 – 949. (in Chinese).

[7] CAI Z, SUN N, WANG B, *et al*. Experimental research on effects of different fertilization on nitrogen transformation and pH of red soil[J]. Scientia Agricultura Sinica, 2012, 45(14):2877 – 2885.

[8] MOHANTY S, NAYAK AK, KUMAR R, *et al*. Carbon and nitrogen mineralization kinetics in soil of rice – rice system under long term application of chemical fertilizers and farmyard manure[J]. European Journal of Soil Biology, 2013, 58(0):113 – 121.

[9] ZANG Y, LIU Q, RONG X, *et al*. Effects of combined application of organic fertilizer and chemical fertilizer on double cropping rice nutrient utilization and leaching loss from paddy soil[J]. Journal of Soil and Water Conservation, 2012, 26(1):22.

[10] XIN JS, XU MG, TIAN YG, *et al*. Study on the evolution trend of the quality of cultivated land[M]. Beijing: China Agricultural Science and Technology Press, 2008. (in Chinese).

[11] LI ZF, XU MG, PANG HC, *et al*. The rice yield trends in three hydragric paddy soils in south China and its fertility factors[J]. Acta Pedologica Sinica, 2014,51(5):953 – 962.

[12] YANG LZ, SUN B. Nutrient cycling and balance of Chinese agro-ecosystem and its management[M]. Beijing: Science Press, 2008. (in Chinese).

[13] JIANG C, HUANG JH, LI XQ, *et al*. Responses of soil nematode community to long-term application of organic manure in upland red soil[J]. Acta Pedologica Sinica, 2011, 48(6): 1235 – 1241. (in Chinese).

[14] LIU YR, LI X, YU J, *et al*. Mechanisms for the increased fertilizer nitrogen use efficiency of rice in wheat-rice rotation system under combined application of inorganic and organic fertilizers[J]. Chinese Journal of Applied Ecology, 2012, 23(1):81 – 86. (in Chinese).

[15] SUNY, LIAO Y, ZHENG S, *et al*. Effects of long-term fertilization on soil organic carbon pool and carbon sequestration under double rice cropping [J]. The Journal of Applied Ecology, 2013. 24(3):732 – 740.

[16] YUAN HC, QIN HL, LIU SL, *et al*. Response of abundance and composition of the bacterial community to long-term fertilization in paddy soils[J]. Scientia Agricultura Sinica, 2011, 44(22):4610 – 4617. (in Chinese).

[17] HOU HQ, LIU XM, LIU GR, *et al*. Effect of long-term located organic-inorganic fertilizer application on rice yield and soil fertility in red soil area of China[J]. Scientia Agricultura Sinica, 2011, 44(3): 516 – 523. (in Chinese).

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can learn from Shanghai's experience to actively establish "concentrated residential area for the workers in Shanghai" which has achieved good economic and social benefits.

4.2.3 Increasing the wages of migrant workers to improve the stability of their work. Young migrant workers have high expectation of their income, which reflects that it is necessary to increase the wages of migrant workers, and appropriately improve the wage standards. The specific wage increase process can be carried out in accordance with two indicators: one is the growth rate of living standards in rural areas and small towns, and the other is the growth rate of national economy, which objectively requires an increase in wages of workers.

4.2.4 Developing the formal employment channels and regulating the informal employment channels for migrant workers. The survey shows that 52.9% of migrant workers find a job in the city through the introduction of close friends and relatives; 14.6% of migrant workers accidentally find a job; only 8.2% of migrant workers find a job through employment agency. The informal employment channels are instable, so it is necessary to rely on laws to regulate the informal employment channels and develop formal employment channels for the migrant workers.

4.2.5 Creating a positive cultural atmosphere for young migrant workers. Working life is monotonous, for want of entertainment. Surfing the Internet, chatting, listening to music and other lifestyles prevalent in the city, are also favored by the young migrant workers, but it is only survival adaptation in general, far from the city assimilation. Therefore, it is necessary to actively create a positive cultural atmosphere to make migrant workers truly integrate into city.

References

[1] YE PF. The way of the migrant workers' social inclusion: Based on the involution feature of social interaction[J]. Urban Studies,2012(1): 81 – 85, 109. (in Chinese).

[2] ZENG WM. Problems & causes in local government's social administration [J]. Exploration and Free Views,2014(2):21 – 24. (in Chinese).

[3] YANG YS, SHI MD. Analysis on the problems of migrant workers in China [J]. Truth Seeking, 2011,39(2):43 – 45. (in Chinese).

[4] CAI F. Chinese migrant workers given attention by the whole world——Discussion on the deep urbanization with Chinese characteristics[J]. International Economic Review, 2010(2): 18 – 21. (in Chinese).

[5] LI SZ, REN YK, JIN XY, *et al*. A research on the social integration of Chinese migrant rural workers and its influencing factors: an analysis based on the social support network[J]. Population & Economics, 2008(2):1 – 8,70. (in Chinese).