Summary of Doctoral Thesis

Enrollment year: October, 2015
UGAS Specialty: Bioproduction Science
Name Nguyen Sy Toan

Title	Studies on the changes in soil organic matter and rice yield with manure application and climate change based on the over 30 years long-term experiment and statistical data in Yamagata, Japan

Introduction and purpose

Global climate change has been observed over several decades, which can have a great effect on agricultural production and food security. There are many studies on the effect of climate change on rice yield all over the world. However the responses of rice growth and soil organic matter (SOM) decomposition to climate change during long-term periods (over 30 years) have not been reported in single rice paddy ecosystem, especially in Asian countries. On the other hand, observations from over 30 years long-term in-situ experiments can provide full understanding of the characteristics and functional changes occurring in soils across time with climate change. In addition, it is also helpful to predict soil productivity and carbon stocks under future climate change scenarios. Natural stable isotopes of carbon and nitrogen ($\delta^{13}C$ and $\delta^{15}N$) are widely used to study the dynamic of SOM in various plant-soil ecosystems, but itis rarely applied in long-term experiment in submerged rice paddies. Therefore, three studies were carried out in this thesis to fully understand how climate change and long-term manure application affect SOM and rice yield based on the over 30 years long-term single rice experiment and statistical data in Yamagata Prefecture, Japan.

Materials and methods

In the first part, statistical data was used to test the changes in climate, rice yield as well as their correlations in four areas in Yamagata Prefecture (Murayama, Mogami, Okitama and Shonai) from 1982-2017. In the second part, response of rice yield to climatic parameters was also addressed, in combination with 32 years archive soil samples were used to investigate the changes in SOM components and its mineralization potential in a single rice paddy during 32

years long-term application of inorganic fertilizers and organic matter from 1983-2014, which was located at the Yamagata Integrated Agricultural Research Center, Yamagata, with five treatments as [1) PK, 2) NPK, 3) NPK + rice straw (RS), 4) NPK + rice straw compost (CM1), and 5) NPK + overdosed rice straw compost (CM3)]. In the third part, the labile organic matter through extractable pools by hot water and water extracted methods were carried out to understand how the quality and quantity of labile organic matter were affect by long-term organic matter application. Soil samples were collected after a 31-years long-term experiment as shown above. The amounts of hot water extracted organic carbon and nitrogen (HWEOC and HWEON) at 80℃ and 16 hours, water extracted organic carbon and nitrogen (WEOC and WEON) at room temperature, and their $\delta^{13}C$ and $\delta^{15}N$ were measured for both surface (0-15 cm) and subsurface (15-25 cm) layers. The ratios of soil to water were 1:1.5 and 1:10 for both hot water and water extraction procedures.

Results

For the first part: The results showed that temperatures have been increased significantly in all of four areas (P<0.05), strongly in summer season during rice growing stages. Long-term observation of its impacts on rice yield and yield components were recorded from 1982-2017 in four main rice production areas. Results showed air temperatures in crop season had strong positive correlation with rice yield in the four areas. There was also strong positive effect of temperatures on rice yield in its growth stages. Among 4 yield components, 1000-grain weight and ripening percentage had high positive correlations with rice yield, while the panicle/m^2 and spikelet/panicle did not show a significant correlation. The long period for TP (transplanting day)-HD (heading day) resulted in decreasing yield, while HD-MT (maturing day) duration had no correlation. Our results indicated that rice growth stages could be considered as a strong tool to evaluate the effect of climate change on rice yield.

For the second part: The results for rice yield shows that yield was enhanced by rising temperatures in early summer (Jun-July), and by the application of mineral fertilizer and organic matter. The results indicated that application of rice straw and compost significantly increased soil organic carbon, total nitrogen (SOC and TN) (P<0.05).Meanwhile, without RS and CM did not resulted in significant change in SOC and TN contents. The increase of SOM in RS, CM1 and CM3 also was observed in relatively compared with NPK control. It was

interesting that $\delta^{13}C$ of all treatments decreased annually, as the effects of RS, CM and the residue from rice plant. The high negative correlation of $\delta^{13}C$ values and SOC was found in this experiment, proving that $\delta^{13}C$ could be a SOM tracer. The change in $\delta^{15}N$ was not as clear as $\delta^{13}C$, but RS application led to decrease $\delta^{15}N$, while CM application tended to increase this value, compared to the rest of 5 treatments. Surprisingly, available P increased significantly in all treatments ($P<0.001$). In addition, an anaerobic incubation experiment was conducted in laboratory to identify the effects of long-term application of organic matter and mineral fertilizers application on the changes in soil C decomposition and N mineralization in a rice paddy. Decomposed C (CO_2 and CH_4 productions) and mineralized N (NH_4^+-N production) potentials were measured after 4 weeks anaerobic incubation of soil samples at 30℃ in submerged condition. The results showed that the mean ratio decomposed C to mineralized N (Dec-C/Min-N) lower as the application of organic matters after anaerobic incubation. The mean ratios of Dec-C/Min-N were varied from 5.6 to 6.2. The research gave us a better understanding of C decomposition and N mineralization after long-term organic matter and mineral fertilizers application.

For the third part: The results showed that the amounts of extracted organic carbon and nitrogen (EOC and EON) from hot water and water extraction had a high correlation with those in bulk soil, which increased with the organic matter application, compared to NPK treatment. The $\delta^{13}C$ values in HWEOC and WEOC ranged from -28.3 to -26.4‰, similar to the original rice straw and rice straw compost. There was no correlation between $\delta^{13}C$ values and amounts of HWEOC (or WEOC). Meanwhile, the $\delta^{13}C$ values in bulk soils ranged from -25.7 to -23.2 ‰, and decreased after long-term application of organic matters for both RS and CM treatments, compared to the NPK treatment. These results demonstrated that HWEOC and WEOC were originated from rice plants photosynthesis and the organic matter application, but not from the original bulk soil. The significant positive correlations between amounts of hot water or water extracted organic C (or N) and available N ($P<0.001$) implied that not only HWEOC, but also WEOC, HWEON and WEON could be used as integrated indexes for soil quality in this long-term experiment.

Conclusion and consideration

In conclusion, this study showed that the warming phenomenon had been observed in

four areas in Yamagata Prefecture, mostly happened in summer rather than winter. As the results, rice yields were affected strongly with the temperature in crop season (June-September), as well as in two growth stage of rice plant (Transplanting-Heading-Maturing) ($P<0.05$). The application of rice straw and compost increased SOM and soil fertility. Interestingly, stable $\delta^{13}C$ could be useful and sensitive carbon tracer, and affected by its C pools. More attentions should be paid on the labile pools of organic matter in long time duration.