Summary of Doctoral Thesis

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Title	Possible effects of a mud snail, *Cipangopaludina chinensis laeta*, and temperature on performance of rice plants and survival, development, and reproduction of other aquatic organisms

Introduction

The global warming is possible to alter the biotic and abiotic factor of ecosystem. Increased temperature of the water significantly affected the function of aquatic ecosystem (Walkuska and Wilczek 2010). Extensively applied conventional farming relying on inorganic chemicals brings negative consequences to the surroundings. Many studies revealed the positive correlation between pesticides exposure and cancer diseases in human. Currently, the awareness of the society to avoid contaminated food has been enhancing, for example, the increase of global organic products in the market by 43% for three years in 2005 and producers by 31% for only a year in 2009 (Willer and Yusefi 2007; Hamzaoui and Zahaf 2012). The transformation from conventional to environmentally friendly agriculture is one of possible solutions in reducing the adverse impacts of conventional farming on the environment. In environmentally friendly agriculture, the need of inputs such as inorganic fertilizers should be substituted by the substances which are based on living ecological systems (IFOAM 2005). Diverse aquatic organisms inhabited in paddy ecosystem (Fernando 1993) are potential instruments in providing bio-based nutrients positively affecting soil condition with ultimate impacts on the performance of rice plant. Previous study revealed that mud snails affected positively community structure of aquatic organisms and performance of rice plant (Dewi 2017). However, little is known regarding the mechanisms of the mud snails positively affecting the aquatic organisms.

The aim of this study was to understand the mechanism of how the mud snails and temperature affect the survival, development, and reproduction of other aquatic organisms and performance of rice plants.

Materials and methods

Two experiments were carried out at outside and in the laboratory. Firstly, the effects of ambient temperature and the mud snails on rice plant performance were examined in 2015 using a factorial experiment. The experiments with and without snails were conducted in both inside and outside a greenhouse at the Faculty of Agriculture, Yamagata University, Tsuruoka, Japan. Two hills, each containing 6 rice seedlings, were transplanted into a rectangle plastic container (Stack Container #25; Gurinparu), 450 mm in length, 300 mm in width, and 260 mm in height,

containing 11 kg of air-dried upland soil and 8000 ml tap water. The number of snails introduced into each container for snail treatment and no snail treatment was 6 and 0, respectively. Rice plant performance was assessed by measuring plant height, tiller number, and leaf color estimating leaf nitrogen.

Secondly, in order to understand the effects of temperature and mud snails on the survival, development, and reproduction of other aquatic organisms at individual, population, and community level, laboratory experiments were conducted. The effects of temperature and the mud snails on the biotic parameters of aquatic organisms and the possible mechanism influencing biotic and abiotic interactions were examined. Other aquatic organisms except the mud snails used for the experiments were sakamakigai and kawanina. Biotic and abiotic parameters were also measured in the experimental containers. The experiments used incubators (MIR-253; Sanyo) and a temperature and humidity controlled room. Rectangle plastic containers, 140 mm in length, 95 mm in width, and 155 mm in height were filled with 1400 ml of evaporated tap water. For individual level experiment, one adult sakamakigai, one adult kawanina, one adult mud snail and sakamakigai or kawanina were introduced into each plastic container. For population level experiment, two adults sakamakigai, two adults kawanina, one adult mud snail and two adults sakamakigai or two adults kawanina were introduced into each plastic container. For community level experiment, one male and three females of kawanina and four randomly chosen sakamakigai were introduced into each rectangle transparent plastic container, 225 mm in length, 165 mm in width, and 85 mm in height, of all three treatments. The number of the mud snail added in the treatment was 0, 1, and 2 individuals. The parameters observed were biotic and abiotic factors. The biotic factors include survival, body weight, and reproduction of sakamakigai, kawanina, and mud snails. The abiotic factors comprise organic matters from the organisms, chlorophyll content, nitrate, potassium, dissolved oxygen, pH, and water losses.

Results and Discussion

In first experiment, the presence of mud snails resulted in significantly increased plant height and SPAD value (reflecting leaf color) of the rice plants, although the tiller number was not significantly affected. The effects of temperature (high versus normal) on rice plant performance were assessed by the experiments inside and outside greenhouse. The results suggested that the effects of temperature differed among plant performances; plants grew taller but had fewer tillers when the rice was grown at high temperature, while SPAD was not significantly affected. Significantly more roots appeared on the soil surface when snails were present. In general, the mud snails resulted less excreta at high temperature than at normal temperature. The results of this study indicated that ambient temperature influenced rice plant performance both directly, and indirectly through the activity of the mud snails.

In second experiment, temperature did not affect biotic factors such as the survival, development, and reproduction of other aquatic organisms, while it influenced on abiotic factors at individual, population, and community experiments. On the other hand, the snails gave much influence on the biotic factors than abiotic ones. The similarity of the effects of temperature at individual, population, and community experiments was found in dissolved oxygen, pH, egg clutches of sakamakigai, and juveniles of mud snails. It was suggested that the effects of temperature on those parameters were not affected by increased number of species and

individuals. The difference in the effects of temperatures in individual, population, and community experiments was found in the organic matters, chlorophyll content, and potassium. In addition, the effects of temperatures on those parameters were affected by increased number of species and individuals. In terms of the effects of mud snails, the similarity was found in body weight of kawanina, organic matters, egg clutches of sakamakigai, and juveniles of kawanina suggesting that the effects of mud snails on those parameters were not affected by increased number of species and individuals. The difference was found in the survival of kawanina, body weight of sakamakigai, and nitrate, suggesting that the effects of mud snails on those parameters were affected by increased number of species and individuals. In general, the positive effects of both temperatures and mud snails on community level were seemed to be higher than on either individual or population levels. This was probably because the number of interactions among organisms affected by the number of both species and individuals was getting higher along the gradient of the experimental level.

In addition, this study clearly showed that in the community level mud snails significantly affected the performance of sakamakigai by increasing the survival, body weight, and number of its egg clutches. The enhanced organic matters and concentration of nitrate in the water were also affected by mud snails and the nutrients contained in the substances possibly support the performances of sakamakigai. Furthermore, decreased survival of kawanina, as affected by mud snails, in turn probably increased the performances of sakamakigai by reducing the competition.

Conclusion

This study suggested that one of possible mechanisms how mud snails positively influenced the community structure of aquatic organisms previously studied i.e mud snails provided suitable environment through supplying nutrients which are advantageous to the performance of other aquatic organisms e.g. sakamakigai. This study also revealed that the effects of temperature and mud snails were mostly significant in abiotic and biotic factors, respectively. The magnitude of those effects was different across the spatial levels suggesting that the number of species and individuals played an important role to construct the community structure in the aquatic ecosystem.

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