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博士論文の要約

博士の専攻分野の名称： 博士（農学）

氏名 ZHOU Zhiduo

学位論文題名

多数回中耕除草が無肥料無農薬水田における稲の収量および生育と養分動態
に及ぼす影響

Effect of inter-tillage weeding on rice yield and growth, and nutrient dynamics in paddy field
without fertilizers and agrochemicals

Introduction:

Almost half of the world's population eat rice as their staple food and the rice is planted by more than half of the world's farmers. People believe that a good yield in rice cultivation can be obtained only by using fertilizer and agricultural chemicals. However, excessive chemicals and fertilizers have been used every year and caused many problems, such as the damage of ecosystem and environment, health problems of farmers and consumers and raising cost in rice production to buy chemicals and fertilizers.

Inter-tillage weeding as an effective weeding method without chemicals application, is widely used in organic or natural rice cultivation. Inter-tillage weeding usually performs from about seven days to ten days after transplanting, until the heading stage. The topsoil (0-10 cm) is disturbed between rows of rice plants as they grow. After cultivation, the remnants of the weeds are mixed into the soil, becoming part of the nutrient source. In Japan, it was succeeded in getting a high yield in paddy fields by introducing inter-tillage without agrochemicals and fertilizers, which showed us the possibility to get high rice yield without fertilizers and agrochemicals application by conducting inter-tillage weeding. However, the mechanism of getting high yield by conducting inter-tillage weeding and the specific effect of inter-tillage weeding on rice yield change, rice growth change and nutrient dynamics in fertilizer-free and agrochemical-free cultivation (natural farming) has not been evaluated, especially in the initial several years after conversion from conventional field to natural farming.

In natural farming, rice straw was returned to the paddy field every year. In Hokkaido, the cold climate conditions limit the rice straw decomposition, and the incomplete decomposition

is harmful to rice growth. It has been reported that the inter-tillage weeding can increase dissolved oxygen content in ponded water in paddy field, which may promote organic matter decomposition in paddy fields in previous research. We assume the inter-tillage may also promote rice straw decomposition and nitrogen release. The objectives of this Ph.D study are to clarify the specific effects of multiple inter-tillage weeding on rice growth and yield, and nutrient dynamics after conversion from conventional field to fertilizer-free and agrochemical- free paddy field (natural farming).

Materials and Methods:

From 2018 to 2022, we have conducted field experiments at four treatments with three repetitions: no inter-tillage weeding (0-T), 2-time inter-tillage weeding (2-T), 5-time inter-tillage weeding (5-T), and conventional cultivation (CF). In 2022, three frames (CI) were set in inter-tillage field with agricultural chemical and fertilizer applications as control field. Rice yields, yield components and rice growth (SPAD, height, weight and number of tillering) were measured in plants. The pH, soil temperature, ORP, and Fe^{2+} concentration was measured to evaluate the effect of inter-tillage weeding on soil environmental condition. The nitrogen measurements included ammonium nitrogen, nitrate nitrogen, total nitrogen and dissolved organic nitrogen in soil solution, total nitrogen and exchangeable ammonium nitrogen in soil. The measurements of various forms of nitrogen aimed to evaluate the effect of inter-tillage on nitrogen cycle. Except for nitrogen, phosphorus, potassium, silica and other trace elements in soil or soil solution were also measured to evaluate whether above nutrients were sufficient for high rice production without fertilizer input.

In 2023, field and incubation experiments were conducted. In the field experiments, the rice straw was put into nylon bags with 2 mm holes and then put into the basket. The baskets were buried in soil between rice lines after transplanting. 0-, 2- and 5-times inter-tillage (0-T, 2-T, 5-T) were conducted in every basket with three repetitions for each treatment. In the incubation experiments: 0-, 3- and 5-time inter-tillage were conducted. Rice straws in nylon bags were put into the bottle with soil and incubated at 25°C under flooded condition. ORP in the soil was also measured by the sensor. In both field and incubation experiments, the rice straw in nylon bags were collected along with time, the residue weight and nitrogen concentration of straw were measured to investigate rice straw decomposition and nitrogen release amount from rice straw. All forms nitrogen in soil and soil solution (the same as that

from 2018 to 2022) were also measured to verify the effect of inter-tillage weeding on nitrogen cycles further.

Summary:

In 2018, the yields in inter-tillage fields were all higher than regional average (Ishikari area). Accumulated nutrients were sufficient for high yield rice production after conversion from conventional cultivation to natural farming. In 2019, the nitrogen content in soil and soil solution decreased a lot, which lead to dramatical decrease of yield. The significant difference in weed biomass was not observed among all inter-tillage treatments in both 2018 and 2019, the remained agrochemical residues in the field might still affect the weed growth for these two years. During these two years, the effect of inter-tillage on rice growth and yield was not observed.

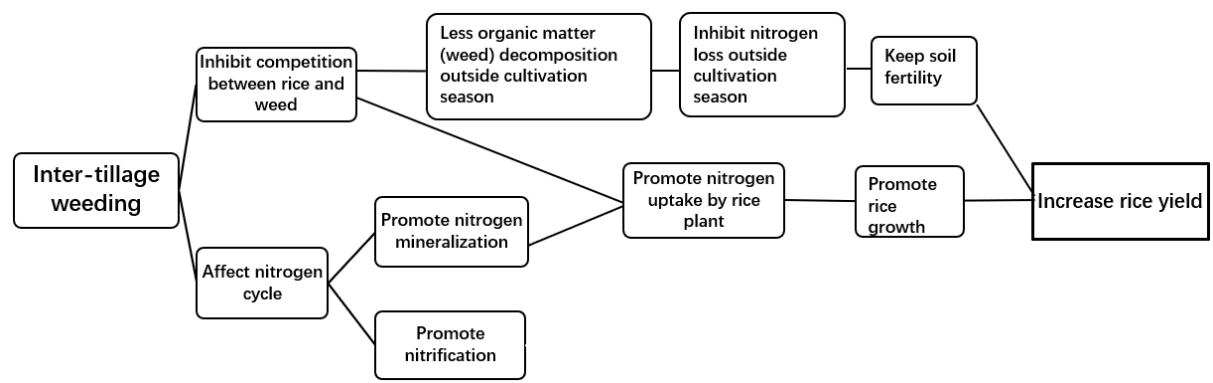


Fig.1. The mechanism of improvement on rice yield by inter-tillage weeding

From 2020 to 2022, inter-tillage can increase rice yield in natural farming and make the yield reach 80% of conventional cultivation, and the positive effects came from two parts, which are shown in Fig.1. The first one is to inhibit the competition between rice plant and weed, and the second one is to affect the nitrogen cycle.

Inter-tillage weeding can promote the nitrogen uptake and then lead to better rice growth by inhibiting the competition between rice plant and weed biomass from the tillering stage to panicle formation stage. In addition, from 2020 to 2022, the average ratio of inorganic nitrogen to total nitrogen in soil solution increased with higher frequency of inter-tillage during inter-tillage period. In 2023, the ratio of inorganic nitrogen to total nitrogen in soil solution in 5-T was significantly higher after July, indicated the improvement of multiple inter-tillage weeding on nitrogen mineralization, which will also provide more inorganic nitrogen which could be absorbed by rice plant directly after several years' constant rice straw

return, further promoting the nitrogen uptake. The better nitrogen uptake increases the yield with high frequency of inter-tillage weeding.

In soil and soil solution, inter-tillage weeding increased the ammonium nitrogen concentration by improving nitrogen mineralization in soil solution. Nitrification could also be promoted by inter-tillage weeding. In the field experiments from 2018 to 2022, the multiple inter-tillage (5-T) slowed down the fertility decrease. Since the significant promotion on nitrogen loss by inter-tillage weeding was not observed in the incubation experiments, the effect on nitrogen loss should be caused by the interaction of plant growth and inter-tillage weeding, especially the weed growth. Because the lower C/N ratio of weed (approximately 45) than rice straw (approximately 70), the weed would decompose faster than rice straw outside the rice growing season. From 2018 to 2022, the total nitrogen absorption amount by weed and rice was almost same in all inter-tillage treatments in each year, but in 0-T and 2-T, more nitrogen was absorbed by weed, the higher nitrogen absorption by weed in 0-T and 2-T will lead to more nitrogen release from weed residue outside season, which might cause the higher nitrogen loss.

In natural farming, the rice straw return supplies nitrogen for rice growth, but the nitrogen immobilization will occur from tillering stage to panicle formation stage, which will influence the rice growth. In Hokkaido, a part of nitrogen in rice straw could be released in the first season after the rice straw return and inter-tillage weeding promoted nitrogen release from rice straw significantly only at harvest. The C/N ratio of reminded rice straw residue was still high after the first season, indicated that the negative impact caused by nitrogen immobilization will still occur in the second season after return in cold climate region like Hokkaido.

Except for nitrogen cycle, there was no significant effect of inter-tillage weeding on potassium, phosphorus, silica and other trace elements concentration in soil. After five years of natural cultivation, all nutrients except for nitrogen were still sufficient for rice growth. Multiple inter-tillage weeding increased soil ORP under flooding condition but had no effect on soil physical properties.