THESIS SUMMARY

(Vietnam)

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Thesis Title

IMPROVEMENT OF RICE CROPPING IN SALINE SOILS IN THE NORTH CENTRAL COASTAL REGION OF VIETNAM

（ベトナム北中部沿岸部の塩性土壌地帯における稲作農業の改良に関する研究）

Thesis summary

1 General summary

In the north central coastal region of Vietnam, some agricultural land is seriously affected by soil salinization. Therefore, income of farmers in this region is very low. In order to increase income of farmers, the improvement of rice cropping in saline soils is a crucial and effective solution. To solve these needs, in my doctorate study program, I conducted two studies. The first study entitled *spatiotemporal variability of salinity and its effects on rice production* and the second study entitled *assessment of performance of newly introduced salt–tolerant rice varieties on saline soils*. The objective of the first study is to clarify the current status, variability, and mechanisms of soil salinity. The second study is conducted with a main aim to identify the newly introduced rice varieties that has higher yield than the local variety KD in the saline soils; this is one of an effective solution to promote rice yield in saline soils. In addition, the other aim of the second study is to determine the best yield indicators and quantify their contribution to yield, which can optimize selection of rice breeding lines for the region of the north central coastal of Vietnam.

2 Spatiotemporal variability of soil salinity and its effects on rice production

To clarify the current status, variability and mechanisms of soil salinity, I examined the spatial distribution and temporal variability of soil salinity in paddy fields and evaluated the influence of relative elevation in tens–centimeters scale, ECe, ECw and soil properties on rice yield. Experiments were conducted at 19 different paddy field plots distributed in Quang Phuoc commune, Quang Dien district of Thua Thien Hue province, in the north central coastal region of Vietnam.

Results of physicochemical analysis indicated that soil fertility of all soil samples was low

with pH of saturation paste (4.1 – 6.2), CEC (2.0 – 6.4 $cmol_c$ kg^{-1}), total C (7.8 to 15.2 g kg^{-1}), and total N (0.8 to 1.6 g kg^{-1}). Salinity of main irrigation rivers was low, ranging from 0.06 to 0.11 dS m^{-1}. In saturation extracts, main cations were Na^+, Ca^{2+}, Mg^{2+}; and anions were Cl^- and SO_4^{2-}. Na^+ and Cl^- are considered to be brought by the seawater intrusion. Based on the values of relative elevations and ECe of 19 representative plots, the research site can be divided into low– and high–elevation plots, with elevation of the low–elevation plots ranging from –0.52 to 0.07 m and the high–elevation plots from 0.26 to 0.86 m. The low–elevation plots distributed in the central part of the commune and along the lagoon, and the higher plots were along two main irrigation rivers. ECe and ECw in the high–elevation plots were less than 1.9 dS m^{-1}. Meanwhile ECe and ECw in the low–elevation areas were much higher than the threshold value of 1.9 dS m^{-1}, above which the rice growth is negatively affected. In both high– and low–elevation plots, ECe and ECw from May to September were much higher than in January and the differences between May and September were small. Rice yield in the summer–autumn cropping season was lower than in the winter–spring cropping season. Rice yield in summer–autumn cropping was negatively correlated with ECe (rs = –0.51, $P < 0.05$), while a non–significant correlation was observed in winter–spring cropping.

In conclusion, soils in research site were not suitable for rice growth (production), because of low soil fertility indicated by low pHe, CEC, total C, total N and high ECe. Although the differences in relative elevations between the 19 plots were very small (tens of centimeters), they can lead to large differences in soil salinity; ECe and ECw in the low–elevation plots were much higher than in the high–elevation plots. In the high–elevation plots, soils were irrigated by freshwater with low EC, and not considered to seawater intrusion; thus their ECe and ECw were kept low throughout the year. Because ECe levels were much lower than the threshold for rice growth of 1.9 dS m^{-1}, rice growth and production was not influenced by salinity. However, as introduced in Chapter 2, soils were poor in fertility, as indicated by the low pHe, CEC, total C, and total N; soil fertility is therefore also considered one of the main factors limiting rice production in the high–elevation plots, even if soil salinity is not a serious problem. In the low–elevation plots, soils were subject to seawater intrusion, thus their ECe and ECw were much higher than the threshold value of 1.9 dS m^{-1} for rice growth and soils also had poor fertility; hence, rice yield at the low–elevation plots was considered to be affected by soil salinity, in addition to inherently low soil fertility. Salinity level of soil solution from May to September was the highest in year, which is considered to be caused by seawater intrusion due to the shortage of irrigation water, high temperature, and high surface water evaporation rate during this period.

3 Performance of newly introduced salt–tolerant rice cultivars on saline soils

To increase the yield of rice in the region of the Thua Thien Hue Province, high–yielding varieties can be cultivated instead of low–yielding local rice varieties. However, it is time–consuming and expensive to breed new high–yielding salt–tolerant varieties for specific regions. The most effective strategy, therefore, is to introduce high–yielding, salt–tolerant varieties that have been bred and/or cultivated in other regions to the Thua Thien Hue Province. To achieve

this objective, I evaluated the performance of 13 newly introduced, high–yielding, salt–tolerant rice varieties and one local variety KD on saline soils. Although the correlations between rice agronomic traits and yield have been intensively studied, there have been no reports on these relationships for the new rice varieties cultivated in this province. Therefore, it is important to analyze the relationships between various rice traits and yield to identify the best yield indicators and their contributions to yield. This information can be used to select the best breeding lines to cultivate in the north central coastal region of Vietnam.

Among the 14 studied rice varieties in the seven field experiments, only MNR3 and OM5629 in experimental plot A (2013 winter–spring cropping season; ECw from 3.9 to 4.5 dS m^{-1}) showed significantly higher yields per plant than that of the local variety KD (16.5 g and 15.3 g compared with 8.3 g, respectively). The other varieties showed low yields per plant (9.0 – 13.5 g). In the statistical analysis performed using all the values of three experimental plots in the winter–spring cropping season, the five newly introduced rice varieties of MNR3, MNR4, OM4900, AS996, and OM2395 recorded significantly higher yields per plant, that is, 16.9 g, 16.2 g, 15.6 g, 15.5 g, and 15.4 g, respectively, than that of the local variety KD, 10.9 g. In contrast, the analysis including all the experimental plots did not give any statistically significant difference for yields per plant between thirteen newly introduced rice varieties and local variety KD in the summer–autumn cropping season. The yield per plant of the 14 studied rice varieties in the other six experimental plots was not significantly different from that of the local variety KD. Yield per plant or per hill were positively correlated with five traits; number of productive tillers, panicle weight, number of filled grains, total biomass, and harvest index. The number of grains per panicle and grain fertility were also positively correlated with yield per plant or per hill, but the correlations were weaker (r = 0.2 to 0.4), except for grain fertility in experimental plot C (r = 0.5*** in the 2012 summer–autumn cropping season). Plant height, panicle length, and 1,000–grain weight were not significantly correlated with yield per plant.

In conclusion, since the newly introduced rice varieties of MNR3, MNR4, OM4900, AS996, and OM2395 produced higher yields per plant than that of the local variety, we propose that these five newly introduced rice varieties are suitable for cultivation in saline soils in the winter–spring cropping season in the north central coastal region of Vietnam. In addition, the newly introduced rice variety of OM5629 produced greater yields per plant than that of the local variety KD only in the experimental plot A (winter–spring 2013, ECw from 3.9 to 4.5 dS m^{-1}). Therefore, OM5629 may be suitable for cultivation under the condition of saline soils with ECw $\leq$ 4.5 dS m^{-1} in the winter–spring cropping season. None of the 13 new rice varieties can be suggested as new varieties for cultivation on saline soils in the summer-autumn cropping season in this region; This is because the high ECw, low soil fertility, and low pH (summer–autumn cropping season) resulted in low yields for all of the studied rice varieties. My results of correlations between yield and various agronomic traits showed that, under these conditions, yield was positively correlated with five traits: number of productive tillers, panicle weight, number of filled grains per panicle, total biomass, and harvest index. As these correlations were observed in all seven experiments, I conclude that these five traits are the best yield indicators,

and contribute more to yield than do the other agronomic traits. Therefore, I suggest that these traits should be used to select the best rice varieties for cultivation in this region, which is characterized by sandy loam saline soils with low pH and poor in fertility.

4 Solutions to mitigate the unfavorable effects of salinity and promote rice cropping

Based on these results, some solutions are recommended to mitigate the unfavorable effects of soil salinization and promote rice cropping. A dike with sluice gates stretching along the lagoon was constructed from 1994 to 1995 for preventing saltwater intrusion from the lagoon onto land; however, there are some sections of the dike that haven't been constructed, because of the financial constraints. Therefore, a complete dike system has to be constructed along the lagoon to completely prevent seawater intrusion onto land. Second, because there are difficulties associated with draining in the depression plots, it is necessary to construct adequate drainage facilities to promote rapid drainage of water into the canals during and after flooding and irrigation in these plots. Third, because ECe and ECw increase from May to September, appropriate fresh irrigation water should be supplied frequently for rice fields to lower the ECe and ECw during this period. Farmers must maintain appropriate freshwater levels on the rice fields to compensate for the water lost by evaporation when high air–temperature. In addition, the irrigation freshwater quantity in the rivers must be provided appropriately to push back the saltwater intrusion from lagoon, thus famers can use freshwater for their fields. Fourth, since soil fertility was poor with low organic matter content and low pH, application of organic fertilizers and lime should be repeated annually over a long time period (Corwin and Lesch, 2003). Finally, regarding improving rice breeding: at present, farmers in the Quang Phuoc commune are cultivating the low–yielding local rice variety of KD. Hence, to increase rice yield and income of farmers, this local variety need to be replaced by the six newly introduced rice varieties of MNR3, MNR4, OM4900, AS996, OM2395, and OM5629. However, the newly introduced rice variety of OM5629 may be suitable for cultivation under the condition of saline soils with ECw ≤ 4.5 dS m^{-1} in the winter–spring cropping season.