論文の内容の要旨

生産・環境生物学　専攻
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論文題目 Effects of salinity intrusion on rice production in Red River Delta, Vietnam
− a case study of adaptation at 2 contrasting estuaries for sustainable development－

(ベトナム紅河デルタでの塩水遡上の稲作への影響 – 持続可能な開発のための対照的な 2 つの三角江での適応の事例研究ー）

Seawater intrusion has potential negative impacts on rice production in Red River Delta (RRD), but its spatial variation had not been reported. There were technical limitations of rice production, included (1) high dose of N fertilizer which could be inefficiently used, (2) lower yield due to salinity but no resistant varieties used, and (3) reduction in the water availability for irrigation which can put rice production into the critical status. In additions, converting paddy fields into aquaculture pond were observed in RRD but the effectiveness of this conversion, as well as the effect to rice cultivation, had not evaluated in the relationship with salinity level. This research, therefore, aimed to quantify effects of salinity intrusion on grain yield variation between two estuaries, and within an estuary (Chapter 2); identify technical adaptations to improve rice production (Chapter 3); and analysing effects of salinity on economic efficiencies of rice and aquaculture production (Chapter 4) in RRD.

The on-farm surveys were conducted in total 63 farmer fields in 6 cropping seasons in 3 years to collect all the information about irrigation salinity dynamism, rice management and rice yield. These data were used to analyse salinity impact on rice yield and identifying current problems in rice production in RRD. In order to identify feasible technical adaptation in response of salinity intrusion (increasing salinity, reducing water irrigation) and overused N fertilizer, a series of on-farm experiments were set up in farmer fields (Salinity resistant varietal trial; Water-saving

irrigation trial; survey of Nitrogen use efficiency in farmer fields and fertilizer response trial) in 4 cropping seasons and 3 communes. Finally, a questionnaire survey to collect input and output information on rice and aquaculture cultivation on 311 households with 473 rice fields and 572 aquaculture ponds were conducted.

Salinity intrusion in RRD was spatially and seasonally variated (Chapter 2). The effect of seasonal rainfall pattern (Fig 2.1) caused higher salinity in spring (0.82‰) than in summer (0.32‰). Using 2 estuaries as a case study, we have drawn the contracting picture of the spatial variation in its salinity intrusion intensity. Salinity intrusion to Day estuary (12± 5.7‰ in January at Nam Dien watergate) were higher than in Ba Lat estuary (7.7± 6.1‰ in January at Ngo Dong watergate), leading to higher salinity in the irrigation system of Nam Dien (1.1± 0.3‰ in spring and 0.6± 0.3‰ in summer rice) than in Giao Huong and Giao Thien (0.8± 0.3‰ in spring and 0.2 ± 0.2‰ in summer). The difference between tow estuaries also came from the difference in irrigation management. In Day estuary, where rice and aquaculture practice parallelly inside the dyke, water was intake directly in the nearby water gate with higher salinity water, maybe due to the preference of aquaculture farmers, thus saline stress happens frequently in the year. In Ba Lat estuary, where only rice was cultivated inside the dyke, water was intake by a further upstream gate with lower salinity water, hence saline stress only happened at the beginning of the season. Consequently, GY in ND were reduced by 152 g/m^2 in summer rice and 184 g/m^2 in spring rice. compare to that in GH and GT. The severe salinity intrusion caused rice cultivation discontinuous in ND site while no or litter impact in GH and GT.

Within one estuary, salinity variation among field groups caused by field distance to the dyke or aquaculture area. Salinity was higher in fields near to the dyke or aquaculture area called at-risk fields (0.6‰) than in the other fields which named save fields (0.54‰). At-risk field, in addition, due to its location, was characterised by less soil fertility, higher sand content and higher water depth in the summer, resulting a lower yield (558 g/m^2) than the save fields (649 g/m^2). As adaptations, in at-risk fields, the farmers planted hybrid varieties in spring and tall local varieties in summer; and given smaller amounts of N fertilizer application particularly in summer.

N fertilizer in farmer fields was both overused and low efficiency. N fertilizer dose was high at 218 kg/ha in spring and 185 kg/ha in summer. NUEs were low in general, and spatial variated; e.g, N recovery efficiency (RE, g grain GY obtained per g N fertilizer applied) were higher in spring at 0.27, compared to summer at 0.23, particularly low in at-risk fields (0.19) (Table 3.9). The optimal dose of N fertilizer was 120-180 kg/ha and 100-150 kg/ha for spring and summer rice, respectively without yield penalty in GH, GT meanwhile achieved high values of NUEs.

Shallow water depth irrigation (<5 cm) could maintain a similar level of yield as compared to farmer conventional irrigation management under less-saline conditions (GH, GT fields), but resulted in yield reductions in high saline ND field. The two salinity resistant varieties M2, M14, which were claimed can resist salinity up to 3-5‰ had a lower yield potential than conventional variety in non-saline condition (632 g/m^2, 618 g/m2 vs 751 g/m^2 in safe field in GT) (Table 3.4), but achieved higher GY in high saline-stress condition of ND at 522 g/m^2, 539 g/m^2 compared with conventional variety at 348 g/m^2. These results demonstrated the possibility of systematically applying technical adaptations in RRD to adapt to salinity intrusion problem, but also reducing inputs and increasing the economic efficiency of rice production

Another strategy for salinity intrusion could be diversifying land use pattern. Our results showed that coastal aquaculture generated a much higher income (3592 ± 7672 USD/ha/year) and employment (496 ± 362 manday/ha) than rice (1655 ± 581 USD/ha/year; 122 ± 37 manday/ha). However, the profit was higher in rice (436 ± 541 USD/ha/year) at the average salinity level of 0.4 ± 0.2‰ than aquaculture (109 ± 7853 USD/ha/year) at the average salinity level of 9 ± 8 ‰. Salinity reduced rice profit and is one of the most determining factors of rice profit meanwhile had no impact on the profit of freshwater marine aquaculture. Increasing in salinity reduced rice profit meanwhile have no impact on the profit of freshwater marine aquaculture. At average salinity 0.5‰, rice and aquaculture profit were equal, while at higher salinity (>0.5‰) aquaculture proved a higher profit and could be a potential adaptation to the negative impact of salinity on rice.