Rice production response and technological measures to adapt to salinity intrusion in the coastal Mekong delta

Dang Kieu Nhan[1], *Vu Anh Phap*[2], *Tran Huu Phuc*[2] *& Nguyen Hieu Trung*[3]

[1] *Agricultural Systems Department, Mekong Delta Development Research Institute, Can Tho University (CTU)*
[2] *Crop Resources Management Department, Mekong Delta Development Research Institute, CTU*
[3] *College of Environment and Natural Resources Management, CTU*

Abstract

This report analyses the effect on yield and economic return of salinity-tolerant rice varieties and good farming practices, and suggests strategies for food production to adapt to salinity intrusion in the coastal Mekong delta. Official statistical data and primary data from recent projects in the Mekong delta were analyzed. Results showed that for areas with salinity level of up to 4‰, the growing of rice varieties tolerant to salinity and the application of appropriate agro-chemicals could help farmers maintaining their rice production and income. For salinity levels exceed 4‰, the conversion of rice culture to rice - shrimp rotational farming is an adaptation strategy to improve farmer's income and livelihoods. For national food security goals, rice production could be given to upper and mid-delta areas. Development of good farming technologies, improvement of agricultural extension and development of small-scale irrigation structures are investment priorities to further improve current farming systems and livelihoods of farmers in the coastal Mekong Delta.

1. Introduction

Soil and water salinisation in the dry season is a problem for crop production in the coastal Mekong Delta (Tuong et al., 2003; Carew-Reid, 2007). Annually, around 1.8 million ha is subject to dry season salinity (Carew-Reid, 2007; MRC, 2010), of which around 1.3 million ha is affected by saline water above 5 g/l (Figure 1). During low river flow periods between March and April, saline water intrudes up 40-50 km inland from estuaries through main river systems (White, 2002; Sam, 2006). Rice losses by salinity take place with both high-yielding rice (in double or triple rice cropping systems) and traditional rice (in rice - shrimp rotational farming system). The rice damage by salinity becomes more severe in case of a drought in the early or late periods of the rainy season. The Vietnamese Ministry of Agriculture and Rural Development (MARD, 2011) reported that, out of 650,000 ha of high-yielding rice grown in the lower delta, annually about 100,000 ha of rice is highly risky to dry-season salinity intrusion.

The Mekong delta has been considered as the important rice production region for national food security. Accordingly, about 1.8 million ha of agricultural land in the delta has been set aside for rice production to annually produce about 23 million tons of rice for domestic consumption and exports. In last decades, the Vietnamese government has put a massive investment into the development of salinity-control structures to expand rice production in coastal region in the delta, contributing to a jump in rice production at the cost of environmental degradation and declining natural aquatic resources, eroding livelihoods of poor people (Nhan, unpublished data). Since 2000, facilitated by the Government's agricultural diversification policy, farmers in the lower delta have shifted rice monoculture (under salinity control) to a more adaptive farming system with shrimp farming in the dry season (using saline water from the sea) followed by cultivating rice in the wet season (using rainfall). In 2008, around 700,000 ha were devoted to shrimp production (CSO, 2010), and some 120,000 ha were practicing with rice and shrimp in rotation (Pham Van Du, 2009). It has been planned to expand rice-shrimp area to 200.000 ha in the coming years (Pham Van Du, personal communication). In this system, farmers use rain water to desalinate the top soil layer of the field before rice crop establishment. The rice crop however could suffer from salinity if droughts set in while salinity levels in canal water remain high.

Rice farmers in the coastal Mekong delta have experienced the problem with salinity for decades. The problem, however, would become more severe and unpredictable in the future driven by extreme weather events, Mekong river flow alteration, and sea level rise (Carew-Reid, 2007; ADB, 2009; Nhan et al., 2011a). The Vietnamese government has released the national strategic plan to respond to climate change (MONRE, 2008). The Vietnamese Ministry of Agriculture and Rural Development (MARD) has released an action plan to respond to climate change for agricultural and rural development in the period of 2008-2020 (MARD, 2008). Accordingly, major mitigation measures include: (1) development of large-scale salinity management structures (i.e. dikes, sluices and reservoirs), (2) development of small-scale irrigation infrastructures (i.e. canals, sluices, pumping stations), (3) development of adaptive farming technologies (i.e. crop varieties, farming techniques and farming systems), (4) enhancement of human capacity, and (5) improvement of policy systems and institutional arrangements. However, there have been arguments for approaches and investment priorities to adapt to potential salinisation to safeguard food production and sustain livelihoods of farmers. In this report, we have attempted to test if adaptive rice farming technologies can play an important role and if they need to be paid more attention in designing adaptation plans in response to salinisation in the delta. By integrating and analyzing both primary and secondary data, this report presents yield performance of different rice varieties and the effect of adaptive farming practices on yields and income in saline environments. Findings are then translated into policy implications for adaptive rice production in the context of climate change and sea level rise in the Mekong delta.

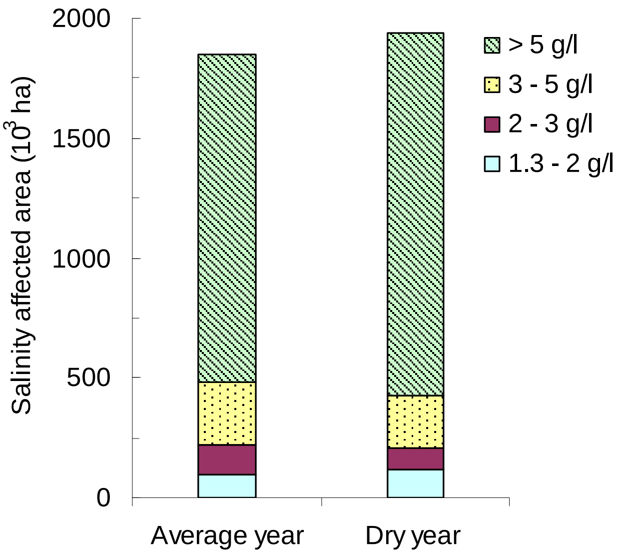

Figure 1: Salinity affected area in different hydrological years in the Mekong delta (drawn from data in MRC, 2010).

2. Study scope, data sources and analysis

The present study has focused on four major points: (1) identification of drivers of rice cropping patterns and rice damage by salinity, (2) evaluate salinity response of rice varieties, (3) evaluate the effect of rice farming practices on rice yield and income under saline conditions, and (4) comparing rice production and economic return between major rice-based farming systems in coastal provinces of the Mekong Delta.

For identifying drivers of rice cropping patterns and rice damage by salinity, we reviewed literature, analysed official statistical data and own field records. Data on canal water salinity and rainfall were obtained from Provincial Department of Agriculture and Rural Development, and Provincial Statistical Offices in 2010 and 2011. For evaluating the effects of rice varieties and farming practices, we analysed primary data collected from different projects on rice variety selection, and on rice farming technology development for salinity-affected areas in the Mekong delta, which were funded by the Ministry of Education and Training, the Mekong Delta Development Research Institute, coastal delta's provinces (Soc Trang, Ben Tre, Ca Mau and Kien Giang), and agro-chemical companies. The data were obtained from both on-station and farmer's field trials in the period of 2005 – 2010. For comparing rice production and economic returns of rice-based farming systems, we analysed household's survey data in 2008 and 2010 obtained from projects funded by SEI-Asia and the World Bank.

Analysis of variance and *post-hoc* Tukey HSD tests were applied to test for the effect of rice varieties and farming techniques. Univariate regression was used to evaluate yield response of different rice groups to salinity.

3. Results and discussions

3.1. Drivers of rice cropping patterns and rice damage by salinity

In the coastal delta, cropping patterns and rice damage are strongly driven by level and timing of salinity intrusion, amount and timing of rainfall, water structures, food security policy, and farm income. Salinity level and rainfall distribution are negatively related. Rainfall is low in the dry season (December – April), when salinity level in canal water is high (January – June) and vice versus (Figure 2). Canal water salinity concentrations increase progressively and reach a peak level in April – May, when the Mekong flow is lowest. Salinity level and timing at a certain location depends upon the distance to estuaries, canal systems and the availability and/or the operation of salinity-control structures.

Three dominant farming systems are practiced: (1) two or three rice crops per year, (2) rice – shrimp rotational farming, and (3) shrimp farming alone (Figure 2). The first farming system is common in areas with relatively high elevation and some distance from estuaries, having salinity-control structures (salinity duration < 3 months). The second farming system is dominant in low-lying areas with salinity-control structures and saline water duration of up to 8 months. The last farming system is practiced in low-lying areas with saline water duration of more than 8 months, because of the proximity to estuaries and/or the lack of salinity-control structures. Implementing the first farming system, farmers have grown high-yielding rice varieties, while the second farming system is linked to traditional rice varieties, which are relatively tolerant to high water depth. Most likely, salinity damages rice growth in particular during early and late periods of the rainy season, due to low rainfall and slow soil desalinization and/or salinity intrusion from estuaries. This pattern is in particularly relevant for traditional rice cropping in a rice-shrimp farming system, where salinity remains high in early stages of the crop, due to the lack of freshwater to wash out soil salinity (Figure 2).

Intensive rice production had been commonly practiced before 2000, as the result of the food security policy of the government. Since 2000, with the promotion of agricultural diversification by the government, farmers have shifted intensive rice production to shrimp farming alone or in the rotation with rice to improve farm income. Consequently, area under shrimp farming has increased by 7% per year in the period of 2000 and 2008 (calculated from CSO, 2010), and rice farming area has reduced proportionally (Figure 3). In the same period, however, fruit and upland crop farming did not change much. Implementing national food security policy, the state government secures a certain area of each coastal province for rice production. Additionally, increasing rice prices have further extended the area of three rice crops per years.

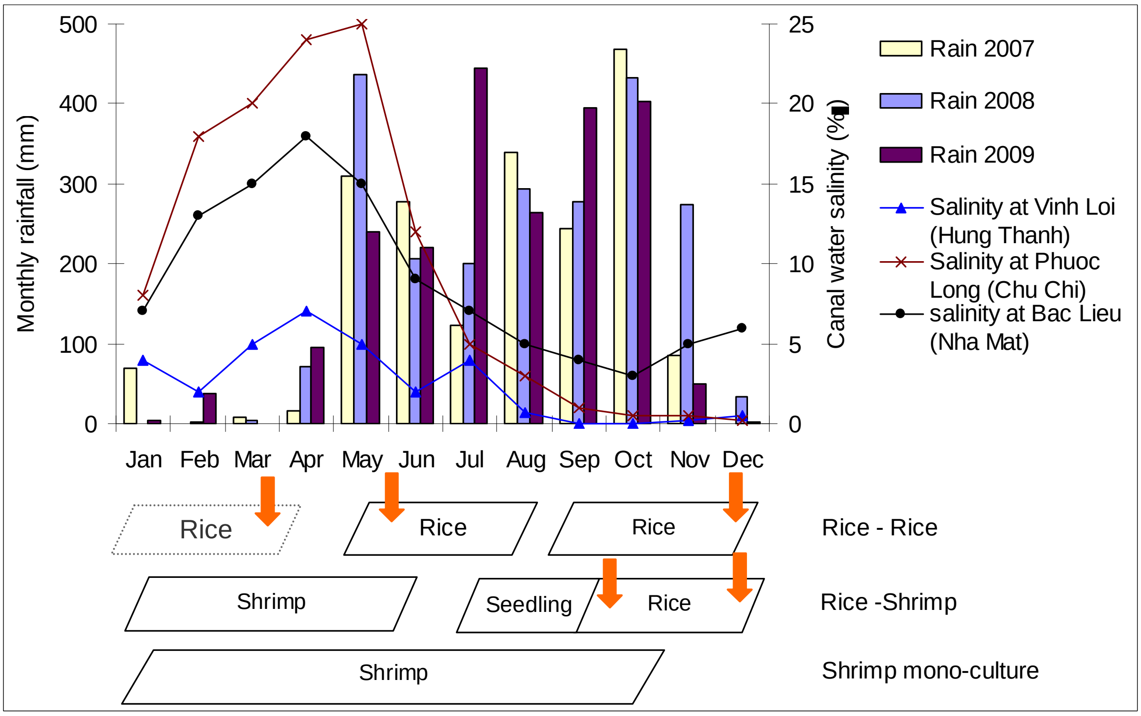

Figure 2: Rainfall distribution, salinity trends and major farming patterns in coastal Mekong Delta. Downward arrows present salinity stress timing of rice crops (drawn from data records of Department of Agriculture and Rural Development and Statistical Office of Bac Lieu and Soc Trang provinces).

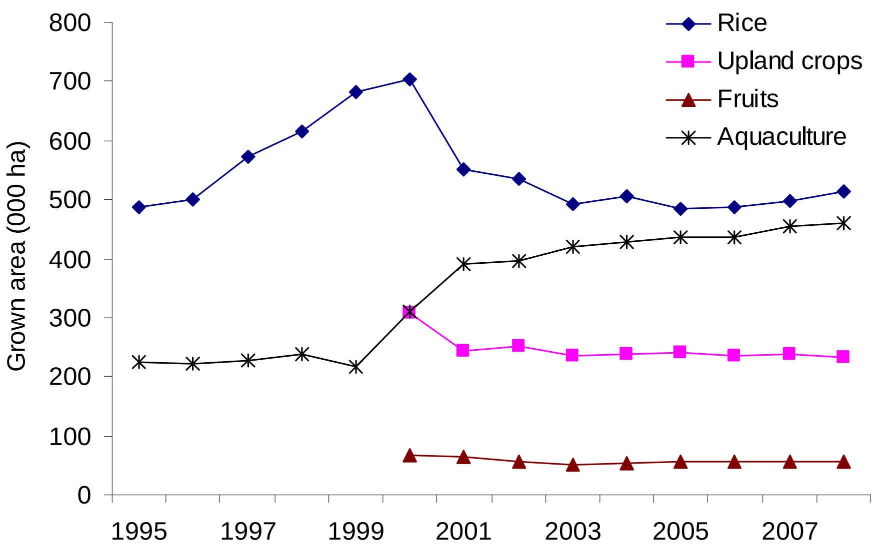

Figure 3: Trends in agricultural land use in coastal provinces: Tra Vinh, Bac Lieu and Ca Mau (drawn from census data in CSO, 2010).

3.2. *The effect of rice variety*

High-yielding rice varieties

In double (or triple) rice farming system, farmers have grown high-yielding rice varieties with short-growth duration (95 – 105 days). Spot experiments conducted in green/net-house conditions in 2006 and 2009 tested the effect of salinity level and stress timing on yields and yield components of different rice varieties (Table 1). Results show that rice varieties respond to salinity differently. The salinity sensitivity of a rice variety is not only determined by the salinity level but also by the salinity stress time. Salinity stress (concentration of 3‰) during tillering and heading stages influenced rice yields and yield components (number of panicles, filled grains, and grain weight), even with salinity-tolerant varieties (Table 1). Under salinity level of 3‰, rice yields reduced by 20-45% when salt stress occurred during the tillering stage and by 10-40% if salt stress occurred during the heading stage. Yield reduction became more severe with salinity 6‰ at the tillering stage. The effect of salinity stress at heading stages was not clear with rice varieties IR28, MTL119 and MTL547. These findings imply that salinity tolerance (sensitivity) of a rice variety differs with salinity stress timing and duration. Rice plant is more sensitive to salinity during seedling, panicle initiation and flowering stages than other stages (Yoshida, 1981; Zeng et al., 2001; Grattan et al., 2002). More on-station and field trials are needed to test for salinity response of salinity-tolerant rice varieties at different salinity stress timings to provide farmers good rice varieties under specific salinity conditions. An emerging question is whether farmers should change rice varieties with different salinity-tolerance characteristics for every crop in the year, because salinity timing differs with crops. Such a strategy requires ways to provide cheap rice seeds to farmers.

The effect of salinity on yields and yield components of the tested rice varieties was evaluated under field trials conducted in 2009 in Soc Trang province. Under field conditions in the dry season crop, soil salinity (layer 0-5 cm) increased gradually from around 1‰ at the early stage (i.e. September - October) to around 2‰ at the late stage of the crop (i.e. November – December) (Figure 4). In contrast, in the wet season, soil salinity in the same depth decreased gradually from around 2‰ at the beginning (i.e. May – June) to 1‰ at the end of the crop (i.e. August). Unlike the results obtained from spot experiments aforementioned, these relatively low salinity level affected yields differently depending on rice varieties (Table 2). Such low salinity levels caused during the early or late stage of cropping reduced yields by about 35% for sensitive (i.e. IR28) and moderately tolerant rice varieties (i.e. MTL 547) but only by 10% for the salinity-tolerant variety Tep Hanh DB. Fewer filled grains per panicle is the effect of salinity and the major reason of lower yields of the varieties less tolerant to salinity. In both greenhouse and field studies, Grattan et al. (2002), Motamed et al. (2008) and Clermont-Dauphin et al (2010) found that the number of filled grains per panicle and grain weight are most sensitive yield components to salinity.

Results from a multi-location testing programme showed the significance of growing rice salinity tolerant rice under saline-affected conditions in the coastal Mekong delta (Table 3). Under saline soils of 1.5 – 3‰, on average, varieties sensitive and moderately tolerant to salinity yielded about half and 80% of what tolerant varieties yielded. On average, under saline conditions rice varieties suffered a yield loss around 50%, 30% and 10% of their potential yields for varieties sensitive, moderate-tolerant and tolerant to salinity. Under freshwater conditions, the rice varieties yielded the same. It means that, under conditions with the salinity ≤4‰, if farmers grow salinity-tolerant rice varieties, they would gain 1-2 tons rice per ha per crop, compared to growing salinity-sensitivity rice varieties. Therefore, strategies for further improving variety selection, rice seed supply systems and agricultural extension work need to be identified.

Table 1: The effects of salt stress timing on yield components of rice varieties with different level of salinity tolerance[1]

Varieties[2]	Salinity[3] (‰)	Salt stress at tillering stage[4]				Salt stress at heading stage[5]			
		Panicles/ plant	Filled grains/ panicle	1000-grain weight (g)	Grain weight/ plant (g)	Panicle/ plant	Filled grains/ panicle	1000-grain weight (g)	Grain weight/ plant (g)
Experiment in 2006									
IR28	0	7.2	71	26.9	13.1	9.7	53	27.3	13.9
	3	8.6	53	24.7	10.7	8.9	58	26.9	13.7
	6	7.1	47	23.2	7.3	9.5	58	26.7	14.7
MTL119	0	7.7	88	31.7	21.1	10.3	46	26.9	12.7
	3	7.5	71	28.5	15.0	9.7	40	26.3	10.1
	6	7.8	64	26.0	12.6	11.0	42	26.6	12.3
Experiment in 2009									
IR28	0	7.5	53	24.0	9.4	6.4	58	21.9	8.4
	3	5.5	60	21.1	6.9	6.2	52	21.4	6.6
MTL547	0	6.0	69	26.7	11.0	6.3	56	25.2	8.6
	3	5.2	61	20.3	6.4	5.4	55	24.3	7.9
Tep Hanh DB	0	7.2	68	22.2	11.0	6.3	60	23.3	9.3
	3	5.7	56	19.0	6.0	7.1	48	19.4	5.7

[1] Source: Spot experiments were conducted by Vu Anh Phap (experiment in 2005; Phap, 2006), and Vu Anh Phap and Nguyen Thi Bap (2009)
[2] IR28 was considered salinity-sensitive, MTL547 was considered moderate salt-tolerant, MTL119 and Tep Hanh were considered salinity tolerant
[3] Salinity measured in soil layer 0-5 cm
[4] Salt stress at the stage of 30 – 50 days after seeding (DAS)
[5] Salt stress at the stage of 70-80 DAS.

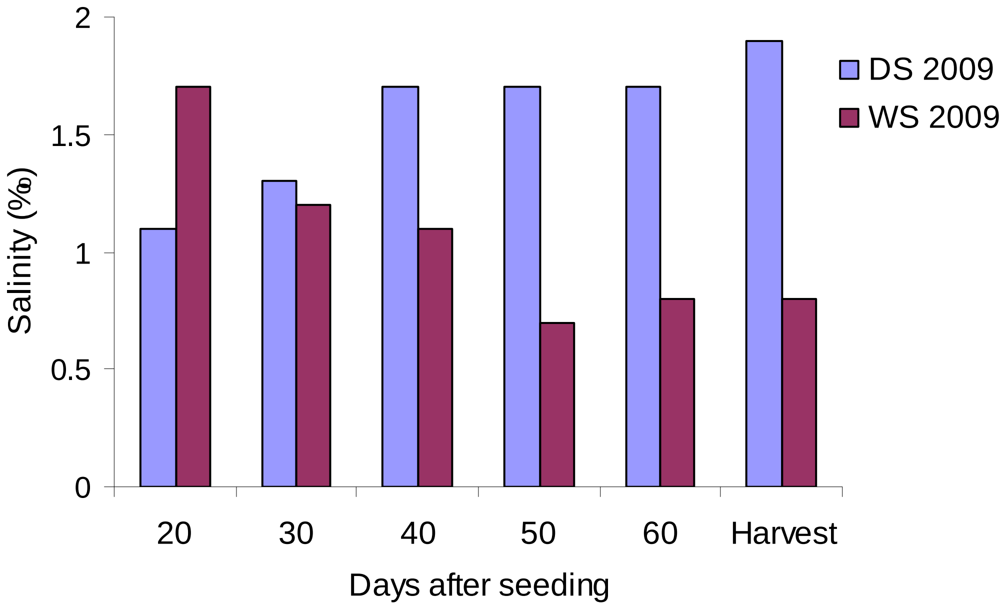

Figure 4: Soil salinity (‰, in layer 0- 5cm) at different stages of rice crops grown in the dry and wet season in 2009 in Long Phu district, Soc Trang province. Source: Drawn from data collected by Vu Anh Phap and Nguyen Thi Bap (2009).

Table 2: Yield performance of different rice varieties under salt-affected fields in Long Phu district, Soc Trang province in 2009

Varieties[1]	Panicles/m^2	Filled grains/ panicle	1000-grain weight (g)	Yield (tons/ha)
Dry season crop				
IR28	358[a]	42[a]	25.1[a]	3.0[a]
MTL547	352[a]	56[b]	25.1[a]	4.1[b]
Tep Hanh DB	368[b]	63[c]	25.5[a]	4.5[b]
Wet season crop				
IR28	295[a]	40[a]	24.6[a]	3.7[a]
MTL547	296[a]	59[b]	26.0[b]	5.1[b]
Tep Hanh DB	255[b]	56[b]	26.1[b]	5.7[b]

Source: Based on primary data collected from Vu Anh Phap and Nguyen Thi Bap (2009)
[1] IR28 is considered salinity-sensitive, MTL547 is moderate salt-tolerant, and Tep Hanh is salinity tolerant
In the same column for each crop, means followed by the same superscript (a, b or c) do not differ with Tukey HSD test at 5% significance.

Table 3: Multi-location field trials on yields (tons ha^{-1}) of rice varieties with different salinity-tolerance level in the Mekong delta in 2005 – 2010.

Year	Sites	Salinity (‰)	No. of tested varieties			Yield		
			Sensitive	Moderate tolerant	Tolerant	Sensitive	Moderate tolerant	Tolerant
2005	Soc Trang	1.5	7	16	13	2.7 ± 0.3^a	3.9 ± 0.1^b	4.7 ± 0.1^c
2006	Kien Giang	1.5	3	8	13	1.5 ± 0.2^a	2.4 ± 0.1^b	3.1 ± 0.1^c
	Soc Trang	1.5	10	13	8	2.8 ± 0.1^a	4.0 ± 0.1^b	4.8 ± 0.1^c
2006	Ben Tre	2.0	6	7	7	2.0 ± 0.1^a	2.8 ± 0.1^b	3.5 ± 0.2^c
2007	Soc Trang	2.0	17	15	11	2.9 ± 0.1^a	4.0 ± 0.1^b	4.9 ± 0.1^c
2008	Ben Tre	2.0	3	8	7	3.1 ± 0.1^a	3.8 ± 0.0^b	4.3 ± 0.1^c
2009	Soc Trang	2.0	8	23	25	2.3 ± 0.1^a	3.8 ± 0.1^b	5.0 ± 0.2^c
	Soc Trang	7.0	6	5	7	0.4 ± 0.1^a	1.2 ± 0.1^b	2.4 ± 0.4^c
2010	Soc Trang	3.0	0	7	11	-	4.0 ± 0.0^b	4.7 ± 0.1^c
2005-2010	Average					2.5 ± 0.1^a	3.6 ± 0.1^b	4.4 ± 0.2^c
2006-2010	Multi-location testing	< 0.5	18	37	41	4.7 ± 0.1^a	4.9 ± 0.1^a	4.7 ± 0.1^a

Source: calculated from Phap's raw data

In the same row, means followed by the same superscript (a, b or c) do not differ with Tukey HSD test at 5% significance.

Figure 5 shows rice yield responses to salinity for different rice varieties, regardless of dry season or wet season. Regression equations presented in Figure 5 show the potential yield of rice varieties of around 5 tons per ha per crop under freshwater conditions. The potential yield reduces by 0.2, 0.9 and 1.4 ton per ha per crop for every unit (1‰) increase in salinity with tolerant, moderate tolerant and sensitive varieties. The results from Figure 5 show that the yield of salinity-tolerant varieties did not reduce significantly with salinity level up to 2‰. These results could be comparable with those found by Asch and Wopereis (2000). They reported that rice yields reduce by 0.4 – 0.6 ton/ha per 1‰ increase in water salinity for salinity levels above 1.3‰ (1‰ = 1.5 dS/m).

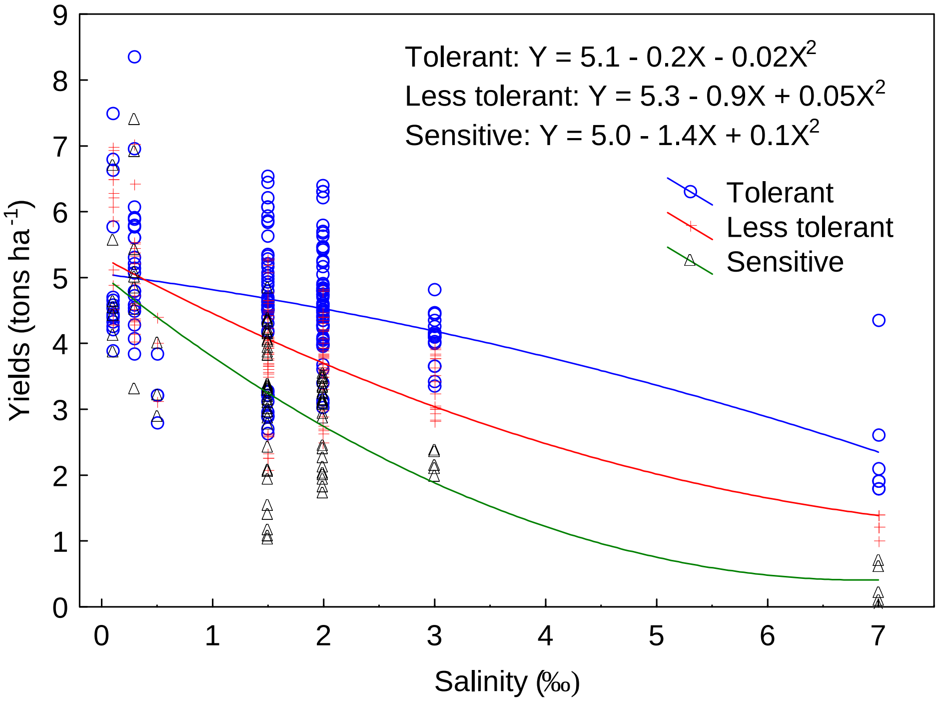

Figure 5: Relationships between soil salinity and yields of rice varieties with different level of salinity tolerance (drawn from Phap's raw data).

Traditional rice varieties

In rice-shrimp rotational farming, farmers grow traditional rice varieties with photo-sensitivity and long-growth duration. Traditional rice varieties can better grow in the conditions of relatively high water and high salinity level, compared to high-yielding rice varieties. As part of the program on rice variety section for saline-affected environments in the coastal region of the Mekong delta, field trials were conducted in 2009 in Ca Mau province to evaluate yield performance of 79 rice varieties under salinity-affected environments. Rice transplantation was applied using 45-day-old-seedlings. Soil salinity increased after transplanting rice, decreased gradually till mid-cropping season and subsequently increased towards the rice harvest (Figure 6). Drought events caused the increase in soil salinity at 15 days after transplanting, but subsequent rains removed soil salinity till mid-cropping season. Combined low rainfall at the end of the rainy season and salinity intrusion from main rivers resulted in another increase of salinity at the end of the rice crop. Under such conditions, tolerant, moderate tolerant and sensitive rice varieties yielded an average of 3.8, 2.9 and 1.9 tons per ha, respectively (Figure 7). The average yield of salinity-tolerant rice varieties is comparable with the potential yield of traditional rice (around 4 tons/ha). Farmers could suffer a rice loss of 1 – 2 tons paddy per ha if they grow rice varieties less tolerant to salinity in their rice-shrimp farming system with salinity occurrence in the rice crop.

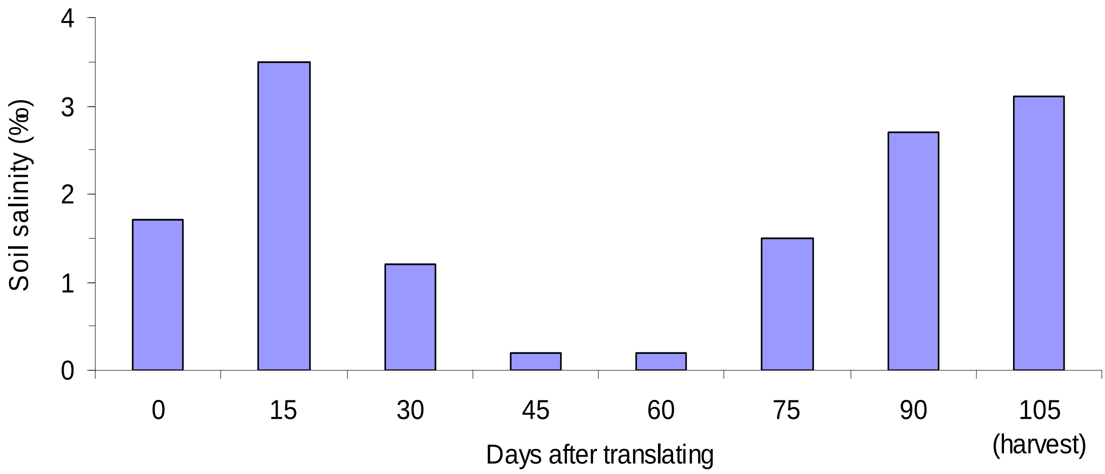

Figure 6: Soil salinity (0-5 cm depth) of the trial field during the rice crop in 2009 (drawn from Phuc's raw data in 2009).

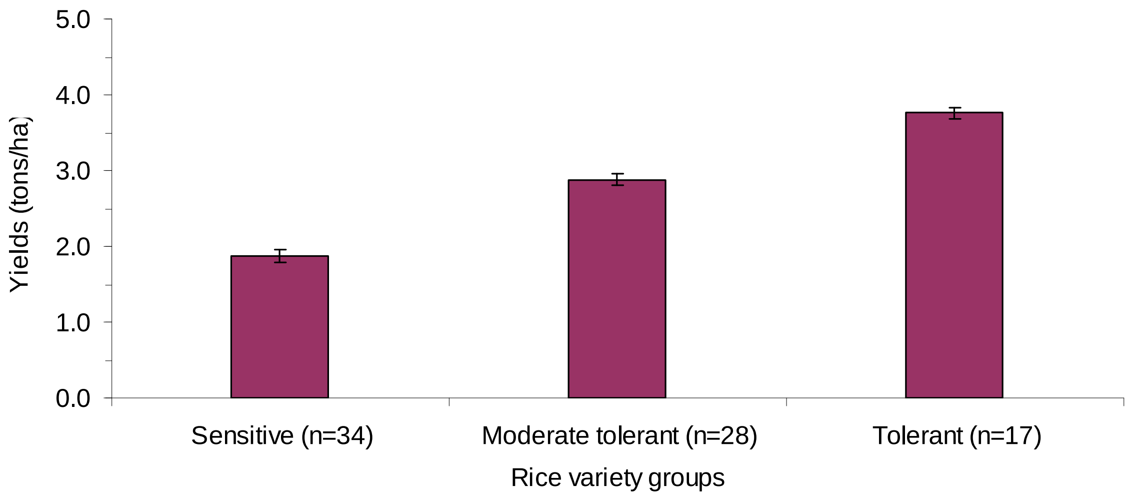

Figure 7: Yields of traditional rice varieties grown under saline condition in coastal Mekong delta (mean ± SE) in 2009 (calculated and drawn from Phuc's raw data in 2009).

3.3. The effect of agro-chemical application

As mentioned above, growing rice varieties tolerant to salinity could be part of a mitigation strategy for salinity intrusion in coastal Mekong delta. In addition, other farming techniques could also add synergies to dealing with salinity problem. Field trials showed that application of the plant-growth inductor Brassiosteroids and potassium fertilizer improved filled grains, grain weight and hence increased yields by around 10% under saline conditions (Figure 8; Tables 4 and 5). Application of Brassiosteroids and potassium fertilizer would increase the economic return by 1,0 – 1.3 million VND/ha/crop (Figure 9). Previous studies in on-station as well as on-farm trials revealed for rice varieties less tolerant to salinity that under soil salinity of up to 3‰, the application of 24-Epibrassinolide and copper chloride ($CuCl_2$) results in rice yields increasing by 11 - 35% (Nguyen Thi Bap, 2009). Plant-growth inductors like 24-Epibrassinolide and copper chloride increase proline contents in rice plants, resulting in higher osmotic pressure of plant cells and hence increased water up-take by plants (in Nguyen Thi Bap, 2009).

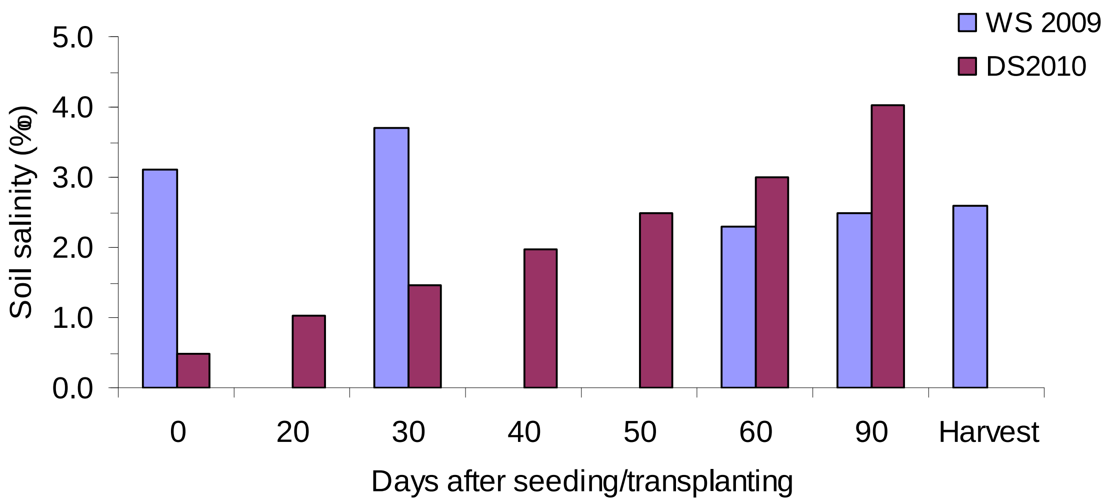

Figure 8: Soil salinity (0-5 cm depth) of the trial fields during the rice crops in 2009 -2010 in Soc Trang and Ca Mau (drawn from Phap's raw data in 2009 - 2010).

Table 4: The effect of Comcat application on yields and yield components of rice variety OM5629 in Long Phu, Soc Trang in the dry season crop in 2010.

Treatments[1]	Panicles/m^2	Filled grains/ panicle	1000-grain weight (g)	Yield (tons/ha)
With Comcat	621^{a}	47^{a}	23.4^{a}	5.8^{a}
Without Comcat	624^{a}	41^{b}	22.7^{b}	5.4^{b}

Source: Based on Phap's data in 2010.
[1] Comcat is the trade name of Brassiosteroids

Table 5: The effect of potassium (K) application on yields and yield components of traditional rice varieties in Ca Mau in 2009.

Treatments	Panicles/m^2	Filled grains/ panicle	1000-grain weight (g)	Yield (tons/ha)
Without K	245^{a}	65^{b}	24.1^{b}	3.2^{c}
With 30 kg K_2O/ha	233^{a}	66^{ab}	25.1^{a}	3.5^{a}
With 60 kg K_2O/ha	232^{a}	68^{a}	24.9^{a}	3.3^{b}

Source: Based on Phap's data in 2009.

3.4. The effect of adaptive farming system

Under favourable conditions for shrimp farming in the dry season, shifting rice mono-culture (2 or 3 crops per year) to rice and shrimp rotational farming could be an option to increase farm income for farmers (Tables 6 and 7). Tiger shrimp (*Penaeus monodon*) and white-leg shrimp (*Litopenaeus vannamei*) are commonly grown in the delta. The shrimp species can tolerate and live in a wide range of water salinity (3 - 45‰) (Ye el al., 2009; Bray et al., 1994). Practicing rice-shrimp, farmers produce less rice, around 8 tons of rice/ha/year, but earn higher income, on average of 15 million VND/ha/year, which leads to higher benefit-cost ratio if compared to the commonly-practiced double rice cropping system. In rice-shrimp farming, both rice and shrimp are grown at low material and labour input level. In practice, shrimp can be grown well in areas with salinity duration of at least 6 months and relatively high canal flows to flush pollutants out. MARD has promoted further development of rice-shrimp farming system in the coastal Mekong delta, from around 150,000 ha currently to 200,000 ha towards 2015, by converting two-rice cropping land with low economic efficiency (an internal report). However, shrimp farming in the Mekong delta is still economically risky from high shrimp mortality. Compared to shrimp mono-culture, rice-shrimp farming system has been considered more sustainable (Joffre and Bosma, 2009).

Figure 9: Partial financial calculations of economic return and cost (million VND/ha) of Brassiosteroids and potassium fertilizer application on rice production (calculated from Phap's data in 2009 and 2010).

Table 6: Rice and shrimp yields in different farming systems in the coastal region of the Mekong delta in 2009. Mean ± SE.

Farming systems	1st WS rice	2nd WS rice	Traditional rice	1st shrimp crop	2nd shrimp crop
Two rice crops (n = 44)	5.8 ± 0.2	4.9 ± 0.2			
Rice – shrimp (n = 48)			3.1 ± 0.3	358 ± 48	176 ± 37

Source: Calculated from Nhan's data in 2010. WS (wet season)

Table 7: Input costs and economic returns (10^6 \$VN) of rice and shrimp farming systems in the coastal region of the Mekong delta in 2009. Mean ± SE.

Farming systems	Total variable costs		Gross return		Gross margin	Benefit-cost ratio
	Rice	Shrimp	Rice	Shrimp		
Two rice crops (n = 46)	25.3 ± 1.1		46.8 ± 2.0		21.6 ± 1.9	0.9 ± 0.1
Rice – shrimp (n = 48)	6.0 ± 0.6	24.1 ± 7.9	16.3 ± 2.1	50.4 ± 9.5	36.8 ± 5.1	1.2 ± 0.3

Source: Calculated from Nhan's data in 2010.

3.5. Practical implications for adaptive rice production

MARD (2011) has estimated that around 100,000 ha of 650,000 ha under rice are at risk due to annual salinity intrusion in the coastal region. In situations with salinity levels of up to 4‰, the conversion to adaptive farming practices could lead to an increase of rice production of around 100,000 - 200,000 tons annually (equivalent to 30 – 60 million USD) if salinity-tolerant rice varieties were planted. Additionally, around 100 – 130 billion VND (equivalent to 5 – 6.5 million USD) could be gained by applying agro-chemicals appropriately. As a consequence for areas with salinity level of up to 4‰, rice production and income levels could be maintained by the introduction of adaptive farming practices without investments in large-scale hydraulic structures. However, if salinity levels exceed 4‰, practicing rice-shrimp rotation could be an option, considering natural resource use efficiency and farmer's livelihoods. In addition, appropriate adjustments of the rice cropping season, rice transplantation practice, and better desalinization of paddy soil through on-farm and off-farm small-scale irrigation structures would be advisable to adapt to changes in salinity and rainfall timing. On top of these measures, long-term and reliable weather forecasts are of great importance.

Toan et al. (2011) suggest in their hydrological simulations that 50,000 - 300,000 ha in the coastal delta could become brackish or saline during dry seasons due to the combined effects of sea level rise, intensive rice development in upper delta, and intensified water use upstream. Toan et al. (2011) also suggest that 170,000 - 330,000 ha that would be affected by brackish or saline water due to sea level rise could become freshwater environment if large-scale salinity-control structures were put in place. However, recent impact assessments have showed that intensive rice production from recent irrigation development projects in coastal areas in the delta gives low income, low efficiency of resource uses and environmental degradation (Nhan et al., 2011b). Therefore, to deal with potential salinity intrusion and to secure rice production, the necessity of massive investments in such large- scale salinity-control structures is still questionable.

4. Conclusions

The present report provided evidence for positive effects of good farming technologies on sustained rice production and income, and suggested strategies to adapt to salinity intrusion in the Mekong delta. For areas with salinity levels of up to 4‰, the planting of salinity-tolerant rice varieties and the application of appropriate agro-chemicals could help farmers maintaining their rice production and their farming income. For salinity levels above 4‰, the conversion of rice mono-culture to rice-shrimp rotational farming is an adaptation strategy to further improve farmer's income and livelihoods. Other non-structural measures like adjustments of rice cropping seasons, rice transplantation practices, soil desalinization, and the provision of adequate weather forecasts can help dealing with changes in the timing of salinity intrusion and rainfall. To pursue national food security goals, upper and mid-delta areas could be assigned to rice production. Such strategies would make the investment in large-scale structural measures obsolete.

Clearly, further improvement of current farming systems and current livelihoods of farmers to adapt to salinity in coastal areas is necessary. Investment priorities include: development of adaptive farming practices for rice and rice-based farming systems, improvement of agricultural extension and development of small-scale (on-farm and off-farm) irrigation structures to further improve water use efficiency.

References

Asch, F., Wopereis, M. S. C., 2000. Yield responses of irrigated rice to salinity depend on development stage and stress level. 3rd International Crop Science Congress, August 17th-22nd, 2000. Hamburg, Germany.

Asian Development Bank (ADB), 2009. Building climate resilience in the agriculture sector in Asia and the Pacific. Asian Development Bank and International Food Policy Research Institute. Mandaluyong City, Philippines.

Bray, W.A., Lawrence, A.L. and Leung-Trujillo J.R. (1994). The effect of salinity on growth and survival of Penaeus vannamei, with observations on the interaction of IHHN virus and salinity. Aquaculture 122, 133-146.

Carew-Reid, J. 2008. Rapid Assessment of the Extent and Impact of Sea Level Rise in Viet Nam, Climate Change Discussion Paper 1, ICEM –International Centre for Environmental Management, Brisbane, Australia.

Clermont-Dauphin, C., Suwannang, N., Grünberger, O., Hammecker, C., Maeght, J.L. 2010. Yield of rice under water and soil salinity risks in farmers' fields in northeast Thailand. Field Crops Research 118: 289–296.

CSO (Can Tho Statistical Office), 2010. Socio-economic statistical data of the Mekong Delta 2000 – 2009. Can Tho, Vietnam.

Grattan, S. R., Zeng, L., Shannon, M.C., Roberts, S.R. 2002. Rice is more sensitive to salinity than previously thought. California Agriculture 56 (6): 189-195.

Joffre O.M., and Roel, H. Bosma, 2009.Typology of shrimp farming in Bac Lieu Province, Mekong Delta, using multivariate statistics. Agriculture, Ecosystems and Environme132, 153–159

MARD, 2008. An action plan framework to respond to climate change for agricultural and rural development in the period of 2008-2020 (Decision No. 2730/QĐ-BNN-KHCN, dated on September 5th, 2008).

MARD, 2011. Rice production evaluation for 2010 and work-plan for 2011 for the Southern Vietnam. Agricultural Publishing House. pp. 129-146.

Motamed, M.K., Asadi, R., Rezael, M., Amiri, E. 2008. Response of high yielding rice varieties to NaCl salinity in greenhouse circumstances. African Journal of Biotechnology 7 (2): 3866-3873.

MRC (Mekong River Commission) 2010. Impacts of Changes in Salinity Intrusion. Assessment of basin-wide development - Technical Note 8.

Nguyen Thi Bap, 2009. Current situation of rice production under salinity-affected conditions in Soc Trang province and the effect of plant-growth inductors on salinity tolerance of rice. Msc. Thesis in Rural Development, Can Tho University (in Vietnamese with English Abstract).

Nhan, D.K., Trung, N.H., Sanh, N.V. 2011a. The impact of weather variability on rice and aquaculture production in the Mekong Delta. In: M.A. Stewart and P.A. Coclanis (eds.), Environmental Change and Agricultural Sustainability in the Mekong Delta, Advances in Global Change Research 45, pp. 437-452.

Nhan, D.K., Binh, N.T., Tri, V.P.V. 2011b. Water competition and potential conflicts in the Mekong Delta of Viet Nam. A technical report submitted to The World Bank.

Pham Van Du, 2009. An overview on rice-shrimp farming system in coastal Mekong delta. In: Proceedings of the 1st workshop on sustainable development of rice-shrimp farming system in coastal Mekong delta, 24th September 2009 in Soc Trang town. MARD and Soc Trang PPC, pp. 2-6.

Sam, L., 2006. Saline water intrusion in the Mekong delta. Agricultural Publishing House (in Vietnamese).

Toan, T.Q., Trung, N.H., Nhan, D.K., 2011. Report on hydrological simulation of the Vietnamese Mekong delta. An internal technical report.

Tuong, T.P., Kam, S.P., Hoanh, C.T., Dung, L.C., Khiem, N.T., Barr, J., Ben, D.C. 2003. Impact of seawater intrusion control on the environment, land use and household incomes in a coastal area. Paddy Water Environment 1: 65-73.

Zeng, L., Shannon, M.C., Lesch, S.M. 2001. Timing of salinity stress affects rice growth and yield components. Agricultural Water Management 48: 191-206.

Ye, Le., Jiang, S., Zhu, X., Yang, Q., Wen W., Wu, K., (2009). Effects of salinity on growth and energy budget of juvenile Penaeus monodon. Aquaculture 290, 140–144.

Yoshida, S. 1981. Fundamentals of rice sciences. International Rice Research Institute, Manila, Phillipes.

White, I., 2002. Water Management in the Mekong Delta: Changes, Conflicts and Opportunities. Technical Documents in Hydrology No. 61, IHP-VI, UNESCO, Paris, France.