

Development new rice varieties in the coastlines of Mekong Delta, Vietnam

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Abstract— To increase productivity and improve quality, new rice varieties need to be salinity tolerance and resistant to many kinds of insects, diseases, and high levels of nutrients, resistant to disadvantageous conditions, and promises to reduce using pesticides, chemical fertilizers. Great efforts have been focused on germplasm research to discover genes resistant to disease and insect, efficient in using salinity level with good grain quality and productivity. With the development of climate-resilient varieties, scaling up or dissemination of seeds is done by province, following the locality's is Winter-Spring (DongXuan Season) and Summer – (Wet season). For instance, in the case of Winter-Spring crop, the plan of Mekong delta is to expand some lines such as HATRI 190, HATRI 192, HATRI 170 were developed that can yield 4-5 tons ha⁻¹ under salt stress of 10.0 to 12.0 dS m⁻¹, and are being out-scaled. Normally, this expansion initiative requires inclusion of key rice varieties, that is, local or extra varieties and promising varieties, all of which will be included in the plan for developing the rice sector for each province.

Keywords— rice varieties, improve quality, salinity tolerance.

I. INTRODUCTION

Rice is a major export commodity of Vietnam and a source of livelihood of smallholder farmers, particularly in the Mekong Delta, which contributes more than fifty percent of the country's total rice production. Millions of farmers in the Delta are living below poverty level as their farming is affected by occurrences of drought, flooding, and salinity from saltwater intrusion. An estimated 1,867,910 hectares of the total rice crop area is affected by salinity (Buu et al 2004). High Agricultural Technology Research Institute for Mekong delta (HATRI) recognizes the importance of developing modern climate-resilient rice varieties as well as associated management practices that respond to the challenges of climatic variability in such stress-prone areas. In the case of Vietnam, a rice variety that will be seed-multiplied, first needs to undergo evaluation trials at the HATRI. Moreover, an equally daunting task is bringing the new varieties to the farmers' fields where productivity is still not at optimal level due and where there are institutional constraints related to extension activities. Country protocol

for varietal release and dissemination requires that provincial officers and farmers will have to be invited to assess the performance of the varieties in the field. Upon initial assessment and acceptance, farmers and local staff in the districts and provinces will evaluate the variety this time for deployment and multiplication (Lang et al 2016a). This is an ideal strategy to bring rice varieties to the local farmers. The MARD, IFAD-CURE, and other funding institutions, which share the same goal of raising productivity in the salinity-prone rice areas in the Mekong Delta, supported the development, validation (Lang et al 2015), and eventual dissemination of climate-smart varieties. The key in achieving such goal involves partnerships and participatory approaches for a need-based strategy of developing varieties and eventual delivery to farmers from 2017-2018. The estimated rice production for the three rice growing seasons 2015 correlates well with data at the district level collected from the province statistics offices with R²s of 0.93 for the Winter-Spring, 0.86 for the Summer-Autumn and 0.87 for the Autumn-Winter season (Kersten Clauss et al 2018). Our research activities in the Mekong Delta focus on the

development of proper technologies for **Cultivating climate-resilient rice varieties in the coastlines of Mekong Deltat** enhancing and stabilizing farm level productivity and for improving farmers livelihoods. This is being achieved through the development of rice varieties with tolerance to prevailing abiotic stresses, adoption of proper soil, water for higher and stable productivity of these varieties .These efforts are being supported in part, by funds provided by the Program on salinity for climated change through Tay Nam Bo project.

II. MATERIAL AND METHODS

Some lines 24 lines obtained from the High Agricultural Technology Research Institute for Mekong delta, Vietnam (HATRI).

Phenotype analysis

A field experiment was transplanted to an irrigated lowland field in a randomized complete block design in three replications in the field of HATRI at BinhThuy, Can Tho. 24 lines with their parents were used to evaluate agronomic characteristics and salinity detection through sensory test and genotypic analysis using SSR markers in lab of HATRI. Data on important agronomic traits like plant height, panicle length, filled grains/panicle, unfilled grain/panicle, 1000-grain weight, harvest index and yield were recorded.

Ten randomly selected plants of each genotype were used for agronomic data analysis. Data on plant height (cm), number of effective tillers/plants, panicle length (cm), number of filled grains/panicle, 1000-grain weight (g), days to maturity and grain yield/plant (g) were recorded and subjected to statistical analyses using SAS software. After harvesting, the seeds of each genotype were dehulled for evaluation of the grain quality and aroma. The grains were classified into different types based on their dimension according to Dela Cruz and Khush.1989 . Ten seeds of each cultivar removed rice hull and mashed by hand. Take rice powder of each cultivar and put on each experimental tube or petri dish. Add 5ml KOH 1.7% into each petri dish and cover. Store the samples in room temperature for 30 minutes. The samples were scored, corresponding to absence of aroma, slight aroma, moderate aroma and strong aroma, respectively.

Technology evaluation and adaptation. While varieties have already been developed that should be adapted to the local conditions, it is still necessary to evaluate their performance to meet national varietal release requirements. As these varieties perform completely differently undersality conditions than current varieties, comprehensive management practices must be developed so that farmers can fully benefit from them. This will involve (a) initiating testing programs of new varieties in various locations in all province deemed to be susceptible to salinity; (b) conducting comparisons of differing sources of salinitytolerance and combinations of sources to determine which are best suited for different salinity affected areas (different levelstress); (c) conducting of field trials (on-farm and on-station) to refine best management practices for each location; and (d) obtaining feedback results from field and agronomic experiments into varietal development and gene identification programs.

Data Analysis

The agro-morphological data were initially analyzed through examining variance to verify genetic variation in the traits measured. The few traits with insignificant genetic variation, based on the F-test, were not considered for further analyses

III. RESULTS AND DISCUSSION

Breeding for salinity tolerance in rice

The results show that some lines such as at 20 days after transplanting. At 35 days after transplanting, the highest variety was Evaluation of breeding lines from with local check varieties namely Pokkali and OXY 10 is conducted regularly in both wet season 2018. These lines are evaluated in farmers' fields as well as on station at HATRI. Different traits were assessed, including crop duration, plant height, panicle/ filling and sterility/ plants, quality traits as well as salinity tolerance. Lines that are early maturing (90-110 days) semi dwarf (90-110 cm) with medium number of panicles/hill (7-15 panicles) and high number of grains/panicle (77-199 grains) were selected for further testing in rice-rice cropping pattern when their salinity tolerance is high (survival after 20-25 day salinity at EC = 8 DS/m) and duration of about 98 d, similar to OXy 10. They were these lines will be suitable for salitniy affected (Table 1)

Table 1. Yield and yield components of rice varieties tested at HATRI

No.	Lines	Panicles/ plants (no.)	Filled grains/ Panicle (no.)	unFilled grains/ Panicle (no.)	P 1000 grains (g)	yield (g/10 plants)	% Survival in salinity EC- 8DS/m
1	IR28 (Checked)	18 c	198 d	12 l	26.7 cde	75 m	5.2 v
2	Pokkali (checked)	16 de	148 n	14.2 j	26.8 cd	56.5 t	78.8 i
3	HATRI 402	17 cd	77 x	14.2 j	27.6 b	99 g	45.8 mn
4	HATRI503	16 de	169 i	14.5 ij	26 g	95 i	45.6 n
5	HATRI506	15 ef	210 c	16.8 f	26.8 cd	93 j	47.8 k
6	HATRI 507	18 c	230 a	16.9 f	27 c	94 i	42.3 s
7	HATRI 506	12 g	120 t	20.3 b	26.5 def	96 h	45.9 m
8	HATRI 302	13 fg	145 o	18.9 c	26.8 cd	95 i	46.8 l
9	HATRI477	14 ef	187 f	17.5 e	26.9 c	99 g	44.8 p
10	HATRI 468	15 ef	176 h	16.8 f	26.4 ef	153 a	44.5 r
11	HATRI 1	12 g	189 e	18.9 c	26.8 cd	124 c	68.9 j
12	HATRI 170	10 h	163 j	18.4 d	26.8 cd	114 e	95.3 e
13	HATRI190	12 g	152 m	17.5 e	26.5 def	121 d	92.4 g
14	HATRI192	13 fg	148 n	16.8 f	26.7 cde	112 f	95.8 d
15	HATRI 194	14 ef	199 d	20.3 b	26.5 def	49 u	97.5 c
16	HATRI60	12 g	185 g	21.3 a	26.4 ef	86 k	99.8 a
17	HATRI62	14 ef	175 h	20.1 b	26.5 def	112 f	99.5 a
18	HATRI61	15 ef	126 r	12.3 kl	26.3 f	135 b	99.8 a
19	HATRI144	15 ef	142 p	10.2 n	26.8 cd	99 g	74.2 i
20	HATRI188	9 h	158 k	10.5 n	26.8 cd	86 k	79.3 i
21	HATRI195	9 h	135 q	15.4 g	26.9 c	68 o	99.7 a
22	HATRI 50	7 i	147 n	14.2 j	28.7 a	67 o	45.2 o
23	HATRI2	4 j	156 l	11.2 m	24.2 h	65 p	0 y
24	HATRI3	13 fg	112 v	10.5 n	26.8 cd	65 p	77.5 i

New lines provided a substantial enhancement in the level of tolerance of all the lines varieties. Only 11 lines (HATRI 1, HATRI 170, HATRI 190, HATRI 192, HATRI 194, HATRI 60, HATRI 62, HATRI 61, HATRI 144, HATRI 188, HATRI 195) carried 90-99% survival salinity condition in the field.

Use of DNA markers to accelerate progress in breeding for salt tolerance:

Identification of molecular markers associated with quantitative trait loci (QTLs) linked with useful agronomic or adaptive traits will help speed the progress in breeding

once developed, because these DNA markers will become effective tools for selection. Moreover, positional cloning using DNA markers will make it possible to isolate agronomically useful genes, which can also be used in breeding across species via transgenic approaches. The study used restriction fragment length polymorphism (RFLP) and

simple sequence length polymorphism (SSLP) markers to saturate the segment of chromosome 1 containing a major salt tolerance gene controlling the Na⁺/K⁺ ratio. RFLP and SSLP analyses were conducted to construct linkage maps based on an F8 recombinant inbred line (RIL) mapping population (Bonilla et al 2002). We developed several mapping populations using salt tolerant and sensitive genotypes and used them for mapping of QTLs associated with salinity tolerance during seedling stage (Lang et al., 2001, Lang et al 2015). Two QTLs with relatively large effects were identified, one on chromosome 1 (linked to marker 18EC) and the second on chromosome 8 (linked to marker 12EC). Microsatellite markers closely linked to these loci were identified such as RM223 associated with the QTL on Chromosome 8. This marker was further evaluated for its

effectiveness in breeding using a set of 24 improved varieties, including tolerant (Pokkali) and sensitive (IR28) checks. These cultivars were genotyped at this marker and then phenotyped for salinity tolerance at 12 dS m⁻¹ in culture solution (Yoshida et al., 1976) using visual SES scores. The results indicated an accuracy of more than 95% in identifying tolerant cultivars using this marker (Table 2). These results indicated the usefulness of this marker in parental surveys and in identifying tolerant lines from segregating populations; however, further tests are needed to confirm its effectiveness in different genetic backgrounds. More efforts are needed to develop closely linked markers to these two QTLs to be used for their routine introgression into popular varieties and elite breeding lines.

Table 2. Comparison between the phenotype and genotype of 24 varieties under salt stress of 12 dS m⁻¹. Lines were genotyped using markers specific for Saltol locus on chromosome 1 and phenotyped under salt stress in hydroponics

Number	varieties	Genotype	phenotype	Note
1	IR28(Checked S)	S ^y	S	S
2	PokkaliChecked for R)	T	T	T
3	HATRI 402	S	S	S
4	HATRI503	S	S	S
5	HATRI506	S	S	S
6	HATRI 507	S	S	S
7	HATRI 506	S	S	S
8	HATRI 302	S	S	S
9	HATRI477	S	S	S
10	HATRI 468	S	S	S
11	HATRI 1	T	T	T
12	HATRI 170	T	T	T
13	HATRI190	T	T	T
14	HATRI192	T	T	T
15	HATRI 194	T	T	T
16	HATRI60	T	T	T
17	HATRI62	T	T	T
18	HATRI61	T	T	T
19	HATRI144	T	S	S
20	HATRI188	T	T	T
21	HATRI195	T	T	T

22	HATRI 50	S	S	S
23	HATRI2	S	s	s
24	Oxy 10(Checked)	T/S	T	Not clear

[¥]T: tolerance and S: sensitive. [£]Oxy 10 and Pokkali were tested in the field and seeds provided to farmers in several provinces for further testing.

Advancing rice research

Confronting the huge challenges of developing varieties in the less-favorable rice areas necessitates partnerships and strategies that capitalize on and foster synergism among related projects in Vietnam. Having strong financial support from the government and other external programs, Vietnam has been successful in scientific and development work leading to releases of a significant number of climate-resilient varieties and suitable crop management practices. The well-focused development agenda of the national government has been a driving force in raising the level of productivity in difficult rice ecosystems. Moreover, HATRI institutions has also been instrumental in catalyzing support, resources and capacities that is now creating impact on Vietnam's rice productivity at the farmers' fields, and producing surplus for local and export markets.

The project has been breeding for salinity using MAS, building up on the prior knowledge and system of rice breeding at the (HATRI) institute. In collaboration with other Vietnam institutions, and Rice Climate for salinity project, HATRI has developed several climate-resilient rice varieties such as grain quality and salinity-tolerant varieties by introgressing *Saltol* and quality QTLs into elite genotypes. For its expansion efforts, partners distributed seeds of salinity - tolerant elite lines for field evaluation in farmers' fields. Beginning in 2017, HATRI aim (1) to breed and develop new rice varieties (2-3 varieties) suitable for export standards and adapted to the conditions in the Mekong Delta, salinity - tolerant, early- maturing, high-yielding, and with good quality, as well as with resistance to major insects/pests; (2) and to build up technical procedures for cultivation of new rice varieties in salinity tolerance of the Delta.

With HATRI 's involvement in Rice Climate activities, at least fourteen (14) varieties have been supported that have now been doing **releases** (Table 3). Most of these stress-tolerant varieties can provide, on average, a

yield advantage of 1.0- 1.5 tons per hectare compared to the farmers' popular varieties. The average yield of a popular variety in the mid-1990s was only 3.0 tons/ha (Buu et al 2017). But with the usage of new rice varieties that have been released over the years, the average yield has been increasing and has reached 5.5 tons/ha in 2017 for salinity-tolerant varieties, and about 6.0 ton/ha for salinity -tolerant varieties. The released varieties that have been developed through marker-assisted selection (MAS) are TLG 1 (both for salinity- and submergence-prone areas), TLG 1, and HATRI 170; and for salinity, HATRI60, HATRI 61, HATRI 62. The other varieties in the table have been developed through conventional breeding methods that required at least a decade-worth of work. Results of adaptation trials were used to pass the rigorous evaluation process. For instance, shows the comparative yield performance of three varieties included in trials in 2017-2018, which indicated the good performance of salinity -tolerant varieties, particularly HATRI 10, HATRI 60, TLG1. This eventually became part of the bases for farmers' selection and continued adoption in affected environments to this today.

Yield testing on rice varieties

To select the rice varieties with high yield potential, insect pest resistance for condition in Mekong delta. To find out the rice varieties with desirable traits for hybridization in rice improvement programs.

Including lines rice varieties with Pokkali, OXY 10 for checked, growing dry seasons 2017-2018. Yield testing experiments were laid out in completely randomized block designs with 3 replications in BaTri's experimental field. Statistical analysis was cited (Gomez and Gomez, 1982). Data records on agronomic characters, yield and yield components were also guided as SES (IRRI, 1996). Insect, disease screening experiments were laid out in single replication. Evaluation of insect and disease reaction at seedling stage (IRRI, 1996). Agronomic characters were presented in table 3.

Table 3: Yield and yield components of lines for salinity in rice at 2017-2018 at Ba Tri with salinity EC= 10 DS/m

Lines	Duration (days)	Height (cm)	Panicle/m ²	Yield (tons/ha)
HATRI 1	100	107 <i>b</i>	303.66 <i>ab</i>	4.473 <i>bcde</i>
HATRI 190	95	109.33 <i>b</i>	266.66 <i>bc</i>	5.13 <i>ab</i>
HATRI 170	96	107.33 <i>b</i>	242 <i>c</i>	5.16 <i>ab</i>
HATRI 194	100	108 <i>b</i>	274 <i>bc</i>	4.726 <i>abcde</i>
HATRI 162	105	108.33 <i>b</i>	284 <i>abc</i>	4.95 <i>abcd</i>
HATRI 188	98	95.66 <i>d</i>	284.33 <i>abc</i>	3.84 <i>cde</i>
HATRI 144	98	115 <i>a</i>	272.66 <i>bc</i>	4.69 <i>abcde</i>
HATRI 192	95	106.66 <i>b</i>	290.33 <i>abc</i>	5.84 <i>a</i>
TLG1	94	98.67 <i>cd</i>	293.67 <i>abc</i>	4.35 <i>bcde</i>
HATRI 195	100	101.67 <i>c</i>	338.33 <i>a</i>	4.32 <i>bcde</i>
POKKALI	115	129.67 <i>e</i>	318.67 <i>ab</i>	3.66 <i>e</i>
OXY 10 (Checked)	105	101.33 <i>c</i>	285.33 <i>abc</i>	3.8 <i>de</i>
HATRI 475	95	99.33 <i>cd</i>	287.67 <i>abc</i>	4.07 <i>bcde</i>
HATRI 60	95	107.33 <i>b</i>	320 <i>ab</i>	5.09 <i>abc</i>
CV	0	2.16	10.16	14.26

It is indicated that almost of rice varieties in experiment are less than 100 days duration. Plant height ranged in 120 cm for Pokkali.

Grain yield and yield components of 16 lines rice were presented in table 4. It was indicated that HATRI 90 and HATRI 192 gave highest yield in experiment (5.13 - 5.16 tons/ha) and be higher than Oxy 10 (checked Rice farmers).

The success of new varieties is assured through eventual testing and selection in target sites in partnership with farmers and under their own management to guarantee relevance and adoption. Special emphasis is placed on crop establishment because the early stages of seedling growth are extremely sensitive to salt stress (Moradi et al., 2003; Ismail et al., 2007; Lang et al 2018). This is achieved through combined use of salt tolerant genotypes, coupled with proper nursery management and seedling handling that ensures maximum survival of transplanted seedlings.

Combination of traits for multiple stresses. One of the difficulties in rice areas severely affected by variability in climatic conditions is the occurrence of multiple stresses over a cropping season. To address this concern and with the advances in molecular biology particularly using MAS, the breeding program of HATRI used pyramiding technique to combine genes responsible for tolerance to a combination of stresses. For

instance, in 2017, in developing high-yielding rice varieties tolerant to salinity and quality total of ten (10) single and multiple crosses were done for combining salinity and quality rice into the high-yielding genetic background. Genetic diversity is emphasized as a success factor in breeding, as well as in understanding the relationship between genotype and phenotype. Strategic development of the varieties focus on the following: (a) adaptation to effects of salinity, both at the seedling stage and flowering stage, (b) improved yield to exceed 5-6 tons/ha, and (c) providing the basis of genetic diversity.

Emphasis on grain quality. Grain quality is considered an important trait contributing to farmers' preference or selection of a variety. This is also taken into consideration in breeding works to know which traits are most popular among traders. For instance, to develop long and medium grain rice cultivars, 20 crosses were made in 2017. The F₂, BC₁, BC₂, BC₃ seeds were planted at HATRI in the wet season and dry season. Samples of seed from each harvested plant were sent to the Riceland quality lab for grain quality evaluation at HATRI and selected crosses were evaluated using MAS for amylose content, aroma and blast resistance. The best yielding lines selected from these experiments were advanced to the HATRI. Twenty advanced long grain lines were also tested in the 6 provinces for trials, indicating that long grain rice cultivars could be ready for release in the near future.

Table 4. Most in-demand stress-tolerant varieties and their characteristics

Genotype	Maturity (days)	Origin	1000 grain wt. (g)	Amylose (%)	Cooked rice quality	BPH	Blast	BLB (score)	Yield (ton/ha)	Remarks by farmers
Salinity-tolerant and good quality varieties										
OM4900	95-100	Origin: C53/ Jasmine 85/	28.8	16.8	Glutinous, and aromatic rice, "World's longest cooking rice"; excellent for cooking, requires less water	Tolerant	Tolerant	3 -- 5	7-8	Excellent (Salinity-tolerant, high yield, aroma) no lodging
HATRI 10	95-100		27.5	19.6	Glutinous, soft, excellent for cooking, elongation trait, requires less water	Tolerant	Tolerant	5	6-8.5	Good (Salinity-tolerant) KienGiang, Bac Lieu, and TraVinh (5% of areas grow this variety)
TPG1	93 - 85	hybrid of M362/A S996	25.6	22	Glutinous	Tolerant	Tolerant	3 -- 5	6-8	Very good (Salinity-tolerant, high yielding)
HATRI 170	95-100		26	22	Glutinous, hard	Tolerant	Tolerant	3 -- 5	5-7	Very good (Salinity-tolerant, high yielding)
TLG1	95-100	Origin: OMCS2 012/ Pokkali	27.3	21.5	Glutinous	Tolerant	Tolerant	3 -- 5	5-7	Excellent (Salinity-tolerant, high yielding); Bac Lieu, KienGiang and TraVinh; farmers liked the variety that >408 ha in 2009 and increased to 1,496 ha in the Mekong Delta in 2010.
HATRI144	90-95		27.5	21.86	Glutinous	Tolerant	Tolerant	3	5-7	Good (high yielding), tolerant to salinity, alkalinity, iron and boron toxicity, and phosphorous and zinc deficiency;

										suitable in irrigated and rainfed lowland areas; popularly grown in salinity- and alkaline rice areas such as KienGiang, TraVinh and Long An
HATRI 61	95-105		27.5	23.5	Glutinous	Tolerant	Tolerant	3 -- 5	5-7	Good (Salinity-tolerant, high yielding) tolerant to salinity, alkalinity, iron and boron toxicity, and phosphorous and zinc deficiency; suitable in irrigated and rainfed lowland areas
HATRI 20	95-105		26.8	23	Glutinous	Tolerant	Tolerant	5	5-7.5	Very good (Salinity-tolerant, high yielding)
HATRI192	95-100		25.6	21	Glutinous and scent	Tolerant	Tolerant	3 -- 5	6-7	Good (drought, high yielding)
HATRI 144	105-110		26.5	24.5	Glutinous	No data	No data	3 -- 5	3-4	Excellent (drought-tolerant)
HATRI 181	95-100		28.8	16.8	Glutinous and scent	Tolerant	Tolerant	3 -- 5	7-8	Very good (drought - tolerant, high yielding, aromatic)
HATR60	95-100		27.5	22	Glutinous	Tolerant	Tolerant	5	7-8.5	Very good (sality-tolerant, droughthigh yielding)

Evaluation of salinity stress varieties in farmers' fields

Performance stability is one of the most important properties of a genotype to be released as a variety to ensure wide adoption. To ensure this, we tested 12 indica rice varieties at 7 different locations during the wet season 2018 and dry seasons of 2018-2019, using a randomized block design with three replications in each case. Duration, grain yield ($t\ ha^{-1}$) were presented in Table 4, 5. The experiment was conducted in 7 provinces, Can tho (checked), TraVinh, Ca Mau, SocTrang, Long An, Ben Tre and Bac

Lieu. The highest grain yield across the 7 sites was obtained from HATRI 190, TLG 1 during dry seasons. Most of the varieties showed excellent stability index. An understanding of environmental and genotypic causes and GxE interaction is important at all stages of plant breeding, for both selection based on specific traits or on yield (Yan and Hunt, 1998; IRRI, 1997)

Table 5. The Yield of 12 lines in rice at Mekong delta dry season 2018-2019

Numbers	Lines	Mekong delta						Can Tho	mean
		Bac Lieu	Ba Tri (Ben Tre	Ca Mau					
					Long An	TraVinh	SocTrang		
1	HATRI 1	7.55	7.81	7.68	7.00	6.17	7.52	7.90	7.37ab
2	HATRI 190	7.80	7.77	7.79	6.9	7.87	7.78	8.10	7.71a
3	HATRI 170	7.28	7.28	7.29	7.51	7.75	7.56	7.80	7.49ab
4	HATRI 475	7.52	7.84	7.53	7.05	6.84	7.67	7.10	7.36ab
5	HATRI62	7.39	7.01	7.21	7.16	7.53	7.78	6.50	7.22ab
6	HATRI 60	7.44	7.24	6.71	7.63	7.97	6.25	7.65	7.27ab
7	HATRI 188	7.55	7.43	7.89	7.20	7.58	7.93	6.42	7.42ab
8	HATRI144	7.07	7.16	7.26	7.52	7.31	7.57	7.12	7.28ab
9	HATRI192	7.12	7.45	7.61	7.27	6.62	7.58	7.47	7.30ab
10	TLG1	7.64	7.85	7.12	7.59	7.32	7.73	7.93	7.59ab
11	HATRI194	7.37	7.48	6.47	7.48	7.72	7.04	7.30	7.26ab
12	Oxy 10 (check)	6.52	7.29	6.9	7.23	7.08	6.84	6.97	6.97b
	EMS	0.272	0.17	0.16	0.13	0.12	0.16	0.14	
	Mean	6.43	6.63	6.12	5.79	5.81	5.68	6.93	
	(Ij)	0.24	0.44	-0.07	-0.39	-0.38	-0.50	0.74	

Table 6. The yield of 12 lines in rice at Mekong delta on 20018 wet season

Lines	Mekong							
	BacLieu	Ba Tri	Ca Mau	Long An	Tra Vinh	Soc Trang	Can Tho	
HATRI 1	5.62ab	5.54ab	5.86ab	5.70ab	6.00a	5.40ab	5.69ab	
HATRI 190	5.80 ab	5.70 ab	5.40ab	5.30 ab	5.00 ab	4.50b ab	5.28ab	
HATRI 170	5.88 ab	5.33 ab	5.70 ab	4.90b	5.20 ab	4.85b	5.06ab	
HATRI 475	5.70 ab	5.10 ab	5.20 ab	5.00 ab	5.40 ab	5.20 ab	4.86ab	
HATRI62	5.40 ab	4.90b	5.00b	4.80b ab	5.10 ab	5.15 ab	5.76ab	
HATRI 60	5.46 ab	5.15 ab	5.30 ab	5.80 ab	5.15 ab	5.00 ab	4.93ab	
HATRI 188	5.46 ab	5.90 ab	6.20a	5.75 ab	5.80 ab	6.00a	5.85a	
HATRI144	6.20a	6.00a	5.90 ab	5.30 ab	6.10a	6.00a	6.33a	
HATRI192	4.84b	5.80 ab	5.55 ab	5.20 ab	5.35 ab	5.50 ab	5.93ab	
TLG1	5.62 ab	5.85 ab	5.70 ab	5.40 ab	5.10 ab	5.20 ab	5.48ab	
HATRI194	5.50 ab	5.70 ab	5.60 ab	5.10 ab	5.30 ab	5.00 ab	5.37ab	
Oxy 10 (check)	4.67b	4.85b	4.55b	4.80b	4.85b	4.77b	4.75b	
CV%		14.59	15.37	14.67	17.05	15.41	14.57	11.24
LSD 0.05		0.88	0.75	0.71	0.79	0.73	0.67	0.53
Mean	5.51	5.48	5.49	5.25	5.36	5.24	5.44	

Potential application site

For the salinity-tolerant varieties, scaling up can be done by region, where the stresses have been determined and estimated. In different provinces, based on results of multi-location trials, the following are the potential expansion areas for dissemination and farmers' use of the now popular varieties (Table 7).

Table 7. Potential areas for expansion of salinity-tolerant varieties.

Province (District)	Yield Potential (tons/ha/cropping)	Cropping intensity (/year)	Level of Salinity (indicate level of EC)	Recommended varieties
Bac Lieu (Hoa Binh Town)	5-6 tons/ ha	3	EC = 8-10 ds/m	Region of 3 crops: 2 for salinity and another crop HATRI170, HATRI 144
Tra Vinh (Cau Ke district)	6-7 tons under normal condition; under saline soil, yield is lower at 4-5 tons/ha	2	EC = 8-10 ds/m	HATRI 20, HATRI 190, HATRI 192
Soc Trang	6-6.2 tons	2 varieties + another crop	EC = 10-12 ds/m	HATRI170
Ben Tre	5-6 ton/ ha	2 cropping, since areas are severely affected by salinity	EC = 12-15 ds/m	HATRI170, HATRI 190, HATRI 192, HATRI 475
Ca Mau (Tran van Thoi District)	3-5 tons/ha (yield is very low caused by salt, sulfate soil, and drought)	1 crop	EC = 12-15 ds/m	HATRI 170, HATRI 144
Kien Giang	6-7 tons/ha	2 crops	EC = 12-15 ds/m	HATRI60, HATRI 62

IV. DISCUSSION

Salt-affected soils of the Mekong delta are highly degraded, with a complex of abiotic stresses including salinity, acid sulfate, toxic levels of aluminum and iron and deficiency in some nutrients such as P and K. To enhance and sustain productivity of these soils, we adopt an integrated approach involving the development of adapted high yielding and salt tolerant varieties developed via novel breeding methods, proper management of resources and introduction of effective cropping patterns that can meet farmers' needs and market demands (CGIAR .2016).

In different provinces, based on results of multi-location trials, the following are the potential expansion areas for dissemination and farmers' use of the now popular varieties (Table 7). The strong advocates of technology are still the leaders of the locality, who are normally the president of the commune and director of province of the agriculture agency. Farmers observe the trials or their neighbors' field and exchange of information among themselves. If the local community does not accept or refuses to accept the technology or rice variety, the varieties cannot be applied and disseminated. While it depends on the province, the farmers typically make the decision to adopt or refuse to

grow the new rice varieties. And because it is difficult to convince farmers to grow a particular variety, sometimes unexpected difficulties in the management delay or hamper the dissemination such that the new rice varieties do not reach all farmers. Messengers from farmers also significantly decide on the adoption of newly released rice varieties.

V. CONCLUSIONS AND FUTURE PROSPECTS

Development of salt tolerance varieties is generally considered the most effective entry point for improving productivity of salt affected soils, and it is also the cheapest option for farmers. Through the use of innovative breeding strategies involving conventional and modern tools, together with effective phenotyping techniques, good progress was made in developing salt tolerant varieties with broad adaptation to the conditions of the Mekong Delta. Some varieties such as HATRI 190, HATRI 170, HATRI 192 were developed that can yield 4-5 tons ha⁻¹ under 8.0 to 10.0 dS m⁻¹, and are being out-scaled. The success of new varieties is assured through eventual testing and selection in target sites in partnership with farmers and under their own management to guarantee relevance and adoption. This is achieved through combined use of salt tolerant genotypes, coupled with proper nursery management and seedling handling that ensures maximum survival of transplanted seedlings.

Future efforts should focus on further collection and evaluation of local germplasm to identify landraces with greater tolerance of salt stress, as sources of new genes or alleles for breeding. Additional breeding efforts such as mutation breeding and identification of soma clonal variants should continue to develop better pre-breeding material. To benefit from the new and exciting developments in the field of genomics, additional resources and efforts should be directed towards identification of QTLs and genes underlying tolerance to the multiple stresses experienced in these problem soils of Mekong Delta, for their subsequent integration into modern varieties and elite breeding lines through marker aided breeding. Special efforts should also be placed on training of young scientists to prepare a new generation that can effectively tackle these problems in a team approach.

In the future, stronger linkages and exchange of knowledge through project networks and meetings will also give considerable impacts on capacity strengthening, as well as meeting with scientists, extension workers, civil society organizations in affected areas to plan on the distribution of

seed and other adaptation activities to assure farmer acceptance of seed, and determine the quantity of seed required for distribution. Consultation and meetings with people from different sectors involved in the project will also address the development of seed multiplication plan for different varieties needed for different areas identifying the most likely partners to participate in the finalization of seed development and distribution; and identifying training needs of these in terms of technology adaptation, evaluation, and dissemination.

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