Evaluation on the yield of some rice varieties with tolerance to salt stress, a case study

Thi Ai Lien Quan*, Cong Thanh Vo

Department of Genetics and Plant breeding,
College of Agriculture and Applied Biology, Can Tho University

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Abstract:

In recent years, sea water has intruded into paddy fields along the coastal areas of the Mekong River Delta. This phenomenon, e.g abiotic stress, has caused rice yields to decrease significantly. A set of six new varieties of rice, including a variety control, IR28, were tested in Long An Province, a region subjected to abiotic stress, from August 2013 to December 2013. The experiments were arranged according to randomized complete block design, with three replications. Results showed that one new mutant cultivar of rice named CTUSM1 was tolerant to soil and water conditions (ECe, EC 6 dSm^{-1}) at the seedling stage; with a yield of 4.43 ton/ha, amylose content of 16.56%, protein content of 6.78%, and a significant resistance to pests and diseases.

Keywords: ***ECe (electrical conductivity extract), high yield, saline-tolerant rice, seedling stage.***

Classification number: ***3.1***

Introduction

Rice is very sensitive to salinity stress and is currently listed as the most salt sensitive cereal crop, with a tolerance threshold of 3 dSm^{-1} for most cultivated varieties [1], whereas, generally, a soil is only considered saline (salt-affected) if it has an ECe (electrical conductivity of its saturation extract) above 4 dSm^{-1} [2]. Even with an ECe as low as 3.5 dSm^{-1}, rice loses about 10% of its yield, with 50% yield loss having been recorded for rice at ECe 7.2 dSm^{-1} [3].

Rice plant response to salinity varies according to the growth stage. In the vast majority of rice cultivars, plants at the early seedling phase are most sensitive to salinity [4-5]. According to [6], salinity stress during seedling phase can reduce plant dry weight by two-fold compared to when stress occurs in the ripening phase. When employing irrigated rice planting in coastal areas, salinity may occur at any stage of plant growth. Therefore, it is important to determine the response to salinity in rice plants throughout the growth stage.

Salt infected soils are around 700.000 ha during the dry season from December to May annually [7]; Can Giuoc and Can Duoc districts are located in the southeast of Long An province, which is affected by the Vam Co and Soai Rap rivers, where rice-shrimp farming is popular. During this time, farmers take advantage of salt water by using it for their shrimp cultures. In the following season, farmers use natural rain water (from June to December) to remove salt from the paddy fields, and then begin planting rice. Although the salinity of soil is decreased, it is still high due to the previous shrimp culture season. Therefore, the aim of this research is to identify rice varieties (1) with high salinity tolerance at the seedling stage, and (2) that can escape salt water which intrudes into canals from December on via a shorter maturity term - around 120 days.

Material and method

Material and location

Experiments were carried out in the autumn-winter crop of 2012 and of 2013 in the two districts Can Giuoc and Can Duoc of Long An province. Four varieties (CTUSM1, CTUSM2, BN2, and OM5629 x TP6) were developed and selected up to F7 by crossing (OM5629 xTP6) and mutation method of temperature shocked (CTUSM1 and CTUSM2) [8].

Method

Experiments were designed by a randomized complete block with 3 replications, 6 treatments (CTUSM1, CTUSM2, OM4900, BN2, OM5629 x TP6, IR28 (variety control).

VCU testing (Procedure to conduct tests for Value of cultivation and use of rice varieties, 2011) applied the fertilizer formula: 100N-60P_2O_5-50K_2O, phosphate fertilizer was used in all trials as basal dressing, nitrogen and potassium fertilizers were applied according to the time (Table 1).

*Corresponding author: Email: qtalien@ctu.edu.vn

Table 1. Ratio of Nitrogenand Potassium fertilization according to time (% by weight).

Time application	N	K_2O
Before transplanting	50	30
The first when recovering and tillering (10 days after transplanting)	30	40
The second at panicle initiation	20	30

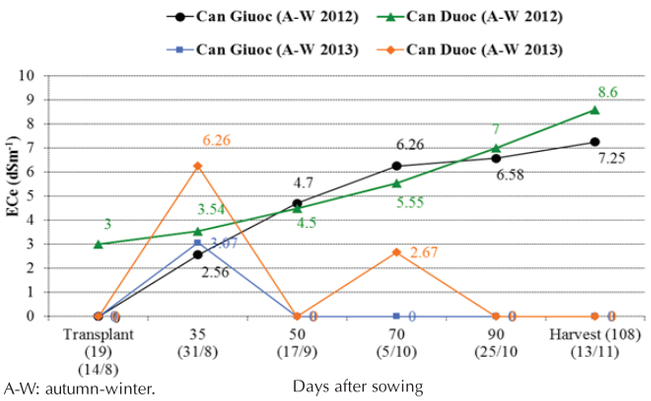

Fig. 1. ECe of water in the autumn-winter 2012 and autumn-winter 2013 crops at Can Giuoc and Can Duoc districts, Long An province.

Table 2. ECe and pH of soil through the growth stage of the rice plant.

Stages / Location	Transplanting		Flowering		Harvest	
	ECe (dSm^{-1})	*pH*	*ECe (dSm^{-1})*	*pH*	*ECe (dSm^{-1})*	*pH*
Can Giuoc (A-W 2012)	4.56	7.30	5.68	6.78	9.12	6.34
Can Giuoc (A-W 2013)	2.97	6.68	4.37	6.59	3.27	6.26
Can Duoc (A-W 2012)	5.68	6.94	8.75	5.95	10.96	6.45
Can Duoc (A-W 2013)	4.80	6.99	5.92	6.35	5.78	6.91

The following methods were followed for analysis of amylose content [9]; protein content [10]; Gelatinization temperature [11]; Gel consistency [12]; Grain length and shape [13].

Water EC and salinity were measured by EC meter (Hanna instrument HI 2550). Five points in the experimental paddy fields were recorded randomly, then the means were calculated;

Soil samplings followed [14]: pH, ECe were sampled at four growing stages of rice: transplanting, panicle initiation, ripening, and harvesting.

Method to analyze data: Excel and SPSS programs were used to carry out data analysis. An F-test was used to determine the differences among treatments. A Duncan test was applied to compare means among treatments.

Results and discussions

Salinity dynamics

EC of water: The EC at the seedling stage (from transplant to 35 days after sowing) varied from 2.5 to 6.2 dSm^{-1} in the autumn-winter 2012 and autumn-winter 2013 crops in the Can Giuoc and Can Duoc districts (Fig. 1). Most of plants in the IR28 (control) died, while other varieties developed successfully. At the panicle initiation stage (50 days after sowing, DAS), salinity decreased to fresh water conditions (0 dSm^{-1}) in the autumn-winter 2013 term while the other season ranged from 4.5 to 4.7 dSm^{-1}. During the boosting stage (70 DAS), salinity increased from 2.7 to 6.3 dSm^{-1}. In 2012, at the harvesting stage (90-108 DAS), salinity increased from 7.3 to 8.6 dSm^{-1} while in 2013 salinity decreased to fresh water conditions (0 dSm^{-1}) due to high rain fall. According to [15, 16], rice is very sensitive to salinity at the seedling stage; its height, root length, emergence of new roots, and dry matter should be expected to decreases significantly at EC 5-6 dSm^{-1}. Thus, our new five varieties can be considered tolerant at the seedling stage.

ECe of soil: The ECe of soil at the seedling stage in the A-W 2012 and A-W 2013 crops ranged from 2.97 to 5.68 dSm^{-1} in these two districts. And the pH in these two districts was around neutral: 6.68-7.30 (Table 2). At the stage from flowering to harvest, the ECe of soil increased from 5.68 to 9.12 dSm^{-1} in the season of A-W 2012 in Can Giuoc district while at the Can Duoc site it increased from 8.75 to 10.96 dSm^{-1} in the same season (A-W 2012).

Agronomical characteristics, yield components and yield

The term from germination to maturity of rice varieties spanned from 97 to 110 days over the autumn-winter 2012 and autumn-winter 2013 periods in the Can Giuoc and Can Duoc districts of Long An province (Table 3). According to research of [17], maturity reached in from 90-105 days is suitable for shrimp-rice farming models. Most of these rice varieties with a suitable maturity term [18, 19] have shown that an ideal phenotype of rice should be high yield, with the plant height being semi-dwarf (about 90-130 cm). According to [20], the Mot Bui Do variety of traditional rice has been chosen as a main cultivated variety for rice-shrimp models in some Mekong River Delta provinces such as

Table 3. Maturity and height of rice varieties at Can Giuoc, Can Duoc districts in A-W 2012.

Variety/line	Maturity (days)				Height (cm)			
	A-W 2012		A-W 2013		A-W 2012		A-W 2013	
	Can Giuoc	Can Duoc	Can Giuoc	Can Duoc	Can Giuoc	Can Duoc	Can Giuoc	Can Duoc
CTUSM1	100	100	105	105	93.5^{ab}	107^{c}	93.5^{ab}	108^{bc}
CTUSM2	100	100	104	103	84.4^{b}	97^{d}	84.4^{b}	105^{bc}
OM4900	105	105	104	105	99.2^{a}	112^{b}	99.2^{a}	122^{a}
BN2	101	101	96	96	83.2^{b}	110^{bc}	83.2^{b}	109^{b}
OM5629 x TP6	105	105	104	105	98.6^{a}	116^{a}	98.6^{a}	126^{a}
IR28	97	97	96	96	82.8^{b}	102^{c}	82.8^{b}	102^{c}
F					*	*	*	*
CV (%)					*6.29*	*1.90*	*6.29*	*2.86*

Table 4. Yield component of rice varieties.

Variety/line	Panicle/m²				Spikelets/panicle				Weight 1000 grains (g)			
	A-W 2012		A-W 2013		A-W 2012		A-W 2013		A-W 2012		A-W 2013	
	Can Giuoc	Can Duoc	Can Giuoc	Can Duoc	Can Giuoc	Can Duoc	Can Giuoc	Can Duoc	Can Giuoc	Can Duoc	Can Giuoc	Can Duoc
CTUSM1	235^{c}	243^{b}	251.3^{b}	286^{a}	97^{b}	83^{b}	105.7^{a}	81^{b}	23.2^{b}	23.7^{b}	23.2^{b}	22.8^{bc}
CTUSM2	261^{b}	244^{b}	291.3^{a}	297^{a}	83^{c}	80^{b}	79.0^{b}	87^{b}	22.6^{b}	22.3^{c}	22.2^{bc}	22.2^{bc}
OM4900	192^{d}	195^{c}	196.0^{c}	205^{b}	101^{ab}	79^{b}	114.0^{a}	90^{b}	24.9^{a}	25.6^{a}	25.2^{a}	25.6^{a}
BN2	260^{b}	230^{b}	249.3^{b}	290^{a}	81^{c}	76^{b}	79.5^{b}	79^{c}	22.7^{b}	21.6^{d}	23.4^{b}	21.9^{c}
OM5629 x TP6	195^{d}	165^{d}	203.7^{c}	176^{b}	107^{a}	116^{a}	114.7^{a}	116^{a}	24.8^{a}	25.4^{a}	24.9^{a}	25.2^{a}
IR28	283^{a}	322^{a}	201.3^{c}	201^{b}	50^{d}	27^{c}	50.4^{c}	51^{d}	21.9^{c}	22.6^{c}	21.6^{c}	23.3^{b}
F	*	*	*	*	*	*	*	*	*	*	*	*
CV (%)	*4.52*	*3.39*	*3.60*	*8.45*	*4.10*	*6.03*	*8.12*	*6.39*	*1.60*	*1.59*	*3.24*	*3.00*

Bac Lieu, Ca Mau, Kien Giang, yielding a plant height from 100-120 cm, this height being considered as sufficient for shrimp-rice models, so the plant height of all six tested varieties/lines of this experiment appear to be suitable phenotypes for high yield shrimp-rice models.

There is a wealth of research on yield components and yields. In [21-25], ideal phenotypes of high performance rice were examined, with following components analyzed: panicles per hill (8-10 panicle for transplanting) or 3-4 panicles/hill (sowing), number of panicle/m² was 270-300 panicle, with 150 spikelets/panicle and a spikelet rate reaching over 80% (Table 4).

As for the ECe, it changed a lot from the seedling stage to the harvest stage. Final yields of varieties/lines in this experiment ranged from that of control IR28 (which exhibited the lowest yield (0.57-1.40 ton/ha)) to that of the mutant line CTUSM1 (3.52-4.43 ton/ha) which exhibited the highest yield (Table 5). IR28 died after one to two weeks DAS, while CTUSM1 tolerated these conditions. The yield of CTUSM1 was also higher than that of MTL119, which exhibited a tolerance at the seedling stage of 6‰ tested by Yoshida solution (4.4 ton/ha in fresh water soil; 2.0- 3.0 ton/ha in saline soil, ECe 1.4 dSm^{-1}, 0 ton/ha in ECe 2.11 dSm^{-1}). [26, 27] reported that OM9605 and OM5953 could tolerate salt concentration at 6-8 dSm^{-1}, giving yields from 5 to 7 ton/ha under fresh water conditions.

Evaluation of pest resistance in the experimental field

Rice leaf blast caused by fungus *Pyricularia oryzae* appeared on CTUSM2 and OM4900 varieties were scored at level 3 while CTUSM1 was at level 0. Moreover, OM4900 was also affected by neck blast. Other varieties/lines were not sensitive to this fungus. Leaves of six varieties/ lines were damaged by rice leaf folder *Cnaphalocrosis*at at level 3, damage was about 11-20% from tillering to maturity (Table 6).

Table 5. Yield of rice varieties.

Variety/line	Actual yield (ton/ha)				Theoretical yield (ton/ha)			
	A-W 2012		A-W 2013		A-W 2012		A-W 2013	
	Can Giuoc	Can Duoc	Can Giuoc	Can Duoc	Can Giuoc	Can Duoc	Can Giuoc	Can Duoc
CTUSM1	3.87^{a}	3.52^{a}	4.43^{a}	3.78^{a}	5.28^{a}	4.82^{ab}	6.14^{a}	5.28^{a}
CTUSM2	3.31^{b}	3.11^{b}	3.58^{c}	4.36^{a}	4.91^{a}	4.37^{c}	5.14^{bc}	5.73^{a}
OM4900	3.19^{b}	2.69^{c}	3.26^{c}	2.86^{b}	4.83^{a}	3.98^{cd}	5.63^{ab}	4.72^{b}
BN2	3.21^{b}	2.46^{c}	3.68^{bc}	3.37^{ab}	4.75^{a}	3.81^{d}	4.63^{c}	5.02^{ab}
OM5629 x TP6	3.75^{a}	3.22^{ab}	4.17^{ab}	3.66^{ab}	5.20^{a}	4.86^{a}	5.82^{ab}	5.14^{ab}
IR28	1.26^{c}	0.71^{d}	0.57^{d}	0.79^{b}	1.09^{b}	1.97^{e}	1.19^{d}	1.40^{c}
F	*	*	*	*	*	*	*	*
CV (%)	*5.20*	*6.50*	*29.23*	*14.72*	*5.93*	*6.17*	*10.23*	*9.54*

Table 6. Pest resistance of six rice varieties in the paddy field experiment.

(Damage level)

Variety/line	Pyricularia oryzae	Xanthomonas oryzae pv. oryzal	Bipolaris oryzae	Agrotis ipsilon	Cnaphalocrosis	BPH
CTUSM1	0	0	0	1	3	3
CTUSM2	3	0	0	1	3	3
OM4900	3	0	0	1	3	0
BN2	1	0	0	1	3	0
OM5629xTP6	0	0	0	1	3	3
IR28	0	0	0	1	3	3

BHP: Brown plant hopper.

Table 7. Some rice quality traits of varieties/lines in the basic experiment

Variety/line	AC (%)	P (%)	GC (level)	Length of grain (mm)	Ratio of L/W	GT (level)
CTUSM1	16.56^{bc}	6.78	3^{b}	7.1^{abc}	3.2^{c}	3
CTUSM2	17.77^{b}	5.48	3^{b}	6.7^{d}	3.0^{d}	2
OM4900	16.01^{bc}	5.90	1^{c}	7.0^{bc}	3.2^{bc}	2
BN2	23.52^{a}	6.52	5^{a}	7.3^{a}	3.5^{a}	2
OM5629xTP6	14.88^{c}	6.31	3^{b}	7.2^{ab}	3.4^{ab}	2
IR28	24.90^{a}	6.39	5^{b}	6.9^{c}	3.5^{a}	7
F	*	*ns*	*	*	*	
CV (%)	*7.60*	*11.64*	*13.70*	*1.91*	*2.72*	

AC: amylose content; P: protein content; GC: Gel consistency; GT: Gelatinization temperature; L/W: Length/Wide.

Quality traits of 6 varieties/lines

Among all varieties in this experiment, amylose content of BN2 and IR28 was the highest (20-25%) while the other CTUSM1, CTUSM2, OM4900, OM5629 x TP6 had low amylose content ranging from 14.88 to 16.56% (Table 7).

Conclusions

The basic experiment of VCU (Value of Cultivation and Use) in the paddy field results was conducted over two years: 2012 and 2013 in Can Giuoc and Can Duoc districts, Long An province, an elite line CTUSM1 appeared excellent - it could tolerate salt at the seedling stage - under soil and water conditions of ECe and EC, respectively < 6 dSm^{-1}, and a high yield of 4.43 ton/ha was observed. High quality features were observed: amylose content 16.56%, protein content 6.78%, length of grain 7.1 mm, resistance to pests and diseases in the paddy field. CTUSM1 should be checked for the adaptable ability in various ecological areas.

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REFERENCES

[1] United States Department of Agriculture (2016), *Bibliography on Salt Tolerance. Fibres, Grains and Special Crops*, Salinity Laboratory United States Department of Agriculture Research Service: Riverside, CA, USA.

[2] P. Rengasamy (2006), "World salinization with emphasis on Australia", *J. Exp. Bot.*, **57**, pp.1017-1023.

[3] D.L. Umali (1993), *Irrigation-Induced Salinity a Growing Problem for Development and the Environment*, The Word Bank: Washington, DC, USA.

[4] L. Zeng and M.C. Shannon (2000), "Salinity effect on seedling growth and yield components of rice", *Crop Sci.*, **40**, pp.996-1003.

[5] T.U. Haq, J. Akhtar, S. Nawaz, R. Ahmad (2009), "Morpho-physiological response of rice (*Oryza sativa* L.) varieties to salinity stress", *Pak. J. Bot.*, **41(6),** pp.2943-2956.

[6] L. Zeng, M.C. Shannon , S.M. Lesch (2001), "Timing of salinity stress affect rice growth and yield components", *Agric. Water Manage.*, **48**, pp.191-206.

[7] N.T. Lang, S. Yanagihara, B.C. Buu (2001), "A microsatellite marker for a gene conferring salt tolerance on rice at the vegetative and reproductive stages", *Sabrao,* **33(1),** pp.1-10.

[8] Quan Thi Ai Lien, Nguyen Bich Ha Vu, Vo Cong Thanh (2013), "Mutation on seasonal rice for tolerance to saline condition by temperature-sensitive method", *Vietnam J. of Agriculture and rural development,* **2**, pp.77-85.

[9] G.B. Cagampang and F.M. Rodriguez (1980), *Methods analysis for screening crops of appropriate qualities,* Institute of plant breeding, University of the Philippines at Los Baños, pp.8-9.

[10] O.H. Lowry, N.J. Rosebroug, A.L. Farr, R.J. Raldall (1951), "Protein measurement with the Folin phenol reagent", *J. Bio.Chem.*, **193**, pp.265-275.

[11] P.R. Jennings, W.R. Coffman, H.E. Kauffman (1979), *Rice improvement*, IRRI, Philippins.

[12] S.X. Tang, G.S. Khush, B.O. Juliano (1991), "Genetics of gel consistency in rice", *Journal of Genetics*, **70**, pp.69-78.

[13] B.O. Juliano and P. Villareal (1993), *Grain Quality Evaluation of World Rices,* International Rice Research Institute, Manila, Philippines.

[14] TCVN - Committee on Science and Technology Government (1985), *Decision No. 447/QD/UBKHKTNN dated 18 September 1985, TCVN 4046:1985, Arable land - sampling method.*

[15] G.A. Pearson, S.D. Ayers, D.L. Eberhard (1966), "Relative salt tolerance of rice during germination and early seedling development", *Soil Sci.,***102**, pp.151-156.

[16] M. Akbar, Y. Yabuno (1974), "Breeding for saline-resistant varieties of rice. II. Comparative performance of some rice varieties to salinity during early developing stages", *Jap. J. Breed.*, **25**, pp.176-181.

[17] Nguyen Thi Lang, Nguyen Van Tao, Nguyen Duy Bay, Bui Chi Buu (2001), *Rice breeding salinity tolerance in the Mekong Delta,* The results of scientific research in 2000-2001, CLRRI. Agricultural Publishing House, pp.49-62.

[18] M. Dingkuhn, Penning De Vries, F.W.T. De Datta, S.K. Van Laar (1991), "Concept for a new plant type for direct seeded flooded tropical rice", *In: Direct Seeded Flooded Rice in the Tropics*, International Rice Research Institute, Los Banõs, Philippines, pp.17-38.

[19] P.R. Jennings (1964), "Plant type as a rice breeding objective", *Crop Sci.*, **4**, pp.13-15.

[20] Nguyen Thi Lang, Trinh Thi Luy, Bui Chi Buu, Albel Ismail (2010), "The genetic association between the yield, yield component and salt tolerance in rice", *OmonRice*, **17**, pp.99-104.

[21] Belford and Sedgley (1991), "Conclusions - ideotypes and physiology: tailoring plants for increased production", *Field Crops Res.*, **26**, pp.221-226.

[22] G.S. Khush (1995), "Breaking the yield frontier of rice", *Geo. Journal*, **35**, pp.329-332.

[23] G.S. Khush, P.S. Virk, A. Evangelista, B. Romena, A. Pamplona, V. Lopena, N. Dela Cruz, S. Peng, C.V. Cruz, M. Cohen (2001), "Germplasm with high yield potential", *In: 2001 annual report*, International Rice Research Institute, Los Baños, Philippines, pp.4-5.

[24] S. Peng, G.S. Khush (2003), "Four decades of breeding for varietal improvement of irrigated lowland rice in the International Rice Research Institute", *Plant Prod. Sci.*, **6**, pp.157-164.

[25] S. Peng, K.G. Cassman, S.S. Virmani, J. Sheehy, G.S. Khush (2005), "Yield potential of Tropical rice since the release of IR8 and the challenge of increasing rice yield potential", *Crop Sci.,* **39**, pp.1552-1559.

[26] Nguyen Ngoc De, Le Xuan Thai, Pham Thi Phan (2003), "Selection of suitable rice varieties for monoculture and rice-shrimp farming systems in the Mekong Delta of Vietnam", *In: Rice-shrimp farming in the Mekong Delta: Biophysical and socioeconomic,* issues edited by Nigel Preston and Helena Clayton ACIAR Technical Reports No.52e (printed version published in 2003), pp.53-65.

[27] Nguyen Thi Lang, Bui Duong Khuyeu and Bui Chi Buu (2013), "Results of research, selection, testing and trial production OM5953 salt tolerant rice varieties", *Journal of Agriculture and rural development*, **2**, pp.40-46.