Journal of Advanced Zoology
ISSN: 0253-7214
Volume 43 Issue 1 Year 2022 Page 355-367

Evaluation Of Agronomic Traits And Adaptation Of Some Promising Salt-Tolerant Rice Lines/Varieties Growing In The Coastal Areas In Thanh Hoa Province, Vietnam

Pham Van Dan[1], Nguyen Huy Hoang[2], Do Thi Thao[3], Nguyen Thi Thu Trang[4], Ta Hong Linh[5], Tran Thi Hue Huong[6], Le Hung Linh[7]*

[1,2,3,4]Center for Technology Development and Agricultural Extension (CETDAE), Vinh Quynh, Thanh Tri, Hanoi, Vietnam;
[5,6]Vietnam Academy of Agricultural Sciences, Vinh Quynh, Thanh Tri, Hanoi, Vietnam
*[7]*Agricultural Genetics Institute, Hanoi, Vietnam*

***Corresponding author:** Le Hung Linh*
**Agricultural Genetics Institute, Hanoi, Vietnam. Email: lehunglinhagibio70@gmail.com*

Article History

Received:
Revised:
Accepted:

Abstract

Rice (Oryza sativa L.) is the main food in Vietnam and plays an important role in economic activity in this country. However, rice yield and growing areas are adversely influenced by the threats of the devastation caused by the rise of sea level. This study aimed to evaluate the salt effects in field experiments of 19 promising salt tolerance rice lines/varieties carrying QTL/Saltol, which were selected from the BC_2F_5 breeding combination between FL479 and Bac Thom 7 (BC7). The field experiments were conducted in two consecutive seasons at three saline-affected rice growing areas, including Nga Son, Hoang Hoa and Quang Xuong districts, Thanh Hoa province. The results showed that among those promising rice lines, the HL15 line had the best yield components in all experimented sites, and good agronomic traits with short plant height and shorter growth duration than the BC7 variety (115-117 days) in the spring season and 102-103 days in the summer season, respectively. All tested had the same level of pest resistance/infection as the control variety BT7 under production conditions using pesticides including HL1, HL13 and HL15, which were mildly infected with the bacterial leaf blight, while HL15 variety showed high resistance to pests and diseases. Moreover, the HL2, HL15 and HL19 lines had scored 3, equivalent to FL478 (tolerant), and the survival rate was over 85% compared with the control variety. Overall, our findings showed that the promising purebred variety HL15 had a range of good agronomic characteristics, resistance to major pests and diseases, high yield potential and salinity tolerance of 6‰. The HL15 variety was renamed as SHPT15 and continued to conduct procedures to recognize it as a new rice variety.

Keywords: Salt-tolerant rice, Coastal regions, Thanh Hoa province, Soil salinity

1. INTRODUCTION

Saline intrusion is one of the main unfavorable conditions affecting agricultural production in the coastal areas of Vietnam, particularly in the two main bowls of rice-producing areas of Red River and Cuu Long Deltas, where have experienced the highest levels of salt impact[1-2]. Due to the adverse influences of climate change, sea level rise is identified as one of the reasons for the saltwater intrusion. As highlighted by Le and Tuan[3] and Linh et al[4], sea level rise causes flooding in aquifers of coastal and estuarine regions, causing salinization in all or a part of the aquifers in these regions. The climate change scenario updated by the Ministry of Natural Resources and Environment in 2020 indicated that, by the end of the 21st century, if the sea level rises by 1m, the area at risk of flooding will be 13.2% of the area of the Red River Delta, 5.49% of the Central coastal provinces from Thanh Hoa to Binh Thuan, 17.15% of the area of Ho Chi Minh City, 47.29% of the Mekong Delta. It has been resulted in reducing the area of coastal regions in Vietnam, and with the serious effects of saline intrusion, rice production will be affected in both productivity and quantity.

Saline soil affects the growth and development of rice, leading to a reduction in yield of 20 – 25%, resulting in a significant reduction of food production, which can threaten national food security[5-6]. Rice yield is significantly reduced at EC > 3 dS/m, so rice is classified as a crop sensitive to salinity[7-8]. If the salinity of irrigation water is 4.8 mS/cm (3‰), rice yield can be decreased by 50%[9-10]. The salt threshold of rice is different at different stages of growth and development. Rice is tolerant to salinity at the germination stage, but it is sensitive to salinity at seedling, flowering, and grain filling. Zeng and Shanon[11] reported that at very low salinity (1.9 dS/m), which has caused a detrimental effect on the growth of seedlings, especially at stage 2-3 leaves of rice seedlings, but this effect was not associated with the decline in grain yield at later stages. When the salinity is above 3.4 dS/m, the survival rate of seedlings is reduced. At a salinity of 6 dS/m, there was a reduction in pollination, fertilization, and grain filling, leading to an increase in the number of unfilled seeds and a decrease in the weight of 1000 seeds. According to the report of Thao et al[12], after 12 days of testing at the salinity of 15dS/m in the Mekong River delta, the control variety IR28 died completely (level 9), other varieties/lines were rated at level 5- moderate level, especially D1-1 line was rated at level 3 (tolerant level), and the variety OM6677 being grown in Ca Mau was rated at level 7 (sensitive level). Two lines D1-1 and NQBDB can tolerate salinity (19 dS/m) at the seedling stage. It implies that the salt tolerance of rice varieties is mostly dependent on their genetic backgrounds or some genes or QTLs are responsible for their salt tolerance, which were identified in this country[13-14].

Vietnam is known as the center of rice genetic diversity and is rice in various rice germplasms with valuable traits and plays a pivotal role in rice breeding for sustainable agriculture production[13]. Therefore, the salinity tolerance of rice varies depending on rice varieties, however different salt-tolerant rice varieties have different salt tolerance, and this factor is very important to help rice adapt to many environmental conditions. This is also the theoretical basis for the selection of salt-tolerant rice varieties adapted to saline conditions in different ecological regions. Based on the requirements to select salt-tolerant rice varieties for adapting to ecological conditions with stability, high yield and quality for Northern Central Coast provinces, the objective of this study was to conduct field experiments to evaluate the agronomic traits and adaptation of the selected promising salt tolerance rice lines in 3 salt-affected districts of Thanh Hoa province.

2. MATERIALS AND METHODS

2.1. Plant materials used in this study

The plant materials used in the experiment were 19 promising salt-tolerant rice varieties/lines which were homozygous for *saltol* QTL. These varieties/lines were selected from crossing between FL478 (rice variety imported from IRRI and BT7- mega rice variety. These varieties/lines are presented in the following Table 1.

Table 1. List of salt-tolerant rice varieties/lines used in this study

No	Variety/Line	QTL *Saltol*	Selected generation	Collection origin
1	HL1	+	BC_2F_5	Agricultural Genetics Institute (AGI)
2	HL2	+	BC_2F_5	AGI
3	HL3	+	BC_2F_5	AGI
4	HL4	+	BC_2F_5	AGI
5	HL5	+	BC_2F_5	AGI
6	HL6	+	BC_2F_5	AGI
7	HL7	+	BC_2F_5	AGI
8	HL8	+	BC_2F_5	AGI

9	HL9	+	BC_2F_5	AGI
10	HL10	+	BC_2F_5	AGI
11	HL11	+	BC_2F_5	AGI
12	HL12	+	BC_2F_5	AGI
13	HL13	+	BC_2F_5	AGI
14	HL14	+	BC_2F_5	AGI
15	HL15	+	BC_2F_5	AGI
16	HL16	+	BC_2F_5	AGI
17	HL17	+	BC_2F_5	AGI
18	HL18	+	BC_2F_5	AGI
19	HL19	+	BC_2F_5	AGI
20	BT 7 (control)	-	-	Purebred mega variety

"+" implies carrying QTL Saltol; "-" presents without Saltol QTL

2.2. Experiment design

The field experiment was carried out in two consecutive seasons (spring and summer-autumn seasons) in 2017 in saline-affected rice-growing areas of three coastal districts of Thanh Hoa province including Nga Son, Hoang Hoa and Quang Xuong. The experiment was designed in a randomized complete block (RCB), with 3 replications[15]. The experimental plot area was 10 m^2 (2.5 x 4.0), density was 35 plants/m^2. The amount of fertilizer used for 1ha was 8 tons of manure, 450 kg of lime powder, 100 kg N, 90 kg P_2O_5, and 90 kg K_2O in the spring crop, and the amount of nitrogen was reduced to 90 kg N/ha in the summer-autumn season[16]. In this study, we also collected some major information on saltwater intrusion status and its effect on rice production in the studied site used in this study.

Greenhouse experiment was conducted in AGI in Hanoi to evaluate the salt tolerance of some rice lines grown in Yoshida nutrient solution added NaCl at a concentration of 6‰ based on the method developed by International Rice Research Institute (IRRI)[17] with some minor modifications[4]. Briefly, the germinated rice seeds with a radicle length of 1.5-2.0 mm were placed in holes covered by a net on a foam float, which was placed in a rectangular plastic container containing 18 L of Yoshida nutrient solution 1x with pH = 4.7 - 5. Each line/variety was sown on 6 foam floats, each float had 5 holes with 3 replicates. After 3 days, each float only had 3 seedlings after removing the weakest seedlings. The nutrient solution was replaced every week to avoid K stress for seedlings. The solution pH was adjusted daily using 1N HCl or 1N KOH. When the seedlings had 3 leaves, starting to form the 4th leaf (about 20 days after sowing), NaCl was added to the solution to reach the targeted concentrations of 3‰ at the beginning, then increased to 6‰ after 4 days.

2.3. Data collection

Data collected in the field experiment in Thanh Hoa province included growth duration, some agro-biological characteristics of rice lines/varieties including plant height, maximum number of tillers, number of panicles per tiller, number of productive panicles per tiller; indicators for monitoring pests and diseases; components of yield and grain yield. The monitoring criteria, methods of assessment and data collection were followed in accordance with National Technical Regulation on Testing for Value of Cultivation and Use of Rice varieties (01-55: 2011/BNNPTNT) issued by Ministry of Agriculture and Rural Development of Vietnam[18]. The salt tolerance of rice lines/varieties grown in nutrient solution was assessed based on the tolerance level through growth observation based on the SES evaluation criteria by IRRI. Results were recorded when the control variety IR29 started to die (at SES 7) or 15 -20 days after increasing the salt concentration of the nutrient solution.

Table 2. Standard evaluation system (SES) for growth stages of rice plants (IRRI,1997)

SES Scale	Description	Salt tolerance
1	Normal growth, no symptoms on young leaves	Strongly tolerant
3	Normal growth, but burnt on leaf tips, and old leaves discoloured	Tolerant
5	Growth reduced, most leaves discolored, whitish and rolled, only a few elongating	Moderately tolerant
7	Growth completely ceases, most leaves dry, some plants dying	Sensitive
9	All plants dead or dying	Highly sensitive

Analysis of salinity and soil properties: Soil samples were taken at a depth of 20 cm before transplanting rice in the experimental field. Then they were air-dried to analyze Organic Compounds (OM) using the Tiurin method, pH measurement; total nitrogen using Keldahl method, total phosphorus using the colorimetric method on a spectrophotometer, available phosphorus by Oniani method, total and available potassium using the flame photometric method, exchangeable cations (K^+,Na^+,Ca^{2+},Mg^{2+}) using absorption spectroscopy method, anions (Cl^- and SO_2^-) using ion chromatography method, cation exchange capacity (CEC) using Keldahl method (NH_4Oac, pH= 7), salinity (EC) using conductivity electrode (EC meter, handy lab LF 11, S1 Analytics GmbH).

2.4 Data analysis

Data were analyzed using computer software, specifically: The software Office Excel 2007, IRRISTAT 5.0 and STATISTIX 8.2 for analyzing statistical data collected from the experiment of rice varieties selection. The stability of rice varieties was assessed based on grain yield calculated using the model of Eberhard and Russell[19]with regression coefficient bi (interaction between environment and genotype) and deviation from regression (S^2di) compared with the regression line. Regression parameter bi (adaptation parameter): If bi>1: variety adapted to favorable conditions (intensive cultivation variety).
bi = 1: wide-adapted variety, stable variety.
bi < 1: varieties adapted to unfavorable conditions.
With: $\sum bi = 1$.

Deviation from regression (stable parameter) S^2di: If S^2di approaches 0: the variety is stable. If S^2di is non-zero, the variety is not stable; where $\sum S^2di = 0$
A variety is considered as stable when the regression coefficient (bi) is not 1 with no significance, and S^2di gradually approaches 0. The variety adapts to favorable conditions (intensive cultivation conditions) when bi>1 and S^2di gradually approaches 0 and the variety adapts to unfavorable conditions when bi < 1 and S^2di gradually approaches 0. Environmental index *Ij*:
$I_j = L_i - X_{TB\ chung}$: environmental index (L: score of tested variety).
If Ij > 0: favorable environment.
If Ij < 0: unfavorable environment.
In this research, the software *ondinh.com* developed by Nguyen Dinh Hien was used to analyze the data, evaluate the grain yield of rice varieties, and select stable varieties for ecological regions conducted the experiments.

3. RESULTS AND DISCUSSION

3.1. Saltwater intrusion status and its effects on rice production in the studied sites

Thanh Hoa is a coastal province, located in the key economic region of the North Central of Vietnam. Rice production plays a significant role in the long-term agricultural economic development of this province, especially in the coastal area. Thanh Hoa has the largest rice land area in the North Central, with about 231,000 hectares in 2021[20], thus, this province has faced severe damage from saltwater intrusion. There has been an increase in the rice land area affected by salinity, from 3,200 ha in 2014 to 7,816 ha in 2018. The area of saline soil is interspersed and scattered along 102 km of the coastline, which is detrimental to agricultural cultivation, especially rice cultivation. According to the survey, the saline soil regions had up to over 50% of the rice yield losses. The report on climate change of the province in 2018 also showed that in 2014 Thanh Hoa had 198 ha of rice lost all due to severe salinization[21]. The areas of rice land that have been affected by salinity in Thanh Hoa are mainly in the coastal districts including Hoang Hoa, Nga Son, Hau Loc, Quang Xuong, etc,. Assessing the area of rice cultivation land affected by salinity in 6 coastal districts of the province showed that the area of rice land affected by salinity for a whole year in Hau Loc, Nga Son, Hoang Hoa, Tinh Gia and Quang Xuong was 3,827 ha (33.1%), 1,419 ha (9.1%), 2,258 ha (29, 1%), 1,369 ha (6.7%), and 143 ha (1.8%)[21], respectively. The average rice yield tends to increase, but on saline soils, rice yield has decreased over the years, with 2.9 tons/ha in 2014, 2.8 tons/ha in 2015, 2.5 tons/ha in 2016, 2.6 tons/ha in 2017, and 2.7 tons/ha in 2018. Thus, rice yield reduced due to salinity was from 1.1-2.2 tons/ha, corresponding to 27.0- 46.2%. Rice yield was most severely affected in 2017 and 2018, with rice yield sharply reduced from 2.0-2.2 tons/ha in areas with high salinity. Rice yields of coastal districts of Thanh Hoa province ranged from 4.5 tons/ha in Hau Loc to 5.7 tons/ha in Quang Xuong in the winter-spring seasons, and from 4.7 tons/ha to 5.0 tons/ha in the summer-autumn seasons. Thus, the average rice yield in the coastal districts of Thanh Hoa province was much lower than that of the province (6.5 tons/ha).

In recent years, in the North Central provinces, especially Thanh Hoa province, there have been a number of research programs on climate change adaptation solutions in rice production. However, the results of research on selection of rice varieties for saline soils have been limited and also a new research problem, so there have not been suitable salt-tolerant rice varieties for saline soils in coastal districts of Thanh Hoa. Currently, the varieties are commonly grown in the coastal districts of Thanh Hoa province are BT7 (as mega variety); Thien uu 8, F1, Bio 404, HT1, NX30, BC15, etc. have low salt tolerance and long growth duration. Therefore, in this study, we used BT7 as the control rice variety. Also, our research was focused on researching and selecting rice varieties with high salt tolerance, high yield and good quality and especially short and medium growing durations that are suitable for cultivation in local farming conditions is currently an urgent requirement. The results of analyzing soil samples in 3 studied sites are presented in Table 3.

Table 3. Result of soil analysis in Quang Nham, Hoang Truong and Nga Thai, July – August 2017

No	Sample code	Analytical indicators													
		Moisture (%)	pH_{KCl}	OM (%)	N (%)	P_2O_5 (%)	K_2O (%)	P_2O_5 mg/ 100 g soil	Exchangeable cations (meq/100g soil)		CEC (meq/100g soil)	EC (mS/cm)	Total soluble salts (%)	Cl^- (%)	SO_4^{2-} (%)
									Ca^{2+}	Mg^{2+}					
1	QN-QX01	3.31	5.84	3.23	1.58	0.08	0.972	16.34	5.33	3.45	10.25	3.35	1.52	0.37	0.06
2	QN-HL02	2.82	5.87	3.30	1.69	0.09	1.053	18.51	4.74	3.47	9.89	3.24	1.47	0.38	0.07
3	QN-HL03	2.31	5.91	3.43	1.77	0.09	1.132	20.71	4.12	3.37	9.54	3.12	1.38	0.42	0.06
Mean		**2.82**	**5.88**	**3.33**	**1.68**	**0.09**	**1.05**	**18.52**	**4.73**	**3.43**	**9.89**	**3.24**	**1.46**	**0.39**	**0.06**
4	NT-NS01	3.51	5.15	3.73	2.09	0.13	2.310	22.95	5.58	2.03	8.37	1.70	0.70	0.31	0.07
5	NT-NS02	3.43	5.12	3.76	2.10	0.13	2.301	22.64	5.12	1.95	8.14	1.65	0.64	0.28	0.07
6	NT-NS03	3.48	5.15	3.70	2.07	0.13	2.301	21.98	5.31	2.08	8.44	1.68	0.76	0.32	0.11
Mean		**3.47**	**5.14**	**3.73**	**2.09**	**0.13**	**2.30**	**22.52**	**5.36**	**2.02**	**8.32**	**1.68**	**0.70**	**0.30**	**0.08**
7	HT-HH01	3.75	6.67	3.78	2.16	0.14	2.09	21.80	6.04	4.14	12.98	3.12	2.04	0.77	0.09
8	HT-HL02	3.87	6.59	3.65	2.07	0.14	2.03	22.98	6.32	4.17	13.45	3.19	1.83	0.68	0.10
9	HT-HL03	3.98	6.52	3.62	1.98	0.15	1.98	24.46	6.57	4.20	13.92	3.26	1.59	0.58	0.12
Mean		**3.87**	**6.59**	**3.68**	**2.07**	**0.14**	**2.03**	**23.08**	**6.31**	**4.17**	**13.45**	**3.19**	**1.82**	**0.68**	**0.10**

(QN-QX: Quang Nham- Quang Xuong; NT-NS: Nga Thai - Nga Sơn; HT-HH: Hoang Trường- Hoang Hoa)

3.2. Selection of salt-tolerant rice varieties

3.2.1. Agronomic characteristics, yield components and yield of potential salt tolerant rice lines/varieties

The experiment was conducted in the spring and summer seasons in 2017 in 3 districts of Thanh Hoa, including Quang Xuong, Hoang Hoa and Nga Son. These are the coastal districts which have large rice land areas affected by saltwater intrusion. The observation of growth duration and plant height of potential rice lines/varieties in the spring and summer seasons in 2017 in 3 districts of Thanh Hoa showed that the growth duration of the tested lines/varieties in the spring season at 03 study sites ranged from 114 days to 127 days, in which there were 11 lines/varieties with shorter growth duration than the control variety BT7 (from 1-7 days) including HL13, HL6, HL15, HL12, HL4, HL18, HL11, HL5, HL3, HL7 and HL17, 02 lines/varieties with similar growth duration to the control including HL14 and HL19; and 06 lines/varieties with longer growth time than BT7 (1-6 days) including HL10, HL8, HL2, HL9, HL16 and HL1. HL1 and HL16 were two lines/varieties that had the longest growing duration (126-127 days). In the summer season, the tested lines/varieties had an average growth duration at 3 sites ranging from 102.3 to 114 days. The lines/varieties HL11 and HL15 had 2 days shorter growth duration than the control variety BT7 (105 days). There were 04 lines/varieties with similar growth duration as the control BT7, including HL4, HL5, HL8 and HL10. The other lines/varieties had longer growth duration than the control variety BT7 from 2 to 10 days, in which HL14, HL9, HL16 and HL1 were the lines/varieties with the longest growth duration.

Plant height of rice lines/varieties in the spring season ranged from 105.8 to 118.6 cm, in which there were 07 lines/varieties had a lower height the control variety BT7 from 2.0 to 5.2 cm, including HL6, HL3, HL15, HL18, HL13, HL7 and HL5; and 05 lines/varieties with no significant difference in height with the control including HL17, HL12, HL4, HL1, HL11. The other 07 lines/varieties were higher than the control variety BT7. In the summer season, the plant height of the tested lines/varieties alsovaried from 104.3 - 116.8 cm with 11 lines/varieties shorter than BT7, 3 lines similar height to the control, and 5 lines/varieties higher than the control variety.

Table 4. Growth duration and plant height of tested rice lines/varieties in the spring and summer seasons of 2017 in Thanh Hoa province

Line/Variety	Plant height (cm)				Growth duration (days)			
	Quang Xuong	Hoang Hoa	Nga Son	Mean	Quang Xuong	Hoang Hoa	Nga Son	Mean
Spring season								
HL1	110.5	109.8	111.8	110.7	128	126	127	127
HL2	115.5	114.8	116.7	115.7	126	124	125	125
HL3	106.3	105.6	107.2	106.4	119	121	120	120
HL4	110.5	109.8	111.4	110.6	115	117	116	116
HL5	108.5	109.1	109.4	109	117	119	118	118
HL6	105.3	105.9	106.2	105.8	115	117	116	116
HL7	107.2	107.8	108.1	107.7	118	120	122	120
HL8	113.5	114.1	114.4	114.0	125	123	121	123
HL9	117.1	117.7	118.0	117.6	128	125	122	125
HL10	113.3	112.9	114.4	113.5	125	122	119	122
HL11	112.5	111.7	113.6	112.6	120	117	114	117
HL12	109.5	108.7	110.6	109.6	117	116	115	116
HL13	107.3	106.5	108.6	107.5	115	114	113	114
HL14	118.5	117.7	119.6	118.6	122	121	120	121
HL15	105.9	106.7	107.4	106.7	117	115	116	116
HL16	116.3	115.5	117.5	116.4	128	126	124	126
HL17	108.8	109.2	110.4	109.5	119	120	121	120
HL18	106.5	107.7	108.1	107.4	116	117	118	117
HL19	114.5	115.7	116.1	115.4	120	121	122	121
BT7 (control)	110.3	111.1	111.5	111.0	120	121	122	121
Summer season								
HL1	108.7	107.8	107.4	108.0	115	114	113	114
HL2	113.6	112.7	112.3	112.9	107	106	105	106
HL3	104.9	104.2	103.8	104.3	110	109	108	109
HL4	108.5	107.8	107.4	107.9	105	104	104	104.3
HL5	106.5	105.8	105.4	105.9	105	104	104	104.3
HL6	105.8	105.1	104.7	105.2	108	107	107	107.3
HL7	106.2	105.5	105.1	105.6	107	106	106	106.3
HL8	111.5	110.8	110.4	110.9	105	104	104	104.3
HL9	115.1	114.4	114.0	114.5	113	112	112	112.3
HL10	111.3	110.6	110.2	110.7	105	104	103	104
HL11	110.5	111.1	110.7	110.8	103	102	102	102.3
HL12	107.5	108.1	107.7	107.8	110	109	109	109.3
HL13	104.6	105.2	104.8	104.9	110	109	109	109.3
HL14	116.5	117.1	116.7	116.8	112	111	110	111.0
HL15	106.3	106.9	106.5	106.6	103	102	102	102.3
HL16	114.3	114.9	114.5	114.6	114	113	112	113
HL17	106.8	107.4	107	107.1	107	106	105	106
HL18	104.5	105.1	104.7	104.8	108	107	106	107
HL19	112.5	113.1	112.7	112.8	110	109	108	109
BT7 (control)	111.5	110.9	110.5	111.0	105	104	105	104.7

Agronomic characteristics of tested salt-tolerant rice lines/varieties

The leaves of all rice lines/varieties were medium green. The flag leaf shape was diverse, with lines HL9, HL14 and HL15 had long and straight flag leaves, while HL10, HL5, and LH2 had medium and straight flag leaves, and the other lines/varieties had short and straight flag leaves. The panicle length of tested rice lines/varieties was medium. The grain size of most rice lines/varieties was medium with the color of light brown and brown. However, there are 07 lines/varieties had bright yellow grains including HL1, HL2, HL4, HL6, HL9, HL11 and HL15, in which HL1, HL9 and HL15 had long grains.

Table 5. Morphological characteristics of tested rice lines/varieties

Line/Variety	Leaf sheath color	Flag leaf shape	Panicle length	Grain
HL1	Green	Short, straight	Medium	Long grain, medium width, light yellow
HL2	Green	Short, straight	Medium	Long grain, medium width, light yellow
HL3	Green	Medium, straight	Medium	Medium grain, medium width, brown
HL4	Green	Medium, straight	Medium	Medium grain, medium width, brown
HL5	Green	Short, straight	Medium	Medium grain, medium width, brown
HL6	Green	Short, straight	Medium	Medium grain, medium width, light yellow
HL7	Green	Long, straight	Medium	Medium grain, medium width, brown
HL8	Green	Medium, straight	Medium	Medium grain, medium width, brown
HL9	Green	Short, straight	Medium	Long grain, short width, light yellow
HL10	Green	Short, straight	Medium	Medium grain, short width, brown
HL11	Green	Long, straight	Medium	Long grain, medium width, light yellow
HL12	Green	Medium, straight	Medium	Medium grain, short width, brown
HL13	Green	Medium, straight	Medium	Medium grain, short width, brown
HL14	Green	Medium, straight	Medium	Medium grain, short width, brown
HL15	Green	Short, straight	Medium	Long grain, medium width, light yellow
HL16	Green	Long, straight	Medium	Medium grain, medium width, brown
HL17	Green	Medium, straight	Medium	Medium grain, medium width, brown
HL18	Green	Long, straight	Medium	Medium grain, medium width, brown
HL19	Green	Medium, straight	Medium	Medium grain, medium width, brown
BT7(control)	Green	Short, straight	Medium	Medium grain, short width, brown

***Resistance to pests and diseases*:**
Most tested rice lines/varieties had similar resistance to pests and diseases to the control variety BT7, especially in the summer season when they were sensitive to bacterial leaf blight disease. The lines/varieties with a low resistance to bacterial leaf blight disease were HL5, HL8, HL10, HL12 and HL17, while HL1, HL13 and HL15 were mildly infected with this disease when the plants grew and developed well. The lines/varieties in the experiment were only mildly infected with sheath blight disease and rice blasts from the end of tillering to flowering stages. For pests, the observation showed that leaf roller and stem borers mainly appeared in the tillering and panicle initiation stages of tested rice lines/varieties, in which BT7 (the control), HL6, HL7, and HL19 were varieties that were seriously affected, only while HL15 was most resistant.

Yield components and yield of tested rice lines/varieties in Thanh Hoa in the spring and summer seasons of 2017

Observation results of yield component and yield of tested rice lines/varieties in Thanh Hoa in the spring and summer seasons of 2017 showed that the number of panicles per tiller depends on genotypes, cultivation techniques and ecological conditions. There were 3 tested rice lines/varieties that had a higher number of panicles per tiller than the control variety BT7 (5.3 panicles per tiller) in both crop seasons, including HL1, HL4, HL10, HL17 (from 5.4 to 5.7 panicles per tiller). The number of grains per panicle: there were 15 tested lines/varieties that had a higher number of grains per panicle than the control BT7 (125.6 grains per panicle) in the spring season, in which HL2 had the highest number of grains per panicle (144.5 grains per panicle). In the summer season, there were 6 lines/varieties that had a higher number of grains per panicle than the control BT7 (117.7 grains), in which HL1 had the highest number of grains per panicle (127.1 grains). Unfilled grain percentage (%): unfilled grain percentages of all tested lines/varieties in 3 study sites were higher than the control variety BT7 in both crop seasons. In the spring season, the unfilled grain percentage of tested lines/varieties was from 13.0 to 23.8%, while that of BT7 was 11.0%. In the summer season, the unfilled grain percentages of tested lines/varieties ranged from 16.2 to 21.4%, while BT7 only had 7.3%. The unfilled grain percentage of HL15 was the lowest among tested lines/varieties.

One thousand (1000)-grain weight (g): in the spring season, HL13 and HL18 had lower 1000-grain weight than the control BT7 (18.8 g), there was 1 variety that had a similar 1000-grain weight to the control and 16 lines/varieties had higher indicator than the control, ranged from 19.0 to 23.0 g. In the summer season, there were 13 lines/varieties that had higher 1000-grain weight than the control BT7 (18.9 g), ranging from 19.1 to 22.5 g. In both crop seasons, HL15 had the highest 1000-grain weight among tested lines/varieties.

The results showed that the average yield of tested rice lines ranged from 34.0 quintals/ha (HL8) to 56.0 quintal/ha (HL15) in the spring season, and from 36.0 quintals/ha (HL7) – 54 quintals/ha (HL5) in the summer season, while the control variety BT7 had an average yield in 3 study sites ranged from 47.0 quintals/ha (in the spring season) to 45 0.0 quintals/ha (in the summer season). There were 4 lines/varieties including HL15, HL4, HL1 and HL2 that had the highest yield, which was higher from 5.4 -10.2 quintals/ha than the control with a statistically significant difference at 95 confidence level. HL15 had the highest yield in both crop seasons in all study sites, ranging from 55.0 quintals/ha (in Nga Son) to 58.0 quintals/ha (in Hoang Hoa) in the spring season, from 53.0 quintals/ha (in Nga Son) to 55.0 quintals/ha (in Quang Xuong) in the summer season.

Table 6. Yield components of tested rice lines/varieties in 2017

Line/Variety	Number of panicles per tiller				Number of grains per panicle				Unfilled grain percentage (%)				1000-grain weight (g)			
	Quang Xuong	Hoang Hóa	Nga Son	Mean	Quang Xuong	Hoang Hoa	Nga Son	Mean	Quang Xuong	Hoang Hoa	Nga Son	Mean	Quang Xuong	Hoang Hoa	Nga Son	Mean
Spring season																
HL1	5.5	5.5	5.4	5.5	142.7	145.9	140.9	143.2	15.2	17	18.3	16.8	21.3	21.1	21.6	21.3
HL2	5.5	5.4	5.4	5.4	144.5	149.5	144.5	146.2	21.0	19.8	21.1	20.6	22.0	21.7	22.5	22.1
HL3	5.2	5.2	5.2	5.2	131.5	129.5	124.5	128.5	17.5	19.3	20.6	19.1	19.6	19.3	20.1	19.7
HL4	5.4	5.4	5.3	5.4	143.9	142.7	137.7	141.5	18.6	20.4	21.7	20.2	22.3	22.0	22.8	22.4
HL5	5.2	5.2	5.3	5.2	134.1	131.9	126.9	131.0	18.1	19.9	21.2	19.7	19.9	19.6	20.4	20.0
HL6	5.3	5.5	5.3	5.4	126.5	124.5	119.5	123.5	18.1	19.9	21.2	19.7	22.6	22.3	23.1	22.7
HL7	5.2	5.2	5.2	5.2	124.5	122.5	117.5	121.5	19.7	21.5	22.8	21.3	19.3	19.0	19.8	19.4
HL8	5.5	5.5	5.5	5.5	135.7	133.5	128.5	132.6	19.1	20.9	22.2	20.7	18.9	18.6	19.4	19.0
HL9	5.2	5.2	5.3	5.2	120.5	118.5	117.5	118.9	19.4	21.2	22.5	21.0	22.6	22.3	23.1	22.7
HL10	5.7	5.7	5.7	5.7	132.7	130.5	125.5	129.6	19.8	21.6	22.9	21.4	20.3	20.0	20.8	20.4
HL11	5.1	5.1	5.3	5.2	137.7	135.5	128.9	134.0	20.2	22	23.3	21.8	22.1	21.8	22.6	22.2
HL12	5.5	5.5	5.2	5.5	137.5	135.5	130.5	134.5	21.0	22.8	24.1	22.6	19.6	19.3	20.1	19.7
HL13	5.3	5.3	5.3	5.3	128.7	126.5	121.5	125.6	21.9	23.7	25	23.5	18.6	18.3	19.1	18.7
HL14	5.3	5.3	5.3	5.3	139.5	137.5	132.5	136.5	22.4	24.2	25.5	24.0	19.3	19.0	19.8	19.4
HL15	5.3	5.3	5.3	5.3	137.1	136.9	133.6	135.9	11.8	13.4	13.8	13.0	22.9	22.6	23.4	23.0
HL16	5.4	5.3	5.3	5.3	131.5	129.5	124.5	128.5	16.2	18.0	19.3	17.8	20.6	20.3	21.1	20.7
HL17	5.5	5.6	5.6	5.6	143.7	141.5	136.5	140.6	21.6	23.4	24.7	23.2	18.8	18.5	19.3	18.9
HL18	5.3	5.2	5.2	5.2	131.5	129.5	124.5	128.5	22.0	23.8	25.1	23.6	18.7	18.4	19.2	18.8
HL19	5.2	5.2	5.2	5.2	133.5	131.5	126.5	130.5	22.2	24	25.3	23.8	21.6	21.3	22.1	21.7
BT7 (control)	5.3	5.4	5.3	5.3	142.4	140.2	135.2	125.6	10.2	12	10.7	11.0	18.8	19.0	18.8	18.9
Summer season																
HL1	5.4	5.5	5.4	5.4	141.5	97.1	142.7	127.1	15.0	19.3	18.7	17.7	21.2	20.5	20.8	20.8
HL2	5.2	5.3	5.5	5.3	141.7	97.0	139.2	126	17.8	18.1	19.0	18.3	21.9	21.2	20.6	21.2
HL3	5.5	5.3	5.3	5.4	122.1	89.2	124.5	111.9	17.3	17.6	18.9	17.9	19.5	18.8	19.1	19.1
HL4	5.5	5.5	5.5	5.5	134.9	92.7	139.3	122.3	18.4	18.7	19.3	18.8	22.2	21.5	21.8	21.8
HL5	5.2	5.3	5.3	5.3	124.7	87.6	132.5	114.9	17.9	18.2	18.2	18.1	19.8	19.1	19.4	19.4
HL6	5.3	5.3	5.3	5.3	113.1	89.2	127.5	109.9	17.9	18.2	18.2	18.1	22.5	21.8	22.1	22.1
HL7	5.3	5.2	5.3	5.3	120.7	80.1	127.9	109.6	19.5	18.8	18.8	19.0	19.2	18.5	18.7	18.8
HL8	5.7	5.6	5.5	5.6	124.9	88.7	124.5	112.7	18.9	18.2	18.2	18.4	18.8	18.1	18.3	18.4
HL9	5.2	5.2	5.3	5.2	127.7	86.9	130.7	115.1	19.2	18.5	18.5	18.7	22.5	21.8	22	22.1
HL10	5.7	5.7	5.5	5.6	125.1	84	132.5	113.9	19.6	18.9	18.9	19.1	20.2	19.5	19.7	19.8
HL11	5.3	5.4	5.4	5.4	130.5	88.1	127.7	115.4	20.0	19.3	19.3	19.5	22	21.3	21.5	21.6
HL12	5.3	5.3	5.2	5.3	136.5	89.2	132.5	119.4	20.8	20.1	20.6	20.5	19.5	18.8	19	19.1
HL13	5.4	5.3	5.3	5.3	132.7	86.7	128.7	116	21.7	21.0	20.0	20.9	18.5	17.8	18	18.1
HL14	5.5	5.5	5.3	5.4	133.9	87.6	129.9	117.1	22.2	21.5	20.5	21.4	19.2	18.5	18.7	18.8
HL15	5.3	5.3	5.5	5.4	136.9	91.6	134.3	120.9	13.4	17.3	18.0	16.2	22.6	22.3	22.5	22.5
HL16	5.5	5.5	5.4	5.5	122.9	80.2	124.5	109.2	16.0	16.3	18.3	16.9	20.5	19.8	19.5	19.9
HL17	5.3	5.3	5.5	5.4	135.7	88.8	130.7	118.4	21.4	20.7	19.7	20.6	18.7	18	17.7	18.1
HL18	5.2	5.3	5.3	5.3	129.9	87.1	132.5	116.5	21.8	21.1	20.1	21.0	18.5	17.8	17.5	17.9
HL19	5.3	5.2	5.5	5.3	128.9	84.1	128.7	113.9	22.0	21.3	20.3	21.2	21.4	20.7	20.4	20.8
BT7(control)	5.3	5.3	5.4	5.3	134.4	89	129.6	117.7	10.0	11.0	1.0	7.3	18.8	19.1	18.8	18.9

Table 7. Practical yield of tested rice lines/varieties in Thanh Hoa in the spring and summer seasons of 2017

Line/Variety	Yield in spring season (quintal/ha)				Yield in summer season (quintal/ha)			
	Quang Xuong	Hoang Hóa	Nga Son	Mean	Quang Xuong	Hoang Hoa	Nga Son	Mean
HL1	52.0	52.0	51.0	52.0	50.0	48.0	49.0	49.0
HL2	51.0	54.0	52.0	52.0	50.0	49.0	50.0	49.0
HL3	39.0	42.0	40.0	40.0	37.0	36.0	38.0	37.0
HL4	52.0	55.0	53.0	53.0	51.0	50.0	51.0	51.0
HL5	41.0	44.0	40.0	41.0	41.0	40.0	38.0	40.0
HL6	43.0	43.0	39.0	42.0	42.0	41.0	39.0	40.0
HL7	37.0	37.0	33.0	36.0	37.0	37.0	35.0	36.0
HL8	37.0	37.0	33.0	35.0	41.0	37.0	35.0	38.0
HL9	41.0	41.0	40.0	41.0	47.0	43.0	37.0	42.0
HL10	45.0	45.0	44.0	45.0	44.0	42.0	41.0	42.0
HL11	45.0	51.0	51.0	49.0	48.0	49.0	48.0	48.0
HL12	43.0	47.0	47.0	46.0	41.0	44.0	45.0	43.0
HL13	35.0	41.0	39.0	38.0	38.0	40.0	37.0	38.0
HL14	41.0	46.0	44.0	44.0	41.0	41.0	42.0	41.0
HL15	57.0	58.0	55.0	56.0	55.0	54.0	53.0	54.0
HL16	44.0	44.0	40.0	43.0	43.0	41.0	38.0	41.0
HL17	43.0	43.0	41.0	42.0	39.0	37.0	39.0	39.0
HL18	34.0	35.0	33.0	34.0	39.0	35.0	37.0	37.0
HL19	47.0	46.0	44.0	46.0	43.0	41.0	42.0	42.0
BT7	47.0	47.0	46.0	47.0	46.0	45.0	44.0	45.0
$CV_{(\%)}$	**5.8**				**5.2**			
$LSD_{0.05}$	**2.7**			**1.2**	**2.2**			**2.5**

3.2.2. Yield stability of tested rice lines/varieties in saline regions in coastal districts in Thanh Hoa province

The analysis of genotype-environment interactions is an important work in plant breeding for different ecological regions. In plant breeding, the analysis of the interaction between the variety and the environment has been focused on stability and adaptability. In fact, when new varieties are produced in different ecological regions, their yield and quality vary depending on ecological and seasonal conditions. Research on the stability of each trait of a plant line/variety is necessary to give reasonable recommendations for producers and production areas to select rice lines/varieties with high stability and wide adaptability on saline soils in the North Central Coast, Vietnam. Evaluation of yield stability of 20 experimental rice lines/varieties in the spring and summer seasons in 2017 at 3 study sites including Hoang Hoa, Nga Son and Quang Xuong based on the model of Eberhard Russel[19] to analyze the stability through the regression line of the environmental index and the deviation from the regression line.

According to this model, a variety is considered to be stable when the regression coefficient bi = 1 and the deviation from the regression line S^2di is small (gradually approaching to 0), this means the variety will perform relatively stable mean value of yield in different ecological conditions. The target of breeders is to breed varieties that have higher yields than the mean value. Therefore, a variety is considered to be an ideal variety with stability when it has a deviation from the regression line S^2di close to 0, and the regression coefficient (bi) close to 1. When yield data were analyzed using the software ondinh.com, there will be a summary table for selecting stable varieties based on the testing value of bi and S^2di. In this table, the values of bi and S^2di with an asterisk are significant differences from 1 and 0, respectively. Results of evaluation of yield stability of tested rice lines/varieties spring and summer seasons of 2017 at 3 study sites of Nga Son Hoang Hoa, and Quang Xuong were presented in Table 8.

Table 8. Yield estimation of tested rice lines/varieties based on regression and environmental index in spring and summer seasons of 2017 (quintals/ha)

Line/ Variety	Mean	Regression coefficient (bi)	Environmental index (I)					
			Hoang Hoa		Nga Son		Quang Xuong	
			Summer -0.841	Spring 1.990	Summer -1.298	Spring -0.260	Summer 0.155	Spring 0.254
HL1	50.072	1.203	49.060	52.466	48.511	49.760	50.259	50.377
HL2	50.506	1.250	49.454	52.993	48.884	50.181	50.700	50.822
HL3	38.561	1.335	37.438	41.217	36.829	38.214	38.768	38.900
HL4	51.739	1.238	50.698	54.202	50.132	51.417	51.931	52.053
HL5	40.328	1.561	39.014	43.435	38.301	39.922	40.570	40.724
HL6	40.883	1.357	39.741	43.585	39.121	40.531	41.094	41.228
HL7	35.644	0.676	35.076	36.989	34.767	35.469	35.749	35.816
HL8	36.289	0.567	35.812	37.418	35.553	36.142	36.377	36.433
HL9	41.222	0.708	40.627	42.631	40.304	41.308	41.332	41.402
HL10	43.461	1.123	42.516	45.696	42.004	43.169	43.635	43.746
HL11	48.744	0.472	48.347	49.648	48.132	48.622	48.818	48.864
HL12	44.511	0.248	44.302	45.005	44.189	44.447	44.550	44.574
HL13	38.189	0.554	37.723	39.291	39.470	38.045	38.275	38.329
HL14	42.422	0.981	41.597	44.374	41.149	42.168	42.574	42.671
HL15	55.050	1.347	53.917	57.731	53.302	54.700	55.259	55.392
HL16	41.344	1.654	39.953	44.636	39.198	40.915	41.601	41.764
HL17	40.167	1.452	38.945	43.057	38.282	39.789	40.392	40.535
HL18	35.294	-0.210	35.471	34.877	35.567	35.349	35.362	35.241
HL19	43.522	1.427	42.322	46.361	41.670	43.152	43.744	43.884
BT7 (control)	45.544	1.059	44.653	47.653	44.169	45.269	45.709	45.813

Analysis of environmental index (I) in Quang Xuong, Hoang Hoa, Nga Son in the spring and summer seasons of 2017 and yield estimation based on the regression with the environmental index of tested rice lines/varieties in Table 8 showed that: I values in Hoang Hoa were -0.841 and 1,990; in Nga Son were -1.298 and -0.260, and in Quang Xuong were 0.155 and 0.254. Thus, in the saline conditions at 3 experimental sites in the coastal districts of Thanh Hoa province, Nga Son had more unfavorable conditions than the other two sites. Quang Xuong has the most favorable conditions for rice plants to grow and develop in both the spring and summer seasons. In 2017, the conditions in all study sites in the spring season were more favorable for growing rice than in the summer season, in which HL15 had the highest yield, estimated at 55.05 quintals/ha.

Table 9 presented values of the regression coefficient (bi) and the deviation from the regression line S^2di for selecting stable rice lines/varieties in the spring and summer seasons at study sites.

Table 9. Summary of reference values for selecting stable rice lines/varieties in spring and summer seasons 2017 in study sites

Line/ Variety	Mean Quintals/ha	Regression coefficient (bi)	Ttn	P	$S2_{di}$	Ftn	P
HL1	50.072	1.203	0.504	0.679	0.136	1.148	0.668
HL2	50.506	1.205	0.475	0.670	0.885	1.966	0.904
HL3	38.561	1.335	0.497	0.677	2.034	3.220	0.988*
HL4	51.739	1.238	0.454	0.664	0.863	1.942	0.901
HL5	40.328	1.561	2.860	0.977*	-0.665	0.274	0.105
HL6	40.883	1.357	0.730	0.745	0.646	1.705	0.856
HL7	35.644	0.676	0.495	0.676	1.882	3.055	0.984*
HL8	36.289	0.567	0.383	0.641	7.418	9.099	1.000*
HL9	41.222	0.708	0.233	0.590	9.349	11.208	1.000*
HL10	43.461	1.123	0.380	0.640	-0.235	0.744	0.435
HL11	48.744	0.472	0.567	0.698	4.724	6.158	1.000*
HL12	44.511	0.248	0.771	0.756	5.274	6.758	1.000*
HL13	38.189	0.554	0.520	0.684	3.872	5.228	1.000*
HL14	42.422	0.981	0.030	0.512	1.746	2.907	0.980*
HL15	55.050	1.347	0.820	0.769	0.248	1.271	0.722
HL16	41.344	1.654	1.468	0.892	0.376	1.410	0.773
HL17	40.167	1.452	0.564	0.697	3.271	4.571	0.999*
HL18	35.294	0.210	1.189	0.850	5.822	7.357	1.000*
HL19	43.522	1.427	0.547	0.692	3.036	4.315	0.998*
BT 7	45.544	1.059	0.399	0.646	-0.772	0.157	0.043

** Significant differences from 1 and 0 with P≥ 95%, respectively b_i và S^2_{di}*

The data in Table 9 showed that: Among the 20 tested rice lines/varieties, 12 lines including HL3, HL5, HL7, HL8, HL9, HL11, HL12, HL13, HL14, HL17, HL18 and HL19 were unstable (lines with marked the sign "*" in columns P tested for regression coefficients significantly different from 1, and columns P tested for S^2di with no significance) across 3 studied sites, Nga Son, Hoang Hoa, and Quang Xuong, in the spring and summer seasons. The other rice lines/varieties were stable in both crop seasons, in which HL15 had the highest yield with an average yield ranging from 54.0-56.0 quintals/ha (the average yield in two crop seasons reached 55.0 quintals/ha).

3.2.3. Evaluation of salt tolerance of potential rice lines/varieties in nutrient solution

After testing potential rice lines/varieties in the field conditions, their salt tolerance was evaluated in a nutrient solution. There were 10 out of 20 potential rice lines/varieties had the *Saltol* QTL in a homozygous state with good agronomic characteristics were used in the experiment conducted in a greenhouse at the AGI in Hanoi, Vietnam. The experiment used Yoshida's nutrient solution. The rice lines/varieties with good germination were selected and evaluated with 30 seeds/varieties. The germinated rice seeds with a radicle length of 1.5-2.0 mm were placed in holes covered by a net on a foam float, which was placed in a rectangular plastic container containing Yoshida nutrient solution[22]. The control variety was IR29 (salt-sensitive variety), BT7 and FL478 (variety transferred salt-tolerant gene). The Yoshida solution volume and seed germination were uniform, and the solution pH was checked daily to maintain at 4.7- 5.

Evaluation of salt tolerance was based on growth observation using SES evaluation criteria. The results were recorded when the control variety IR29 showed signs of death (at SES7) 15 days after adding salt to the solution. Evaluation results after 15 after adding salt into the solution was at the seedling stage of 10 rice lines/varieties on Yoshida nutrient solution with the salinity of 6 ‰ after NaCl addition were presented in Table 10.

Table 10. Evaluation of salt tolerance of potential rice lines/varieties

No	Line/Variety	Saltol	Survival rate (%)	SES scale	Evaluation
1	HL1	+	85	3-5	Tolerant
2	HL2	+	95	3	Tolerant
3	HL4	+	91	3-5	Tolerant
4	HL5	+	97	3-5	Tolerant
5	HL6	+	86	3-5	Tolerant
6	HL10	+	90	3-5	Tolerant
6	HL11	+	89	3-5	Tolerant
7	HL12	+	85	3-5	Tolerant

8	HL15	+	97	3	Tolerant
9	HL17	+	88	3-5	Tolerant
10	HL19	+	93	3	Tolerant
11	IR29 (sensitive)	-	0	9	Highly sensitive
12	FL478	+	98	3	Tolerant
13	Pokkali	+	100	3	Tolerant
14	BT7	-	10	7	Sensitive

(+): Carrying Saltol gene; (-): not carrying Saltol gene;

The data in Table 10 showed that most of the rice lines/varieties had salt tolerant scores of 3 to 5, in which, HL2, HL15 and HL19 scored 3, equivalent to FL478 (tolerant), with a survival rate was over 85 %. The control variety BT7 with poor salt tolerance (score 7) with a mortality rate of 90%, and the salt-sensitive variety IR29 had a mortality rate of 100%. When the salinity of the solution increased to 9‰, the mortality rate of tested rice lines/varieties gradually increased to 90- 100%. Thus, in the nutrient with high salinity, potential rice lines/varieties having the *Saltol* QTL in a homozygous state can tolerate to salinity of 6 ‰.

The purebred variety HL15 had a range of good agronomic characteristics, resistance to major pests and diseases, high yield potential and salinity tolerance of 6 ‰ (Figure 1). The HL15 variety was renamed SHPT15 and continued to conduct author testing, basic testing, and production testing in the national and local testing system in order to be recognized as a new rice variety. In our attempts, some salt-tolerance rice varieties were evaluated for their agronomic traits and tolerant ability in some different ecosystems[4-6,2, 12, 15]. Some promising lines and varieties have been identified and are being grown on a large scale and help increase the income for the farmers in salt-affected coastal areas in this country.

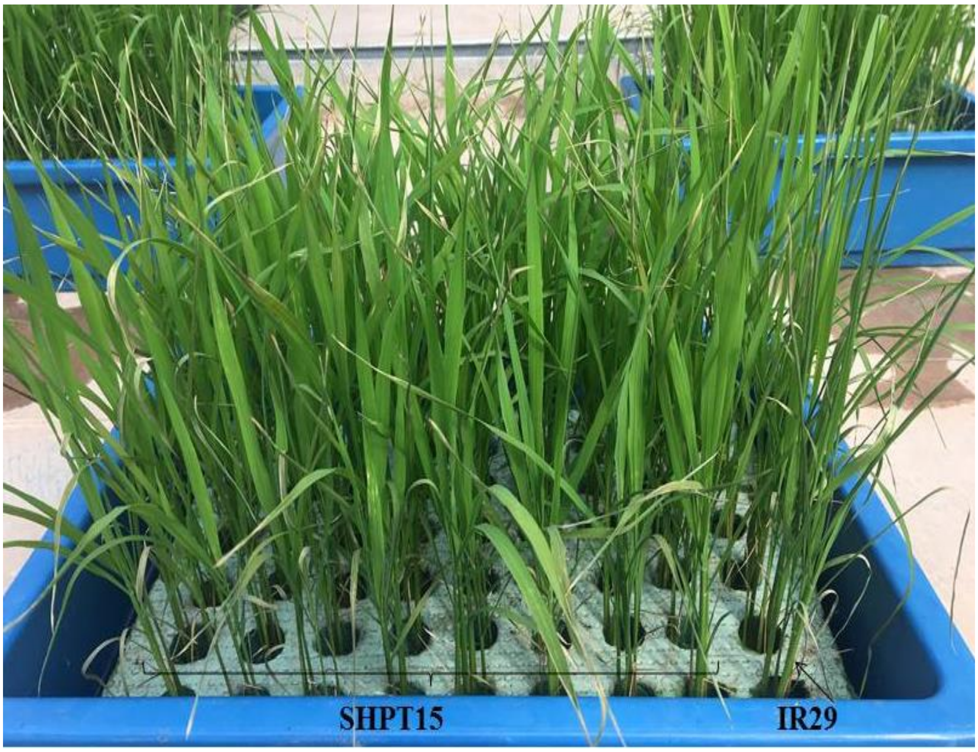

Figure 1. HL15 variety (SHPT15) and IR29 after 15 days of testing salinity at 6 ‰

4. Conclusions

In summary, the salt-tolerant variety HL15 exhibited superior yield components across three study sites, showcasing good agronomic traits and resistance to pests and diseases. Compared to the control variety BT7, the BC2F5 variety demonstrated similar or shorter plant height and growth duration. Notably, HL15 presented potential for production with shorter growth duration (115-117 days in spring and 102-103 days in summer) and yielded the highest practical yield (56.0 quintals/ha in spring, 54.0 quintals/ha in summer). Pest resistance was comparable to BT7, with HL15 showing high resistance to pests and diseases. In saline areas of Thanh Hoa province, HL15 exhibited wide and stable adaptability in both seasons, scoring favorably in survival rates under salt stress. The variety, currently named SHPT15, is recognized as a new rice variety due to its promising agronomic characteristics, resistance, high yield potential, and salinity tolerance of 6‰.

REFERENCES

1. Linh, L.H. Linh, T.H. Xuan, T.D. Ham, L.H. Ismail, A.M. Khanh, T.D. Khanh. 2012. "Molecular breeding to improve salt tolerance of rice (*Oryza sativ*a L.) in the Red River Delta of Vietnam". International Journal of Plant Genomics, (10):1-9.
2. Anh, L.H. Hue, H.T. Quoc, N.K. Nghia, L.T. Trung, K.H. Trung, T.N. Trang, D.H. Xuan, T.D. Khanh, T.D. 2016. "Effects of salt on growth of rice landraces in Vietnam". International Letters of National Sciences, 59: 72-81.
3. Le, T.L. Tuan, M.T. 2018. "Impact of climate change and sea level rise on saltwater intrusion in rivers of Thanh Hoa province". Scientific Conference on Earth-Mining-Sustainable environment EME 2018, pp. 222-230.
4. Linh, L.H. Khanh, T.D. Luan, N.V. Cuc, D.T.K. Duc, L.D. Linh, T.H. Ismail, A.M. Ham, L.H. 2012. "Application of marker-assisted backcrossing to pyramid salinity tolerance (*Saltol*) into rice cultivar- Bac Thom 7". VNU Journal of Science, Natural Sciences and Technology, 28:87-99.
5. Ky, H. Phuc, T.H. Giang, V.Q. Nhi, T.T.Y. Hien, N.L. Tung. 2019. "Evaluation salt tolerance of summer season rice varieties in Cuu Long Delta", Journal of Vietnam Agricultural Science and Technology 7(104):14-19.
6. Huyen, L.T.N. Cuc, L.M. Ham, L.H. Khanh, T.D. 2013. "Introgression the Saltol QTL into Q5DB, the elite variety of Vietnam using marker assisted selection (MAS)". American Journal of BioScience, 1(4):80-84.
7. Francois, L.E. Maas, E.V 1999. "Crop response and management of salt-affected soils". In Handbook of Plant and Crop Stress. (Eds.): M. Pessarakli. Marcel Dekker, Inc., New York, pp. 169-201.
8. Eynard, A. Lal, R. Wiebe, K. 2005. "Crop Response in Salt-Affected Soils", Journal of Sustainable Agriculture, 27(1):1-29.
9. Landon J.R. 1991 "Tropical soil manual. A handbook for soil survey and agricultural land evaluation in the tropics and subtropics". Longman Inc., New York, USA.
10. Khoa, T.N. Diep, N.T. Duong, N.T. Toan, N.N. Pha, P.H. Ha, D.T.T. Dung, K.T. Thuy, T.T. Khanh, T.D. Trung, K.H. 2018. "Predicting, identifying and designing functional marker to identify blast resistance candidate gene (*Pit*) in Vietnamese rice varieties". Journal of Vietnam Agricultural Science and Technology, 11:41-46 (*in Vietnamese with English abstract*).
11. Zeng, L. Shannon, M.C. 2000. "Salinity effects on seedling growth and yield components of rice". Crop Science. 40:996-1003.
12. Thao, T.T.P. Thanh, V.C. Lien, Q.T.A. Mai, D.P. Nhien, D.T.N. Toan, H.V. Son, T.N. Thanh, N.H. Duy, P.V.K. Tho, P.T.A. 2018. "Selecting rice (*Oryza sativa* L.) varieties with salinity tolerance to sodic soil conditions in the Mekong River Delta. Vietnam Journal of Science and Technology, 61(2):30-35.
13. Khanh, T.D. Duong, V.X. Nguyen, P.C. Xuan, T.D. Trung, N.T. Trung, K.H. Gioi, D.H. Hoang, N.H. Tran, H.-D. Trung, D.M. Huong, B.T.T. 2021. "Rice Breeding in Vietnam: Retrospects, Challenges and Prospects". Agriculture 2021, 11:397.
14. Higgins, J. Santos, B. Khanh, T.D. Trung, K.H. et al. 2020. "Resequencing of 672 native rice accessions to explore genetic diversity and trait associations along Vietnam". https://doi.org/10.21203/rs.3.rs-70697/v1 .
15. Hoang, N.H. Cuong, L.V. Phuong, H.T. 2016. Study on growth, development and yield of some quality rice varieties in Yen Dinh district, Thanh Hoa province. Journal of Vietnam Agricultural Science and Technology, 4(65): 79-84 (*in Vietnamese with English abstract*).
16. Dan, P.V. Hoang, N.H. Trang, N.T.T. Linh, L.H. 2023. "Research on cultivation techniques for salt-tolerant rice variety SHPT15 growing in the coastal regions affected by saltwater intrusion in Thanh Hoa province, Vietnam". European Chemistry Bulletin, 12(9):450-460.
17. Gregorio, G.B. Senadhira, D. Mendoza, R.D. 1997." Screening rice for salinity tolerance". International Rice Research Institute (IRRI), 1-30.
18. Ministry of Agriculture and Rural Development of Vietnam. 2011. National Technical Regulation on Testing for Value of Cultivation and Use of Rice varieties 01-55: 2011/BNNPTNT). In Circular No. 48/2011/TT- BNNPTNT on Promulgation of National Technical Regulation on Quality of Plant Seed.
19. Eberhart, S.A. Rusell, W.A. 1966. "Stability parameters for comparing varieties". Crop Science, 6(1): 36-40.
20. General Statistics Office of Vietnam (GSO). 2022. "Annual report in agriculture" https://www.gso.gov.vn/en/agriculture-forestry-and-fishery/
21. Thanh Hoa Department of Agricultural and Rural Development. 2018. Annual report.

22. 22.Yoshida S.1981. “Fundamentals of rice crop science”, The International Rice Research Institute, Los Banos, Philippines.