ASSESSING THE FIELD TRIALS OF THE SALT STRESS-TOLERANT ELITE RICE LINES

Nguyen Thuy Kieu Tien[1,*], Chau Thanh Nha[1], Tran Thi Nhien[1], Nguyen Khac Thang[1], Vo Thanh Toan[1], Tran Thu Thao[1], Tran Ngoc Thach[1]

[1]*CuuLong Delta Rice Research Institute, Tan Thanh Commune, Thoi Lai District, Can Tho City, Vietnam.*
[*]*Correspondence: ntktien10@gmail.com (N. T. Kieu Tien).*

ABSTRACT

Climate change presents a multitude of challenges for rice cultivation, with salinity intrusion causing significant harm to overall production. As a response to these effects, numerous strategies have been employed, with the study and development of new rice varieties being a top priority. The AFACI project has taken the initiative to distribute salt-tolerant rice varieties from the International Rice Research Institute (IRRI) to member countries for field trials in areas affected by salt intrusion. Vietnam's Mekong Delta was chosen as the testing region, with 36 salt-tolerant lines alongside four local check varieties to assess their agronomic traits, yield components, and adaptability in two salinity hotspots (Ca Mau and Soc Trang) and one non-stress site (Can Tho). The exciting results revealed six standout elite rice varieties that displayed promising salt-tolerance capabilities, including IR 117834-10-1 RGA-1 RGA-1 RGA-1, IR 121094-B-B-AJY3-2-B, IR 16T1009 (2019-2020 season), and IR127792-843-1-1-1-3, IRR117839-22-15-B-CMU10-1-B, and IRRI147 (2020-2021 season). These remarkable advancements in rice cultivation hold great promise for the future of farming in areas affected by climate change-induced salinity intrusion.

Keywords: Salinity, salt-tolerant rice varieties, phenotyping, agronomic characteristics.

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important staple food and nourishes more than half of the world's population (Khush 1997). As the estimation of the world's population may increase by ~9 million in 2050, therefore, rice production is also must be increased by about 70 to 110% in the four next decades (Godfray et al. 2010). Currently, rice production is a challenge caused by climate change impacts. Asia and Africa have huge areas with millions of hectares (ha) of agricultural land used for rice production that is not cultivated because of the high salt content in irrigated systems. Rice grain yield and salinity tolerance are complex traits and genetics and are controlled by multiple genes. These traits are strongly affected by biotic stresses (pests and diseases) and abiotic stresses (salinity, drought, cold, submergence, and heat), which are estimated to reduce by 50% of production (Tester and Langridge 2010). Globally, one billion ha of land use is adversely affected by salt water and ~45 million ha of irrigated regions are suffered from salinization issues at various levels (FAO 2010), particularly ~21 million ha of Asia regions (Nazar et al. 2011). In Vietnam, over 37% of the Mekong River Delta (MRD) and 11% of the Red River Delta (RRD) regions can be inundated by salt-related stresses, mainly targeted at coastal regions (Nguyen et al. 2006). Salinity intrusion has occurred virtually in all coastal provinces (about half the districts in 10 of 12 provinces and one city) in the MRD, affecting 300 thousand ha of rice according to Vietnam's National Centre for Hydro-meteorological Forecasting in 2020.

Rice, well-known as a glycophyte, is the most susceptible crop of the cereal crops to salinity stress (Munns and Tester 2008) with a threshold of salt concentration ≤3 dSm^{-1}, above which crop yield will decrease remarkably (Rao et al. 2008; Negrão et al. 2011; Marcos et al. 2018). Salinity stress has resulted in significant negative effects on agricultural production such as the survival rate of most phases of crop growth, osmotic ability, ion toxicity, and soil nutritional deficiency (Munns and Tester 2008; Todaka et al. 2010). Plant salt-tolerance mechanisms often involve regulation of ion homeostasis and ion compartmentalization among various tissues and cells, ion transport and uptake, biosynthesis and accumulation of compatible solutes, osmolytes, activation of reactive oxygen species (ROS) detoxification enzymes, and hormone modulation (Horie et al. 2010; Roy et al. 2014; Reddy et al. 2017). Many salt-responsive quantitative trait locus (QTL) studies have been mapped to detect important genomic regions and their-related genes at various growth phases including germination (Cheng et al. 2015; Wang et al. 2011), seedling (Cheng et al. 2011; Wang et al. 2012; Zheng et al. 2014) and the reproductive stages (Hossain et al. 2015; Kumar et al. 2015). Difference ways of combating salinity stress coupled with increasing rice production are still stagnated with the rate of poor improved varieties.

To challenge the salinity intrusion in rice production, many farming practices have been applied, however, these methods are inefficient in controlling the saline impact. Therefore, the salt-tolerant rice varieties are a reliable strategy for rice production in facing the challenge of saltwater intrusion in the MDR region. Since the improved rice varieties can withstand water and soil salinity. In this study, a collection of elite rice varieties has conducted field trials in different locations to select and develop new rice varieties for salt stress.

MATERIALS AND METHODS

Plant materials and testing sites

A panel of elite rice lines (36 lines) was provided by the International Rice Research Institute (IRRI), Philippines, and 4 local check varieties, namely OM2517 used as the salt-tolerant variety, OM6976 as the intermediate salt-tolerant variety, and OM5451 and IR64 used as salt-sensitive varieties, were sourced from the Cuu Long Delta Rice Research Institute (CLRRI), Vietnam. Three experimental sites were selected for conducting field trials, of which two sites, Ca Mau and Soc Trang, were considered hotspots for salinity stress and one location at Can Tho (CLRRI) was the non-stress site. The detailed information on these sites is described following: Ca Mau: Longitude: 105° 08' 60.00" E; Latitude: 9° 10' 60.00" N; Soc Trang: Longitude: 105° 58' 26.0652" E; Latitude: 9° 36' 9.0756" N; Can Tho: Longitude: 105° 44' 48.6852" E; Latitude: 10° 2' 42.5832" N.

Methodologies

We carried out exciting field trials using an alpha lattice design, complete with two replications and a planting distance of 15 x 20 cm in individual plots spanning 5 m^2. These trials took place under both salt stress and non-stress conditions, truly putting our layout to the test. To provide the plants with the necessary nourishment, they applied a carefully balanced fertilizer mix (80N-40P_2O_5-30K_2O) during three vital growth phases: basal, maximum tillering, and panicle initiation. Following protocol, we installed piezometers in pairs across every 10 m^2 of the field to assess the EC level variations. Lastly, we determined the field's EC and pH levels by analyzing the water collected in the piezometers.

Phenotyping and data analysis

Data collection was collected for both stress and non-stress trials at the rice growth stage from 80 days old to flowering (DTF). The agronomic characteristics and yield components have been collected as plant height (PH), number of tillers per panicle (NT), panicle length (PL), filled-grain number per panicle (FGNP), unfilled-grain per panicle (UFGP), unfilled spikelet percent (USP), 1000-grain weight (TGW), grain yield (YLD). The analysis of variance (ANOVA), principal component analysis (PCA), and correlation analysis were conducted using R software (R core team 2017). Broad-sense heritability (H^2) calculation was performed using the R-Sommer package (Covarrubias-Pazaran et al. 2016).

RESULTS AND DISCUSSION

Measurement of the EC and pH values at the field trials

The EC and pH values in soil and water samples from selected sites were measured at four important stages such as transplanting, tillering, flowering, and maturity (as shown in **Table 1**). During 2019-2020 season, the average pH of the soil was about 6.03-6.44 while the average pH of water was a bit higher 6.03 to 7.27. In this season, the EC was recorded with the difference between soil and water. The EC of water showed lower than in soil that ranged from 0.53 – 4.13‰ and 1.06 – 2.13‰, respectively. In 2020-2021 season, the average pH of soil and water ranged from 4.96-6.63 and 6.94-7.91, respectively. However, the EC of two sites in this season revealed higher compared to the previous season (2019-2020), ranging from 0.97-4.78‰ in soil and 3.38-4.96‰ in water.

Table 1: The pH and EC (‰) results of soil and water samples analyzed in salt-affected locations at four important stages.

Location	Samples	Unit	Transplanting	Tillering	Flowering	Maturity	Aver.
2019-2020 season							
Ca Mau	Soil	pH	6.14	6.65	6.68	6.28	6.44
		EC (‰)	4.57	3.77	3.88	5.00	4.31
	Water	pH	6.78	7.02	6.91	6.28	6.75
		EC (‰)	2.53	2.00	2.10	1.90	2.13
Soc Trang	Soil	pH	7.14	6.40	5.73	4.83	6.03
		EC (‰)	0.76	0.43	0.40	0.51	0.53
	Water	pH	6.83	7.69	7.06	7.48	7.27
		EC (‰)	0.26	0.87	1.54	1.57	1.06
2020-2021 season							
Ca Mau	Soil	pH	4.75	6.55	8.60	-	6.63
		EC (‰)	4.91	2.80	6.63	-	4.78
	Water	pH	7.24	7.93	8.55	-	7.91
		EC (‰)	4.53	3.85	6.49	-	4.96
Soc Trang	Soil	pH	4.95	5.09	4.80	5.01	4.96
		EC (‰)	1.77	1.06	0.76	0.30	0.97
	Water	pH	6.72	8.73	6.11	6.18	6.94
		EC (‰)	5.03	4.86	2.39	1.24	3.38

Evaluation of field trials at Ca Mau, Soc Trang, and Can Tho (CLRRI) in the 2019-2020 season

In the field trials conducted at Ca Mau and Soc Trang (salt-stress condition) and Can Tho (non-stress condition), we uncovered remarkable variations in an array of agronomic traits throughout 10 high-performing rice varieties and local checks (**Table 2** and **Table S1**). Some standout phenotypic traits in the 2019 Wet Season included Days to Flowering (90 days; CLRRI), Plant Height (124.7 cm; ST), Number of Tillers (16.7 tillers; CLRRI), Panicle Length (28.7 cm; CLRRI), Filled Grains per Panicle (3507.3; CLRRI), Unfilled Grains per Panicle (677.3; CLRRI), Uniformity of Seedling Population Rate (43.7%; CLRRI), Thousand

Grain Weight (28.8g; CLRRI), and Rice Yield (5.8 tons/ha; CLRRI). The Coefficient of Variation (CV) for these elite rice varieties ranged from 12.1% to 44.6% among the agronomic traits, with the highest CV observed in UFGP and the lowest in PL. The ANOVA results revealed that both CLRRI and ST locations had significant impacts on various traits, except for UFGP and PL, as well as an interaction between varieties and locations. Investigating the relationships between agronomic traits can significantly benefit breeders when it comes to assessing the practicality of selecting multiple traits simultaneously. Notably, a high broad-sense heritability (H^2) of over 60% was determined for DTF, PH, PL, and TGW (**Table 2**). In contrast, lower broad-sense heritability (H^2) was observed for the remaining traits (PN, FGP, UGDP, USP, and YLD), suggesting considerable environmental influences. In this study, the first two Principal Component Analyses (PCA) accounted for 54.8% of the total variation, giving a clearer picture of trait relationships (**Figure 1**). PCA1 contributed 32.6% to the overall variation, while PCA2 added another 22.2%. These findings indicate that YLD, PH, FGNP, DTF, PL, UFGP, USP, and NT are primarily responsible for most of the variation found within PCA1 – with TGW being the sole exception. Meanwhile, PCA2 helps explain the genotypic variations involving YLD, PH, FGNP, DTF, and NT as opposed to those relating to PL, TGW, UFGP, and USP.

Table 2. Descriptive statistics of the agronomic traits in a set of 10 varieties and local checks under salt-stress (ST) and non-stress (CLRRI) locations during the 2019-2020 season.

Locations	DTF	PH	NT	PL	FGNP	UFGP	USP	TGW	YLD (ton/ha)
Range	68-90	82.7-124.7	6-16.7	22.3-28.7	683.3-3507.3	51.7-677.3	3.6-43.7	21.5-28.8	3.4-5.6
Mean	79.1	110.3	10.6	25.3	1557.9	338.6	17.5	25.8	4.5
CV (%)	15.4	12.1	34.2	10.6	18.5	44.6	36.9	34.7	19.7
H^2	0.83	0.9	0.2	0.6	0.4	0.3	0.4	0.81	0.35
Designation	89.1***	39***	6.3***	6.5***	18.1***	0.9ns	4.8***	95.7***	1.1*
Location	401***	103.4***	328.3***	0.1ns	154.4***	350.4***	102.9***	11**	17.9***
Designation x Location	9.6***	2.8**	5.9***	3.2**	21.1***	6.4***	8.2***	24.3***	7***

DTF: Days to flowering, PH: plant height, NT: number of tillers, PL: panicle length, FGNP: filled-grain number per panicle, UFGP: unfilled-grain per panicle, USP: unfilled spikelet percent, TGW: 1000-grain weight, YLD: grain yield. Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 'ns' not significant.

In this season, the three top rice varieties have been selected namely IR 117834-10-1 RGA- 1 RGA-1 RGA-1, IR 121094-B-B-AJY3-2-B, and IR 16T1009. These outstanding varieties thrived in salt-affected regions during the 2019 Wet Season trials at CM and ST (salt-stress) locations. These varieties not only boasted a significantly higher grain yield under salty conditions (>5 tons ha^{-1}) compared to local checks but also matured earlier by four to ten days when faced with salt stress, making them more resilient choices.

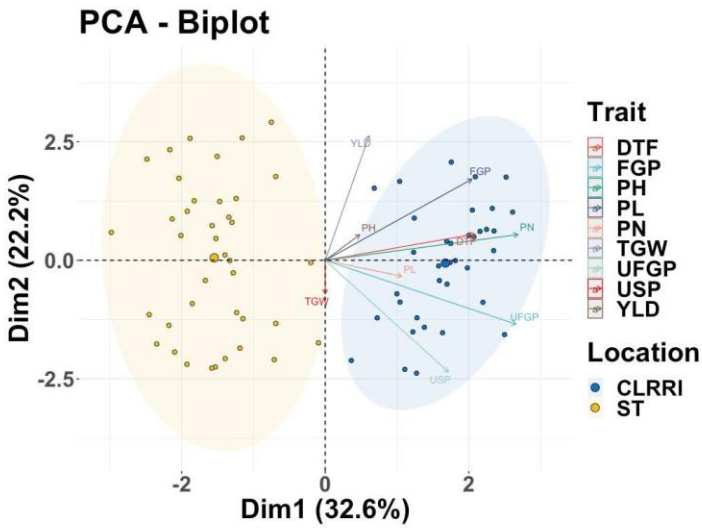

Figure 1. Principal component analysis (PCA) between agronomic traits in a set of 10 IRRI rice varieties across two locations during the 2019-2020 season. CLRRI: CuuLong Delta Rice Research Institute, ST: Soc Trang. DTF: Days to flowering, PH: plant height, PN: number of tillers, PL: panicle length, FGP: filled-grain per panicle, UFGP: unfilled-grain per panicle, USP: unfilled spikelet percent, TGW: 1000-grain weight, YLD: grain yield.

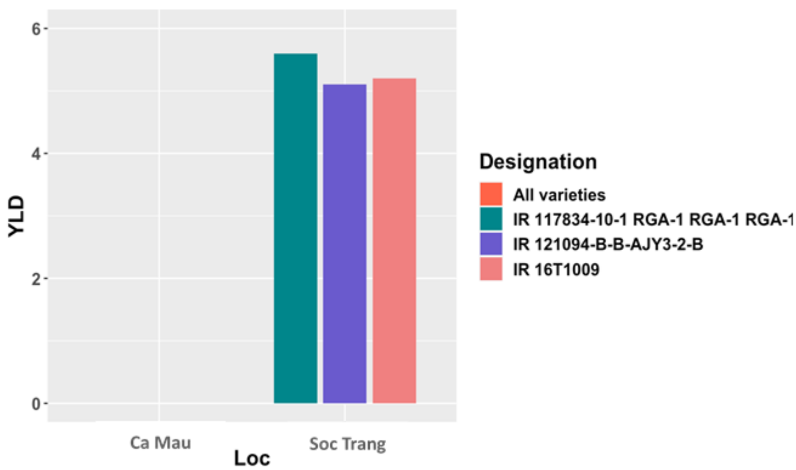

Figure 2. Some elite rice lines have been selected in the season of 2019-2020.

Evaluation of field trials at Ca Mau, Soc Trang, and Can Tho in the 2020-2021 season

The elite rice varieties showed wide variability for the traits identified in three locations (**Table 3; Table S2**). DTF ranged from 70 to 115 days with a mean of 87.7 days. PH ranged from 70 to 143.33 cm with a mean of 101.26 cm. PN ranged from 1.72 to 23 with a mean of 9.85 and PL ranged from 6.1 to 32 mm with a mean of 24.43 mm. In FGNP and UFGP, FGNP ranged from 105.16 to 4553 grains with a mean of 1349.4 grains, while UFGP ranged from 13.72 to 1333 grains with a mean of 382.2 grains. The measured TGW in ST and CT ranged from 20.4 to 30.1g, with a mean of 25.5g. USP ranged from 5.86 to 30.1%, with a mean of 24.25%. Finally, YLD ranged from 0.1 to 7 tons ha^{-1} with a mean of 3.44 tons ha^{-1} (**Table 3**). The ANOVA in all three locations showed significant effects of genotypes, locations, and genotypes x location interactions for all traits except UFGP and PL (**Table 3**). The coefficient of variation (CV) for all evaluated traits ranged from 7.6% to 56.9%. Low CV (<10%) was recorded for PL and FGNP, whereas moderate (10.3– 34.6%) was observed for DTF, PH, PN, YLD, and UFGP. The remaining traits, namely TGW and USP, displayed impressive (>40%) CV levels. It's worth noting that the heritability values remained significantly high, ranging from 0.34 to 0.79, for all monitored traits (**Table 3**). The first two principal components analysis (PCA) encapsulated 63.5% of the total fluctuation (as seen in **Figure 3**). Specifically, PCA1 unraveled 48.1% of the comprehensive variation, while PCA2 contributed a substantial 15.4%. Interestingly, traits such as PL, PH, FGNP, NT, UFGP, and YLD showcased the highest positive loadings among all examined traits within PCA1, whereas DTF, USP and TGW demonstrated negative loadings. As for PCA2, FGNP, UFGP, NT, TGW, and YLD served as major contributors to the variation. In contrast, DTF, USP, PL, and PH experienced reverse loadings in PCA2.

Table 3. Descriptive statistics of the agronomic traits in a set of rice varieties at Ca Mau, Soc Trang, and Can Tho during the 2020-2021 season.

Locations	DTF	PH	NT	PL	FGNP	UFGP	USP	TGW	YLD (ton/ha)
Range	70-115	70-142.33	1.72-23	6.1-32	105.16-4553	13.72-1333	5.86-58.1	20.4-30.1	0.1-7
Mean	87.7	101.26	9.85	24.43	1349.4	382.2	24.25	25.5	3.44
CV (%)	13.4	10.3	24.2	7.6	8.3	34.6	56.9	44.7	16.8
H^2	0.79	0.82	0.24	0.65	0.34	0.3	0.3	0.71	0.52
Designation	78.1***	28***	5.2*	8.5***	18.7*	1.4ns	8.8*	54.7**	2.1*
Location	98.1**	100.5***	228.3**	3.1ns	214.4**	35.4ns	112.9**	9.3**	11.9**
Designationx Location	9.6***	2.8**	5.9***	3.2**	21.1***	6.4***	8.2***	24.3***	7.91*

DTF: Days to flowering, PH: plant height, NT: number of tillers, PL: panicle length, FGNP: filled-grain number per panicle, UFGP: unfilled-grain per panicle, USP: unfilled spikelet percent, TGW: 1000-grain weight, YLD: grain yield. Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 'ns' not significant.

The first two principal components analysis (PCA) accounted for 63.5%of the total variation (**Figure 3**). PCA1 explained 48.1% of the total variation, whereas PCA2 contributed 15.4%. In PCA1, PL, PH, FGNP, NT, UFGP, and YLD showed the highest positive loadings among all traits analyzed, and DTF, USP, and TGW exhibited negative loadings. For PCA2, FGNP, UFGP, NT, TGW, and YLD contributed most of the variation, while DTF, USP, PL, and PH showed reverse loadings in PCA2.

During the second year, several rice line panel studies were carried out across diverse locations involving both salt-stressed and non-stressed environments. Through meticulous analysis of the agronomic characteristics, outstanding lines such as IR127792-843-1-1-1-3 (Soc Trang), IRR117839-22-15-B-CMU10-1-B (Soc Trang), and IRRI147 (Ca Mau, Soc Trang) emerged as top rice varieties (**Figure 4**). These exceptional rice varieties have proven to consistently thrive in a wide range of environments.

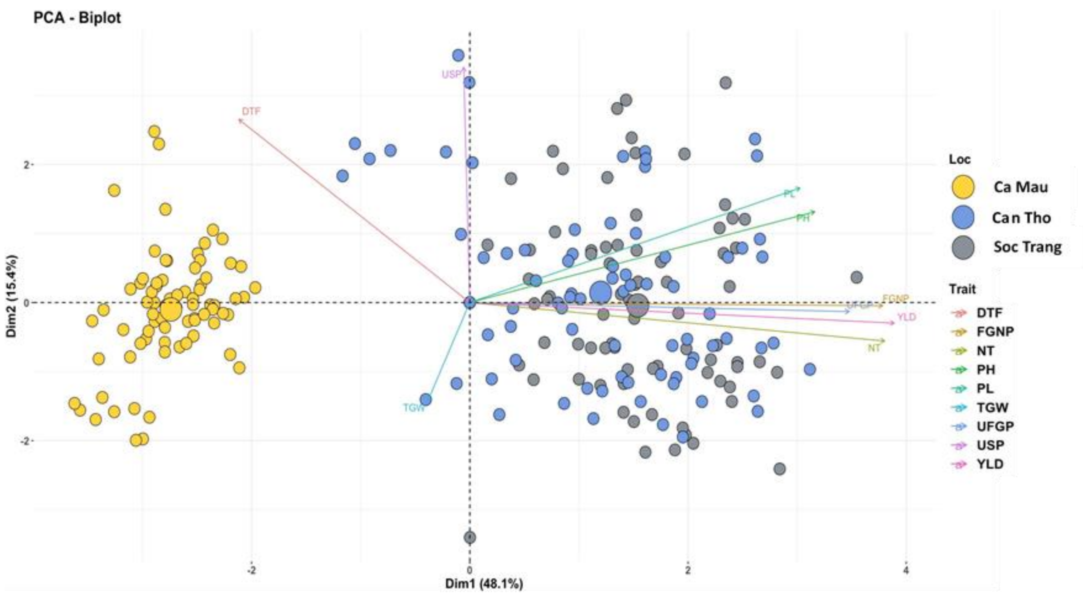

Figure 3. Principal component analysis (PCA) between agronomic traits in a set of rice varieties across three locations during the 2020-2021 season. CLRRI: Cuu Long Delta Rice Research Institute, ST: Soc Trang. CM: Ca Mau. DTF: Days to flowering, PH: plant height, PN: number of tillers, PL: panicle length, FGP: filled-grain per panicle, UFGP: unfilled-grain per panicle, USP: unfilled spikelet percent, TGW: 1000-grain weight, YLD: grain yield.

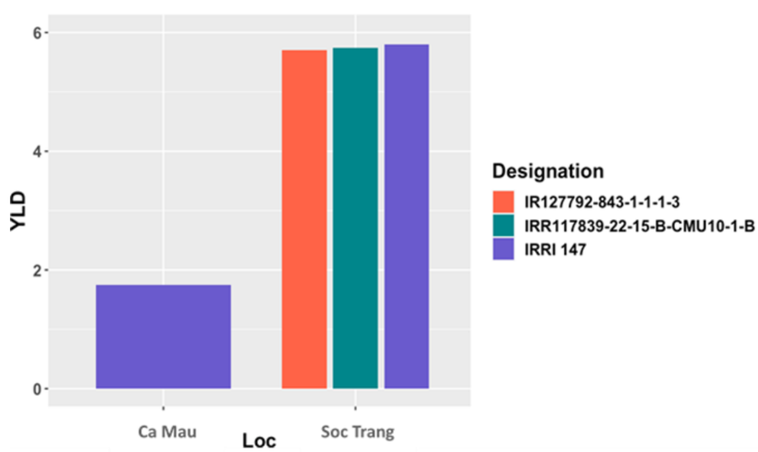

Figure 4. A number of elite rice lines have been selected in the 2020-2021 season.

CONCLUSIONS

Selection of rice germplasms is a regular part of plant breeding activities, intending to identify stable genotypes across three salt stress locations from moderate (Soc Trang) and high (Ca Mau). In this investigation, six rice lines have been identified as potential candidate varieties for salt tolerance and grain yield traits such as IR 117834-10-1 RGA- 1 RGA-1 RGA-1, IR 121094-B-B-AJY3-2-B, IR 16T1009 (2019-2020), IR127792-843-1-1-1-3, IRR117839-22-15-B- CMU10-1-B, and IRRI147 (2020-2021). These selected lines would be performed genotyping analysis to confirm the comparison between the phenotypes versus genotypes and environments. The selected rice varieties need to be evaluated by the Value of Cultivation and Use (VCU) step following The Ministry of Agriculture and Rural Development (MARD) protocol before being released widely to smallholder farmers.

COMPETING INTERESTS

The authors declare they have no conflict of interest, financial or otherwise.

AUTHOR'S INFORMATION AND CONTRIBUTIONS

Nguyen Thuy Kieu Tien, Tran Ngoc Thach designed the research and supervised the project. Nguyen Khac Thang, Vo Thanh Toan, Tran Thu Thao conducted field trials. Chau Thanh Nha, Tran Thi Nhien analyzed the data and wrote the paper with input from all authors.

ACKNOWLEDGEMENTS

The authors sincerely thank the AFACI-Korea project for funding support. We also would like to thank AFACI Secretariats, IRRI scientists, VAAS and CLRRI staffs for their help and support in implementing the project in Vietnam.

REFERENCES

Cheng J, He Y, Yang B, Lai Y, Wang Z, and Zhang H (2015) Association mapping of seed germination and seedling growth at three conditions in indica rice (*Oryza sativa* L.). Euphytica 206:1–13.

Covarrubias-Pazaran G (2016) Genome-Assisted Prediction of Quantitative Traits Using the R Package sommer. PLoS ONE 11(6): e0156744. https://doi.org/10.1371/journal.pone.0156744

Food and Agriculture Organization (2010) Report of salt-affected agriculture. http://www.fao.org/ag/agl/agll/spush/.

Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, PrettyJ, Robinson S, Thomas SM, Toulmin C (2010) Food security: The challenge of feeding 9 billion people. Science 327:812–818. doi:10.1126/science.1185383.

Horie T, Karahara I, Katsuhara M (2012) Salinity tolerance mechanisms in glycophytes: An overview with the central focus on rice plants. Rice 5:11. doi:10.1186/1939-8433-5-11.

Khush GS (1997) Origin, dispersal, cultivation and variation of rice. Plant Mol Biol 35:25-34. doi:10.1023/A:1005810616885.

Kumar V, Singh A, Mithra SV, Krishnamurthy SL, Parida SK, Jain S, Tiwari KK, Kumar P, Rao AR, Sharma SK (2015) Genome-wide association mapping of salinity tolerance in rice (*Oryza sativa*). DNA Res 22:133–145.

Kumar V, Singh A, Mithra SV, Krishnamurthy SL, Parida SK, Jain S, Tiwari KK, Kumar P, Rao AR, Sharma SK (2015) Genome-wide association mapping of salinity tolerance in rice (Oryza sativa). DNA Res 22:133–145.

Marcos M, Sharifi H, Grattan SR, Linquist BA (2018) Spatio-temporal salinity dynamics and yield response of rice in water-seeded rice fields. Agric Water Manag 195:37–46. doi:10.1016/j.agwat.2017.09.016.

Munns R, Tester M (2008) Mechanisms of Salinity Tolerance. Annu Rev Plant Biol 59:651–681. doi:10.1146/annurev.arplant.59.032607.092911.

Nazar R, Iqbal N, Masood A, Syeed S, Fhan NA (2011) Understanding the significance of sulfur in improving salinity tolerance in plants. Environ Exp Bot. 70(2-3):80–87.

Negrão S, Courtois B, Ahmadi N, Abreu I, Saibo N, Oliveira MM (2011) Recent updates on salinity stress in rice: From physiological to molecular responses. CRC Crit Rev Plant Sci 30:329–377. doi:10.1080/07352689.2011.587725.

Nguyen MH, Thu PV, Cuong NT (2006) Evaluating arable soil composition in order to well manage the soil resource of

Vietnam. Proceedings of the 9th Workshop of Vietnam Institute of Meteorology Hydrology and Environment; Vietnam. pp. 437–442.

Rao PS, Mishra B, Gupta SR, Rathore A (2008) Reproductive stage tolerance to salinity and alkalinity stresses in rice genotypes. Plant Breed 127:256–261. doi:10.1111/j.1439-0523.2007.01455.x.

Reddy INBL, Kim BK, Yoon IS, Kim KH, Kwon TR (2017) Salt Tolerance in Rice: Focus on Mechanisms and Approaches. Rice Sci 24: 123–144. doi:10.1016/j.rsci.2016.09.004.

Roy SJ, Negrão S, Tester M (2014) Salt-resistant crop plants. Curr Opin Biotechnol 26:115–124. doi:10.1016/j.copbio.2013.12.004.

Tester M, and Langridge P (2010) Breeding technologies to increase crop production in a changing world. Science 327(5967):818–822. doi:10.1126/science.1183700.

Todaka D, Nakashima K, Shinozaki K, Yamaguchi-Shinozaki K (2012) Toward understanding transcriptional regulatory networks in abiotic stress responses and tolerance in rice. Rice 5:6. doi:10.1186/1939-8433-5-6.

Wang Z, Chen Z, Cheng J, Lai Y, Wang J, Bao Y, Huang J and Zhang H (2012) QTL analysis of Na+ and K+ concentrations in roots and shoots under different levels of NaCl stress in rice (*Oryza sativa* L.). PLoS ONE 7:e51202.

Wang Z, Wang J, Bao Y, Wu Y and Zhang H (2011) Quantitative trait loci controlling rice seed germination under salt stress. Euphytica 178:297–307.

Zheng H, Zhao H, Liu H, Wang J, Zou D (2014) QTL analysis of Na^+ and K^+ concentrations in shoots and roots under NaCl stress based on linkage and association analysis in japonica rice. Euphytica 201:109–121. doi:10.1007/s10681-014-1192-3.

ĐÁNH GIÁ KHẢO NGHIỆM CÁC DÒNG LÚA TRIỂN VỌNG CHỐNG CHỊU MẶN

Hiện nay canh tác lúa đang gặp nhiều thách thức do biến đổi khí hậu gây ra, trong đó xâm nhập mặn gây tổn thất đáng kể đến sản lượng lúa. Có nhiều phương pháp, kỹ thuật đã được áp dụng để phòng và giảm thiểu ảnh hưởng của biến đổi khí hậu (BĐKH) đến sản lượng lúa, trong đó nghiên cứu phát triển giống mới được xem là một trong các khâu quan trọng. Với mục tiêu giảm thiểu tác động của BĐKH chương trình AFACI đã đưa kết quả nghiên cứu về các giống lúa chịu mặn của IRRI thử nghiệm ở vùng nhiễm mặn của các nước thành viên. Tại Đồng bằng sông Cửu Long (ĐBSCL) tổng cộng có 40 dòng được trồng khảo nghiệm, trong đó 36 dòng lúa triển vọng chịu mặn và 04 giống lúa đối chứng. Các dòng này được đánh giá các đặc tính nông học, các thành phần năng suất và khả năng thích ứng với điều kiện mặn. Cà Mau và Sóc Trăng được chọn để khảo nghiệm bộ giống trong điều kiện xâm nhập mặn, trong khi Cần Thơ (Viện Lúa) được chọn để khảo nghiệm trong điều kiện thường để so sánh làm đối chứng. Kết quả khảo nghiệm chọn được 06 dòng lúa triển vọng có đặc tính tốt và thích nghi với điều kiện mặn. Trong đó vụ 2019-2020, có 03 dòng được chọn là IR 17834-10-1 RGA-1 RGA-1 RGA-1, IR 121094-B-B-AJY3-2-B và IR 16T1009; vụ 2020-2021, 03 dòng được chọn gồm có IR127792-843-1-1-1-3, IRR117839-22-15-B- CMU10-1-B và IRRI147.

Từ khóa: *mặn, giống lúa chịu mặn, đánh giá kiểu hình, đặc tính nông học.*

SUPPLEMENTARY

Table S1. Descriptive statistics of nine agronomic traits in a set of 10 varieties and local checks under salt-affected Soc Trang (ST) and non-affected Can Tho (CLRRI) locations during 2019-2020.

No.	Designation	Locations	DTF	PH	NT	PL	FGNP	UFGP	USP	TGW	YLD (ton/ha)
1	IR 112462-B-25-2-1-1	CLRRI	84	113	16	24.3	3107.3	400	11.7	26.3	5.7
2	IR 112462-B-25-2-1-1	ST	75	104	7.3	24.7	1076.7	77.7	6.6	23.5	4.8
3	IR 117834-10-1 RGA-1 RGA-1 RGA-1	CLRRI	87	111	13	27	1788.7	573.3	24	26.4	5.8
4	IR 117834-10-1 RGA-1 RGA-1 RGA-1	ST	77	101.7	7.7	24.7	1485	51.7	3.6	24.5	5.6
5	IR 117841-2-1 RGA-1 RGA-1 RGA-1	CLRRI	81	116.3	14	24.3	2115.3	524.7	19.7	23.5	4.7
6	IR 117841-2-1 RGA-1 RGA-1 RGA-1	ST	77	116.7	8	24	1086.3	125.7	10.1	22.6	4.6
7	IR 121094-B-B-AJY3-2-B	CLRRI	90	123.7	9	26.7	898	677.3	43.7	21.5	5.1
8	IR 121094-B-B-AJY3-2-B	ST	86	124.7	9	23.7	1551	71	4.6	25.3	5.3
9	IR 15T1302	CLRRI	84	115	13.3	24.7	2001.7	548.3	21	27.8	4.7
10	IR 15T1302	ST	72	114.3	6	25	683.3	146	17.2	27.2	4
11	IR 16T1009	CLRRI	87	114.3	12	28.7	1402.7	648.3	31.3	26.6	3.9
12	IR 16T1009	ST	77	115	7.7	24.7	1224.7	70.7	5.3	25.5	5.2
13	IR 16T1075	CLRRI	81	118	10	26	1025	594.3	36.7	28.6	3.8
14	IR 16T1075	ST	75	117.3	8.7	25.7	1102	160	12.2	27.4	4.3
15	IR 58443-6B-10-3	CLRRI	84	114.3	14.7	27.3	2544	461.3	15.3	28.8	4.8
16	IR 58443-B-10-3	ST	77	116	7	27.3	1067.3	102	8.9	28.3	4.8
17	IRRI 104	CLRRI	70	82.7	16.7	25.3	3507.3	377.3	9.3	25.3	5.3
18	IRRI 104	ST	70	104.7	8	22.3	841.3	263.7	23.2	26.4	3.4
19	IRRI 154	CLRRI	84	107.3	14.3	25	2332.3	501	17.7	25.5	4.8
20	IRRI 154	ST	77	107	8	26.3	1248.3	83	6.1	25.7	4.8
21	IR64 (Salt-sensitive)	CLRRI	78	97	12	27.7	1570.3	587	27.7	25.2	4.1
22	IR64 (Salt-sensitive)	ST	77	96.3	9.7	25.3	1072.7	244	18.5	26.6	3.4
23	OM 5451 (Salt-sensitive)	CLRRI	81	111	12	23.7	1491.3	625.7	29	22.8	3.9
24	OM 2517 (Salt-tolerant)	ST	68	106.3	9.7	23.3	1166	213.3	16.5	28.8	4

Table S2. Descriptive statistics of nine agronomic traits in a set of IRRI varieties and local checks under salt-affected (Soc Trang) and non-affected (CLRRI-Can Tho) locations during 2020-2021.

No.	Designation	DTF	PH	PN	PL	TGW	FGP	UFGP	USP	YLD	Loc
1	IR127773-B-12-AJY-1-1-1	95.5	101.2	12.8	26.4	26.8	2093.3	387.5	33.3	2.9	ST
2	IR127768-319-1-AJY1-1-1	99	105.8	13.5	24.8	28.3	1408.7	1112	53.2	3.2	ST
3	IR127768-311-1-AJY1-2-2	74	109.7	14	26	27.6	3360.8	904	43.5	3.2	ST
4	IR127768-311-1-AJY1-1-1	97.5	120.2	13.7	24.9	24.7	2830	555	44.7	3.4	ST
5	IR127792-843-1-1-3-2	87	95.2	13.8	24.8	28.2	1529.5	554	33.6	3.5	ST
6	IR127780-B-10-AJY1-1-2	94.5	111.8	12.5	29.3	24	2921.3	650.7	21.4	3.7	ST
7	IR 112462-B-25-2-1-1	89.5	106.8	13.7	22.9	26.7	2795.5	628.2	22.8	3.7	ST
8	IR 117834-10-1 RGA-1 RGA-1 RGA-1	93.5	96.5	15.7	23.7	26.2	1879.2	693	22.4	3.7	ST
9	IR121188-28-1-CMU2-2-B	75	92	21.8	27.4	25.6	2111.2	573.8	17.8	3.8	ST
10	IR127768-319-1-AJY2-2-1	95.5	115	10.5	26.5	22.9	2884.8	697.5	42.8	3.8	ST
11	IR127803-B-19-AJY-1-1-1	102.5	106.2	12.2	24.7	25.2	1574.3	724.7	39.5	3.8	ST
12	IR127779-306-1-CMU1-2-1	101	112.7	12.5	25.9	25.4	2462.5	1105.7	56.8	4.1	ST
13	IR 58443-B-10-3	83.5	111.2	14.2	24.4	24.9	2413.2	388.8	30.1	4.2	ST
14	IR117676-318-1-1-1	81	122	11.5	28.6	22.3	3134.8	439.8	25	4.2	ST
15	IRRI 104	70	97.3	14.8	24.7	28.7	2246.7	675.8	7.7	4.2	ST
16	IR16T1054	74	106.3	17.2	27.2	27.4	1782.7	327.3	29	4.2	ST
17	IR 16T1009	76	108.2	16.3	27.6	25.7	2135.3	646.5	19.6	4.4	ST
18	IR 117841-2-1 RGA-1 RGA-1 RGA-1	76.5	115.2	15.2	25.1	25.5	2048.2	194.7	14.3	4.4	ST
19	IR117833-3-1RGA-1RGA-1RGA-1	89.5	91.8	14.8	28.7	23.3	1491.3	296.5	23	4.4	ST
20	IR117841-1RGA-1RGA-1RGA-2	78.5	111.7	14.3	29.2	25.6	1929.5	546	34.5	4.4	ST
21	IR 121094-B-B-AJY3-2-B	82.5	115.7	16.7	25.8	25.5	1607.3	509.3	26.5	4.5	ST

22	IR 16T1075	77	111	14.2	25.9	25	1959	338.3	15.6	4.5	ST
23	IR18T1012 (Sal19DS-02N1#32)	76.5	104.8	12.7	30.7	23.3	1134.8	358.2	28.6	4.6	ST
24	IR117841-8-1RGA-1RGA-1RGA-1	86	104.3	15.8	29.1	21.9	2437.7	739.7	31.3	4.7	ST
25	IR108135-B-1-AJY-B-1	89.5	124	11.7	29.4	22.1	1542.2	218.7	12.9	4.7	ST
26	IR117840-3-1RGA-1RGA-1RGA-2	85	90.5	13.8	27.2	25	1524.3	443	31.8	4.9	ST
27	IR117834-24-1RGA-1RGA-1RGA-1	96.5	84.8	14	26.7	25.8	3239.8	682.3	23.9	5	ST
28	IR 15T1302	75.5	110	12.5	26.6	24.8	1560.5	267.3	18.2	5.1	ST
29	OM5451	73	100.3	15	15.7	24.3	1498	682.1	18.8	5.1	ST
30	IR121461-40-2-1-B-3	80.5	109.8	13.5	26.6	26.2	2875.8	790.5	13.1	5.2	ST
31	IR121461-2-1-1-B-2	82	109.8	15.7	24.4	26.4	1877.7	582.2	16.5	5.2	ST
32	IR127795-1140-1-1-2-3	70	96.2	13	24.2	24.7	3113.3	651.2	13.6	5.4	ST
33	OM2517	73.5	98.7	18	23.8	23.8	1500.8	701.3	15.2	5.5	ST
34	IRRI 154	87	97.7	21.2	25.9	24.7	1550.2	735.2	11.1	5.6	ST
35	IR127792-843-1-1-2-2	77.5	95.2	15.2	25.5	27.9	2195.5	483.2	16.5	5.6	ST
36	IR127792-843-1-1-1-3	77.5	96.5	17	23.3	25.8	2793.8	953	14.8	5.7	ST
37	IRR117839-22-15-B-CMU10-1-B	88.5	100.2	14.5	25.7	27.1	1466.7	665	25	5.7	ST
38	IRRI 147 (Sal19ds-02N1#55)	78	104.2	11.7	25.9	24.8	2335.8	788.2	14.5	5.8	ST
39	IR 58443-B-10-3	98.5	79.7	4.2	23.5		284	69.5	19.7	0.2	CM
40	IRR117839-22-15-B-CMU10-1-B	90.5	84.8	4.1	21.9		242.8	64	20.9	0.2	CM
41	IR117841-8-1RGA-1RGA-1RGA-1	96.5	87.2	4.2	22.9		337.1	93.6	22	0.4	CM
42	IR127779-306-1-CMU1-2-1	102.5	95.2	3.7	23.3		251.9	133.1	35.6	0.4	CM
43	IRRI 104	83.5	71	3.5	17.7		214.1	55.2	20.7	0.4	CM
44	IR121461-2-1-1-B-2	87	86	4.5	21.6		204.7	110.8	34.1	0.5	CM
45	IRRI 154	93	83	3.7	21.3		259.5	119.3	31.5	0.5	CM

46	IR 117834-10-1 RGA-1 RGA-1 RGA-1	92.5	79.5	3.6	19.1	256.3	67	22.5	0.5	CM
47	IR 117841-2-1 RGA-1 RGA-1 RGA-1	88	84.3	4.6	20.9	266.3	116.7	30.3	0.6	CM
48	IR127792-843-1-1-1-3	91.5	88.8	2.4	23.8	160.2	50.7	22.7	0.6	CM
49	IR117676-318-1-1-1	95	99.3	2.9	22.6	175.2	37	18.4	0.6	CM
50	IR127768-311-1-AJY1-1-1	101	95.7	5.2	20.8	413.9	114	21.3	0.6	CM
51	IR121461-40-2-1-B-3	92	91.8	4.6	21.4	297.3	92	23.7	0.7	CM
52	IR127768-319-1-AJY1-1-1	104	82.7	4.9	23.4	311.4	209	38.6	0.7	CM
53	IR127795-1140-1-1-2-3	84	76.8	3.9	20.1	273.6	19.3	6.5	0.7	CM
54	IR121188-28-1-CMU2-2-B	95	88.3	3	22.9	218	82.2	31.1	0.7	CM
55	IR 16T1009	91	87.7	3.4	21.8	231.6	80	26.5	0.8	CM
56	IR117841-1RGA-1RGA-1RGA-2	91.5	91	5.2	19.8	305.3	90.8	23.2	0.8	CM
57	IR117834-24-1RGA-1RGA-1RGA-1	90.5	76.2	4	20.4	227.9	70.9	23.8	0.8	CM
58	IR 112462-B-25-2-1-1	97	78.8	5.1	19.3	331.4	110.6	24.8	0.9	CM
59	IR108135-B-1-AJY-B-1	93.5	88.2	4	21.9	273.2	71.4	20.8	0.9	CM
60	IR117833-3-1RGA-1RGA-1RGA-1	91.5	82.2	4.7	20.8	296.7	106.6	25.8	0.9	CM
61	IR127768-319-1-AJY2-2-1	95.5	92.7	2.7	24.7	265.9	53.1	16.4	0.9	CM
62	IR127773-B-12-AJY-1-1-1	96.5	87.7	4.3	20	264	119.4	31.3	0.9	CM
63	IR127792-843-1-1-3-2	92.5	79.8	4.2	20.9	233.8	160.8	39.6	0.9	CM
64	IR16T1054	88	89.5	3.9	20.8	204.5	85.4	29.2	0.9	CM
65	IR18T1012 (Sal19DS-02N1#32)	91.5	93.3	5.3	21.5	397.9	107.7	21.4	1	CM
66	OM2517	90.5	77.7	4.1	18.7	320.9	46	14.8	1	CM
67	IR 16T1075	94	98.3	3.3	23.3	215.8	103.7	32.9	1.1	CM
68	OM5451	85	80.2	2.8	17.8	183.3	28.1	13.7	1.1	CM
69	IR127792-843-1-1-2-2	91.5	84	4	21.9	190.7	51.8	21.1	1.1	CM

70	OM429	87.5	77	3.1	17.1		202.3	35	14.5	1.1	CM
71	IR 15T1302	97	92.5	3.2	23.2		288.6	103	26.2	1.1	CM
72	IR127780-B-10-AJY1-1-2	92.5	94.5	3.7	22.3		286.8	55.3	15.8	1.2	CM
73	IR117840-3-1RGA-1RGA-1RGA-2	91.5	83	5.4	21.2		315.5	142.2	29.1	1.2	CM
74	IR127803-B-19-AJY-1-1-1	95	90.5	5.2	22.5		471.8	122.9	20.4	1.3	CM
75	IR 121094-B-B-AJY3-2-B	97	90	5	21.1		377.6	90	18.7	1.4	CM
76	IR127768-311-1-AJY1-2-2	96	97.5	5.7	21.3		432.9	105.5	19.6	1.4	CM
77	IRRI 147 (Sal19ds-02N1#55)	90.5	90.7	5.9	21.4		446.6	71.3	13.9	1.8	CM
78	IR127779-306-1-CMU1-2-1	115	106.2	8.7	26.7	25	1686.5	166.8	28	3.5	CT
79	IR127792-843-1-1-2-2	81	99.8	7.8	25.2	28.4	1225.7	274.2	17	4.1	CT
80	IR127768-319-1-AJY2-2-1	112	111.2	9	26.8	22.9	1505.7	245.8	42.5	4.2	CT
81	IR127768-311-1-AJY1-1-1	114.5	112.5	11.7	23.2	26.4	2157.8	259.5	17	4.3	CT
82	IR127780-B-10-AJY1-1-2	94	116.2	9.5	29	25.5	1849.2	426.8	25	4.3	CT
83	IR127768-311-1-AJY1-2-2	81	125.2	13.2	26	27.6	2511	916.3	14.5	4.4	CT
84	IR127768-319-1-AJY1-1-1	115	107.5	7.3	25.5	28.7	772.7	167.8	36	4.4	CT
85	IR127792-843-1-1-1-3	82	107.5	15	22.7	25.2	2993	1034	11	4.4	CT
86	IR127792-843-1-1-3-2	85	99.3	10	24.8	28.4	1046.8	349.3	22	4.4	CT
87	IRRI 104	71	88.7	14.3	25	25.6	2980.7	461	22	4.8	CT
88	IR127773-B-12-AJY-1-1-1	88.5	109.8	9.7	25.8	28.2	1622	310.3	24	4.9	CT
89	IR127795-1140-1-1-2-3	74	96.7	10.2	24.2	25.1	1696	362.5	11.7	5	CT
90	IRRI 147 (Sal19ds-02N1#55)	84.5	110.7	9.7	24.3	26.6	1707.5	511	17	5.1	CT
91	IR 117834-10-1 RGA-1 RGA-1 RGA-1	84.5	107.7	14.7	24.8	27.3	1828	677.2	15	5.2	CT
92	IR127803-B-19-AJY-1-1-1	111	118.7	6.5	28.8	26.1	705.7	233.7	27.2	5.2	CT
93	IR16T1054	82	115.8	13.5	26.5	29.1	1698	326.5	37.8	5.2	CT

94	IRR117839-22-15-B-CMU10-1-B	84.5	111.7	14.5	25.2	25.1	1694.5	863.2	15.2	5.2	CT
95	IR121461-2-1-1-B-2	78	114.2	10.5	25.2	26.7	1283.3	397	10.7	5.3	CT
96	IR108135-B-1-AJY-B-1	84	141.7	8	27.7	21.3	1073.5	271.5	32.7	5.4	CT
97	IR 16T1075	81.5	119.5	11	27.3	25.7	1286.7	290.2	24	5.4	CT
98	IR18T1012 (Sal19DS-02N1#32)	84	123.7	10.3	31.5	21.8	965.3	299.7	32	5.4	CT
99	IR117833-3-1RGA-1RGA-1RGA-1	83.5	105.5	13.8	27.3	23.7	1679.7	324.2	31.2	5.5	CT
100	IR117834-24-1RGA-1RGA-1RGA-1	86	91.3	12.3	26	25.7	2252.7	500.7	26.8	5.5	CT
101	IR117841-8-1RGA-1RGA-1RGA-1	84	122	10.3	28.3	22.6	1720.3	1033.7	22.7	5.5	CT
102	IR 58443-B-10-3	84	116.2	9.5	23.8	25.5	1613.2	152	35.3	5.6	CT
103	IR117840-3-1RGA-1RGA-1RGA-2	84	96.5	11.3	27.2	26.1	1167.7	315.7	27.7	5.6	CT
104	IRRI 154	80	106.5	15.5	26.8	22.3	2547.2	845.8	54.7	5.6	CT
105	IR 15T1302	81.5	120.8	11.2	26.8	25.3	1768	712.3	12.7	5.7	CT
106	IR117676-318-1-1-1	79	131.8	7	27.5	23.2	1546	241.8	19.3	5.7	CT
107	IR121461-40-2-1-B-3	79	119.5	8	27.2	26.2	1281.7	346.2	31.8	5.7	CT
108	IR 16T1009	83.5	125.3	9.2	28.7	26.4	1238.7	463.5	16.8	5.8	CT
109	IR 112462-B-25-2-1-1	86	109.7	14.7	24.2	28.4	2765.3	794.8	8	6	CT
110	IR 121094-B-B-AJY3-2-B	86	129.5	14.5	25.2	24.2	1832.8	577.8	23	6	CT
111	IR117841-1RGA-1RGA-1RGA-2	79.5	123	13	28.2	25.7	1697.3	863.8	13	6	CT
112	IR 117841-2-1 RGA-1 RGA-1 RGA-1	80	125.3	10	25.7	29.1	1422	175.3	43.3	6.1	CT
113	IR121188-28-1-CMU2-2-B	82	104.7	10	27.5	26	1406.7	545.8	20.7	6.1	CT
114	IR64	77.5	105.8	12.3	24.8	23.3	1403.3	655	9	6.2	CT
115	OM 2517	72	99.7	13	23.3	24.7	1520.7	725	19.8	5.6	CT