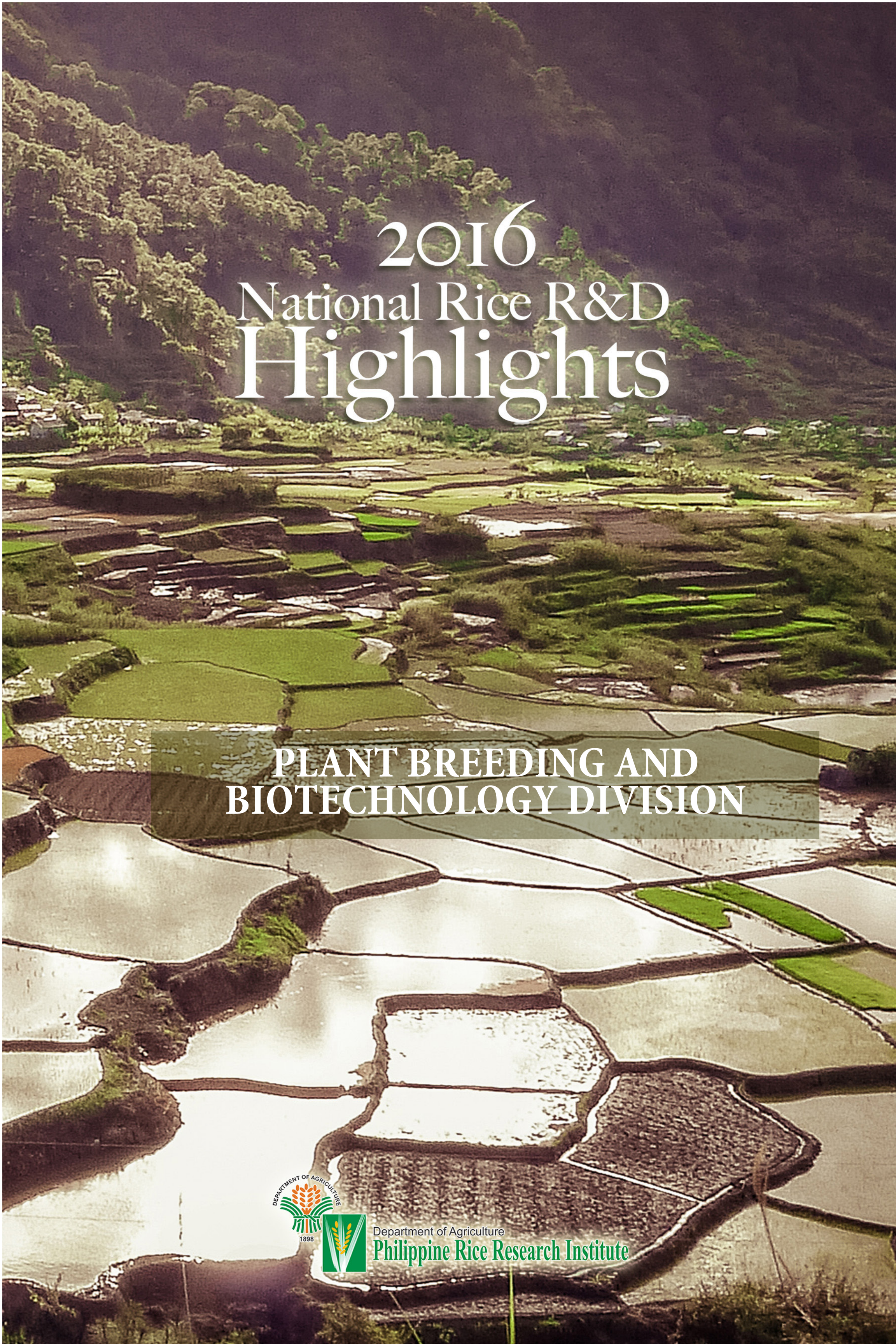


2016 National Rice R&D Highlights

PLANT BREEDING AND BIOTECHNOLOGY DIVISION

Department of Agriculture
Philippine Rice Research Institute

TABLE OF CONTENTS

Plant Breeding and Biotechnology

Division Head: Norvie L. Manigbas

Executive Summary

Rice is the most important staple food consumed by more than half of the world's population. Majority of Filipinos and several Asian countries depend on rice as primary economic food. Rice can be grown in different ecosystems, one of which is the irrigated lowland system where inbred and hybrid rice can be direct seeded or transplanted. Other environments include; rainfed, saline-prone, cold-elevated, high temperature, flood prone, and upland areas. Aromatic, glutinous, pigmented and japonica rice are some of the specialty types that commands higher price in the market. Recently, the demand is increasing in accordance with the continuous increase in human population; hence, it is a prerequisite to improve the yield potential and resistance of the existing varieties. Basically, breeding is directed to achieve desired traits such as high grain yield, resistance to abiotic and biotic stresses, and grain qualities acceptable to consumers. Main differences are the selection environment and the expression of these traits in the environments.

Changing environmental conditions poses numerous challenges to varietal improvement. Restricting factors affects rice growth and development under different environmental conditions. These factors greatly affect yield which in turn affects the ability to cater the incessant increase in rice demand. Under these complex and variable environments, breeding objectives must shift to developing varieties which are adapted to specific target environment such as drought, submergence, high temperature, low temperature and rainfed conditions. To address these constraints and challenges, different breeding strategies, including; integrated management technologies, Marker-Assisted Selection, classical hybridization and biotechnology, in vitro culture, in vitro mutagenesis, anther culture, root plasticity development, and incorporation of Rice Tungro virus and bacterial blight disease resistance genes are employed to generate and develop improved breeding lines for the target ecosystem.

At the molecular level, identifying good donors at the pre-breeding phase is prerequisite in any breeding programs. Varieties and wild types are screened for particular traits in search for genes and donors useful in breeding.

With the increasing role of hybrid technology in augmenting domestic rice supply, additional higher-yielding rice varieties must be developed through a more-focused and market oriented outlook. Hybrid rice breeding at The Central Experiment Station has been adaptive to this need by stream-

lining activities to be more output-oriented and resource efficient. Consequently, new parent lines with good combining potential have been developed, good-performing testcrosses have been generated and performance testing of promising hybrids in the breeding pipeline made more comprehensive. The continuous development of high-yielding hybrid varieties that are resistant to pests and diseases and possess excellent grain qualities are also one of the essential solutions to keep up with the increasing demand for rice and the changing environment.

Currently the Plant Breeding and Biotechnology Division is composed of a total of 149 service contractors (57 researchers and 91 laborers) and 13 regular staff. It conducts, monitors and evaluates a total of 57 national and international collaborative researches. With these studies, researchers were able to publish scientific papers to ISI-refereed journals, and present posters and publish papers as a result of its continued challenging work for rice research.

The division was able to develop breeding lines from different rice ecosystem 2016 recommendation which include; PR37241-3-1-2-1-1 and PR36720-17-1-2-1 for irrigated lowland environment (inbred), PR30245-AC-123 for rainfed lowland (direct-seeded), and PR30025-99AC-WSAL-1086 and PR30245-IR64-ID-18-1-4 for saline environment.

Also, the division has accommodated a total of 48 international and national students, on the job trainees and research interns which has created and enhanced collaborative researches local and international. This facilitated continued sharing of knowledge and expertise in the field of plant breeding and biotechnology.

I. Pre-Breeding and Germplasm Enhancement

Project Leader: AADelaCruz

Identifying good donors at the pre-breeding phase is a prerequisite in any breeding programs. In rice, released varieties and wild rice are being screened for particular traits in search for genes or donors useful in breeding programs. But natural variations for important traits, such as resistance to various biotic and abiotic stresses, are limited. Relying solely on natural genetic variation may not be enough to address the needs in the future thus tapping other alternatives methods of increasing genetic diversity may also be very important. In support to the various rice breeding programs, this project is being implemented to broaden the base of germplasm resources through identification of new gene sources or by developing new sources. Eventually, this project will help increase the access and utilization of desirable traits and/or genes existing in the rice germplasm.

Induced Mutations for Quality Improvement in Rice

TF Padolina, RC Braceros, LR Pautin, and APP Tuaño

In 2016, advanced mutant lines from modern and traditional backgrounds were generated. These lines had improved yields and other morpho-agronomic traits and were advanced accordingly to appropriate breeding nurseries. Different grain quality parameters on physical and milling potentials, physico-chemical traits and some value-adding traits have been preliminary screened while ensuring higher productivity and resistance over their parent stock. Modern varieties such as PSB Rc10, NSIC Rc152, NSIC Rc150 and MS16 were targeted to reduce chalkiness, improve physico-chemical properties and milling quality, respectively. Promising mutant lines converted from the hybrid Mestizo 1 were selected with acceptable yield and better bacterial leaf blight resistance while retaining its aroma and excellent grain quality. Traditional varieties like Azucena, Dinorado and Ballatinaw were also chosen to improve yield while retaining good grain quality and also being screened for other value traits like higher nutrient content, anti-oxidant properties and some tolerance to abiotic stress like drought.

Activities:

- Characterization of promising mutant lines with unique and value-added traits for % amylose content, low phytic acid content, high anthocyanin content, drought/heat tolerance, and high yield.

Results:

- Figure 8, shows the advance mutant lines derived from various backgrounds with improved yield, and amylose content. The improved traits will be further verified along with the grain quality assessment. Promising mutant lines will be forwarded to the crossing block for use in rice breeding as donor germplasm.

- Best lines with improved traits were characterized as follows: 3 MS16, 7 lines PSB Rc10, 6 lines both for NSIC Rc150 & NSIC Rc152 with low to intermediate amylose and chalky traits (Figure 1&2), 1 Ballatinaw to confirm anthocyanin content (Figure 3), 6 more Azucena to test for low phytic acid content (Figure 4), Mestizo mutants selected with BLB resistance (Figure 5) and Dinorado and Ballatinaaw mutants for high yield (Figure 6).

- Two mutant lines Dinorado Susi-20kR-11-3-2-2, Dinorado Susi-20kR-22-6-1-1 elevated in the Multi-location yield trial produced 7389kg/ha and 7122kg/ha respectively, comparable PSB Rc18 with 6.8t/ha.

- Other mutant lines nominated for various stages of testing are the following: 1 Dinorado mutant with good grain quality advanced to NCT-I; 1 Ballatinaw with low phytic and tolerance to heat advanced to NCT-HT; 1 Azucena mutant with drought tolerance and good grain quality advanced to NCT-HT; 2 Mestizo mutants with drought and good grain quality advanced to NCT-HT and MET. Field stand is shown in Figure 7.

- One Nipponbare mutant line designated as Nipponbare-25kR-AC-29-1-1-1-1, a japonica type variety passed the NCT standards for special purpose and recommended for further deliberation of the Technical Secretariat of the National Seed Industry Council. It exhibited 14.7% yield advantage over MS11, the yield check with good adaptation in PhilRice CES and SCRC in Cagayan. It matures in 117 days, plant height of 100cm, and with number of productive tillers of 14. It showed intermediate resistance to blast, bacterial leaf blight, sheath blight, stemborer, and green leaf hoppers. It has premium milling and head rice recovery, low amylose content, short and bold grains and comparable acceptability rating in cooked and raw forms with Koshihikari , the grain quality check.

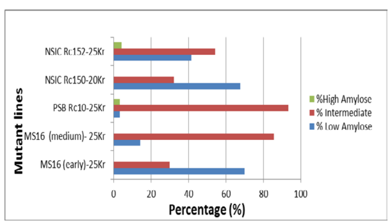


Figure 1. Profile of amylose content of selected mutants from irradiated modern varieties.

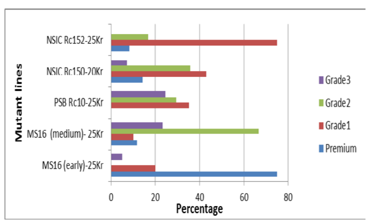


Figure 2. Classification of chalky character of selected mutants from irradiated modern varieties.

Figure 3. Ballatinaw and one of its mutants for anthocyanin.

Sample	Breeder/Source	High Inorganic Phosphate (HIP) Scores: 2.5 ~0.30 ug Pi	% of seeds analyzed	3.0 ~0.46 ug Pi	% of seeds analyzed	Total seeds with lpa[1]	% lpa seeds in the total	Total seeds analyzed	Average HIP score of the line	Remarks
AZU 9	TF Padolina	43	**46.7**	1	**1.1**	44	**47.8**	**92**	2.5	Analyzed all seeds
AZU 50	TF Padolina	42	**54.5**	1	**1.3**	43	**55.8**	**77**	2.5	from one panicle.
AZU 51	TF Padolina	58	**51.3**	10	**8.8**	68	**60.2**	**113**	2.6	Whole seeds were
AZU 52	TF Padolina	121	**56.8**	3	**1.4**	124	**58.2**	**213**	2.5	used for HIP
AZU 55	TF Padolina	42	**36.8**	3	**2.6**	45	**39.5**	**114**	2.5	scoring.
AZU 60	TF Padolina	90	**67.2**	14	**10.4**	104	**77.6**	**134**	2.6	

[1]Seeds with LPA phenotype have HIP scores equal to or greater than 2.5.

Figure 4. Selected Azucena mutants for low phythc acid content.

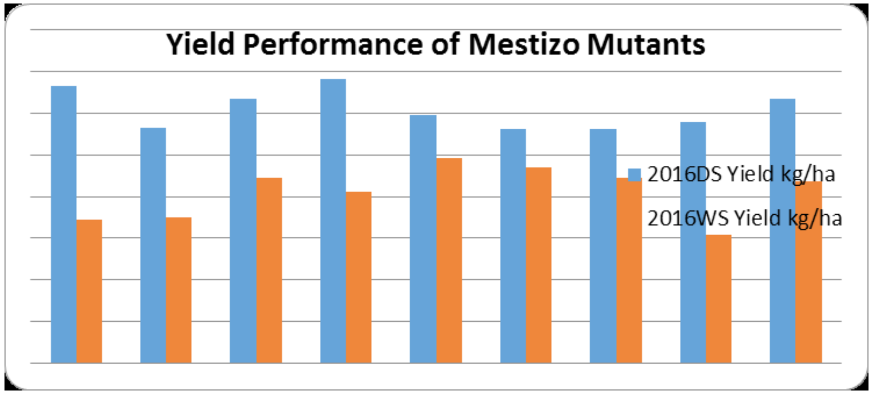


Figure 5. Best performing Mestizo mutants, 2016.

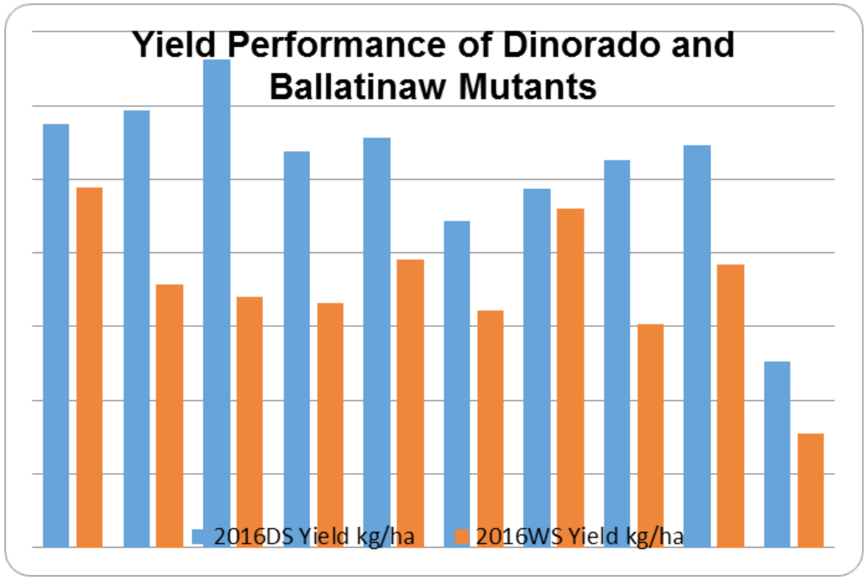


Figure 6. Selected mutants derived from Dinorado and Ballatinaw cultivars, 2016.

Figure 7. Seed increase of selected mutant lines for further characterization and purification, PhilRice CES, 2016.

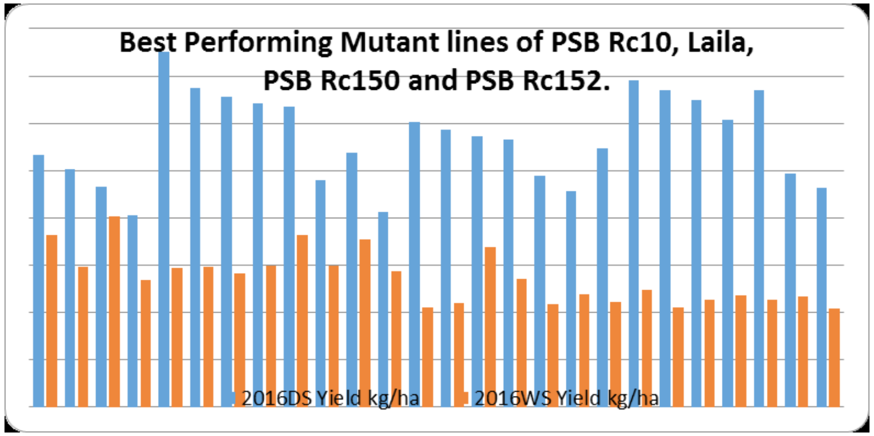


Figure 8. Best performing mutant lines of modern varieties for grain quality improvement.

Development of herbicide tolerant and disease-resistant rice through induced mutations

RMiranda, CTe, and NRSevilla

The genetic variation of modern rice varieties has narrowed as a result of decades of breeding. To be able to continue to make gains from rice breeding, access to a diverse natural germplasm is essential. Induced mutation is one strategy to produce novel genetic variation that can be exploited for varietal improvement. Among the important factors that adversely affect yield are diseases and weeds, especially with the changing climatic patterns. This study, therefore, aims to enhance the genetic variation in the PhilRice rice varietal development program specifically for disease resistance and tolerance to herbicide.

Activities:

- Screening of 13 putative herbicides tolerant NSIC Rc192 mutant for herbicide tolerance under screenhouse and field condition (Figure 9)

- Screening of 30 putative RTV resistant mutant lines of NSIC Rc192 and performed molecular evaluation of resistance through detection of known genes using two identified markers, RM8213 for Glh14 and RM5495 for tsv1.

- Evaluation of five mutant lines with BLB resistance (MSL 37 and MSL 40), and colored pericarp trait (MXB-42, MXB-44, and MXB-VP) for PVP application.

Results:

- Five out of the 13 putative herbicide-tolerant NSIC Rc192 mutant lines were selected after the 2nd cycle screening.

- Mutant lines HT3 and HT8 survived in the 3rd cycle screening and are now undergoing the final evaluation for herbicide tolerance (Figure 10).

- For RTD resistance, 11 out of the 43 individual plants were detected with tsv1 based on use of SSR marker RM5495. The WT do not have tsv1.

- Six mutant lines including the two MSL lines were evaluated in the field for two seasons, however the application for PVP was set on hold due to budget constraints. Performed and completed the agro-morphological characterization between mutants and wild types.

Figure 9. Herbicide tolerance screening of putative mutants of NSIC Rc192 under field and screenhouse condition.

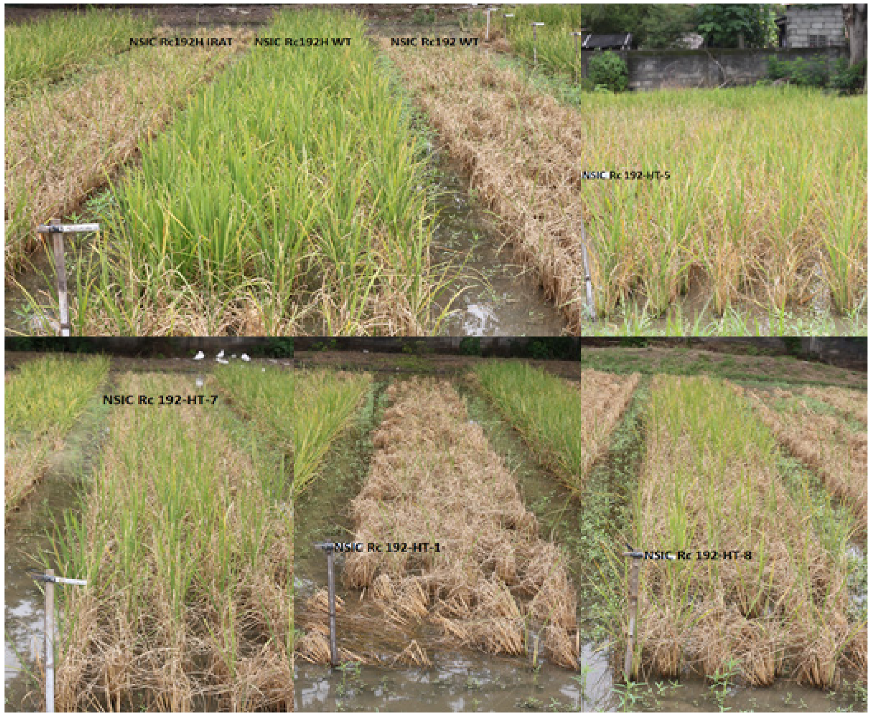


Figure 10. Herbicide tolerance screening results of putative mutants of NSIC Rc192 under field condition.

Breeding for very early maturing rice varieties with high yield

TFPadolina and LRPautin

The breeding and development of highly productive lines that are very early or those which mature in less than 100 days (some farmers even clamor for 75-day varieties of rice) is not only a fascinating challenge to plant breeders. It is an important and timely breeding objective to pursue. The government through the Department of Agriculture has recently crafted an intensified campaign to increase our rice production further and attain rice self-sufficiency in the process. Very early maturing (VEM) varieties offer sustainable breakthrough interventions not only to increase total productivity under favorable conditions but under the less favorable environments as well – considering the impacts of water availability in the physical rice environment, of climate change on the timing and length of production seasons, and of dwindling lands for rice cultivation.

The practice of a shorter production cycle using very early varieties promotes higher efficiency of fertilization and even reduces the production costs since it also shortens the vulnerable time of the crop to pest attacks in the field and thereby minimizes the application of pesticide inputs. In well irrigated fields, ultra-early maturing varieties could provide the soil with a longer "rest" period (fallow) for dry matter incorporation. Another advantage is it can help break the pest cycle.

Results:

- During 2016 trials, 36 uniform lines were evaluated under direct seeding culture and 32 under transplanting method. In general, performance of top yielding materials varied according to crop establishment methods.

- Under the direct seeding method, seven lines were identified with yields ranging from 5.6 to 9.2 t/ha at maturities between 82 to 100 days after sowing (DAS). In Figure 11, four of these materials namely: PR40366-7-1-1, PR40370-7-7-2, PR40407-5-2-2 and PR40401-7-2-2 consistently showed better yield in two consecutive dry seasons (DS) of 2015 and 2016 as compared to the maturity (IR58 and PSB Rc4) and yield (PSB Rc82) checks. They also showed consistent early maturity less than 100 days (84 to 93 days). Incidence of stem borer (whiteheads) was observed during 2015 DS, while damage to brown plant hopper (BPH) and typhoons caused significant yield reduction in the 2016 as compared to 2015. Field stand is shown in figure 13A and B.

- Under transplanted culture (TPR, 2016 DS) (Figure 12), eight other entries were identified with target yield of > than 5 t/ha. Yields were in the range of 5.9 to 7.7 t/ha at maturities between 95 to 104 DAS. The best entries were PR43612-B-15 (7.7 t/ha) and PR43608-B-17(7.5 t/ha) both maturing in 103 days showed 114% yield increase than IR58 (95 days) with only 3.5 t/ha. During the WS, nine entries showed high yield from 5.3 to 8.2 t/ha with maturity range of 98 to 110 DAS. These lines out yielded the two check varieties, IR58 and PSBRc10 (102 days) but only two entries of the same maturity as the checks such as PR43609-B-1 (98days) and PR42464-B-3-1-2 (102 days) passed the yield target by 24.0 and 8.4%, respectively. Field stand is shown in figure 13c.

- Mutation techniques were also employed in the selection of VEM traits: ion beam and gamma ray irradiation treatments. For ion beam treatment this was commissioned through the Philippine Nuclear Institute (PNRI) and was sent to Japan while for gamma rays was treated at the facility of PNRI. The most advanced and promising mutant materials: ion beam- NSIC Rc134 (20Gy) and (40Gy) and Co60 irradiated PSB Rc10 and NSIC Rc134 (250Gy) were nominated in the multi-location yield trials (MYT) in 2016 DS in four sites, PhilRice CES, Bicol, CMU and Negros. As compared to the highest yielding and most stable check, PSB Ec82, only one mutant NSIC Rc134 (20gy)-40 was comparable. PSB Rc10 mutants were inferior to all the checks used.

- Selected pre-breeding VEM lines will be nominated in the crossing block as parent materials for early traits. Other useful materials will be further evaluated as potential varieties.

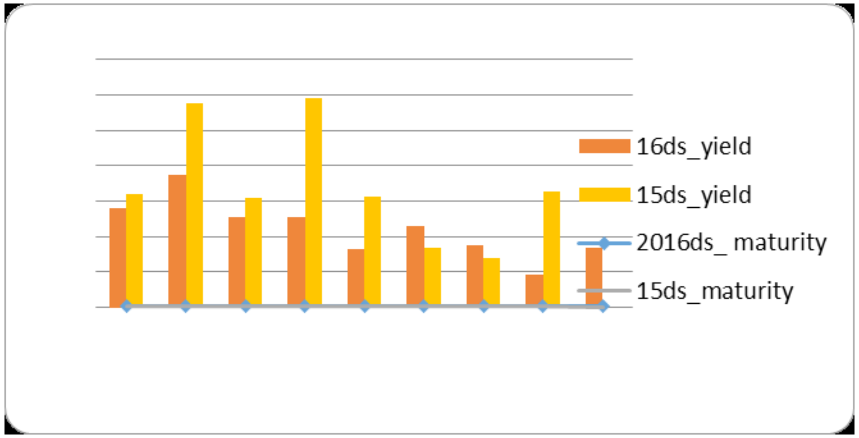


Figure 11. Yield and maturity levels of selected VEM entries under DSR, PhilRice CES, 2015 and 2016 DS.

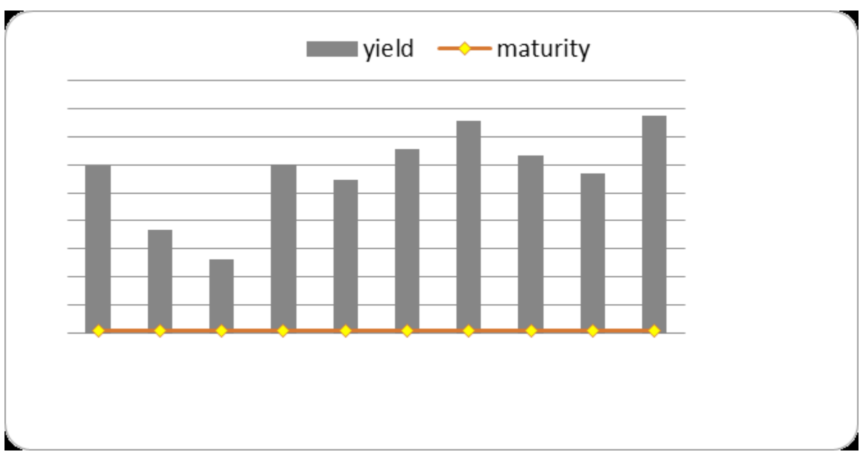


Figure 12. Yield performance and maturity of selected VEM under TPR, PhilRice CES, 2016 DS.

Table 1. Summary of selected early maturing entries and their yielding ability under TPR, 2016 WS.

ADVANCED LINES	PARENTAGE	MAT (DAS)	YIELD (kgha)	incr
IR58	Check	102	3210	
PSBRc4	Check	102	4928	
PR42464 B-3-1-2	**NSIC Rc130 X NSIC Rc112**	**102**	**5345**	
PR45733-B-1	FFZ X HY-RU109	110	7583	
PR45734-B-1	PR37241-1-1-1-2-1 / UEM 269	110	8213	
PR43608- B-7	PSB Rc10 X NSIC Rc134	108	6558	
PR43609- B-1	**SHZ-2 X PSB Rc4**	**98**	**6110**	
PR43611- B-9	IR82187-17-3-2-1-2 X PSB Rc10	108	8153	
PR43611- B-10	IR82187-17-3-2-1-2 X PSB Rc10	108	8195	

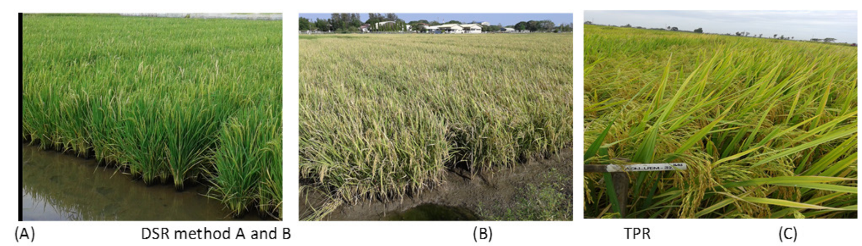


Figure 13. Field stand of VEM materials under DSR and TPR methods, PhilRice CES, 2016 DS.

Figure 14. Lodged VEM entries due to strong winds and typhoon in October, 2016.

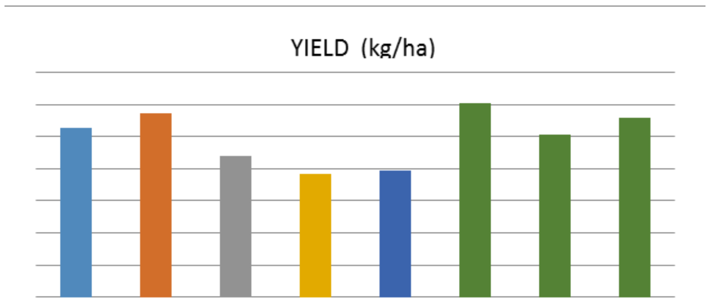


Figure 15. Average yield level of advanced VEM mutants in the MYT, across 4 locations (Nueva Ecija, Albay, Bukidnon, and Negros) 2016 DS.

Finding durable and novel blast resistance genes effective against Philippine's Magnaporthe grisea pathogen population
JM Niones, JT Niones, TE Mananghaya, RP Mallari, JP Rillon, ML Palma and TF Padolina

Rice blast, caused by Magnaporthe oryzae severely affected rice production both in upland and irrigated ecosystem as well as the genetic variability and rapid evolution of the pathogen primarily that causes the breakdown of host plant resistance. High yielding with durable resistance to major diseases are breeding targets of all rice breeding program. Many blast resistant genes and QTL have been identified and these blast resistance genes are pyramided through marker aided selection. Our objective is to transfer effective blast resistance genes (Pish, Piz, QTL, Pi9, Pi40, Piz5) into popular and high yielding rice varieties in the Philippines. Furthermore, this study also aims to locate putative blast resistance gene/QTL from Philippine traditional and released rice varieties.

Activities:

- Genetic analysis of resistance of Malay 2 and phenotypic analysis of BC1F2 of US2/Malay 2.
- Introgression of blast resistance genes to selected rice genotype background for genetic improvement.

Results:

- DNA genotyping of 273 BC1F1 plants of US2/Malay were conducted using identified 33 SSR polymorphic markers across 12 chromosomes to US 2 and Malay 2 to locate potential blast resistance QTL of Malay 2.
- 300 BC1F2 seeds of US2/Malay2 were established for mapping population and evaluated for blast resistance evaluation using PO6-6, IK81-25, and Maligaya blast isolate. Leaf blast scoring was conducted using NCT for Maligaya isolate and JIRCAS manual for PO6-6 and IK81-25 differential blast isolates. Results showed 68.07% of the population was susceptible while the remaining 31.93% were resistant to rice blast pathogen.
- Malay 2 showed consistent resistant reaction to Maligaya and two differential blast isolates, the PO6-6 and IK81-25, using NCT and JIRCAS manual for leaf blast scoring (Table 2).
- Genotype-phenotype linkage analysis was done to locate the potential blast resistance genes and thirteen (13) putative QTLs were identified in chromosome 1, 2, 3,4,6,7,9,10 and 12. These QTLs had 18 to 50% of the phenotypic variation with 0.29 to 0.38 R2 using Inclusive Composite Interval Mapping (ICIMapping) version 4 (Table 3). These QTLs associated with blast resistance present in Malay-2 will provide breeders a new source of resistance genes for blast breeding program.
- Selected high yielding and popular rice cultivars were used in pyramiding of two different blast resistant genes to increase the resistance to rice blast disease. Two fixed lines with blast R genes were introduced to MET0 (Multi Environment Test) in 2016 DS, the PR42304 (NSIC Rc9/SHZ-2//IRBLzFu) and PR47382-1-1-1-4-B-B-B (NSIC Rc9/IRBLz5-CA).
- PR42304 outyielded NSIC Rc124 H (SL 8H) a private hybrid, the standard check at 0.82% in Nueva Ecija condition, it also showed comparable over all phenotypic acceptability and higher number of productive tillers over SL 8H and exhibited consistent resistant reaction for blast in three consecutive seasons (Table 4).
- 11 entries were introduced to Observational Nursery for agro-morphological characterization and further blast resistance evaluation in 2016 wet season. NSIC R160, NSIC Rc224 and NSIC Rc240 were used for genetic improvement and Pish, Piz5, Pi9, Pi40 and QTL were used for blast resistant gene donors. And to possibly harbor two blast resistant genes, paired crossing of two fixed lines with the same genotype background with different blast resistance genes introgressed will be conducted (Table 5).
- Since two consecutive typhoons hit Nueva Ecija in 2016 wet

season, crop yield data were affected due to most of the entries in Observational Nursery were lodged and submerged in water for several days.

Table 2. Blast resistance evaluation of Malay 2 to Maligaya and differential blast isolate.

Parents	Maligaya Race				Differential Isolate	
	NCT		JIRCAS		JIRCAS	
	Score (ave)	Reaction	Score (ave)	Reaction	Score (ave)	Reaction
Malay-2	**2**	**R**	**1**	**R**	**1**	**R**
US-2	7	S	3	S	5	S

Table 3. Chromosome distribution of putative blast resistant QTL in Malay 2.

	Chromosome	Position (cM)	Left Marker	Right Marker	LOD	PVE (%)
1	1	62.80	RM10701	RM7318	3.0482	33.0909
2	3	17.90	RM14308	RM14860	4.2737	24.8008
3	1	28.80	RM10377	RM10701	3.3509	18.286
4	2	15.00	RM12459	RM12692	7.6633	30.1509
5	3	16.90	RM14308	RM14680	3.0631	21.9296
6	4	79.30	RM16945	RM17116	3.4075	21.8906
7	6	83.00	RM527	RM454	9.1925	43.6897
8	7	18.30	RM20852	RM346	4.0693	24.4724
9	9	9.40	RM23662	RM23793	3.1449	19.1119
10	9	51.40	RM7038	RM7289	5.3879	25.7081
11	9	75.40	RM7289	RM24843	4.7775	22.3773
12	10	75.80	RM25683	RM25934	3.3009	20.655
13	12	61.30	RM27706	RM1300	13.1476	50.0785
Legend:						
LOD	logarithm of odds					
PVE	phenotypic variation					
cM	centimorgan					

Table 4. List of blast materials with blast R genes introduced to MET 0 in 2016 dry season and reaction.

										Yield Advantage 2016 DS, Nueva Ecija		Blast Resistance		
Designation	Parentage	Gen.	Mat.	Gene/s	Tiller	PA(OA)	PA pan	PA grain	Ayld	***NSIC Rc124 H***	***NSIC Rc132 H***	**2014 DS**	**2014 WS**	**2015 DS**
PR42304	NSIC Rc9/SHZ-2//IRBLzFu	F6	105	QTL/Piz	16	5	3	5	**3690**	-6.58	0.82	R	R	R
PR47382-1-1-1-4-B-B-B	NSIC Rc9/IRBLz5-CA	F7	95	Piz5	13	7	5	5	**3590**	-9.11	-1.91	I	R	R
NSIC RC 124 H	Bigante (Private Hybrid)				15	5	5	5	**3950**	0				
NSIC RC 132 H	SL 8H (Private Hybrid)				12	5	3	5	**3660**		0			
Legend:														
PA	*Phenotypic Acceptability (1-9)*													
AYLD	*Actual grain yield per plot in grams*													
R	*Resistant*													
I	*Intermediate*													

Table 5. Genetic improvement of selected background genotype using different blast R genes and phenotypic evaluation.

2016 WS	2016 DS	Parentage	Pedigree Name	Gen.	PA	Reaction	Remarks
ON-1	**ON-3**	NSIC Rc160/IRBLsh-S (CO)	**PR47402-84-10-12-B-B**	**F5**	5	R	ON 2016 WS
ON-2	**ON-4**	NSIC Rc160/IRBLsh-S (CO)	**PR47402-84-11-5-B-B**	**F5**	5	R	ON 2016 WS
ON-3	**ON-5**	NSIC Rc160/IRBLsh-S (CO)	**PR47402-84-11-6-B-B**	**F5**	5	R	ON 2016 WS
ON-4	**ON-7**	NSIC Rc160/IRBLsh-S (CO)	**PR47402-84-15-8-B-B**	**F5**	5	I	ON 2016 WS
ON-5	**ON-8**	NSICRc160/IRBLz5-CA(CO)	**PR47403-85-1-4-B-B**	**F5**	5	R	ON 2016 WS
ON-8	**ON-13**	NSICRc224/SHZ-2	**PR47407-92-14-3-B-B**	**F5**	7	R	ON 2016 WS
ON-9	**ON-14**	NSICRc224/SHZ-2	**PR47407-92-17-1-B-B**	**F5**	5	R	ON 2016 WS
ON-12	**ON-19**	NSICRc240/IR65482-4-136-2-2	**PR47414-99-10-1-B-B**	**F5**	5	R	ON 2016 WS
ON-13	**ON-20**	NSICRc240/IR65482-4-136-2-2	**PR47414-99-14-1-B-B**	**F5**	5	R	ON 2016 WS
ON-15	**ON-22**	NSICRc240/IRBLz5-CA(CO)	**PR47416-101-11-1-B-B**	**F5**	5	I	ON 2016 WS
ON-16	**ON-25**	NSICRc240/IRBL9W	**PR47417-102-7-6-B-B**	**F5**	5	R	ON 2016 WS

Development of PhilRice software for predicting physical attributes of milled rice

IGPacada, EHBandonill, TFPadolina, APTuaño, and BOJuliano

Breeding of rice varieties with desired quality requires intensive evaluation of physical attributes, which in milled rice consist of parameters such as % chalky grains, % immature grains, grain length, and grain shape. The traits are being characterized manually by skilled classifiers and the most laborious task is the determination of chalky grains, wherein two sets of 30g milled rice for each candidate rice line need are evaluated using naked eye. Yearly, the grain quality evaluation team of the Rice Varietal Improvement Group (RVIG) manually evaluates physical attributes of 600-800 promising elite lines. This process is undeniably time consuming and tedious thus, automating classification could be the best alternative approach to speed up the conventional classification process. This study therefore aimed to develop image processing software for predicting chalkiness and other physical attributes and to automate the classification process.

Activities:

- Establishment of National Cooperative Testing (NCT) entries at PhilRice-CES experimental area. Harvesting, seed processing, drying and milling are based on The National Cooperative Testing (NCT) procedures and guidelines for grain quality. Strict compliance was made especially for every activities i.e. exact timing of harvesting, drying using established protocol (appropriate time for sun drying, and consistent temperature and duration when using oven drying), and exact milling time.

- Two 60g was extracted in each mother samples. These were scanned and later analyzed using the developed software.

- The same samples were manually evaluated by the Grain Quality Group of PhilRice-LB for predicting value comparison.

Results:

- A total of 114 NCT samples were scanned and analyzed using the developed software. These samples are from eight ecosystems namely irrigated lowland, cool elevated, hybrid, rainfed, saline, special purpose, and upland.

- Correlation to manual classification is in progress.

General evaluation of donor germplasm

AADelaCruz, TFPadolina, and PAMCubian

One of the most difficult tasks in carrying out a successful breeding program is the choice of germplasm. Rice breeders need to be sure that the source germplasm has desirable genetic variability to be able to develop a variety with a set of desirable characteristics. Wide variations among genotypes have greater chances to select superior characteristics of agronomic importance. Then again, it is important to have parents that complement each other well, with good specific and general combining abilities. To facilitate the development of economically high-yielding cultivars with various desirable agronomic traits, consideration on other characteristics should there be given when selecting the parent material such as aspects related to difference in grain type and shape, plant height, and resistance to biotic and abiotic stresses. This study is therefore being implemented primarily to evaluate donor germplasm for unique yield component characteristics and provide rice breeders with parentals for use in their various breeding programs.

Activities:

- Established plant materials in the crossing block for use in various breeding programs (irrigated lowland, direct seeding, special purpose, hybrid, rainfed lowland, heat tolerance).

- Conducted general evaluation/ characterization of selected rice germplasm accessions.

Results:

- A total of 1072 rice germplasm accessions were assembled in the crossing block for use in rice breeding for the year 2016. Among these, 176 (114 in the DS while 62 in the WS) were characterized for major yield enhancing traits. Several promising rice accessions were identified, however only the top 3 rice accessions were presented. Table 6 shows the top accessions selected based on the standard basis of selection, grain length, grain shape and days to maturity. The standard basis for selection of parents recommends use of rice accessions with ≥ 25g 1000 grain weight, ≥ 150 grains per panicle, and ≥ 85% filled spikelets.

- The heaviest 1000 grain weight was recorded in Mustaqilik (36), Holliber 1 and Malagkit from Thailand (35) and PR39496-3-1-5 (34) in the dry season while Arabel (37), Mustaqilik (33) and Ballatinao (30) in the wet season. The highest number of grains per panicle, on the other hand, was recorded in IR10N118 (288), PR39502-13-7-85 (282) and

BG 34-11::IRGC 15782-1 (255) during the dry season whereas IR10N118 (339); PR46840-B-B (313) and C39 (260) in the wet season. Meanwhile, the highest percent filled spikelet was recorded in PR29163-R2-2-1-4 (96.7) during the dry season followed by Gayabyeo (95.7) and ARC 15872::IRGC 43249-C1 (95.5) while in the wet season IR86385-87-1-1-B had 93.6%, Attey (89.9) and HHZ 4-SAL5-LI1-LI1 (89.6). Results showed that Mustaqilik and IR10N118 had great potential in breeding for traits with heavy grain weight and number of grains, respectively.

- In terms of grain length, most of the rice accessions evaluated were classified with "extra-long grains", top on this was Fermoso, tall, long grain (11.6), Arabel (11.2) and WAS 203-B-B-2-4-1::C1 (11.1) for DS while Guyod (11.3); Arabel (10.8); IR 11N400 and Mustaqilik (10.5) in the WS. Some of the rice accessions classified with "long grains" were Giza 177 and Hangangchal (7.4), IR10N118 (7.3) and SANGJUBYEO (7.2) in the DS whereas Paro Dumbja White, IRBLzt-T, and IRBLsh-B (7.4) ILPUMBYEO and Hangangchal (7.3); IRBL11-Zh (7.1) in the WS. Meanwhile, only 1 rice accession was consistently classified with "medium grains": Attey (6.3 in the DS while 6.2 in the WS).

- With regards to grain shape (length/width), most of the evaluated rice accessions were "slender" while others were "bold". The top "slender" rice accessions identified in the DS were BR6902-14-4-2-5 (5.8), Fermoso, tall, long grain (5.1) and Aromatic 1 (5) while Basmati 370 and Guyod (6.0); PR36246-HY-1-16-1 (5.9); IR 11N400 (5.7) in WS. On the other hand, the top bold rice accessions identified in the DS were C21, C39 and Homsodera (2.9).

- In terms of maturity, the most early-maturing rice accession identified in the DS was Chang Bai 9 with 89 days maturity followed by Sakha 101 (91) and Aromatic 1-2 seg (94) whereas IRBLt-K59 and IRBLks-S (89); SANGJUBYEO, IRBL11-Zh, IRBLzt-T, Homsodera, IRBLks-F5, IRBLta2-Re and Arabel (93); Holilber and Fermoso, tall, long grain (94) in the WS.

- The genetic diversity of the about 400 crossing block materials is also being analyzed.

Table 6. Top rice accessions identified as potential parents based on the standard basis of selection, grain length, grain shape and days to maturity.

Yield Components			2016DS Number of rice accessions qualified	2016DS Promising Rice Germplasm	2016WS Number of rice accessions qualified	2016WS Promising Rice Germplasm
Standard basis for selection of parents	***1000g wt***	***≥ 25 g***	60	Mustaqilik (36); Holliber 1 (35) and Malagkit from Thailand (35); PR39496-3-1-5 (34)	16	Arabel (37); Mustaqilik (33); Ballatinao (30)
	grain/panicle	***≥ 150***	44	IR10N118 (288); PR39502-13-7-85 (282); BG 34-11::IRGC 15782-1 (255)	28	IR10N118 (339); PR46840-B-B (313); C39 (260)
	%filled spikelets	***≥ 85%***	61	PR29163-R2-2-1-4 (96.7); Gayabyeo (95.7); ARC 15872::IRGC 43249-C1 (95.5)	6	IR86385-87-1-1-B (93.6); Attey (89.9); HHZ 4-SAL5-LI1-LI1 (89.6)
Grain length	***extra long***	***>7.4mm***	107	Fermoso, tall, long grain (11.6); Arabel (11.2); WAS 203-B-B-2-4-1::C1 (11.1)	51	Guyod (11.3); Arabel (10.8); IR 11N400 and Mustaqilik (10.5)
	long	***6.4-7.4mm***	6	Giza 177(7.4) and Hangangchal (7.4); IR10N118 (7.3); SANGJUBYEO (7.2)	10	Paro Dumbja White, IRBLzt-T, and IRBLsh-B (7.4) ILPUMBYEO and Hangangchal (7.3); IRBL11-Zh (7.1)
	medium	***5.5-6.3mm***	1	Attey (6.3)	1	Attey (6.2)
	short	***<5.5mm***	0	-	0	-
Grain shape (L/W)	***slender***	***>3.0***	78	BR6902-14-4-2-5 (5.8); Fermoso, tall, long grain (5.1); Aromatic 1 (5.0)	62	Basmati 370 and Guyod (6.0); PR36246-HY-1-16-1 (5.9); IR 11N400 (5.7)
	bold	***2.0-3.0***	36	C21, C39 and Homsodera (2.9)	0	-
	round	***<2.0***	0	-	0	-
Maturity	***early***	***≤100 days***	11	Chang Bai 9 (89); Sakha 101 (91); Aromatic 1-2 seg (94)	11	IRBLt-K59 and IRBLks-S (89); SANGJUBYEO, IRBL11-Zh, IRBLzt-T, Homsodera, IRBLks-F5, IRBLta2-Re, Arabel (93); Holilber and Fermoso, tall, long grain (94)

Genetic improvement and mechanism of resistance to stemborer in rice

IGPacada, GSRillon, GDCSantiago, and MBdelaCruz

The Genetic Resources Division (GRD) of PhilRice conducted a massive screening of traditional varieties (TRVs) for insect resistance, and some of these TRVs showed resistance/tolerance to stemborer. Verification should be implemented and investigating its mechanism of resistance should also be thoroughly examined. The yellow stemborer emerges in Luzon while the white stem borer occurred in Mindanao. The confirmation and investigation of resistance/tolerance of identified TRVs will be validated in these two areas by exposing them on high natural stem borer infestation in the field. Mechanism of resistance classification will be followed, this is to determine if non-preference, antibiosis, tolerance, and avoidance is involved.

Activities:

- Conducted field evaluation (validation/confirmation) of identified TRVS having tolerance/resistance against stem borers. Assessment of deadheart (DH) and whitehead (WH) is based on The National Cooperative Testing (NCT) procedures and guidelines for stem borer and Standard Evaluation System (SES) for rice. Table 7 shows the rating score used for DH and WH.

Results:

- During the March to June establishment, high occurrence of DH and whitehead WH was observed. The resistant check TKM-6 exhibited susceptible reaction with 38.79 to 43.64 % and 25.9% for DH and WH respectively.

- Out of 15 TRVs that has intermediate and resistant reaction in the last field evaluation, three of them showed susceptible reaction with a percentage that range from 51.78 to 59.68.

- From 136 new set of TRVs evaluated, two showed as moderately resistant (MR), six moderately susceptible (MS), 29 susceptible (S), and 99 highly susceptible (HS) to DH. While for WH evaluation, eight displayed as resistant (R), six moderately resistant (MR), four moderately susceptible (MS), one susceptible (S), and 10 highly susceptible (HS) (Figure 16).

- TRVs with no gathered data is due to rat infestation.

Table 7. Reactions of 136 TRVs to deadheart and whitehead.

Rating Scale	Reaction	% Deadhearts	% Whiteheads
0	HR	No Injury	No injury
1	R	1-10	1-5
3	MR	11-20	6-10
5	MS	21-30	11-15
7	S	31-60	16-25
9	HS	61 and above	26 and above

Note: HR (Highly Resistant); R (Resistant); MR (Moderately Resistant); MS (Moderately Susceptible); HS (Highly Susceptible)

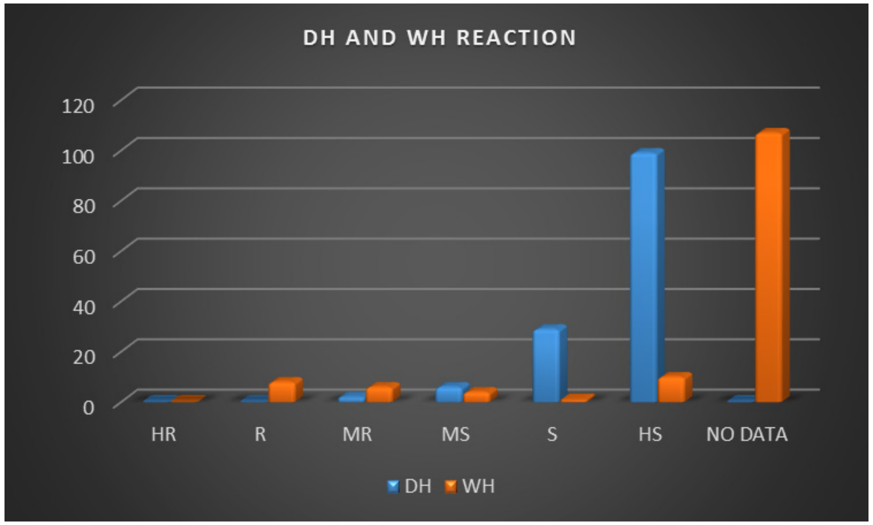


Figure 16. Reaction of 136 TRVs to DH and WH.

Increasing the yield of Gal-ong, a traditional rice variety (special rice), through induced-mutation

ESAvellanoza, RTMiranda, AADelaCruz, and JCYabes

Traditional rice varieties are famous for its good grain, eating quality, and aroma. However, seeds produced from these varieties for commercialization and for export purposes are limited owing to low productivity. Mutation is defined as sudden heritable change in a characteristic of an organism. Mutation techniques have played a significant role in increasing rice production in the Asia-Pacific Region. Released mutant rice varieties have semi-dwarf statute, earlier maturity, improved grain yield, disease and cold-tolerance, and improved grain quality. The use of gamma radiation, chemical and several methods for induced mutation has been proven effective means to generate novel alleles. Gal-ong, though a very popular TRV in Abra and Benguet owing to its excellent grain quality and aroma, has low yield thus used as the plant material in this study.

Activities:

- Generation of new gamma-irradiated M1 plants and corresponding M2 populations.

- Confirmation of traits of 96 Gal-ong M3 entries selected from a separate related research output for 28 characteristics and segregation analysis. These materials were generated from PhilRice CES and Batac selections in during 2015WS.

- Genotyping of Gal-ong wild type and 35 M3 Gal-ong mutants with improved morpho-agronomic characteristics.) 60 genome-wide simple sequence repeat (SSR) markers.

- Advanced mutant lines of 87 Gal-ong individual plant selections for generation of M4 plants for field evaluation, trait confirmation and segregation analysis.

Results:

- 3,213 Gal-ong M1 plants were established in PhilRice CES for generation of M2 population, however resulted to lower production of M2 materials (500g) due to stemborer infestation (Figure 17 A and B). Seeds from 14 Gal-ong M1 plants which were not severely affected by stemborer infestation (Figure 17C) were harvested for further verification of reactions to stemborer.

- Five M1 plants were selected with altered grain characteristics (Figure 17D), such as pericarp color (colored and white), endosperm color (translucent and opaque), and grain shapes.

- Table 8 shows the promising Gal-ong mutants selected in 2016DS (A) and 2016WS (B).

- For the screening of available markers for genotyping, 42 SSR markers out of the 60 tested showed sharp band amplifications on gel. These markers will be used in the molecular characterization of most promising Gal-ong mutants.

- About 2,000 individual M2 Gal-ong plants are currently being evaluated for any of the following traits: tiller count/panicle density/panicle length/plant height/days to maturity/percent spikelets fertility.

- In terms of maturity, 25 individual mutants were confirmed with early maturity (86DAT).

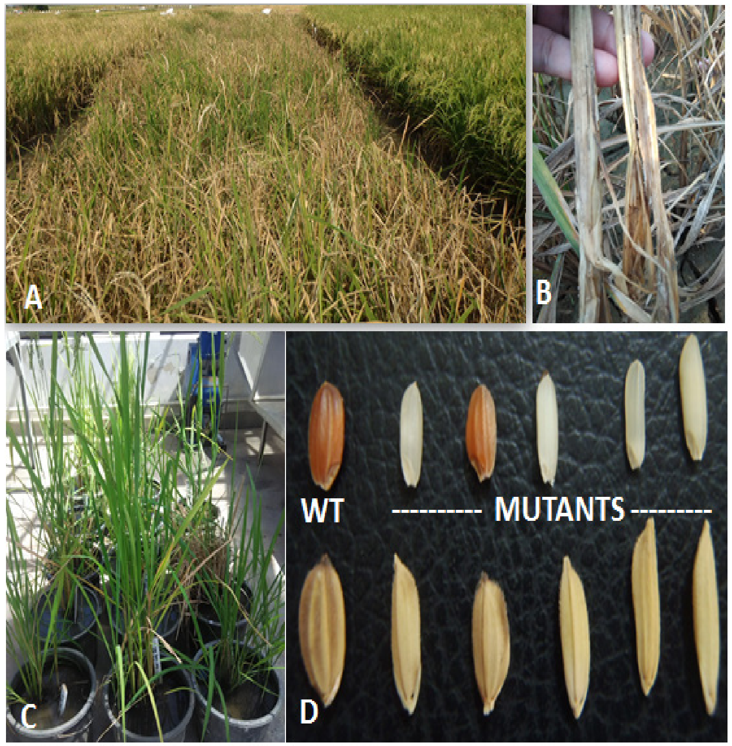


Figure 17. (A) Gal-ong M1 plant materials in the field with severe stemborer infestation and recovering plants; (B) damage caused by stemborer; (C) balled and ratooned M1 plants in the screenhouse; (D) Gal-ong wild type and selected M1 seeds with altered grain traits.

Table 8a. Putative M3 Gal-ong mutants with altered traits (2016DS, PhilRice CES).

CHARACTERISTICS	No of Entries
Bold grains	3
Gal-ong like straw bold grains	1
Gal-ong like with more unfilled grains	1
Gal-ong type mixed	1
Gal-ong type mixed grains	2
Gal-ong type/mixed /short	1
Long grains/ shortened plants opaque	1
Long grains	5
Semi bold *Gal-ong* type with mixed grains	2
Semi bold *Gal-ong* type with unfilled and mixed grains	2
Semi bold grains	10
Semi bold, *Gal-ong* type mixed grains	2
Semi bold, *Gal-ong* type mixed grains with unfilled grains	1
Shortened plant/with unfilled and semi bold grains	1
Abnormal grains *Gal-ong* like but smaller grains	15
Dense panicles	2
Gal-ong like with slender mixed grains	1
Gal-ong type mixed grains	1
Long fine grains	1
Long grains	5
Medium stature	2
More tillers	2
Semi bold *Gal-ong* like	1
Semi bold grains	20
Semi bold/short plant	1
Long grains/ short plant	8
Slender grains	3
Very short, long grains	1

Table 8b. Putative mutant traits of 87 Gal-ong in M4 generation, 2016 WS, PhilRice, Batac.

CHARACTERISTICS	No of Entries	Remarks
Shortened plant with long grain, early maturing	24	***Gal-ong* (WT)** low, tilllering, very tall stature, big bold grains, long panicle and late maturing
Medium stature, dense panicles	4	
Medium stature, long fine grains	1	
Medium stature, long grains	10	
Medium stature, more tillers	2	
Medium stature, semi bold long grains, early maturing	15	
Short plant, semi bold	1	
Short plant, Long grains	8	
Slender grains	3	
Very short, long grains	2	

II. Development of Irrigated Lowland Rice

Project Leader: JM Niones
Senior Consultant: TF Padolina

Philippine food security challenged by increase food demand and threatened by declining rice production area and water availability. Thus, ensuring rice security in the Philippines, it needs to feed 21 persons per hectare with a small harvest area of only 4.2M hectares. On the other hand, our yield growth was 1.83% per annum over the last 10 years and the challenge to increase this productivity is under pressure. Irrigated lowland areas comprising approximately 71% of the total harvest area is the most reliable environment of developing new intensive–culture rice crops. With the advent of modern and innovative technologies, based on genetic enhancement and extensive phenotyping will led to development and release of next generation high and stable yielding rice ideotypes. The primary objective of irrigated lowland breeding project is the development of superior rice varieties with high and stable yield, resistant to RTV, BLB and Blasts, good grain quality, and resilient to changes of climate.

Results:

- Six elite breeding lines: PR37241-3-1-2-1-1, PR36720-17-1-2-1, PR36723-B-B-3-3-3, PR35766-B-24-1, PR36930-B-7-3 and PR27958-135-1-2(J) were approved as new varieties by the National Seed Industry Council (NSIC) for transplanting and direct-seeding culture (Table 9a).

- PR45076-B-B-29-3-8 and PR 45092-B-19-1-1-4 with yield of 8.4 tha-1 and with yield advantage (YA) of 50% over PSB Rc82 (5.6 tha-1).

- Thirteen (13) elite rice lines that were successfully introgressed with either or both Glh14 and tsv1 and had retained at least 2 BB resistance genes (Table 9b).

Table 9a. Irrigated lowland transplanted elite breeding lines approved by the National Seed Industry Council (NSIC) in 2015 and identified by the Rice Technical Working Group for NSIC approval in 2016.

PROMISING ENTRY	REMARKS	OUTSTANDING FEATURES
PR36723-B-B-3-3-3	Regionally recommended for direct-seeding culture in Luzon	Passed yield standards over the the check variety, NSIC Rc224; early maturing variety at 106 days as direct seeded; exhibited intermediate to resistant reaction to major pests and diseases; passed grain quality standard parameters including eating quality
PR35766-B-24-1	Regionally recommended for direct-seeding culture in Visayas	Passed yield standards over the the check variety, PSB Rc82; very early maturing variety at 106 days as direct seeded; exhibited intermediate to resistant reaction to major pests and diseases; passed grain quality standard parameters including eating quality
PR36930-B-7-3	Regionally recommended for direct-seeding culture in Luzon and transplanting culture in Visayas	Passed yield standards over the the check variety, PSB Rc18; early maturing variety at 114 days as transplanted and 107 days as direct seeded; exhibited intermediate to resistant reaction to major pests and diseases; passed grain quality standard parameters including eating quality
PR27958-135-1-2(J)	Nationally recommended for transplanting culture	Passed yield standards over the two check varieties, NSIC Rc220SR and MS11; exhibited intermediate to resistant reaction to major pests and diseases; passed grain quality standard parameters including eating quality
PR37241-3-1-2-1-1	Regionally recommended for transplanting culture in Luzon and Visayas Nationally recommended for direct-seeding culture	Passed yield standards over the check variety, PSB RC82; exhibited intermediate to resistant reaction to major pests and diseases; passed grain quality standard parameters including eating quality
PR36720-17-1-2-1	Nationally recommended for transplanting culture	Passed yield standards over the check variety, PSB RC82; exhibited intermediate to resistant reaction to major pests and diseases; passed grain quality standard

Table 9a. Reactions to RTD of selected 2016WS MAS-bred elite rice lines introgressed with Glh14 and/or tsv1.

	ENTRY	Cross combination	14 dpi % HR	14 dpi % LD	21 dpi % HR	21 dpi % LD	*Xa4*	*xa5*	*Xa7*	*Xa21*	*tsv1*	*Glh14*	Remarks
1	MAS 8-1	PR37273/17-19-6	8	0	- 10	22	+	-	+	+	B	A	RTV resistant at 21 dpi
2	MAS 165-1		20	18	20	25	+	+	-	+	A	A	mild RTD infection at 14 dpi but RTV resistant at 21 dpi
3	MAS 168-1	PR37246/22-103	23	14	22	7	+	+	-	+	A	A	
4	MAS 205-3		19	16	13	20	+	+	-	+	A	A	
5	MAS 213-2		29	24	22	32	+	+	-	+	A	A	
6	MAS 103-1	PR37951/22-103	16	22	20	29	+	+	-	+	A	B	severe RTD infection at 14 dpi but RTV resistant at 21 dpi
7	MAS 168-2		21	32	23	27	+	+	-	-	A	A	
8	MAS 169-1		31	31	32	24	+	+	-	-	A	A	
9	MAS 177-1		13	22	11	17	+	+	-	-	A	A	
10	MAS 205-2	PR37246/22-103	20	30	11	16	+	+	-	-	A	A	
11	MAS 207-1		42	15	35	11	+	+	-	-	A	A	
12	MAS 211-2		18	22	6	20	+	+	-	x	A	A	
13	MAS 213-1		23	18	16	22	+	+	-	-	A	A	
14	ARC11554	Resistant check	10	0	-5	0					A	A	RTD resistant
15	TN1	Susc check	13	34	11	100					B	B	severe RTD infection

Hybridization and Pedigree Nursery

JM Niones, SJE Labarosa, TF Padolina, OE Manangkil, PAM Cubian, WV Barroga, PNM Marcelo, AB Rafael, and TF Padolina

Crop genetic improvement is the most viable and economical approach to increasing food production and productivity in the future. PhilRice rice breeding program focused on pre-breeding and germplasm enhancement that led to the development of rice varieties. With breeding's ultimate objectives is to developed rice varieties with high and improved yield, resistance to pest and diseases and good grain quality relative to current popular high yield commercial varieties. In the advent of innovative technologies will allow the development of new rice plant type variety based on genetic enhancement and extensive phenotyping. Thus, effectiveness of selection depends on the précised and rigid phenotypic evaluation as well as the interaction of the genotypes to different target environments.

Activities:

- Breeding materials in the modified bulk were exposed to zero input to ascertain early generation breeding lines with potential for low input technology.

- Segregating generations in the bulk method were selected on the basis of field stresses and removal of undesirable traits such those with high susceptibility to prevailing pests and lodging.

- Identified crosses/derived lines were currently advanced to F4 to F6 generations for further evaluation in the pedigree nursery.

Results:

Transplanted irrigated lowland

- The extent of materials that were evaluated in 2016 dry season ranges from F1-F7 which were in different nurseries and gone through selection processes both in the field and laboratory – kernel quality evaluation (Table 10).

- There were 75 F1 crosses planted and evaluated during the dry season. Of these crosses, only 50 crosses were advanced in the Hybrid Population Non-Selection (HPNS) under the bulk nursery. Discarded crosses were based on poor plant type, high sterility and susceptibility to field pest and diseases.

- In the said season, a total of 59 new crosses were accomplished and will be entered in the F1 nursery for the 2016 wet season. Single-way cross was used in developing F1 generations which were targeted for high yield and resistance to biotic and abiotic stresses.

- There were 120 crosses evaluated in the Hybrid Population Non-Selection. The selection resulted to 104 entries advanced to Hybrid Population for Selection (HPS). In the HPS there were 33 crosses/populations evaluated planted in a panicle-to-the-row method with zero fertilizer input. After thorough observation and keen selection, 2,319 derived lines were advanced to pedigree nursery.

- In the pedigree nursery, a total of 2,144 entries were planted and evaluated. After panicle selection and kernel evaluation there were 1,104 derived lines retained. While there were 78 uniform lines elevated to Advanced Observational Nursery (AON). A total of 3423 F4 – F6 lines were evaluated in the pedigree nursery in WS. A total of 691 entries will be initially retain and 66 uniform lines were initially selected to be elevated to AON for 2017 DS.

Direct-seeding irrigated lowland

- In the pedigree nursery, 126 single crosses were generated; 36 F2 populations survived from anaerobic germination (AG) screening with excellent (1) to fair (5) AG tolerance and selected 790 plants (average: 25 plants/population); Selected 337 lines for advance evaluation and 87 bulked lines with good phenotype in direct-seeded environment (PA: 3-5, SES).

- 11 populations and 4 breeding lines had excellent (1) AG and SV; 13 populations and 5 breeding lines had good rating under wetbed condition; 2 breeding lines had intermediate AG tolerance under controlled condition; 7 breeding lines were lodging resistant.

- In segregating generations (F2 to F8), 5263 lines were evaluated. Selection among and within lines based on phenotype were done which generated 2378 lines for advance generation and 87 uniform lines for performance yield trial. Summary of selections per generation is shown in Table 11. Entries in WS (F3-F8) will be re-evaluated in 2017DS due to damage caused by strong thunderstorm and typhoons.

Table 10. Early generation breeding lines for irrigated lowland transplanted rice during 2016 DS.

NURSERY	Segregating materials		Filial Generation		Segregating materi
	2015 WS	2016 DS	2015 WS	2016 DS	for 2016 WS
F1 NURSERY	156c	75c	F1	F1	59c
HYBRID POPULATION FO NON-SELECTION (HPNS)	37c	120c	F2	F2-F3	50c
HYBRID POPULATION FO SELECTION (HPS)	19c	33c	F3-F4	F3	104c
PEDIGREE NURSERY	3259dl	927dl + 1217d (retained)	F4-F10	F4-F7	2319dl + 1104dl (retained)

Table 11. Selections in pedigree nurseries for direct seeding.

Nursery	Entries	Selections
Pedigree Nursery		
F2	86	2378 plants
F3	854	115 Lines (L)
F4	791	95 L; 4 Bulk (B)
F5	556	45 L; 14 B
F6	493	27L; 38 B
F7	213	30 L; 16 B
F8	134	25 L; 15 B

Performance evaluation of transplanted rice breeding lines

EC Arocena, GM Osoteo, and TF Padolina

Advanced uniform lines selected from early generation nurseries passed through the field performance trials, the Advanced Observational Nursery (AON), and Preliminary Yield Trial (PYT). These studies evaluated the advanced breeding lines' uniformity, yield and other agronomic characteristics, field reactions to prevailing pests and grain quality for possible multi-location evaluation in the Multi-location Yield Trial (MYT) and then to Multi-Environment Trials (MET) following the sequential evaluation stages and the most promising are eventually nominated to the National Cooperative Trial (NCT).

Activities:

- Breeding lines selected from the Pedigree Nursery were advance and evaluated in the Advanced Observational Nursery (AON). Promising lines in the AON that outperformed the standard checks are advanced and evaluated in the Preliminary Yield Trial (PYT). Selected promising lines in the PYT are advanced to MYT/MET.

Results:

- There were 181 AON entries evaluated during the season. Of these, 34 test entries which outyielded PSB Rc82 (5.6t/ha), the highest yielding check were elevated to PYT and 71 entries were retained. PSB Rc18 produced 5.0t/ha-1.

- The top 10 entries which out-yielded both PSB Rc82 and PSB Rc18 (5.0t/ha) had yields ranging from 7.4t/ha-1 to 8.4t/ha-1 with YA over PSB Rc82 by 32.1%-50.0%. These were mostly with maturity comparable to PSB Rc82 of 111 days (Figure 18).

- The best line PR45076-B-B-29-3-8 matured in 109 days; with 96 cm plant height, 13 productive tillers, good kernel quality, and was spared from the prevailing diseases and insect pests, with dense and long panicles and erect plant type. This line is a derivative of the cross PR36248-HY-2-2-5/HHZ 5-SAL8-DT3-SUB1.

- Among the 104 PYT test entries evaluated, 64 were retained for further evaluation and selection while nine promising entries are new candidate for Multi-location Yield Trial (MYT) and simultaneously for seed increase and purification.

- Four entries in Group I that gave 6.8% to 12.6 YA over NSIC Rc222-1 (6.5 tha-1), the highest yielding check, with yields ranging from 6.9 tha-1 to 7.3tha-1. These entries had good to excellent kernel quality, dense and long panicles with good PA (Figure 19).

- Five entries in Group II showed 5.4% to 10% higher yield than NSIC Rc222 (5.8tha-1 with yields ranged from 6.2tha-1 to 6.4tha-1 (Figure 20).

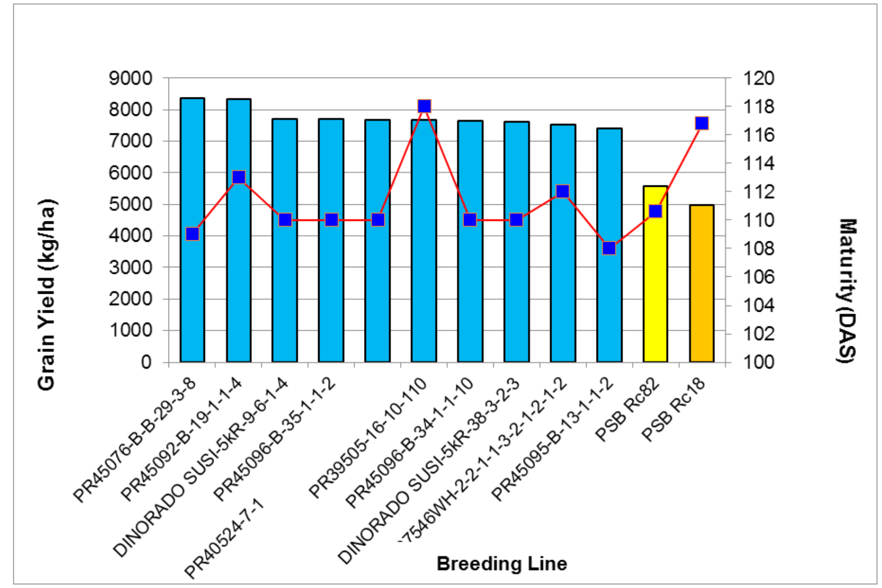


Figure 18. Ten top yielding test entries in the AON, 2016.

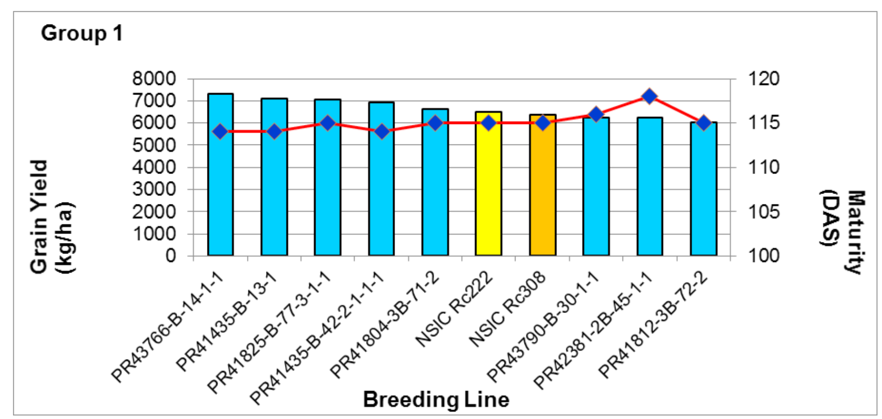


Figure 19. Ten top yielding test entries in Group I, PYT, 2016.

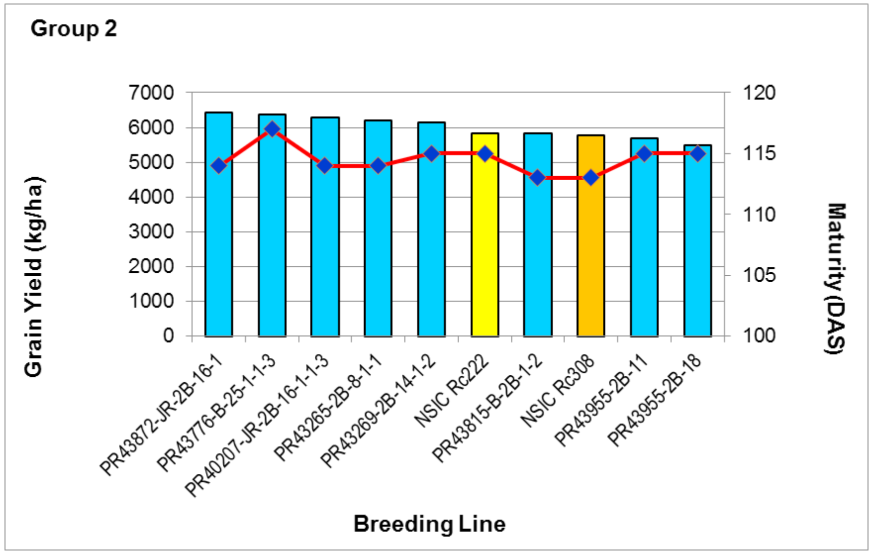


Figure 20. Ten top yielding test entries in Group II, PYT, 2016.

Performance evaluation of direct-seeded breeding lines

Oliver E. Manangkil, WV Barroga, PNM Marcelo, and AB Rafael

Performance evaluation of uniform lines from pedigree selections determines the yield, reactions to biotic and abiotic stresses, and over-all acceptability of the breeding lines.

Activities:

- Component studies such as screenings for anaerobic and lodging tolerance, multi-location trials, pest, diseases, and grain quality evaluations are done in this stage of variety development.

Results:

- Eighty-two breeding lines and 3 checks were established in ON. Top ten high yielding entries is shown in Figure 22a. The 2 highest yielders had 31% to 42% yield advantage over the checks, early to medium maturity, fair anaerobic germination tolerance (5, SES) and intermediate to resistant to lodging (PR=1.01-1.63kgf). Whiteheads were observed during the trial.

- Two entries were new in the NCT Phase I while 6 entries completed evaluation and will be deliberated this 2016. Six DSR breeding lines nominated to MYT had yields of 7 ton/ha to 9t/ha (CES data). The lines had early to medium maturity, good to fair AG tolerance (3-5, SES) intermediate to resistant to lodging (PR=0.91 to 1.63kgf). One entry in MAT was not recommended by the RTWG because it did not pass the 5% yield advantage over the check.

- In WS, 106 breeding lines and 6 checks were established. Top 10 entries is shown in Figure 22b. Three breeding lines were advanced to AYT with 6ton/ha yields, excellent to fair anaerobic tolerance and intermediate amylose content. Trial was damaged by strong thunderstorm and typhoons.

Figure 22. Top 10 high yielding breeding lines in DS (a) and WS (b) under ON, 2016.

Multi-location Yield trial
EC Arocena, HT Ticman, and TF Padolina

The new stratified multi-environments testing in the early generation will significantly improve the quality of materials prior to National Cooperative Tests (NCT). This will, lead to the release of inbred varieties with stable and higher yielding ability, better resistance to biotic stresses, and enhanced adaptation to different environments. Moreover, along with improved performance, opportunities exist for realizing better varieties with wider adaptation as well as for identifying genotypes with superior location-specific performance.

Activities:

- Promising lines from the PYT were advanced to the MYT conducted in four test locations namely PhilRice-CES, PhilRice-Bicol, PhilRice-Negros, and CMU. There were 95 test entries evaluated with PSB Rc82, NSIC Rc222 and NSIC Rc298 as check varieties for Group I and PSB Rc18 and NSIC Rc240 for Group II.

- A plot size of 7.2 sq. m (1.2m x 6m) set in RCBD with three replications and planting distance of 20 x 20 cm was used. Fertilizer rate applied varied in each location based on local recommendation.

- Uniformity, heading date, plant height, tillering ability, phenotypic acceptability, field reactions to pests and diseases, and yielding ability were observed.

Results:

- At PhilRice CES, in Group I, yields of the test entries ranged from 5089kg/ha to 9983kg/ha. The highest yielder, PR41818-3B-47 (9983 kg/ha) numerically out-yielded the highest yielding check variety NSIC Rc298 (9630 kg/ha) with yield advantage (YA) of 3.7% (Table 12).

- Twenty-eight test entries with yields ranged from 7684 kg/ha to 9983 kg/ha numerically out-yielded the other two check varieties, PSB Rc82 (7493 kg/ha) and NSIC Rc222 (7434 kg/ha) with YA ranged from 2.6% to 34.3%.

- Maturity of the test entries ranged from 104 to 123 DAS with PA scores ranged from 3 to 6. Some entries were observed with moderate to severe infection/infestation to bacterial leaf blight, sheath blight and stemborer.

- In Group II, yields of the test entries ranged from 4262kg/ha to 8505kg/ha. Five test entries (7609 kg/ha-8505 kg/ha) numerically out-yielded the highest yielding check, NSIC Rc240 (7547 kg/ha) with yield advantage ranged from 0.8% to 12.7%.
- Sixteen test entries (6773 kg/ha-8505 kg/ha) numerically out-yielded PSB Rc18 (6763 kg/ha) with yield advantage ranged from 0.1% to 25.8%.

- Maturity of the test entries ranged from 111 to 130 DAS with PA scores ranged from 3 to 6. Some entries were observed with moderate infection/infestation to bacterial leaf blight, and stemborer.

- In Bicol, yields of the test entries in Group I ranged from 1859kg/ha to 5097kg/ha. PR42067-23-1-4-2 (5097kg/ha) was the highest yielder and the only entry with 5.1% YA over PSB Rc82, the highest yielding check. Yields in group II ranged from 2072kg/ha-4944kg/ha). PR39502-13-7-83 (4944kg/ha) and PR43299-1-10-1 (4788kg/ha) recorded 9.5% and 6.1% YA respectively over NSIC Rc240 (4514kg/ha), the highest yielding check.

- In CMU, yields of the test entries ranged from 859kg/ha-3851kg/ha owing to the effect of severe rat infestation and BLB infection. Under such condition, PR43872-JR-2B-23-2 produced the highest yield (3851kg/ha) with 47.0% YA over PSB Rc82. Majority of the test entries outperformed PSB Rc82, the highest yielding check. In Group II, yields ranged from 1013kg/ha-3859kg/ha. PR42050-9-2-1-3 (3859kg/ha), the highest yielding entry. Similarly as in Group I, majority of the test entries outperformed NSIC Rc240 (1891kg/ha), the highest yielding check.

- Across three locations, yield ranged from 3313kg/ha-5678kg/ha for Group I and 3349kg/ha-5223kg/ha for Group II. In Group I, PR41804-3B-67-1 (5678kg/ha) was the only entry which consistently performed one of the top ten performing entries in the three locations. Four other entries were among the top ten performers in two locations. In Group II, yield ranged from 3349kg/ha-5223kg/ha. There were three top performing entries with more than 5% YA over NSIC Rc240, the highest yielding check in this group. These were PR42333-2B-43 (5223kg/ha), the highest yielder across three locations and ranked 2nd in PhilRice CES, and 4th in CMU with YA of 12.3%, PR46743-1-35-1 (4929kg/ha) which is the top yielder in PhilRice CES and ranked 10th in PhilRice Bicol with YA of 6.0% and PR43790-B-32-1-1 (4915kg/ha) which ranked 3rd both in PhilRice CES and PhilRice Bicol with YA of 5.7%.

- In summary, PR41804-3B-67-1 showed good performance in CES, Bicol and CMU while PR42333-2B-43 in CES and CMU, PR46743-1-35-1 and PR43790-B-32-1-1 both in CES and Bicol (Table 12).

- 44 advanced breeding lines (32 test entries in Group I and 12 test entries in Group II) showed yield potential of 7-8 tha -1, group I under Nueva Ecija conditions.

- PR41818-3B-47 (10 tha-1) with good PA, plant type with dense panicle, 3.7% YA over NSIC Rc298 (9.6 tha) (Figure 21).

- 20 test entries with 7.9 tha-1 to 8.9 tha -1 yield and with YA of 5.0% to 34.3% over PSB Rc82 (7.5tha-1) Group II.

- 2 test entries with yields of 7.9 tha -1 and 8.5 tha -1 and YA of 5.0% and 12.7%, respectively.

- NSIC Rc240 (7.5tha -1). Moderate to severe infection/ infestation to bacterial leaf blight, sheath blight and stemborer.

Table 12. Yield performance of the selected promising test entries across locations in the MYT, 2016.

ENTRY NO	DESIGNATION	Mean Yield (kg/ha) - CES	Rank	Mean Yield (kg/ha) - BICOL	Rank	Mean Yield (kg/ha) - CMU	Rank	Grand Mean	Rank	YA (%) over HYC
Group I										
16	PR41804-3B-67-1	8463	**10**	5029	**4**	3541	**6**	5678	**2**	3.2
50	NSIC Rc298 (highest yielding check (HYC))	9630	**2**	4430	20	2448	39	5503	**9**	
48	PSB Rc82	7493	**29**	4850	9	2615	34	4986	**26**	
49	NSIC Rc222	7434	**31**	4472	17	2596	35	4834	**31**	
	Minimum	**5089**		**1859**		**859**		**3313**		
	Maximum	**9983**		**5097**		**3851**		**5678**		
	Location Mean	7652		4223		2796		4901		
	CV (%)	13.1		14.4		26.8		11.7		
Group II										
51	PR46743-1-35-1	8505	**1**	4309	**10**	1973	42	4929	**4**	6.0
53	PR43790-B-32-1-1	7804	**3**	4687	**3**	2254	38	4915	**5**	5.7
85	PR42333-2B-43	7900	**2**	4091	17	3679	**4**	5223	**1**	12.3
100	NSIC Rc240	7547	**6**	4514	5	1891	**43**	4650	**14**	
99	PSB Rc18	6763	**18**	4041	20	1713	**46**	4173	**35**	
	Minimum	4262		2072		1013		3349		
	Maximum	8505		4944		3859		5223		
	Location Mean	6446		3896		2694		4359		
	CV (%)	13.1		13.2		25.4		9.9		

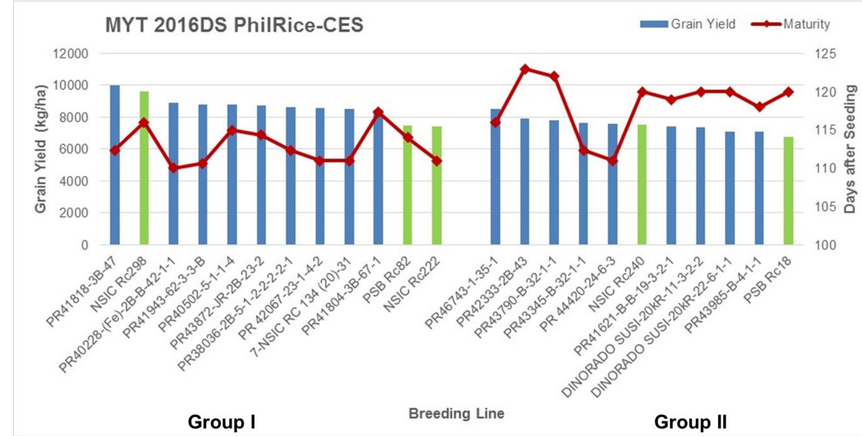


Figure 21. Grain yield (kg/ha) and maturity of the top 10 high yielding entries in Group I & II, MYT at PhilRice-CES, 2016.

Early seedling vigor, anaerobic tolerance and lodging resistance evaluation

WV Barroga, OE Manangkil, PNM Marcelo, and AB Rafael

Subsurface seeding or seeding under soil or water (anaerobic condition) could categorically control weeds and pests problems in direct seeded system. Varieties that are intolerant to anaerobic conditions and have low seedling vigor would result in high seedling mortality owing to low germination and slow seedling growth. Susceptibility to lodging at flowering to maturity affects yield and grain quality.

Activities:

- In line development, evaluations of anaerobic tolerance and early seedling vigor are done in F2 and in ON. Tolerant F2 and ON lines are advanced to pedigree nurseries or nominated to yield trials and hybridization block.

- Lodging resistance is done in advance breeding lines. Anaerobic tolerant and lodging resistant lines are also included in crossing works.

Results:

- Eighty-six F2 populations and 54 breeding lines from ON were evaluated for anaerobic germination and early seedling vigor in wetbed. Eleven populations and 4 breeding lines had excellent (1, SES) AG and SV while 13 populations and 5 breeding lines had good (3, SES) rating.

- Fifty-two breeding lines were evaluated under controlled conditions. Two breeding lines had intermediate AG tolerance. In WS, 69 F2 populations and 19 breeding lines in ON were evaluated in wetbed. Two populations and 1 breeding line had excellent rating while 9 populations and 3 breeding lines had good rating. Two breeding lines had intermediate AG tolerance under controlled condition. Breeding line with resistance to AG was nominated in hybridization block for use in crossing activities.

- Ten lodging resistant breeding lines were identified. In the wet season, most entries including checks lodged before data gathering due to strong thunderstorm and typhoon but 2 lines were observed lodged moderately (Figure 23). Some lodging resistant lines will be nominated in hybridization block as source parents.

Figure 23. Promising lodging resistant breeding lines.

Marker-assisted selection for pest and disease resistance genes in inbred variety development

AA dela Cruz, MJC Duque, RC Braceros, OE Manangkil, and TF Padolina

Recognizing the economic importance of bacterial leaf blight (BB) and rice tungro disease (RTD), the Irrigated Lowland Breeding Program of PhilRice uses routine marker-assisted selection (MAS) to facilitate introgression and pyramiding of various BB and RTD resistance genes in promising rice breeding lines. However, previous MAS only focused on development of BB resistant inbred rice while initial attempts to improve resistance of rice breeding for RTD resistance only focused on introgression of Glh14 alone. In this study, resistance genes against BB (Xa4, xa5, Xa7 and Xa21), and RTD (Glh14 and tsv1) are being pyramided into rice breeding lines in various combinations to hasten the development of disease resistant rice varieties and eventually help prevent crop failures and alleviate rice productivity particularly in endemic areas, by providing opportunity for effective disease control.

Activities:

- Marker-assisted selection of rice lines introgressed with target BB and/or RTD resistance genes.

- Evaluation of reactions of promising rice lines to 3 most virulent PXoo races (PXo 79, PXo 99 and PXo 347).

- Evaluation of promising rice lines to rice tungro.

Results:

- In 2016, a total of 418 rice lines (100 in DS and 318 in WS) were established in the rice breeding nursery.

- Table 13 shows the 2016WS MAS-bred elite rice lines introgressed with 3-4 BB resistance genes. These promising materials, derived from 6 different cross combinations, will be subjected to further evaluation of yield and resistance to BB.

- Table 14 shows the 13 elite rice lines that were successfully introgressed with either or both Glh14 and tsv1 and had retained at least 2 BB resistance genes. When forcibly inoculated with tungro viruses in the screen house, these promising rice lines exhibited obvious signs of tungro symptoms at 14 days post inoculation (dpi) but apparently had recovered at 21 dpi as manifested by the reduced percent reduction in height and number of leaves with yellow to orange discolorations.

- Table 15 shows the reactions to PXo races 79, 99 and 347 of 13 MAS-bred rice lines with different number and/or combinations of BB resistance genes. Rice lines introgressed with Xa4 alone (E-25-14 and E-25-15-40) exhibited moderate resistance against PXo-347 but susceptible to PXo-79 and PXo-99. Meanwhile, rice lines introgressed with at least two BB resistance genes exhibited stronger level of BB resistance.

- In 2016DS, 2 MAS-bred rice lines (PR37241-3-1-2-1-1 and PR36720-17-1-2-1) were released as new rice varieties.

Table 13. Elite rice lines introgressed with various combinations of BB and RTD resistance genes in 2016WS.

	Cross	*tsv1*	*Glh14*	*Xa4*	*xa5*	*Xa7*
Elite 16	PR43343-B-11-2-2/EUREKA(SL9)	B	A	+	-	-
Elite 175	PR46756	B	B	+	-	+
Elite 175	PR46756	B	B	+	+	-
Elite 16	PR46756	B	B	+	+	-
PR46733-72	PR40526-23-1-2/Eureka	B	B	+	+	-
PR46734-79	PR40091-46-1-2/Eureka	B	B	+	+	+
PR46734-81	PR40091-46-1-2/Eureka	B	B	+	+	+
PR46734-84	PR40091-46-1-2/Eureka	B	B	+	+	+
ILMAS-164-5		B	B	+	+	+
ILMAS-184-5		B	B	+	+	+
ILMAS-186-1		B	B	+	-	+
ILMAS-187-5		A	B	+	+	-
ILMAS-193-1		A	A	+	+	+
ILMAS-194-1		B	B	+	+	+
ILMAS-195-1		B	B	+	+	+
ILMAS-196		B	B	+	+	+
PR43347-23-3	PR40519-4-3	A	A	+	-	-
PR43354-20-2-1	PR402527-1-1	B	B	+	+	-

Table 14. Reactions to RTD of selected 2016WS MAS-bred elite rice lines introgressed with Glh14 and/or tsv1.

	ENTRY	Cross combination	14 dpi % HR	14 dpi % LD	21 dpi % HR	21 dpi % LD	*Xa4*	*xa5*	*Xa7*	*Xa21*	*tsv1*	*Glh14*	Remarks
1	MAS 8-1	PR37273/17-19-6	8	0	- 10	22	+	-	+	+	B	A	RTV resistant at 21 dpi
2	MAS 165-1		20	18	20	25	+	+	-	+	A	A	mild RTD infection at 14 dpi but RTV resistant at 21 dpi
3	MAS 168-1	PR37246/22-103	23	14	22	7	+	+	-	+	A	A	
4	MAS 205-3		19	16	13	20	+	+	-	+	A	A	
5	MAS 213-2		29	24	22	32	+	+	-	+	A	A	
6	MAS 103-1	PR37951/22-103	16	22	20	29	+	+	-	+	A	B	severe RTD infection at 14 dpi but RTV resistant at 21 dpi
7	MAS 168-2		21	32	23	27	+	+	-	-	A	A	
8	MAS 169-1		31	31	32	24	+	+	-	-	A	A	
9	MAS 177-1		13	22	11	17	+	+	-	-	A	A	
10	MAS 205-2	PR37246/22-103	20	30	11	16	+	+	-	-	A	A	
11	MAS 207-1		42	15	35	11	+	+	-	-	A	A	
12	MAS 211-2		18	22	6	20	+	+	-	x	A	A	
13	MAS 213-1		23	18	16	22	+	+	-	-	A	A	
14	ARC11554	Resistant check	10	0	-5	0					A	A	RTD resistant
15	TN1	Susc check	13	34	11	100					B	B	severe RTD infection

Table 15. Multiple comparisons of means (Tukey HSD) of lesion lengths in MAS-bred rice lines infected with 3 most virulent Xoo races in the screen house.

	Rice Line	BB Resistance Gene(s) Present	lesion length (cm) Pxo-99	*Pxo-79*	*Pxo-347*
1	E-25-14	*Xa4*	33.88^{a} *	16.75^{b} *	9.64^{a} ***
2	E-25-15-40	*Xa4*	33.43^{a} *	17.34^{b} *	11.72^{a} **
3	E-32	*Xa4+Xa21*	1.94^{b}	0.42^{c}	0.97^{b}
4	E-36	*Xa4+Xa21*	1.61^{b}	0.46^{c}	0.82^{b}
5	F3-209-2	*Xa4+Xa21*	1.47^{b}	0.45^{c}	0.80^{b}
6	E-2	*Xa4+Xa21*	1.47^{b}	0.49^{c}	0.88^{b}
7	E-3	*Xa4+Xa21*	1.80^{b}	0.44^{c}	0.95^{b}
8	E-66	*Xa4+Xa21*	1.77^{b}	0.48^{c}	0.80^{b}
9	E-86	*Xa4+Xa21*	3.40^{b}	1.50^{c}	1.10^{b}
10	ILMAS-381-3	*Xa4+Xa7+Xa21*	1.09^{b}	0.36^{c}	0.14^{b}
11	ILMAS-406-3	*Xa4+Xa7+Xa21*	2.70^{b}	0.53^{c}	0.22^{b}
12	E-62-28	*Xa4+Xa7+Xa21*	2.19^{b}	0.69^{c}	0.33^{b}
13	E-62-28-47	*Xa4+Xa7+Xa21*	1.65^{b}	0.49^{c}	0.30^{b}
14	IRBB64	*Xa4+xa5+Xa7+xa21*	1.97^{b}	0.27^{c}	0.35^{b}
15	IR24	no BB resistance genes	36.39^{a} *	20.08^{a}	9.60^{a} ***

Disease reaction: R- resistant; MR- moderately resistant (***); MS- moderately susceptible (**); S- susceptible (*); Means with the same superscripts are not significantly different at 5% level

-The evaluation of reactions to BB of 13 MAS-bred rice lines was conducted by a BS Biology thesis student

Development of Next Generation Rice Plant Type to Break Yield Plateau

AY Cantila, SE Abdula, and JL Balos

Severe food shortages are therefore likely to occur in 20-30 years if the trend is not reversed (Kush et al., 2005). To meet these food needs, rice varieties with higher yield potential are needed. In the Philippines, the maximum yield potential of modern high-yielding varieties grown under the National Cooperative Tests is ~10 t/ha and ~11 t/ha for inbred and hybrid rice, respectively (NCT results). Developing next generation rice varieties with yield potential of 15~20 ton/ha (or yield advantage of 40-70%), is therefore necessary. With the present plant architecture of most breeding program which is dwarf to semi-dwarf and early maturing, this yield could not be achieved given the thermodynamic and biological limits of the crop. The study is conducted with an aim to evaluate potential germplasm with more than 500 spikelets per panicle and develop segregating plants with architecture height of 1.2 ~1.8 meters, erect leaves and resilient to major biotic and abiotic condition for the irrigated ecosystems.

Activities:

Agronomic Evaluation of Selected lines in the ON, PYT, and GYT.

Selection in the early generation.

- At least 300 g of F2/M2 seeds derived from self F1/M1 plants was sown in the wet bed nursery. Plants that exhibit the target plant types and agronomic characteristics were selected from the population. Each selected plant will constitute the next generation until F4/M4. Stable/M4 plants in the selected family were bulk-harvested and a random bulk sample was taken and advanced to Observation Nursery (ON). Each ON entry was therefore represented in the F5/M5 pedigree nursery by three different families.

Observational Nursery.

- Elite lines and other cultivars was planted each in 1.2m x 5m (6 rows x 25 hills) with 20cm x 20cm planting distance. The selected line was entered into the preliminary yield trial. Selection of desirable entries was based on resistance to biotic and abiotic stresses aside from the desired phenotype. A complemented experiment on biotic and abiotic stresses was conducted in the screenhouse following published protocols.

Preliminary Yield Test.

- The yield trial determined the fate of the lines produced in Activity 3. An isoline or near–isoline was tested against their recurrent parent/ or non-mutant. The usual replicated yield test methodology was followed. Outstanding entry was elevated to Advanced Yield Trial and was recommended for trial into the farmer's field through the participatory variety selection (PVS) or be used further in the variety development project.

Results:

- Most of lines from "conventional crosses" were not good in its phenotypic stand despite under strict selection.
- Only lines from "gamma irradiation" had good phenotypes and could be further selected (Figure 24).
- However, 22 next gen lines (12 RILs, recombinant inbred lines and 10 gamma irradiated lines) were tested to different locations and analyzed based on crop cut GY (t/ha).
- Based on Yield stability index: RIL-64.1-1-2-3-4 (S6), RIL-64.4-1-2-3-4 (S9), RIL-64.5-1-2-3-4 (S10), M19-250GY.1-1-2-3-4 (M1) and PHB77-250GY.1-1-2-3-4 (M9) were stable lines across locations (Figure 25).
- The highest mean GY (t/ha) however were RIL-12.1-1-2-3-4 (4.87), M19-250GY.4-1-2-3-4 (4.11), PHB77-250GY.2-1-2-3-4 (4.08), M19-250GY.1-1-2-3-4 (3.85), M19-250GY.3-1-2-3-4 (3.83), RIL-16.2-1-2-3-4 (3.74), RIL-64.5-1-2-3-4 (3.64), RIL-64.4-1-2-3-4 (3.6), PHB77-250GY.1-1-2-3-4 (3.34) and RIL-24.1-1-2-3-4 (3.32).

Figure 24. Lines from "gamma irradiation" with good phenotypes and could be further selected.

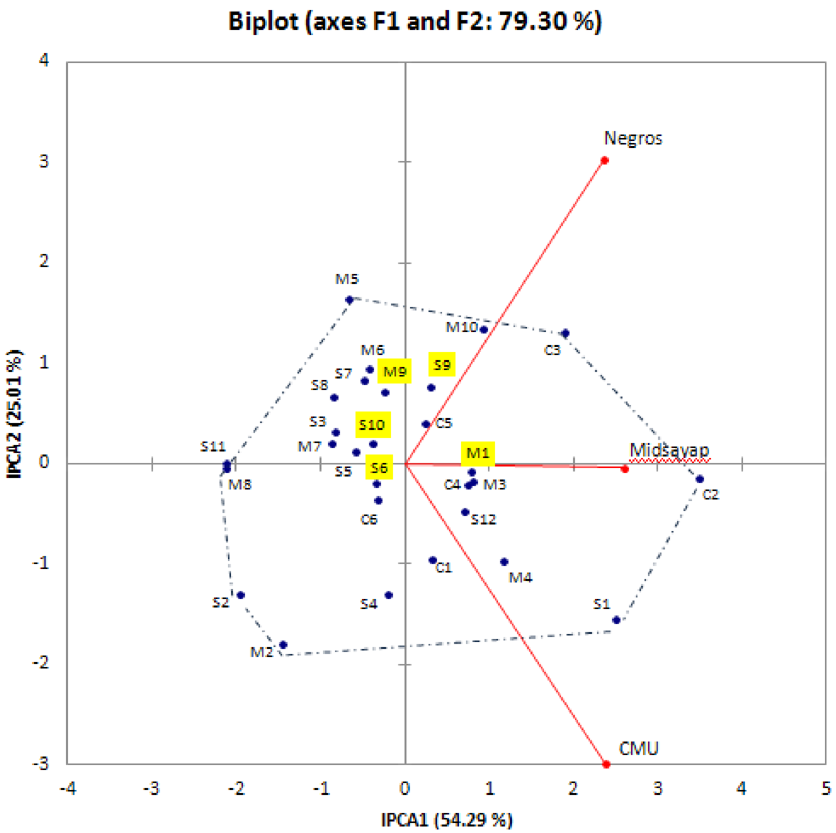


Figure 25. Biplot of 22 Next Gen lines along with the six check varieties in the determining stable lines.

III. Hybrid Rice Breeding and Genetics

Project Leader: JD Caguiat

The successful development of hybrid rice in the country as a supplemental strategy to inbred rice development provides an effective approach to increase rice yield and consequently, offer higher income opportunities to farmers. Inspired by the success of hybrid rice in China, the Philippines has adopted the technology as a means to further increase rice yield from 20-30% with the same input level used in inbred rice varieties. The continuous development of high-yielding hybrid varieties that are resistant to pests and diseases and possess excellent grain qualities to keep up with the increasing demand for rice and the changing environment is essential. The main purpose of this project is to increase rice productivity in the irrigated lowland ecosystem using hybrid rice technology. This project covers the development of parent lines and F1 hybrids, breeding methodology and seed production research, and screening and testing of hybrids in various target environments.

Development 0f Hybrid Parent Lines

RA Millas, MSF Ablaza, KA Garcia, MM Rosario, VP Luciano, JE Carampatana, LV Gramaje, FP Waing, and JD Caguiat

Challenges in hybrid breeding include the selection, development and improvement of suitable parental lines. An essential component of F1 hybrid production is the Cytoplasmic Male Sterile (CMS) line development because failure in purity of this will result to poor hybrid. Introduced CMS lines often are not adapted to local conditions, with very low resistance to biotic stresses and poor grain quality. Therefore, because of its important role, diverse CMS lines with good qualitative and quantitative traits must be developed.

Maintainer and restorer lines are very essential components in the development of hybrid rice as well for the multiplication of CMS lines and production of F1. Continuous research on the identification of inbred cultivars that can either maintain the sterility or restore the fertility of CMS lines is necessary in developing high-yielding germplasm pools. Therefore, there is a need to develop new and improve existing maintainer and restorer lines.

The study aimed to: (1) develop new and diverse hybrid parent lines, male sterile lines (A- and S- lines; (2) improve morpho-agronomic characteristics of parent lines; and (3) convert potential B lines into new A lines and utilize potential R lines to further enhance the restorer line genepool of hybrid breeding program of PhilRice.

Activities:

- Development and improvement of new hybrid rice male parent lines through pedigree and recurrent selection.
- Development and improvement of new female parent lines (CMS and maintainer lines).
- Development of new marker-based derived elite lines.

Results:

- For restorer line improvement and development, a total of 1339 lines for dry season and 2252 lines from F1 to F8 generation for wet season were evaluated. Out of these, a total of 1887 lines were selected to be advanced for 2017 DS trial (Table 16). Advance restorer lines in the F8 generation were also evaluated for grain yield potential, percent seed setting, morpho-agronomic traits and uniformity. A total of 81 restorer lines including four check varieties namely PSB Rc18, PSB Rc28, NSIC Rc240 and NSIC Rc222 were established in Alpha Lattice Design with 2 replications. Grain yield ranges from 6.2t/ha to 8.2t/ha for dry season, and 4.1t/ha to 11.4t/ha for wet season. A total of 11 restorer lines with a yield of 6.1t/ha to 8.2t/ha (>6t/ha) during 2016 DS and 10 restorer lines with a yield of 7.1t/ha to 11.5t/ha (>7t/ha) during 2016 WS passed the standards. These lines will be forwarded to the Source Nursery ready for utilization as new parent lines for hybridization. PR45836HY-B-91-90-86-47-28 line which matures 112 DAS and PR45958HY-B-56-97-100-82-57 line with a maturity of 116 days, were the highest yielder (Table 17a ,2b).
- The maintainer line nursery was composed of 51 lines for improvement. 168 B lines were selected with desirable traits. Through hybridization, 97 BxB crosses were assembled and F1 seed were generated for 2017 DS. One hundred forty-nine entries (F2, F3 and F4 populations) were selected based on phenotypic acceptability and response to naturally occurring pests and diseases. For B-line yield trial, nine from F6 and six from F7 promising maintainer lines with yield range of 5.2 to 11.8 t/ha and 5.2 to 9.6t/ha were identified. These lines will undergo one more trial in order to validate the data gathered affected by typhoon Karen. Enough seeds were generated from these entries for the next experiment.
- For upcoming CMS lines, 86 elite maintainer lines with the desired traits were evaluated, selected and undergo conversion in BC Nursery. These potential maintainer lines were product of B line improvement, recurrent selection and anther culture-derived lines. Out of 102 entries for conversion, 22 F1 will be forwarded to BC1F1. For the 27 backcross entries, 120 plants were found to have 100 percent sterility. New potential CMS line (PR46622A) with desirable traits and sterility stability was evaluated in BC4F1. In addition, Twenty-two entries for PVP characterization composed of elite maintainer lines and one CMS line were seed increased and initially characterized. A follow-up characterization together with the BPI-NSQCS personnel will be proposed on the 2017DS.
- A recombinant inbred population, PR47221-G038 (PR34641-2B-19-1-1/Leuang IRGC 22761), with 200 lines was established in replicated yield trial for an initial yield trial evaluation. Phenotypic data such as panicle number per plant, grain yield (harvested from 5 hills) and plant height were gathered. Grain yield data of PR47221-G038 ranged from 3.0 to 9.4t/ha with an average yield of 6.0 t/ha. The predicted yield data of the top performing lines with genotype considered as random effects factor, and replication and block considered as fixed effects factors are shown in Table 18. Moreover, the consistent top performing PR40614-AC, PR40613-AB, PR40615-AD, PR47236-GB-13, PR47239-G028, PR47222-G007, PR47234-G019, PR47238-G027, PR40853, G008, G009, and G015-G020 lines were selected and further evaluated in replicated yield trials in wet season. Phenotypic data such as panicle number per plant, grain yield (harvested from 5 hills) and plant height were gathered. Grain yield data ranged from 2.8 to 8.3 t/ha with an average yield of 5.4t/ha. The predicted yield data of the top performing lines with genotype considered as random effects factor, and replication and block considered as fixed effects factors is shown in Table 19.
- Field establishment of various selected populations were done in the pedigree nursery. A new population composed of 24 F1s and 22 F2s from different cross combinations were developed. Selections based on PAcp were done for the F3 to F5 populations. The selected lines were comprised of: 14 populations in F2 generation denoted as G152 to G173; 10 populations in F3 generation denoted as G140 to G149 and 20 populations in F5 generation. Selection was carried out based on phenotypic acceptability among populations. These selected lines will be established in 2017 DS for further evaluation in the pedigree nursery.

Table 16. Number of plants evaluated in restorer line development and improvement nursery on 2016 DS and WS.

	2016 Dry season				2016 Wet season		
Generation	No. of cross combination	No. of plants evaluated	No. of plts selected	**Generation**	No. of cross combination	No. of plants evaluated	No. of plts selected
F1	62	62	62	**F1**	52	52	52
F2	45	49	45	**F2**	62	62	62
F3	16	108	41	**F3**	45	900	610
F4	62	669	210	**F4**	16	123	100
F5	10	131	50	**F5**	62	630	319
F6	12	226	96	**F6**	10	150	87
F7	6	94	41	**F7**	12	288	65
				F8	8	47	47

Table 17a. Grain yield performance of advanced restorer lines evaluated at PhilRice CES during 2016 DS.

Entries	% Seed Set	Grain Yield (kg/ha)
PR45836HY-B-91-90-86-47-28	84.09	8,255.36
PR45833HY-B-68-52-59-35-18	95.65	8,068.61
PR45837HY-B-114-131-140-83-42	74.06	7,970.24
PR45830HY-B-40-6-15-8-5	87.33	7,547.08
PR45838HY-B-132-171-166-89-47	90.07	7,519.15
PR45837HY-B-114-131-140-83-44	73.56	7,515.47
PR45838HY-B-139-181-173-95-48	84.01	7,503.30
PR45838HY-B-139-181-173-96-50	84.19	7,483.38
PR45840HY-B-164-224-117-118-60	65.64	7,342.39
PR45842HY-B-189-247-248-131 -67	82.69	7,327.23
NSIC Rc240	73.04	7,038.60
PSB Rc82	76.76	6,511.65
PSB Rc18	78.5	6,494.22
NSIC Rc222	69.54	6,154.34

Table 17b. Grain Yield performance of advanced restorer lines evaluated at PhilRice CES during 2016 WS.

Designation	% Seed Set	Grain Yield(kg/ha)
PR45958HY-B-56-97-100-82-57	88.59	11,486
PR45851HY-B-223-295-174-133-83	87.78	8,440
PR45837HY-B-125-158-134-110-72	87.02	8,252
PR45837HY-B-125-158-134-110-71	92.91	7,827
PR45957HY-B-37-50-19-33-21	90.4	7,794
PR45947HY-B-206-274-98-80-53	87.84	7,787
PR45958HY-B-53-85-79-72-45	89.3	7,408
PR45957HY-B-37-50-20-35-24	94.8	7,237
PR45957HY-B-50-77-66-60-42	86.9	7,165
PR45957HY-B-3-1-1-1-2	93.89	7,129

Table 18. Predicted yield performance of the top performing G038 lines evaluated in replicated yield trials at PhilRice Central Experiment Station during 2016 DS. PR34641-2B-19-1-1.

Designation	Grain yield (kg/ha)
PR47221-G038-1	9,404.41
PR47221-G038-105	8,491.49
PR47221-G038-48	8,390.95
PR47221-G038-50	8,336.00
PR47221-G038-8	8,289.42
PR47221-G038-13	8,201.92
PR47221-G038-131	8,097.82
PR47221-G038-184	8,037.86
PR47221-G038-55	7,937.06
PR47221-G038-19	7,890.70
PR47221-G038-106	7,878.64
PR47221-G038-88	7,861.07
PR47221-G038-35	7,859.41
PR47221-G038-117	7,768.20
PR47221-G038-149	7,751.19
Leuang IRGC 27761	6,101.51
PR34641-2B-19-1-1	5,163.14
NSIC Rc222	6,170.77
NSIC Rc216	6,106.99
PSB Rc82	5,953.36

Table 19. Predicted yield performance of the top performing lines evaluated in replicated yield trials at PhilRice Central Experiment Station during 2016 WS.

Designation	Grain yield (kg/ha)
PR40615-AD4-5-8	8,344.23
PR47229-G026-14-2-3-1-2-2	8,312.17
PR47233-G018-15-1-1-1-1	8,176.88
PR47237-MD13-19-1-1-1	8,127.54
PR47245-G036-26-1-1-3	7,877.67
PR47250-G046-1-1-2-2	7,589.97
PR47237-MD15-5-1-1-1-2	7,502.18
PR47229-G026-14-2-1-1-2-1	7,299.04
PR47251-G047-53-1-2-2	7,134.06
PR47253-AE2-12-2-1-2-2	6,950.28
PR47234-G019-9-3-1-1-1	6,841.95
PR40614-AC3-5-1	6,838.99
PR40615-PR40615-AD-4-6	6,746.24
PR47243-G032-2-2-1-2	6,744.12
PR47224-G009-16-1-2-1-1-1	6,580.12
PSB Rc18	7,780.58
PSB Rc82	6,348.60
NSIC Rc222	6,883.07

Development of three-line experimental hybrids

VP Luciano, MM Rosario, MSF Ablaza, and JD Caguiat

The success of hybrid rice breeding greatly depends on the quality and diversity of elite lines used as parents in developing new hybrids. New approaches such as the use of excellent inbreds and promising lines from Optimum Plant Morphology (OPM), Tropical Japonica (TJ) breeding, and doubled haploid (DH), are essential in discovering promising new hybrid combinations.

The main goals of the study are to identify superior F1 combinations and determine the combining ability of newly developed parent lines. Specifically, the study aims to: identify potential maintainer lines (B) or restorer lines (R) from the early generation and elite lines of irrigated lowland inbred rice breeding project; to develop F1 hybrids from a cross between CMS lines, DH, OPM and TJ lines from the inbred rice breeding project; and to convert potential B lines into new A lines and utilize potential R lines in further enhancing the restorer line gene pool.

Activities:

- Generation of experimental hybrids/testcrosses.
- Evaluation of three-line experimental hybrids/testcrosses.
- Prospecting of potential restorer and maintainer lines based on F1 evaluation.

Results:

- Established in the source nursery were 208 (DS) and 421 (WS) male parent lines composed of breeding lines from different nurseries such as irrigated lowland (IL), double haploids (DH), tropical japonica (TJ), optimized plant morphology (OPM), genome wide assisted selection (GWAS), heat tolerant (HT) and saline (SAL). These entries were crossed with eight and three CMS lines (IR68897A, IR58025A, PR2A, PR15A, PR20A, PR21A, PR27A and PR28A) and (PR15A, PR28A and IR58025A) generating 1538 and 606 F1 seeds, respectively. The generated experimental hybrids along with their parent lines will be evaluated in the testcross nursery (TCN) on 2017.

- For TCN, the 2015 WS testcross between eight CMS lines and 124 male parent lines generated 444 experimental hybrids. These experimental hybrids were evaluated in the testcross nursery on 2016DS. Among the high yielding experimental hybrids, TCN428, TCN132, TCN57, TCN111, TCN224, TCN381, TCN26, TCN268, TCN415, TCN202, TCN66, TCN416, TCN371, TCN393, TCN405, TCN418, TCN427, TCN77, TCN404, TCN297, TCN176, TCN310, TCN110 and TCN 65 showed 3.46% - 96.19% yield advantage over the four check varieties (Mestizo 1, PSB Rc18, PSB Rc82 and Mestiso 19). PR15A x PR35015-GA-5-5-1 has the highest yield advantage of 26.3% to 96.2% over the four check varieties (Table 20). The selected experimental hybrids will be advanced to seed production for observational nursery.
- A total of 1528 experimental hybrids and 208 male parents were established in the TCN, these were evaluated based on their yield in 2016 wet season. Although two consecutive typhoons: Karen and Lawin have affected and caused all entries to lodge, there were 40 lines that showed 18.66% to 147.59% yield advantage over the four check varieties (Mestiso 19, Mestiso 48, PSB Rc222 and PSB Rc82). Whereas PR2A x IR36R-2 obtained the highest yield advantage of 126.10% to 147.59% over the checks. Table 21 lists the high yielding experimental hybrids and their yield advantage.

- Among the top high-yielding parent lines, PR36502HY-1-1-8-1-1-2 and PR34131-B-20-1 have the highest yield advantage of 45.70% to 126.24% and 28.32% to 99.34% over the two check varieties, respectively. There were also 24 prospected potential restorers and 37 prospected potential maintainer lines wherein selection was done based on yield, fertility, sterility and phenotypic acceptability. The 24 prospected potential restorer lines together with their corresponding CMS lines will be crossed and will be advanced for further yield trial evaluation while the 37 prospected potential maintainer lines will be forwarded to CMS nursery for backcrossing.

- For 2016WS, IR36R-11 and MET 3003 male parent lines obtained the highest yield advantage of 143.7% to 166.9% and 88.0% to 105.9%, respectively. Forty lines were selected based on their yield for prospected potential restorer and these will be advance for performance test evaluation. Fifteen (15) prospected potential maintainer lines were evaluated based on their uniformity, phenotypic acceptability and yield.

Table 20. List of high yielding experimental hybrids in the testcross nursery (TCN), 2016DS.

Entry	Yield	Yield Advantage (%)			
		Mestizo 1	*Mestiso 19*	*PSB Rc18*	*PSB Rc82*
TCN428	10117.59	26.3	46.6	69.0	96.2
TCN132	9878.05	23.3	43.1	65.0	91.6
TCN57	9516.70	18.8	37.9	59.0	84.5
TCN111	9241.48	15.4	33.9	54.4	79.2
TCN224	9240.70	15.3	33.9	54.4	79.2
TCN381	8987.55	12.2	30.2	50.1	74.3
TCN26	8842.60	10.4	28.1	47.7	71.5
TCN268	8836.22	10.3	28.0	47.6	71.3
TCN415	8795.35	9.8	27.4	46.9	70.6
TCN202	8752.19	9.3	26.8	46.2	69.7

Table 21. List of high yielding experimental hybrids in the testcross nursery (TCN), 2016WS.

Entry 2016WS	Yield (kg/ha)	Yield advantage over the check varieties			
		M19 5287.6	M48 5132.8	PSB Rc222 4980.4	PSB Rc82 4828.7
TCN95	11955.39	126.10	132.92	140.05	147.59
TCN189	9611.56	81.78	87.26	92.99	99.05
TCN102	9539.20	80.41	85.85	91.53	97.55
TCN2	8951.14	69.29	74.39	79.73	85.38
TCN99	8815.41	66.72	71.75	77.00	82.56
TCN97	8813.24	66.68	71.71	76.96	82.52
TCN520	8039.24	52.04	56.63	61.42	66.49
TCN141	7995.10	51.21	55.77	60.53	65.58
TCN104	7987.04	51.05	55.61	60.37	65.41
TCN1108	7735.61	46.30	50.71	55.32	60.20
TCN471	7696.48	45.56	49.95	54.53	59.39
TCN100	7673.55	45.12	49.50	54.07	58.92
TCN467	7371.02	39.40	43.61	48.00	52.65
TCN6	7302.28	38.10	42.27	46.62	51.23
TCN105	7200.37	36.18	40.28	44.57	49.12
TCN415	7149.24	35.21	39.29	43.55	48.06
TCN1735	7118.85	34.63	38.69	42.94	47.43
TCN13	7106.23	34.40	38.45	42.68	47.17
TCN142	7062.46	33.57	37.60	41.80	46.26
TCN659	7042.59	33.19	37.21	41.41	45.85

Performance Tests of Experimental Hybrids

MSF Ablaza, JOS Enriquez, LV Gramaje, and JD Caguiat

Heterosis breeding is one complementary strategy to negate the growing rice shortage in the country. Utilization of heterosis had contributed tremendously to the increased productivity in many crops specifically in rice as it promises a 15% yield advantage compared to conventional varieties under the same input levels. The increase in grain yield is a result of hybrid vigor that breeders aim to exploit.

Evaluating experimental hybrids, which is an essential segment of variety development, supports in identifying the ones with superior performance in terms of grain yield, level of heterosis and resistance to pest and diseases, over designated check cultivars under local conditions, to be released for public use. A series of tests composed of the observation nursery (ON), preliminary yield trial (PYT) and multi-location yield trial (MYT) serve this purpose. Information collected from these trials become basis for advancing particular entries for the national cooperative tests of hybrid materials (NCT-Hyb).

This study aims to 1) To evaluate the performance of promising hybrids in different nurseries for grain yield, and other important morpho-agronomic traits; 2) To identify hybrids with wide range of adaptation and stable performance across environments; and 3) To identify location/season specific hybrids

Activities:

- Evaluation of promising hybrids in observational nursery based on yield and phenotypic acceptability.
- Evaluation of promising hybrids in preliminary yield trial nursery based on yield, fertility, and phenotypic acceptability.
- Evaluation of promising hybrids in multi-location yield trial nursery in five locations.
- Evaluation of promising hybrids for pre-NCT.

Results:

- In 2016 DS, 39 experimental hybrids developed from crosses between 11 female parents (all CMS) and 27 male parents were evaluated in the observational nursery for grain yield and important morpho-agronomic traits, against three inbred (NSIC Rc222, PSB Rc18 and PSB Rc82) and two hybrid (Mestiso 20, Mestiso 55) check varieties. The trial was laid out in augmented design using 105-hill plots, with the test entries assigned randomly next to each of their male parents without replication into incomplete blocks each with complete sets of checks. Maturity (DAS) ranged from 104 (PR49499H, PR49508H, PR49520H) to 120 (PR49505H, PR49503H) among hybrids, and from 110 (PSB Rc82) to 120 (PSB Rc18) among checks. Plant height at maturity (cm) ranged from 74.98 (PR49533H) to 109.78 (PR49536H) among hybrids, and from 85.20 (PSB Rc82) to 105.06 (Mestiso 20) among checks. Productive tiller count ranged from 9 (PR49506H) to 20 (PR49503H, PR49501H) among hybrids, and from 12 (Mestiso 20) to 16 (PSB Rc82) among checks. For grain yield (kg/ha), means ranged from 1052.83 (PR49527H) to 14201.87 (PR49532H) among hybrids, and from 3214.19 (PSB Rc82) to 5743.76 (Mestiso 20) among checks. Only seven hybrids (PR49532H, PR49507H, PR49511H, PR49504H, PR49510H, PR49537H, PR49506H) out-yielded Mestiso 20 check by at least 5%, while only five (PR49532H, PR49507H, PR49511H, PR49504H, PR49510H) out-yielded PSB Rc18 and NSIC Rc222 by at least 15% (Table 22).

- In 2016WS, 22 experimental hybrids developed from crosses between 7 female CMS parents, and 22 male parents were evaluated in the observational nursery for grain yield and important morpho-agronomic traits, against two inbred (PSB Rc18 and PSB Rc82), and three hybrid (Mestiso 20, Mestiso 48, Mestiso 55) check varieties (see table 23). The trial was laid out in augmented design using 30-hill plots, with the test entries assigned randomly next to each of their male parents without replication into incomplete blocks each with complete sets of checks. Maturity (DAS) ranged from 106 (PR49563H) to 119.33 (PR49547H) among hybrids, and from 109 (Mestiso 55) to 122 (PSB Rc18) among checks. Plant height at maturity (cm) ranged from 74 (PR49557H) to 156.57 (PR49546H) among hybrids, and from 94.12 (Mestiso 55) to 135.85 (Mestiso 48) among checks. Productive tiller count ranged from 6.33 (PR49557H) to 18 (PR49543H) among hybrids, and from 12 (PSB Rc18) to 19 (Mestiso 55) among checks. For grain yield (kg/ha), means ranged from 2258.88 (PR49549H and PR49555H) among hybrids, and from 1538.62 (Mestiso 48) to 4481.38kg/ha (PSB Rc82) among checks. Field evaluation of experimental hybrids at this nursery will be performed again next season due to the damage brought by the two typhoons (Karen and Lawin) that hit Nueva Ecija in September and October 2016.

- For the preliminary yield trial nursery, a total of 14 experimental hybrids were evaluated for grain yield and important morpho-agronomic traits such as maturity, plant height, and number of productive tillers against two inbred (PSB Rc18 and PSB Rc82), and three hybrid (Mestiso 19, Mestiso 48, and Mestiso 55) check varieties in 2016 WS. The cross combinations involved nine female parents (six CMS, and three TGMS lines), and 22 male parents. The trial was laid out in randomized complete blocks with three replications using 224-hill plots. Maturity ranged from 112.5 (PR48765H and PR46840) to 121 DAS (PR48775H and PR48763) among hybrids, and from 112 (PSB Rc82) to 116 DAS (PSB Rc18 and Mestiso 48) among checks. Plant height ranged from 103 (PR46837H) to 123. 7 cm (PR48796H) among hybrids, and from 111 (PSB Rc18) to 124.5 cm (PSB Rc82) among checks. Productive tiller count ranged from 11 (PR48767H and PR48769H) to 14.5 (PR48766H and PR48796H) among hybrids, and from 12.5 (Mestiso 48, PSB Rc18, and PSB Rc82) to 13 (Mestiso 19 and Mestiso 55) among checks. Grain yield ranged from 3018.45 (PR47568H) to 8564.96 kg/ha (PR48765H) among hybrids and from 3279.72 (PSB Rc18) to 7286.53kg/ha (PSB Rc82) among inbred checks. Table 24 indicates the eight experimental hybrids that outperformed all of the hybrid checks (Mestiso 48 with 5214.54kg/ha; Mestiso 55 with 5565.93kg/ha; Mestiso 19 with 5630.18kg/ha). Only the hybrids PR48765 (8564.96kg/ha) and PR48758 (7745.89 kg/ha) out-yielded the highest-yielding inbred check PSB Rc82 (7286.53kg/ha).

- For the multi-location trial, eleven experimental hybrids were evaluated in PhilRice CES, PhilRice Isabela, PhilRice Bicol, PhilRice Negros, PhilRice Agusan, and Mati, Davao del Sur along with three hybrid checks (Mestiso 19, Mestiso 48, and Mestiso 55) and two inbred checks (NSIC Rc222 and NSIC Rc240). Data from other sites are still under processing for analyses and consolidation. The trial was carried out in randomized complete blocks using 244 plots in order to evaluate the grain yield and other important morpho-agronomic traits such as maturity, plant height, and number of productive tillers. Maturity ranged from 109.5 (PR36577H) to 119 DAS (PR48758H) for the experimental entries, while maturity ranged from 112.5 (Mestiso 48 and Mestiso 55) to 116.5 DAS (NSIC Rc222 and NSIC Rc240) for the checks. For the plant height, values for the experimental hybrids ranged from 102.35 (PR48755H) to 127.3cm (PR48768H), while values for the checks ranged from 104.7 (Mestiso 19) to 125.6cm (Mestiso 48). Number of productive tiller ranged from 12 (PR48768H and PR46840H) to 15 (PR48767H) in experimental hybrids, while the values ranged from 12.5 (Mestiso 48) to 14.5 (NSIC Rc222). Grain yield of the experimental hybrids ranged from 3280.46 (PR48768H) to 5918.88 kg/ha (PR48763H) while checks obtained grain yield from 3209 (Mestiso 48) to 5635.05 kg/ha (Mestiso 19). Only two entries consistently outperformed all of the checks, PR48763H (5918.88kg/ha) and PR48766H (5913.54 kg/ha) (Table 25). These lines have 5.04% and 4.94% yield advantage, respectively, over the highest yield check, Mestiso 19, with 5635.05kg/ha.

Table 22. Field performance of observational nursery entries, PhilRice CES, 2016 DS.

Entry	Maturity (DAS)	Plant height (cm)	Tiller count	Grain yield (kg/ha)
PR49532H	112	97.98	14	14201.87
PR49507H	109	87.04	13	11699.50
PR49511H	108	81.84	17	9167.18
PR49504H	116	88.24	12	7752.42
PR49510H	110	78.44	13	7224.30
PR49537H	108	80.18	13	6046.18
PR49506H	111	87.64	9	5919.96
Mestiso 20	115	105.06	12	5743.76
PSB Rc18	120	97.85	13	5653.93
NSIC Rc222	112	97.65	14	5440.62
Mestiso 55	112	91.25	13	3584.96
PSB Rc82	110	85.20	16	3214.19

Table 23. Field performance of observational nursery entries, PhilRice CES, 2016 WS.

Entry	Maturity (DAS)	Plant Height (cm)	Tiller Number	Grain Yield (kg/ha)
PR495 51H	109.67	115.03	13.67	12653.88
PR495 54H	112.67	115.83	9.67	11928.65
PR495 38H	110.33	153.97	16.00	9125.60
PR495 60H	114.00	84.40	9.33	7493.69
Mestiso48	111.50	135.85	14.33	1538.62
Mestiso55	109.33	151.17	19.00	2857.66
PSB Rc82	111.67	117.43	14.67	4481.38

Table 24. Field performance of preliminary yield trial nursery entries, PhilRice CES, 2016 WS.

Entry	Maturity (DAS)	Height (cm)	Tiller Number	Grain Yield (kg/ha)
PR48765H	112.5	120.3	13.5	8564.96
PR48758H	119	116	12	7745.89
PR48755H	122.5	117.7	13.5	7066.59
PR48775H	121	117.1	13	6729.49
PR48796H	117	123.7	14.5	6659.23
PR48767H	116	112.5	11	6631.43
PR48769H	115.5	107.9	11	6457.57
PR46840H	112.5	109.2	13.5	6432.34
Mestiso19	115.5	117.9	13	5630.18
Mestiso48	116	116.3	12.5	5214.54
Mestiso55	111	113.3	13	5565.93
PSB Rc18	116	111	12.5	3279.72
PSB Rc82	112	124.5	12.5	7286.53

Table 25. Field performance of multi-location yield trial nursery entries, PhilRice CES, 2016 WS.

Entry	Maturity (DAS)	Height (cm)	Tiller Number	Grain Yield (kg/ha)
PR48763H	112	115.25	14	5918.88
PR48766H	114.5	112.35	12	5913.54
PR48767H	115	109.7	15	5520.48
Mestiso19	114	104.7	14	5635.05
Mestiso48	112.5	125.6	12.5	3209.38
Mestiso55	112.5	118.6	13	5200.11
NSICRc 222	116.5	120.2	14.5	4789.25
NSIC RC 240	116.5	112.5	14	4921.72

Seed Production of Experimental Hybrids

LV Gramaje, JE Carampatana, MSF Ablaza, KAA Garcia, PLH Duran, and JD Caguiat

Production of ample quality parental seeds is a very crucial part of hybrid rice breeding. Hybrid seed production involves the multiplication of CMS lines (A×B) and production of F1 seeds (A×R), both done alongside seed increase of maintainer and restorer lines. High quality in terms of physical and genetic purity to type must be maintained. The genetic purity of the hybrid parents is essential in the development and commercialization of hybrid varieties since the yield of hybrid rice decreases by 0.1 tha-1 when the purity of hybrid seeds decrease by 1%.

The objectives of this study are: to produce sufficient physically and genetically pure hybrid parent lines, and experimental and newly released hybrids for various yield trials and demonstration nurseries; to evaluate and monitor important traits of the A, B and R lines of each hybrid; and to subject selected entries to in-house and external seed quality control.

Activities:

- Seed production of CMS nucleus seeds.
- Seed production of CMS line breeder seeds.
- F1 seed production for ON nursery.
- F1 seed production for PYT nursery.
- F1 seed production for MYT nursery.
- F1 seed production for National Cooperative Test (NCT).
- F1 seed production of commercially released hybrids.

Results:

- For nucleus seed production, 454 completely sterile CMS lines from the 12 AXB combinations of PR19A x B (23), PR15A x B (8), PR20A x B (18), PR21A x B (22), PR29A x B (13), PR2A x B (4), IR73328A x B (117), IR79128A x B (130) IR80559A x B (57), IR80156A X B (22), IR68897A x B (20), PRH1A x B (20) combinations were generated with seed yield (g) of 3,759.3g, 2,318.7, 2,699.2, 766.9, 608.3, 208.9, 7,316.7, 8,976.7, 10,792.7, 1,903.3, 245.5 and 143.9 respectively (Table 26).

- For breeder seed production, six A × B cross combinations were established in row crossing plots with row ratio of 10 A: four B lines (Figure 26). Seed yield measurements were obtained from six 50-hill crop cut samples and averaged across samples plots. Out crossing rate was also gathered by getting the number of filled grains divided by the total number of spikelets per panicle in support to the seed yield in a hectare basis. (Table 26). Seed yield (kg ha-1) ranged from 400.00 (PR20A) to 2500 (JHX316A). Total weight of CMS line seeds produced was 79,024.7 grams.

- The SPON in 2016 produced seeds of 59 hybrids used in the observational nursery for hybrids in 2016 WS. Hill-to-hill crossing of female and male parents in crossing cages was done at a ratio of 2 male hills: 6 female hills. The target number of seeds to be produced was 300 seeds. Five experimental hybrid crosses for multi-location yield trial (MYT) and twelve from preliminary yield trial (PYT) accumulated a seed weight of 4,260g and 4,510g respectively.

- F1 seeds of eight promising hybrids to augment current seed stock under testing in the NCT-HYB were produced in 2016 DS under SPNCT. Seed yield measurements were obtained from the average of four to eight 50-hill crop cut samples per entry (Table 26 and Figure 27). Actual seed yield (g) of entries were 8171.60 (PR42208H), 711.9 (PR42214H), 4457.90 (PR39391H), 28895.10 (PR36577H) 8898 (PR351188H), 10,174.6 (PR39385H), 11, 802.5 (PR39375H), 6,137.55 (PR40640H) and 9,872.4 (PR47216H). Total weight of F1 seeds produced was 89,121.55 grams.

- Two experimental hybrids were seed produced: Mestiso 48 with 28.5kg for yield check and Mestiso 55 with 4,781.5g seed weight.

Table 26. Seed yield (kg ha-1) and bulk yield of seeds produced in 2016 DS.

CMS Line Multiplication

Entry	Female parent	Male parent	Number of of crosses	Bulk yield (g)
Nucleus seeds				
PR19 A	PR19A	PR19B	23	1,717.7
PR15A	PR15A	PR15B	8	2,318.7
PR20A	PR20A	PR20B	18	2,699.2
PR21A	PR21A	PR21B	22	766.9
PR29A	PR29A	PR29B	13	608.3
PR2A	PR2A	PR2B	4	208.9
IR73328A	IR73328A	IR73328B	117	2,180.2
IR79128A	IR79128A	IR79128B	130	1,824.3
IR80559A	IR80559A	IR80559B	57	5,191.7
IR80156A	IR80156A	IR80156B	22	1,903.3
IR68897A	IR68897A	IR68897B	20	245.5
PRH1A	PRH1A	PRH1B	20	143.9

Breeder Seeds	Female parent	Male parent	Seed yield (kg/ha)	Bulk yield (g)
IR73328A	IR73328A	IR73328B	1100	5,864.9
IR79128A	IR79128A	IR79128B	600	3,101.0
IR58025A	IR58025A	IR58025B	700	6,547.4
JHX316A	JHX316A	JHX316B	2500	55,278.60
PR20A	PR20A	PR20B	400	400
IR79156A	IR79156A	IR79156B	710	7,832.8

Seed Production for the NCT-HYB

	Seed yield (kg/ha)	Bulk yield (g)
PR39391H	600	4457.9
PR36577H	2000.00	28895.10
PR35118H	2000.00	8898
PR39385H	2500.00	10,174.6
PR39375H	2100.00	11,802.5
PR40640H	2300.00	6,137.55
PR47216H	2200.00	9,872.4
PR42208H		8,171.60

Figure 26. Row crossing plot of AxB for Seed production of breeder seeds.

Figure 27. Row crossing plot of AxR for Seed production for National Cooperative testing.

Generating useful variation in hybrid parent lines through induced mutagenesis

MM Rosario, VP Luciano, MSF Ablaza, KAA Garcia, and JD Caguiat

Mutation breeding generates enhanced variant of extensively adapted cultivars through the use of agents that increase the chances of gene mutations. The induced rice mutants have proved to be useful research tools in genetic and physiological assessment on yield-limiting factors in rice. Moreover, induced mutation can aid isolation of new genes that are not obtainable in the germplasm. In vitro culture (IVC), likewise, induces mutation generating gametoclonal or somaclonal variants which may be exploited to improve or develop new varieties. Doubled haploid via Anther culture is one of the most exploited IVC system wherein it greatly reduces the time required to obtain inbreds compared to six or more generations of selfing.

This study aims to: induce mutation in hybrid parent lines using sodium azide/ethyl methane sulfonate (EMS) or gamma irradiation; utilize in-vitro culture and in-vitro mutagenesis in hybrid parent line development; and generate mutant hybrid parent lines with drought tolerance.

Activities:

- Generation of new hybrid parent lines through gamma irradiation.
- Generation of new hybrid parent lines through anther culture.
- Generation advanced of new hybrid parent lines for restorer and maintainer lines development and improvement.

Results:

- In vitro culture (IVC)
  A total of 129 crosses composed of 75 RxR and 51 BxB from 25 hybrid parent lines and 3 Philippine traditional rice varieties (PTRV's) were subjected to anther culture. Of these, 33 (44%) crosses from RxR, 16 (31%) from BxB and 3 PTRV exhibited callus formation (Table 27). Eight (8) crosses (24%) from restorer line development generated 32 doubled haploid plants. Anther culture response of the crosses is shown Figure 28.

- In vitro mutagenesis (IVM)
  IVC response of 5 hybrid rice maintainer lines – PR9B, PR20B, PR21B, PR27B and PR28B was assessed to be able to find a genotype for use as a source of regenerable explants in subsequent IVM experiment. Only PR9B showed the capacity to generate complete plantlets while other lines failed to produce plants. Thus, hybrid rice maintainer line PR9B is the most suitable genotype for IVM study.

  A total of 123 calli were exposed to gamma irradiation with Co60 at 40Gy dosage and were transferred to regeneration media (RM). On the other hand, 343 non-irradiated calli were also sub-cultured to RM and incubated in the lighted room for plant development (Figure 29). Of the 123 irradiated calli, 166 green plants were generated (Table 28) with regenerability of 134.96%, while non-irradiated calli produced 234 plants with 68.22% regenerability.

- Seed Mutation (SM)
  Five hybrid parent lines were subjected to gamma irradiation with 250Gy dosage at Philippine Nuclear Research Institute (PNRI). Irradiated seeds were sown immediately and were transplanted after 21 days. One hundred eighty-six M4 entries from three (3) tungro breeding lines (Matatag 11, 5999 and 21473) and one (1) hybrid maintainer line (PRH1B) were harvested for another round of generation advance. On the other hand, 287 putative mutant sub-families from 10 M5 entries along with their WT were harvested and will be used for testcrossing to identify potential restorer and maintainer lines. In 2016WS, 469 M4 entries from wild types SRT19R and SRT76R were harvested and will be established for its final round of generation advance. In addition, 164 M5 putative entries from three (3) tungro breeding lines (Matatag 11, 5999 and 21473) and one (1) hybrid maintainer line (PRH1B) were harvested and will be used to prospect potential restorer and maintainer lines.

- Source Nursery (SN)
  Three M5 mutants namely PR47102HY-seed mut, PR47204HY-seed mut and PR47205HY-seed mut along with their wild type (WT) PR45611HY, PR35749-HY-R and PR31559-AR32-4-3-2R were testcrossed to three tester lines – PR15A, PR28A and IR58026A. Overall, 104 crosses were generated and F1 performance will be evaluated in the testcross nursery (TCN). Moreover, three Philippine Traditional Rice Varieties (PTRV"s) Imang, Binurnay, Maloit, Tukon-tukod and three Javanica rice lines – Palagadan, Dipak and Ipis were crossed to CMS lines IR68897A, IR58025A, PR27A and PR30A. A total of 11 combinations were generated and will be

evaluated for pollen fertility/sterility for hybrid rice parent line development.

- Anther Culture-derived (AC) hybrid parent lines
  Twenty AC derived lines were testcrossed to 8 CMS lines generating 75 F1. These were evaluated in the TCN along with control checks. Based on their F1 yield performance, PR28A/AC-DHC2-27 attained a % yield advantage of 22.36 and 42.04 over the inbred checks PSB Rc18 and 82, and 6.15% yield advantage compared to hybrid check M19. In addition, based on their F1 pollen evaluation, 3 were prospected as maintainer line and will be used in the development and improvement of maintainer lines.

  Based on their F1 yield performance test hybrids IR73328A/PR46930HY-AC, IR58025A/PR46937HY-AC, PR24A/PR46928HY-AC, IR73328A/PR46928HY-AC and PR9A/PR46935HY-AC were selected in the Observational Nursery (ON) and IR68897A/PR45606HY-AC from Preliminary Yield trial. Seventeen (17) AC lines were established in the F4 nursery of maintainer line development and improvement. Of these, four (23.53%) were selected for advance generation (F5). Selected lines will be used for restorer and maintainer line development and improvement.

Table 27. Crosses that exhibited callus formation and produced regenerants (PhilRice CES 2016).

Entry	# of crosses			# of regenerants
	anther culture	with callus	with plants	
RxR	75	33	8	32
BxB	51	16	0	0
PTRV	3	3	0	0
TOTAL	129	52	8	32

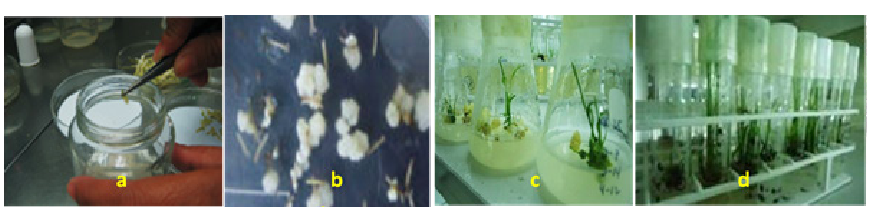


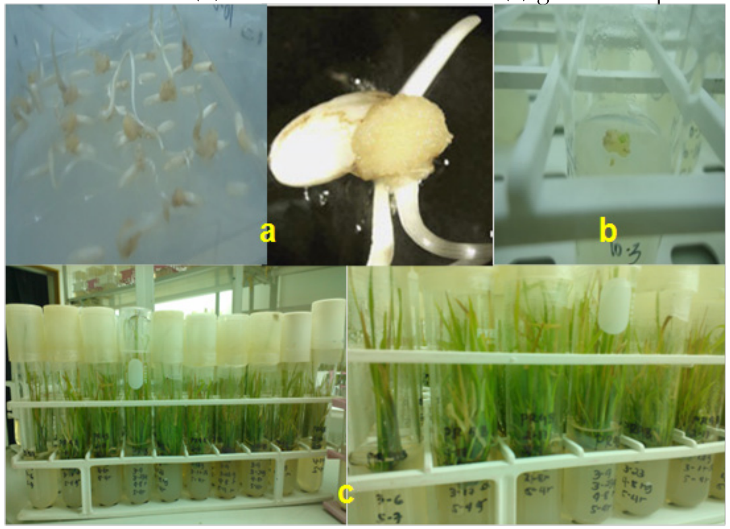
Figure 28. Rice anther culture (a) spikelet excision (b) callused anthers (c) calli with green plants (d) regenerants with well-developed roots.

Table 28. Response of hybrid rice maintainer line PR9B to IVM and IVC (PhilRice CES, 2016DS).

Table 29. Response of hybrid rice maintainer line PR9B to IVM and IVC (PhilRice CES, 2016DS).

Activity	Genotype	Number of callus	Total # of plants	% regenerability
IVM	PR9B	123	166	134.96
IVC		343	234	68.22

Figure 29. Invitro culture of hybrid rice maintainer lines (a) mature seeds with calli in CIM (b) seed-derived callus in R (c) generated plants.



Phenotypic and genotypic characterization of parent lines and hybrids

FP Waing, JIIC Santiago, JOS Enriquez, and JD Caguiat

The need for high-yielding hybrid varieties that can keep up with the increasing demand for rice and the changing environment led to the exploitation of resistance genes to diseases and tolerance to abiotic stress. Marker-Assisted Selection is being utilized for resistance to some diseases in rice such as Bacterial blight, rice blast and tungro, those that can cause 20% to more than 50% yield reduction according to the degree of severity. While for abiotic stress, a major limiting factor in the productivity of rice, plants have acquired various mechanisms for stress tolerance in the course of their evolution. Enhancing or introducing such mechanisms in rice is one effective way to develop stress-tolerant cultivars.

The purpose of the study is to evaluate the reaction of parent lines and hybrids for biotic (blast, bacterial blight, tungro, and GLH); to detect the presence of known resistance genes/QTLs in the breeding pool through molecular markers; and to identify diverse hybrid parent lines and F1 hybrids with resistance to insect pest and diseases.

Activities:

- Assembly and phenotypic screening of hybrid parent lines and hybrids for biotic tolerance (blast, BLB, BPH, tungro, and GLH).
- Genotypic screening of hybrid parent lines and hybrids for biotic tolerance (blast, BLB, BPH, tungro, and GLH) and presence of CMS and fertility restoring gene.

Results:

- A total of 49 parent lines comprised of 32 restorer lines (R lines), and five cytoplasmic male sterile (CMS) lines, including 11 F1 hybrids were assembled for genotypic characterization in 2016DS. Target gene genotyping was conducted to verify the presence of the different resistance genes and QTLs using markers for tsv1 and rtv for tungro resistance, Glh14 QTL for green leaf hopper (GLH), and Xa genes for bacterial leaf blight (BLB) resistance genes. Leaf tissues were collected from each test entries for DNA extraction. Based on the molecular analysis conducted, some of the lines carry resistance genes/putative QTLs (Table 29). Xa4 gene which confers low resistance to BLB was detected in most of the lines. For BLB resistance genes, MYT6 and PPYT7 contained both Xa4 and xa5 genes (Figure 30). Interestingly, the hybrid MYT3 was found to have heterozygous allele in Xa21 gene. This dominant Xa21 gene was found reliably effective against numerous strains of Xanthomonas oryzae pv. oryzae. Parent lines of this hybrid will be further evaluated to determine from which the Xa21 gene of the hybrid originated. Another hybrid, MYT8 was noted to have tungro resistance QTLs. The parent lines carrying various resistance genes will be used as potential source of resistance for hybrid parent line improvement and development of F1 hybrid seed.

- In wet season, 64 promising restore lines and 21 experimental hybrids were assembled and screened for the following biotic stresses: blast screening inside the CPD blast nursery (Figure 31A), BLB lesion length through leaf-clipping method (Figure 31B), BPH and GLH tolerance through compartment box method (Figure 31 C &D) and forced-tube method for tungro disease. Screening activities for selected biotic stresses were done in wet season which is more favorable and conducive for symptom manifestation and disease development. All the screening was successfully done except for tungro in which no visible symptom was observed in susceptible check (TN1). The reaction of selected R lines against each biotic stresses is listed in table 29. Finally, Table 30 shows the summary of the reactions of evaluated entries in various stresses imposed.

- For leaf blast, 32 restorer lines and nine hybrids were resistant to the disease. Additionally, four R lines and 1 hybrid have intermediate reaction to blast.

- In terms of BLB, TCN-150441 and 16DS-MYT 3 showed resistance against both PX079 (local race) and PX099 (most virulent race). Based on genotype data, 16DS-MYT 3 contained both Xa4 and Xa21 genes while TCN-150441 was not yet subjected to marker genotyping. Four R lines and four hybrids were moderate resistant to PX079, and seven R lines and two hybrids were moderate resistant to PX099. Whereas 16DS-MYT 5 was resistant to PX079 but not against PX099.

- For BPH, three R lines (PPYT-17, PPYT-35 and TCN-150486) and 16WS-MYT 5 were found resistant. However, 22 R lines and eight hybrids were moderately resistant.

- PPYT-4 and 16DS-MYT 6 were found resistant to GLH, 43 R lines and 13 hybrids were moderate resistant and the rest were susceptible.

- In addition, seventy-eight (78) known and elite restorer (R) lines were also screened for the presence of fertility restoring

(Rf3, Rf4 and f5n) genes. Three elite restorer lines (SCN27, SCN44 and SCN46) were found having the f5n type allele similar to the variety known with f5n allele. Furthermore, eight cytoplasmic male sterile (CMS) lines were screened and found to contain the allele for wild abortive (WA) gene using the published gene specific marker. Based on the result, the WA-CMS specific markers can be utilized for marker-assisted breeding to fast-track the introgression of these gene and conversion of elite and promising maintainer lines.

Table 29. Reactions of promising hybrid restorer lines to the different stresses imposed including the resistance genes detected through molecular marker genotyping.

Entry code	BIOTIC STRESS REACTION					Gene(s) present
	BPH Damage	GLH Damage	Leafblast	BLB		
				PXO79	PXO99	
PPYT-1	S	MR	R	S	S	*tsv1, rtv, Glh14*
PPYT-2	S	MR	R	S	S	*xa5, Glh14*
PPYT-4	MR	MR	R	S	S	*rtv, Glh14*
PPYT-5	S	R	R	S	S	*Glh14*
PPYT-6	S	MR	R	S	S	*xa5, tsv1, rtv, Glh14*
PPYT-9	MR	MR	R	S	S	*xa5, tsv1, rtv, Glh14*
PPYT-10	S	MR	R	S	S	*Rtv*
PPYT-11	S	MR	R	S	S	*Xa4*
PPYT-12	MR	MR	S	S	S	*xa5, tsv1, rtv*
PPYT-13	S	MR	S	S	S	*xa5, tsv1, rtv*
PPYT-14	S	MR	S	S	S	*Xa4, Glh14*
PPYT-15	MR	S	S	S	S	*xa5*
PPYT-16	MR	MR	S	S	S	*xa5, Glh14*
PPYT-17	R	S	S	S	S	*Rtv*
PPYT-18	MR	MR	R	S	S	*xa5*
PPYT-19	S	S	R	S	S	*xa5, rtv*
PPYT-20	S	MR	R	S	S	*Xa4, xa5, tsv1, Glh14*
PPYT-21	MR	S	I	S	S	*Rtv*
PPYT-22	MR	S	R	S	S	*Xa5, rtv, Glh14*
PPYT-23	S	S	R	S	S	*Xa4, Glh14*
PPYT-24	S	S	R	S	S	*Rtv*
PPYT-25	S	MR	R	S	S	*Glh14*
PPYT-26	S	MR	R	S	S	*Xa4, tsv1, rtv*
PPYT-27	S	S	R	S	S	*xa5, tsv1, rtv*
PPYT-28	S	S	R	S	S	*Xa4, rtv, Glh14*
PPYT-30	S	S	R	S	S	*tsv1, rtv*
PPYT-31	MR	MR	R	S	S	*Rtv*
PPYT-32	S	S	R	S	S	*Xa4, rtv*
PPYT-33	S	S	R	S	S	*Xa4*
PPYT-34	S	MR	R	S	S	*xa5*
PPYT-35	R	MR	S	S	S	*Xa4, rtv*
PPYT-36	S	MR	R	S	S	*tsv1, Glh14*

Table 30. Summary of the reactions of evaluated R lines and experimental hybrids in various stresses imposed.

Type	Reaction	BIOTIC STRESS				
		BPH Damage	GLH Damage	Leafblast	BLB	
					PXO79	PXO99
Restorer lines	Resistant	*3*	*1*	*32*	*1*	*1*
	Moderate resistance/ Intermediate	*22*	*43*	*8*	*4*	*7*
	Susceptible	*39*	*20*	*23*	*59*	*55*
	Total	*64*	*64*	*63**	*64*	*63**
F1 Hybrids	Resistant	*1*	*1*	*9*	2	1
	Moderate resistance/ Intermediate	*8*	*13*	*1*	4	2
	Susceptible	*12*	*7*	*11*	14	17
	Total	*21*	*21*	*21*	*20**	*20**

** one entry has no data*

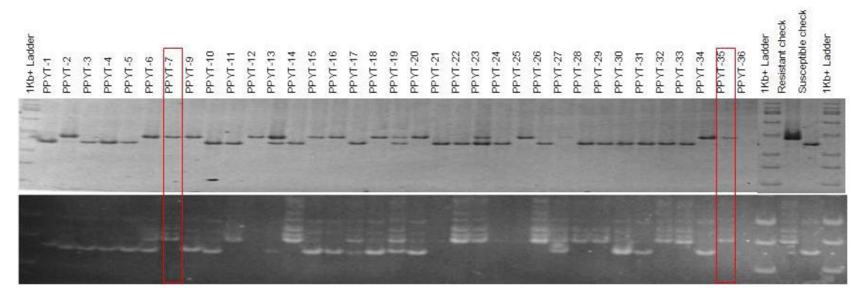


Figure 30. DNA banding pattern of elite restorer lines with BLB resistance genes using Xa4+xa5 markers.

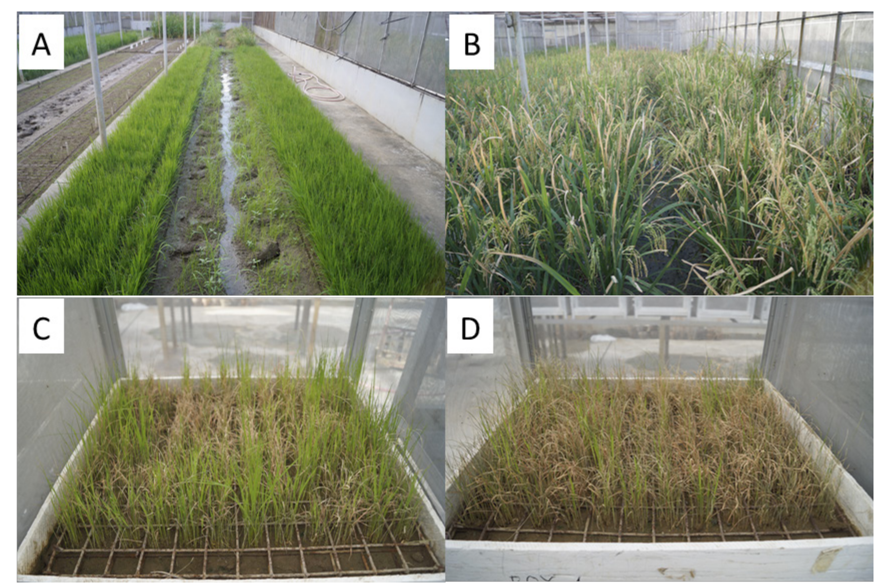


Figure 31. Experimental set-up for screening of (A) blast in nursery, (B) BLB in screenhouse, (C) GLH and (D) BPH in glasshouse.

Yield Prediction of Single Cross Hybrids and Combining Ability Analysis of Parent Lines

LV Gramaje, JD Caguiat, RA Millas, JE Carampatana, and PLH Duran

Demand for sustainable ways to increase the yield potential of rice cultivars is vital to address the plateau in rice production. Hybrid rice technology, among the various means to break yield barrier, offers an opportunity to enhance the yield of rice under fragile conditions as much as 15-20% yield advantage over the conventional high yielding varieties. At present, the implementation of hybrid rice technology is being hampered by the high cost of field evaluation. This is due to the strategy of breeding programs that includes performing all possible crosses in a group of inbred lines and then evaluating the single cross hybrids obtained, followed by the selection of the most promising ones. However, it is quite difficult and expensive to assess a very large number of developed parent lines and evaluation of all possible hybrids. Among the hybrid performance prediction methods, best linear unbiased prediction (BLUP), this combines field testing of related hybrids and obtaining pedigree information or genetic relatedness, holds great promise. Yield prediction of hybrid performance is a result of good combining ability. The combining ability of the different lines has a major importance in hybrid breeding since it provides information for parent selection and the nature and magnitude of gene action involved. The knowledge of genetic structure and mode of inheritance of different characters helps breeders to employ the suitable breeding methodology for their improvement

This study aimed to estimate kinship among parent lines using markers, to determine the yield performance of tested and untested single cross hybrids through best linear unbiased prediction, to measure the general and specific combining ability of hybrid parent lines for yield traits, and to identify the best performing hybrids and parents through BLUP and combining ability.

Activities:

- Generation of hybrid combination for GCA and SCA estimation.
- Yield prediction of hybrid combinations through combining ability.
- Analysis of GCA and SCA of hybrid parent lines and hybrids.
- Generation mean analysis.

Results:

- In 2016 DS, a complete set of 36 F1 hybrids were generated from the combinations of 12 restorers and three female parents following the line x tester mating design (Table 31 and Figure 32). F1 seeds produced from each combination ranged from 300 – 1500 seeds which satisfy the needed amount for replicated yield trial. The generated experimental hybrids along with the parent lines were evaluated in a randomized complete bock design (RCBD) with three replications in 2016 WS. A total of 87 F1 experimental hybrids were generated from inter – heterotic group. The summary of cross combinations was shown in Table 32 for set A and Table 33 for set B. The trial was heavily affected by two typhoons (Karen and Lawin), thus re-evaluation for the yield performance will be done in 2017DS. Also, simultaneous backcrossing for BC1F1 and BC2F1 will be done in separate plots to generate crosses for generation mean analysis. Heterosis will also be measured using mid-parental values and standard heterosis. Yield prediction based on the performance of parents and crosses guided by the genotype data and combining ability estimates will also be done.

Table 31. Testcrosses developed using Line x tester mating design and average yield (kg/ha).

Entry No.	Restorer Lines	CMS Testers		
		IR73328A	IR68897 A	IR80559 A
1	PR34302R	7910	6536	7108
2	PR36244-Hy-1-10-3R	6139	6593	3157
3	PR36248-HY-2-5-1R	3515	3585	4345
4	PR31559-AR32-4-3-2R	8000	7545	6529
5	RB100	8323	7859	7646
6	IR60819-34-2R	5684	6141	6214
7	SRT-3	6747	7453	6458
8	IR72889-69-2-2-2R	3698	5477	4504
9	PR44585-HY-R	2984	2040	2887
10	DT271	2152	1564	1411
11	PR44514-HY-R	1449	ND	3801
12	PR36419-HY-1-2-4-1-2-2	5957	8489	9051

Note: The entries will be validated the following season because the entries were affected by Typhoon Karen and Lawin.

Table 32. Experimental hybrids seed produced for Inter heterotic group (Set A).

	Cross Combinations			Cross Combinations	
Entry	Female	Male	Entry	Female	Male
HG-001	PR2A	PR34142	HG-022	PRH1A	DNRDO
HG-002	PR2A	C7324	HG-023	PRH1A	PR44588
HG-003	PR2A	Matatag	HG-024	PRH1A	Azucena m5-R
HG-004	PR2A	PR34302	HG-025	PRH1A	PR4-2R
HG-005	PR2A	PR35749	HG-026	PRH1A	AB-2R
HG-006	PR2A	PR31559	HG-027	PRH1A	MB-324
HG-007	PR2A	RB100	HG-028	PRH1A	PR45595
HG-008	PR2A	SRT-3	HG-029	PRH1A	PR34142
HG-009	PR2A	PR44585	HG-030	PRH1A	C7324
HG-010	PR2A	PR36419	HG-031	PRH1A	Matatag
HG-011	PR2A	PR44583	HG-032	PRH1A	PR34302
HG-012	PR2A	PR44569	HG-033	PRH1A	IR60819
HG-013	PR2A	PR36414	HG-034	PRH1A	PR36641
HG-014	PR2A	PR72878	HG-035	PRH1A	19R52
HG-015	PR2A	PR44579	HG-036	JX316A	PR34142
HG-016	PR2A	IR63881	HG-037	JX316A	PR36246
HG-017	PR2A	PR37789	HG-038	JX316A	DNRDO
HG-018	PR15A	PR31885	HG-039	JX316A	SN159
HG-019	PR15A	PR36246	HG-040	IR68897A	PR36248
HG-020	PRH1A	PR72889	HG-041	IR68897A	PR36246
HG-021	PRH1A	PR36246	HG-042	IR68897A	IR73012
			HG-043	IR68897A	B77

Table 33. Experimental hybrids seed produced for Inter heterotic group (Set B).

	Cross Combinations			Cross Combinations	
Entry	Female	Male	Entry	Female	Male
HG-044	IR68897A	PR44567	HG-066	IR73328A	PR36248
HG-045	IR68897A	PR44585	HG-067	IR73328A	PR31559
HG-046	IR68897A	DT271	HG-068	IR73328A	RB100
HG-047	IR68897A	PR44514	HG-069	IR73328A	IR60819
HG-048	IR68897A	PR36408	HG-070	IR73328A	SRT-3
HG-049	IR68897A	PR36419	HG-071	IR73328A	PR72889
HG-050	IR68897A	ACC66-1R	HG-072	IR73328A	B77
HG-051	IR68897A	IR73885	HG-073	IR73328A	PR44585
HG-052	IR80559A	PR36248	HG-074	IR73328A	DT271
HG-053	IR80559A	PR44585	HG-075	IR73328A	PR44514
HG-054	IR80559A	DT271	HG-076	IR73328A	PR36419
HG-055	IR80559A	PR44514	HG-077	IR73328A	PR44569
HG-056	IR80559A	PR36419	HG-078	IR73328A	PR36414
HG-057	IR80559A	IR78566	HG-079	IR73328A	PR72878
HG-058	IR80559A	PR44583	HG-080	IR73328A	PR44579
HG-059	IR80559A	PR44569	HG-081	IR73328A	IR63881
HG-060	IR80559A	PR36414	HG-082	IR73328A	PR36240
HG-061	IR80559A	PR72878	HG-083	IR73328A	PR36641
HG-062	IR80559A	PR44579	HG-084	IR73328A	AB-2R
HG-063	IR80559A	IR63881	HG-085	IR73328A	MB-324
HG-064	IR73328A	PR34302	HG-086	IR73328A	PR36620
HG-065	IR73328A	PR36244	HG-087	IR73328A	AB-94

Figure 32. Generation of F1 hybrids using line x tester mating design at PhilRice CES, 2016 DS.

Genetic improvement of maintainer lines for increased seed yield and BLB resistance with good grain quality
IGPacada, TMMPascual, and MTFCelestino

Proper choice of donor parent lines is the key in establishing germplasm pool of maintainer line with bacterial leaf blight (BLB) resistance with no fertility residual effect when converted to Cytoplasmic-genetic male sterile (CMS), and has good grain quality. And to achieve this, combination of conventional breeding and the use of molecular tools should be implemented.

Production costs of F1 seeds explain why hybrid rice seeds are more expensive than inbred varieties. One of the main reason is the low seed set due to low outcrossing rate of seed parent or CMS or A line used in developing hybrids. The possible cause was that all identified maintainer or B line has been directly derived from inbred breeding program and immediately converted to CMS without specific improvement for high outcrossing. Well exerted stigmas influence total outcrossing rate of CMS lines, thus this trait is very important particularly in improving seed set of seed parent.

This study has two component activities, one is aimed to develop maintainer and CMS line with BLB resistance gene and good grain quality, and the other is to breed maintainer and CMS lines with exerted stigmas.

Activities:

- Confirmation of Xa (Xantohomas oryzae) genes from advance lines (generated from maintainer x maintainer breeding population) was conducted using three markers (Xa4, Xa5, Xa7).

- Advance lines were converted to CMS lines with different cytoplasm and later verified if Xa genes were already transferred to them using the above markers.

- Exploratory approach was carried out in developing CMS lines with high outcrossing rate. Maintainer lines were converted to CMS lines with various cytoplasm, and each back cross generation, their degree of sterility and their natural outcrossing abilities were observed.

- Selection of genotypes having exerted stigmas were carried out from generated breeding population. Selection is based on the observed exerted stigma and with stigma exertion rate of >40%.

Results:
BLB resistance
- Two improved maintainer lines confirmed to have Xa4 and xa5 genes.
- Two CMS bred lines (with wild abortive & unknown cytoplasm) were developed in the background of improved maintainer line with Xa4 and xa5 genes.

Enhancing outcrossing rate of CMS lines
- One CMS line was developed with >30% natural out crossing rate.
- Five advance lines were selected from F5 generation with >40% stigma exertion rate.
- Data gathering, analysis and processing for 2016WS results are still in progress.

High Yielding Environment Adaptability Test and F1 Seed Production
JV Galapon, MAU Tabil, DKR Bumagat, DB Rebong II, and ATIO Rebong

In the Philippines, hybrid rice technology has been demonstrated to increase rice yields by an average of 15 to 25 percent over the best modern varieties available nationwide. However, to contribute significantly to the national objective of attaining rice self-sufficiency and food security by further improving the yield potential of rice, this yield advantage of hybrid rice over the current inbred variety should be maintained or further increased. Thus, rice breeders should continue in developing new and better hybrids that would perform better than the existing hybrids. PhilRice Isabela, being the country's hybrid rice center, is mandated to contribute in this aspect. This study therefore aims to evaluate elite three-line hybrid rice genotypes that perform well in high yielding environment, reproduce identified F1 seeds in Region II and CAR and conduct an efficient approach to generate data which will be useful in speeding up release of new and better hybrids.

Activities:
- Evaluate and select hybrids with high yielding capacity and adaptability in high yielding environments.
- Demonstration trial of newly released hybrids (Mestiso 48 and Mestiso 55) in high yielding environment.
- Seed production (AxB) of newly released varieties (Mestiso 48 and Mestiso 55).

Results:
- In 2016DS, 40 entries from F6 and 5 entries from F7 population were screened, closely monitored and evaluated for phenotypic acceptability. Twenty-five (25) restorer lines were selected having 1-5 PAcp rating meaning the entries were good in terms of crop stand/ non-segregating population, having a good and long panicle and long grain; 20 entries in F6 R line population and 5 entries in F7 R line population were advanced in MET 0 having an average yield of 8.98t/ha to 12.10t/ha and 4.24t/ha to 6.89t/ha, respectively.
- Five entries in AYT were selected having an average yield of 6.04t/ha to 6.85/ha and 1 entry in PYT with 8.08t/ha yield.
- Six kilograms of IR68897A (4kg) and IR58025A (2kg) were produced.
- During the 2016WS, established hybrid demo for M48 and M55 with an area of 1000m² in each sites (1) NVSU-Bayombong Campus (June 23, 2016), (2) CSU- Sanchez Mira Campus (June 29 to 30, 2016), (3) on-station (July 4, 2016) and (4) CSU- Lallo campus (July 22 to 23, 2016) (Table 34).
- For the hybrid demo; in NVSU- Bayombong Campus (Figure 34)., Mestiso 48 has an average yield of 4.01t/ha while Mestiso55 has 4.79t/ha. On-station (Figure 33), 4 hybrids were evaluated under irrigated lowland which includes Mestiso48, Mestiso55, Mestiso7 and Mestiso1. Mestiso7 registered the highest average yield of 12.98t/ha, followed by, Mestiso48 having an average yield of 10.20t/ha, Mestiso1 with 8.48t/ha and Mestiso55 with 6.63t/ha average yield. In CSU-Sanchez Mira, only 2.29t/ha and 2.46t/ha average yield of Mestiso55 and Mestiso48, respectively. On the 1000 grain weight, it ranges from 23 to 28g and for the % seed set; it ranges from 53.30 to 80.50%. The hybrid demo at CSU-Lallo was devastated by the typhoons Karen and Lawin. The entries were damaged by the two typhoons that strike northern part of Isabela and Cagayan.
- The hybrid demo at CSU- Sanchez Mira and NVSU-Bayombong attained only 2.29 to 2.49t/ha and 4.01 to 4.79t/ha, respectively. Drought began at 30 to 40% flowering which affected the yield for both sites. As a result, the two hybrid demo sites attained the lowest yield as compared to

on-station. Therefore, the area was deemed unfavorable for hybrid rice so as recommended to seek out more favorable environment to be conducted this DS 2017.

- Established HYEAT trial on the two identified station-based sites (1) on- station (June 30, 2016) and (2) Southern Cagayan Research Center (July 22, 2016). Four entries from NCT and M48 and M55 were demonstrated and evaluated. Mestiso48, Mestiso55, PR39385H and PR47216H have 116 days maturity while PR39375H had 114 days maturity and PR36577H is the early maturing with 111days maturity of all the 6 entries evaluated.

- HYEAT On-station , 4 NCT promising hybrid lines (PR39385H, PR39375H, PR47216H and PR36577H) and two newly released hybrids (Mestiso48 and Mestiso55) were evaluated. PR39375H registered the highest average yield of 6.29t/ha followed by Mestiso48 with 6.26t/ha, PR39385H with 5.87t/ha, Mestiso55 with 5.59t/ha, PR36577H with 5.47t/ha and lastly PR47216H with 4.83t/ha (Table 35). While the HYEAT at SCRC-Iguig was damaged by the typhoon Karen and Lawin when the entries were at milking to hard dough stage.

- Established AXB seed production of M48 and M55 (July 21-22, 2016). M48 has a total area of 2, 120m^2 and M55 has only 1, 220m^2 for WS16. Thorough rouging was properly implemented to maintain its purity. Also, pollen evaluation was done to evaluate the sterility of the spikelet for both M48 and M55. Harvested A lines for both M48 (41kg) and M55 (20kg). For the purification purposes (Figure 35)., harvested A line of M48 is 300g and 700g for M55.

Table 34. Yield data components of the hybrid demo across locations, WS16.

HYBRID DEMO ENTRIES	% Seed Set	1000 grain weight (g)	Yield (t/ha)
NVSU-Bayombong			
M48	75.08	26	4.01
M55	72.77	27	4.79
On-Station			
M48	78.23	27	10.20
M55	80.50	26	6.63
M7	78.17	28	12.98
M1	77.44	28	8.48
CSU-Sanchez Mira*			
M48	53.30	25	2.46
M55	54.18	23	2.29
CSU-Lallo			
M48	Devastated by the typhoon "Karen" and		
M55	"LAWIN"		

*site in CSU-Sanchez Mira was affected by drought during pre-and flowering stage

Table 35. Yield data component of HYEAT entries, on-station, WS16.

Entries	Maturity Days	Plant Height (cm)	1000 Grain Weight (g)	Yield (t/ha)
M48	116	115	31.21	**6.26**
M55	116	127	31.82	**5.59**
PR39385H	116	120	32.93	**5.87**
PR39375H	114	111	32.83	**6.29**
PR47216H	116	115	27.95	**4.83**
PR36577H	111	111	29.40	**5.47**

Figure 33. Hybrid demo (Mestiso 48, Mestiso 55, Mestiso 7 and Mestizo 1), on-station, WS16.

Figure 34. Hybrid demo, NVSU-Bayombong, WS16.

Figure 35. Purification of experimental hybrids, on-station, WS16.

Identification and use of Wide Compatibility Genes (S5n) for Enhancing Heterosis in Rice

IG Pacada, TF Celestino, TMM Pascual,TF Padolina, and NL Manigbas

Wide compatibility varieties (WCVs) are special class of rice germplasm able to produce fertile hybrids when crossed to other rice subspecies like indica x japonica; indica x javanica; japonica x javanica. It contains wide compatibility gene (WCG) or neutral allele (S5n) that resolves the fertility barrier demonstrated in crossing two dissimilar subspecies or cultivar group. WCG is very important particularly in hybrid rice breeding as it can be used to further enhance the heterosis particularly for inter-subspecific hybrids.

Identification of WCV using conventional breeding alone is a very lengthy process and need several manpower to generate desirable number of crosses. The identification of molecular markers in conferring S5n gene simplify the process of mining new rice germplasm with WCG and facilitate the marker aided breeding for WCG with technical precision. This study is aimed to evaluate the published S5n markers and assess their capability to detect S5n gene among potential WCV.

Activities:

- Four S5n gene markers were evaluated and examined for detecting S5n gene among potential WCV.
- Two potential WCV (identified using traditional WCG confirmation), were evaluated for possible existence of WCG using above S5n gene markers.

Results:

- Five informative markers were evaluated and ready to use for mining WC gene.
- Two potential WCV were identified to have WCG using WC marker.
- Data gathering, analysis and processing for 2016WS results are still in progress.

IV. Development of Thermo-Sensitive Genetic Male Sterile (TGMS) Lines and TGMS-Based Two-Line Hybrid Rice

Project Leader: Senen H. Escamus

The discovery of thermo-sensitive genetic male sterility in rice provided new avenues to further exploit heterosis using the two-line system. TGMS are genic male sterile genotypes whose fertility/sterility behavior is conditioned by temperature regimes (Virmani, 1996). This system is useful in the Philippines where temperature differences exist due to elevation, latitude and time of year. The increased chances of finding high yielding hybrids and the more straightforward seed production of TGMS lines makes this system more economically viable.

With the release by the National Seed Industry Council (NSIC) of 2 TGMS-based hybrid rice varieties, the collaborative project between UPLB and PhilRice has demonstrated that breeding and use of TGMS lines to develop two-line hybrids can be successfully done in the Philippines. The project is aimed at developing stable and improved TGMS lines. Likewise, it aims to develop high yielding two-line hybrids that are pest resistant and with acceptable grain and eating qualities.

Development of new and diverse TGMS lines through hybridization and selection

MAT Talavera, MG Ortiguero, and TM Masajo

To keep up with the challenge of developing better two-line hybrids, continuous development of new and more improved TGMS lines is an essential component that needs to be pursued. The objective of the study is to develop new and diverse TGMS lines through hybridization and selection. Earliness, shorter stature, resistance to pests and diseases and good grain quality are some criteria considered in selection. Development of TGMS lines with low critical fertility point will help ensure safe and successful production of F1 seeds at male sterile environment (MSE).

Results:

- 50 F1 crosses were generated during the year. All the F1 populations entered in the pedigree nursery will be advanced to F2 during the 2016 WS.
- 60 F2 populations and 1076 lines in the F3 to F7 generation were established and evaluated at MSE during the year. During DS, 861 plants were selected from F2 to F6 generation for evaluation of fertility behavior at MFE and to generate sufficient seeds for advancement to the next generation of

evaluation. Selection of promising lines during WS is still on going.

- 1076 plants shuttled from MSE to MFE during 15WS were evaluated in 16DS. From these about 500 plants identified as potential TGMS lines were harvested and will be entered in pedigree nursery in 16WS. During WS, severe rain caused part of the rat barrier to fell down which leads to rat infestation. Affected lines were transferred to another MFE site to regenerate and to produce seeds.

- 14 new TGMS lines were characterized for agromorphological characters. These new TGMS lines were crossed to various pollen parents to evaluate its F1 performance and crossability.

Development of new and diverse TGMS lines through recurrent selection
MLG Ortiguero, BT Salazar, and TM Masajo

To reinforce TGMS breeding work at PhilRice Los Baños, an initiative to develop TGMS lines through recurrent selection was added. Recurrent selection as a breeding method is generally used in cross-pollinated crops but could also be employed in self-pollinated crops like rice using genetic male sterility system to facilitate natural cross pollination. The main purpose of the method is to concentrate on fewer individuals in the population desirable traits through recurrent cycles of intercrossing and selection. Compared to the generally used hybridization and pedigree selection, intercrossing among individuals in recurrent selection keeps plants in heterozygous conditions allowing for more chances of genetic recombination.

Results:

- At MSE, 2 composite populations, 198 F2 populations and 818 lines in the F4 to F6 generation were evaluated during the year. From which 734 male sterile plants from various generations were selected and shuttled to MFE site for further evaluation and seed increase. Evaluation of sterile phase of various TGMS lines at MSE for wet season still ongoing.

- Evaluation of the 446 male sterile plant selections from 15WS and 210 male sterile plant selections from 16DS was done at MFE site. Some of the lines evaluated during WS were infested by rats due to breach in barrier system. These lines were transferred to other MFE site for regeneration and seed increase.

- Seven promising TGMS lines were developed using recurrent selection. These lines were evaluated and characterized during 16WS. Experimental hybrids using these lines were generated during WS to evaluate their performance as female parent.

Identification and development of pollen parents for two-line hybrids through recurrent selection
MAT Talavera, MLG Ortiguero, and TM Masajo

Essential to hybrid development programs for both two-line and three-line system is the availability and identification of potentially good-performing pollen parents. Characters such as yield, plant height, lodging resistance, maturity, resistance to pest and diseases, grain acceptability, tolerance to abiotic stresses, and pollen–shedding ability are traits considered in the selection of pollen parents. Drawing pollen parents from existing inbred variety development programs has been the common practice in hybrid breeding. But lately, with growing interest on hybrids and increased demand for pollen parents, finding suitable and diverse inbreds as male parents of hybrids has become increasingly difficult. Furthermore, access and use of improved germplasm developed and introduced from elsewhere are covered by PVP and MTA and provisions therein could be rather restrictive. While the TGMS project at Los Banos will continue to identify and source pollen parents from available materials, it is doing breeding work purposely to develop better pollen parents for TGMS hybrids.

The objective of the study is to develop pollen parents that have good pollen-shedding ability and are high yielding, resistant to pests and diseases and abiotic stresses and with good grain quality

Results:

- 600 F2 populations and 480 lines F2 and F3 generation were evaluated during the year. During DS, a total of 429 lines were selected from various generations. For WS, evaluation of lines still ongoing.

- 17 new pollen parent lines were selected and characterized. These lines were purified during 16WS before evaluated for yield, grain quality and disease and insect resistance in the upcoming 17DS.

- 10 promising genetic male sterile lines were also purified and will undergo seed increase in 16WS. These new lines will be registered for PVP once all the necessary data were gathered.

Development of two-line experimental hybrids

MLG Ortiguero, BT Salazar, and TM Masajo

In order to find good performing hybrids, test cross of the TGMS lines with as many and as diverse pollen parents available is necessary. Not all hybrids exhibit positive heterosis for economic traits, hence there is a need to produce a large number of experimental hybrids for testing and evaluation. The objective of the study is to generate as many experimental hybrids as possible to increase the chances of finding heterotic hybrids.

Results:

- Two-line experimental hybrids were generated through handcrossing using 26 TGMS lines (15 are new) and 100 pollen parents. Promising lines from the NCT, the UPLB breeding nurseries, NSIC released varieties, wide hybridization-derived lines, advance lines derived from recurrent selection were used as male parents.

- 621 new experimental hybrids with sufficient seeds were produced during the year. These new experimental hybrids produced will be evaluated following season in the Hybrid Observation Nursery (HON). From 359 new hybrids produced during 16DS, 300 were tested during 16WS. The remaining new experimental hybrids from 16DS will be planted together with seeds produced during 16WS in HON following season. During 16WS, a total 262 new experimental hybrids were produced. Processing of 2016WS harvests is in progress.

Evaluation and field performance testing of promising two-line hybrids

DJ Lalican, MAT Talavera, MLG Ortiguero, BT Salazar, and TM Masajo

Before a hybrid can be nominated to the NCT, it has to pass a series of evaluation and testing to determine its overall performance. New experimental hybrids have to undergo testing in the Hybrid Observational Nursery (HON) to initially eliminate inferior performing hybrids. Selected hybrids are elevated to the Hybrid Preliminary Yield Trial (HPYT) and Advance Yield Trial (AYT) for a more thorough evaluation for yield, insect and disease reaction and grain and milling qualities. Promising hybrids are channeled to multi-location and yield potential trials.

The objective of the study is to evaluate the performance of new and promising experimental hybrids and to identify and select the best performing hybrids that can be channeled to the National Cooperative Tests.

Results:

Hybrid Observation Nursery (HON)

- HON is composed of new experimental hybrids produced through hand crossing method together with 2 inbred checks (PSB Rc82 and NSIC Rc222) and two hybrid check (PRUP 10 and M19). It was laid out using Augmented RCBD for 20 replicates. Entries include combinations of 22 different TGMS lines and 137 pollen parents. Data on agronomic characters, phenotypic acceptability, yield and chalk evaluation was gathered.

- Yield result of HON DS evaluation is presented in Table 36. Thirteen (13) hybrids were identified superior than both inbred and hybrid checks while a total of 27 test hybrids outyielded both inbred checks. Highest yielding entries was 7855kg ha-1. DS evaluation experienced moderate drought during the vegetative phase due to limitation of irrigation water supplied by the FOD. All the promising hybrids identified passed on the evaluation of grain for chalkiness.

Table 36. Top performing hybrids in HON, 2016DS.

Index No.	Agronomic Characters				Adjusted yield (kg/ha)	Yield advantage (%)			
	Plant height	Tiller No	Maturity group	PA		M19	PRUP10	NSIC Rc222	PSB Rc82
2894	97	8	1	3	7855	39.4	34.1	52.9	86.2
2929	99	10	1	3	7827	38.9	33.6	52.4	85.5
2908	90	8	1	3	7679	36.2	31	49.5	82
2885	116	11	2	3	7415	31.6	26.6	44.4	75.7
2898	109	9	1	3	7225	28.2	23.3	40.7	71.2
2934	98	13	1	3	7225	28.2	23.3	40.7	71.2
2904	105	10	2	3	7158	27	22.2	39.4	69.7
2909	95	9	1	3	7102	26	21.2	38.3	68.3
2915	99	9	1	3	7083	25.7	20.9	37.9	67.9
2884	96	11	1	3	7028	24.7	19.9	36.8	66.6
2899	99	9	1	3	6997	24.2	19.4	36.2	65.8

CV: 16.46

- Wet season evaluation is presented in Table 37. Out of 300 new experimental hybrids evaluated, a total of 49 hybrids recorded yield significantly better than either 1 hybrid check (M10 and PRUP 10). From these 49 hybrids, 32 hybrids were better than both hybrid checks. Yield recorded from the outstanding hybrids ranges from 7212 to 9276 kg ha-1. Chalkiness evaluation is still ongoing.

Table 37. Top performing hybrids in HON, 2016WS.

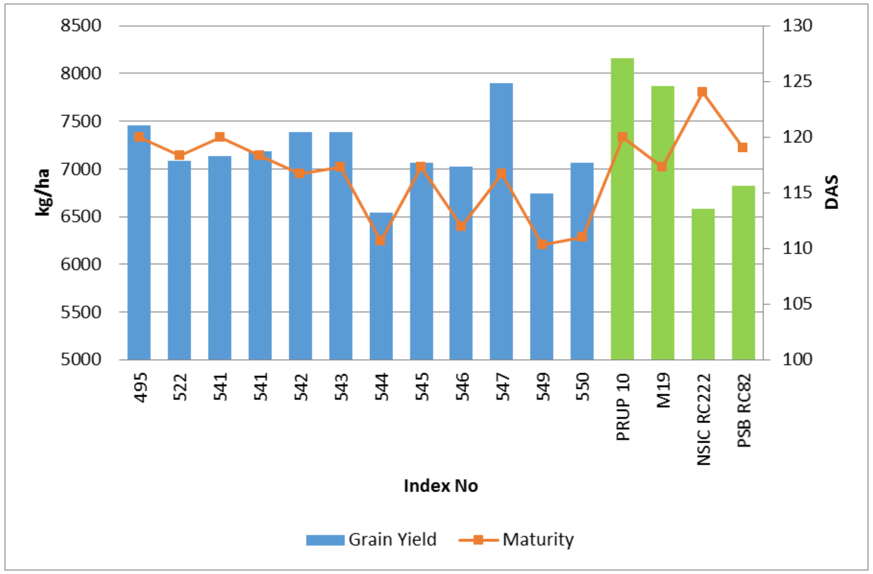
INDEX No	Agronomic Characters				Adjusted yield (kg/ha)	Yield Advantage (%)			
	Plant ht	Tiller No	Maturity group	PA		M19	PRUP10	Rc82	Rc222
3257	122	11	2	3	9276	38.2	45.5	74.4	58.0
3284	118	10	2	3	8689	29.5	36.3	63.4	48.0
3289	117	10	1	3	8450	25.9	32.6	58.9	44.0
3419	114	10	1	3	8387	25.0	31.6	57.7	42.9
3370	122	10	1	3	8375	24.8	31.4	57.5	42.7
3258	121	12	1	3	8304	23.7	30.3	56.1	41.5
3370	109	10	2	3	8241	22.8	29.3	55.0	40.4
3125	114	12	1	3	8159	21.6	28.0	53.4	39.0
3117	124	9	2	2	8093	20.6	27.0	52.2	37.9
3256	107	11	1	3	8061	20.1	26.5	51.6	37.3
3424	113	11	2	3	8043	19.8	26.2	51.2	37.0

CV: 11.92

Hybrid Preliminary Yield Trial (HPYT)

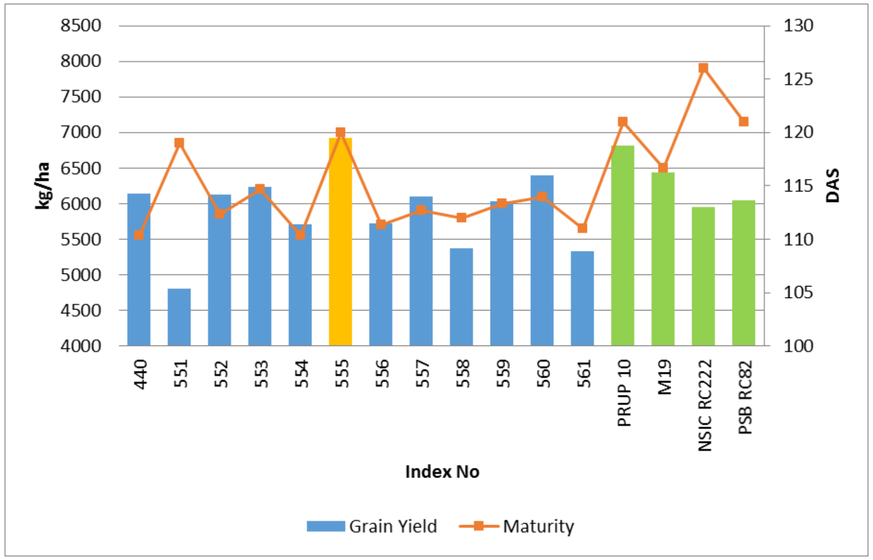
- In the hybrid preliminary yield trial (HPYT), a total of 48 experimental hybrids (24 during WS, another set of 24 during DS), 2 inbred checks (PSB Rc82 and NSIC Rc222) and 2 hybrid checks (M19 and PRUP10) were evaluated for the year. The experiment was set up using Randomized Complete Block Design (RCBD) with three replicates for two sets. Each set contains 12 experimental hybrids and 4 checks. Data gathered were agronomic, yield, and grain quality attributes. Insect and disease resistance were evaluated using natural insect and diseases pressure in the area.

- Results of yield for DS and WS were presented in Figures 36 to 39. For DS, 1 hybrid (HPYT 555) showed yield better than the best hybrid check, PRUP10. It produces yield of 6923 kg/ha which is better than PRUP 10 by 1.6%. This hybrid belongs to medium maturing group with maturity of 120 DAS. It produced 12 tillers in a hill and plant height of 103 cm. In terms of grain quality, it passed chalkiness evaluation and had intermediate AC and GT. For WS result, 5 hybrids (HPYT 559, 561, 562, 567, and 574) recorded yield better than highest hybrid check, M19. YA of these hybrids range from 0.4% to 12.2% against M19. All 4 hybrids were medium maturing with average tiller count of 10 in a hill. Grain quality analysis for these promising hybrids still on going. Promising hybrids identified will be further evaluated in the Advance Yield Trial (AYT).



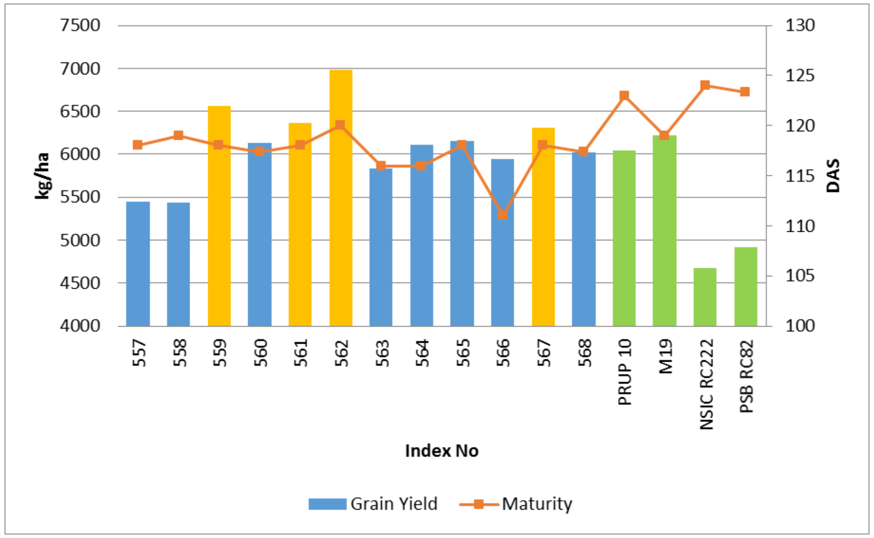
CV: 5.98

Figure 36. Grain yield (kg/ha) and maturity of experimental hybrids evaluated in HPYT 2016 Dry Season (Set 1).



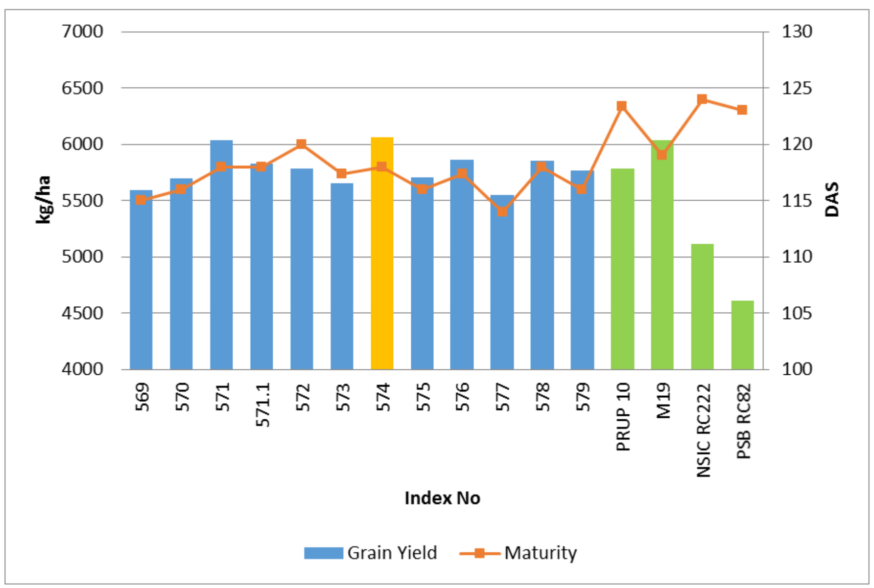
CV: 5.33

Figure 37. Grain yield (kg/ha) and maturity of experimental hybrids evaluated in HPYT 2016 Dry Season (Set 2).



CV: 9.28

Figure 38. Grain yield (kg/ha) and maturity of experimental hybrids evaluated in HPYT 2016 Wet Season (Set 1).



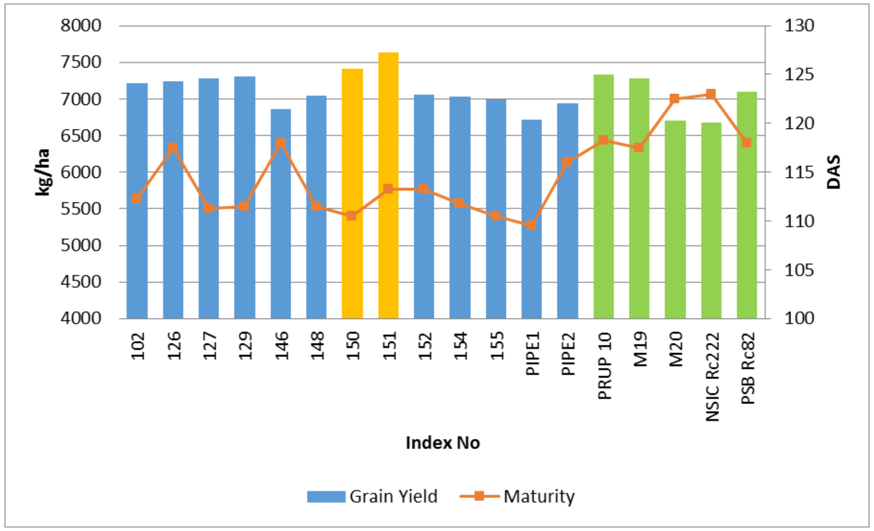
CV: 6.10

Figure 39. Grain yield (kg/ha) and maturity of experimental hybrids evaluated in HPYT 2016 Wet Season (Set 1).

Advance Yield Trial (AYT)

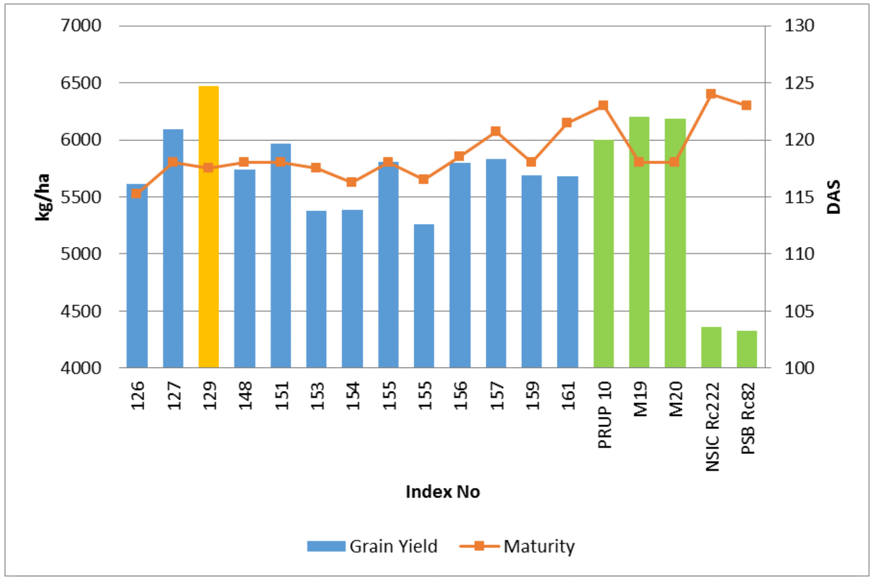
- Advance yield trial is composed of promising experimental hybrids which passed the evaluation in HPYT. The trial was set up using randomized complete block design (RCBD) with 4 replicates. Yield, agronomic characters, and grain quality was evaluated. Summary for the Advance Yield Trial (AYT) was presented in Figure 40 and 41. AYT comprised of 14 promising hybrids, 2 inbred checks (PSB Rc82, NSIC Rc222) and 3 hybrid checks (M19, M20, PRUP10).

- During 16DS, two hybrids (AYT 150 and 151) yielded higher than the highest yielding hybrid check PRUP10. AYT 150 recorded grain yield of 7414kg/ha while AYT 151 had 7641 kg/ha. These two hybrids had yield advantage of 1.0 and 4.1% respectively. Identified promising hybrids belong to early maturing group with plant height of almost 100cm. In terms of grain quality, the two both have long and slender grain, with AC and GT of intermediate. For the 16WS trial, only 1 hybrid (AYT 129) recorded a yield better than the highest yielding hybrid check (M19). AYT 129 yielded 6470kg/ha with yield advantage of 4.3% against M19. This hybrid belongs to an early maturing group, with a plant height of 123cm. During the evaluation, strong winds and heavy rain brought about by Typhoon Lawin caused majority of the entries to lodge. However, this hybrid showed resistance to lodging.



CV: 5.32

Figure 40. Grain yield (kg/ha) and maturity of experimental hybrids evaluated in AYT 2016 Wet Season.



CV: 6.24

Figure 41. Grain yield (kg/ha) and maturity of experimental hybrids evaluated in AYT 2016 wet season.

- Summary of yield performance testing for promising hybrid AYT 127 were presented in Table 38. These promising hybrids were tested for more than 2 seasons (3 wet and 2 dry) before considered for nomination in the multilocation trial, F1 seed yield potential, F1 yield potential trial, and finally NCT. AYT 127 recorded an average yield of 7,286kg/ha across season where highest yield was recorded during 14DS when it reached 10,179kg/ha (Figure 42). This hybrid will undergo optimization of synchronization pattern simultaneous with seed production.

Table 38. Summary of agronomic and yield data of promising hybrid AYT 127 from 14DS to 16WS.

	HPYT	AYT				SUMMARY		
	14DS	14WS	15WS	16DS	16WS	WS	DS	ACROSS
PLANT HEIGHT (cm)	111	115.3	127	105.8	129	124	108	118
TILLER NUMBER/m2	-	257	268	290	-	263	290	272
AVERAGE TILLER NUMBER	11	10	11	12	10	10	12	11
DAYS TO 50% FLOWERING	89	93	99	81	88	93	85	90
YIELD	10,179.00	5,748.00	7,139.00	7,276.90	6,088.00	6,325.00	8,727.95	7,286.18
YA NSIC Rc222	23.46	29.50	29.81	9.00	39.70	33.00	16.23	26.29
YA NSIC Rc82	23.68	43.80	36.67	2.60	40.70	40.39	13.14	29.49
YA M19	23.28	8.90	6.28	0.00	-1.90	4.43	11.64	7.31
PRUP10	-	-	-	-0.09	1.50	1.50	-0.09	0.71

Figure 42. AYT 127 at maturity.

F1 seed production of two-line hybrids for testing and evaluation

BT Salazar, MAT Talavera, and TM Masajo

Producing sufficient amounts of F1 seeds for testing is essential in the development of hybrids. This activity will ensure that breeding advances will not be constrained by limitations in the ability to produce/reconstruct adequate amount of seeds of experimental hybrids particularly those destined for preliminary yield trial and the NCT.

Results:

- Evaluation nursery containing new 75 new pollen parents coming from wide nursery, rainfed nursery and pollen parent breeding was established. From these, 40 genotypes with observed major deficiency (<100 cm plant height and susceptibility to RTV) were identified and will not be recommended to be used as pollen parent in generating new experimental hybrids. The remaining 35 pollen parents will be further evaluated and will be included in the pool of pollen parents used in breeding.

- 105 experimental hybrids were seed produced using the isolation free method during the year. From these, 84 promising experimental hybrids for HPYT and AYT were successfully produced with sufficient seeds. Seed yield ranged from 30 grams to 200 grams.

- Seed production of purple based M19 and M20 were successfully conducted. More than 70kg were harvested from these two hybrids. These two hybrids will be entered in NCT under essentially derived and will be tested for a year.

- Experimental hybrid seed production plot were heavily infested by black bug during 16WS. Severe damage were recorded, hence no experimental hybrids were reconstructed.

V. Breeding of Specialty Rice

Project Leader: Emily C Arocena

Aromatic, glutinous, and pigmented rice are some of the specialty types that commands higher price in the market. Low yield, susceptibility to pests, unstable and occasion-driven demand of these rices limits the wide production of these special types of rices. Recently, the demand is increasing; hence, there is a need to improve the yield potential and resistance of the existing varieties to lure the farmers to expand its cultivation. Consequently, farmers' productivity will increase as well as those of the small scale entrepreneurs solely dependent on the availability of these varieties. Moreover, consumers are now becoming conscious on their wellness and the nutritional content of their rice intake, hence, biofortifying the country's staple food with micronutrients such as Zinc, Iron and beta-carotene is a good and sustainable complement to existing national programs to alleviate micro-malnutrition in the country. Thus, development and improvement of this kind of rice are continuing efforts.

Development of aromatic, glutinous, pigmented, and iron/zinc-dense rice varieties

EC Arocena, Martha V. Chico, HT Ticman, GMOsoteo, and RCBraceros

Rice varietal development largely depends on the breeders and their ability to understand a range of breeding-related disciplines. It involves different steps depending upon the objectives, breeding methodologies and rice production systems. Blending the efforts of an interdisciplinary team undoubtedly achieve maximum results. However, the first and foremost is how well the breeders identify genetic donors based on the target traits and objectives set. Use of parental with diverse genetic make-up will simultaneously expand the genetic base for selection and opportunity to select promising lines with the target novel and/or superior characteristics of agronomic importance.

Activities:

- Line development started from the generation of new crosses involving parentals with the desired specialty traits and agronomic traits such as high yield, resistant to major insect pests and diseases and good grain quality. This was followed by generation advancement and plant selection with the desired traits in the hybrid populations (HP) and line selection in the pedigree nursery. Selected plants with the desired phenotypes were further evaluated in the laboratory for kernel qualities to ensure that the selected plants belongs to the desired specialty type. Only those plants with excellent to fair kernel qualities were advanced for further selection.

- Uniform lines with the desired specialty traits from the Pedigree Nursery were evaluated in the Advanced Observational Nursery (AON). Promising lines that outperformed the checks in the AON will be advanced in the Preliminary Yield Trial (PYT). Promising lines that outperformed the checks in the PYT will be advanced in the Multi-location Yield Trial (MYT) and/or in the Multi-environment Yield Trial (MET).

- The most promising entries that performed better than the checks after completion of the required trials in the MYT or MET will be nominated to the National Cooperative Test for Special Purpose Rice (NCT-SP).

Results:

- Results of the breeding efforts during the year are presented in Table 39. Seventy-eight parental genotypes with good traits were selected to be used in making crosses. There were 99 (34 A, 25 G, 30 P, 10 ZnFe) and 103 (29 A, 24 G, 15 P, 35 ZnFe) new crosses generated. Improvement focused on the resistance and grain quality of the elite breeding lines and/or varieties with the desired specialty and/or value-added traits.

- There were 84 F1 crosses evaluated in DS and 92 in WS. Sixty five crosses were selected in DS and 55 in WS. These F1 crosses will be advanced in the Hybrid Population Non-Selection (HPNS) for 2017 DS.

- In the HPNS, 154 populations were evaluated and 46 entries advanced to HPS and 65 entries were retained for generation advance. In WS, 118 population were evaluated and only 28 entries were selected due to severe infestation of BPH and high lodging incidence because of the occurrence of whirlwind/heavy rain and typhoon in the area.

- Majority of the selected plants in the hybrid populations (HP) and pedigree nursery (PN) were non-glutinous for aromatic selection as shown in Figure 43.

- Fixed lines from the pedigree nursery were evaluated in the observational nursery (ON). There were 248 (120 A, 67 G, 33 P and 28 ZnFe) lines advanced to AON 2016 WS, while 52 (37 A, 5 G, 6 P and 4 ZnFe) lines were advanced to AON 2017 DS. The WS selection of desirable plants was limited due to severe lodging incidence on majority of the lines evaluated caused by the whirlwind/heavy rain and typhoons that occurred in the area.

- In the AON, there were 173 entries evaluated during the DS. Yield range involving the different specialty types were: A-2264kg/ha-8273 kg/ha, G-2551kg/ha-7008kg/ha, Zn/Fe-3321kg/ha-7619 kg/ha and P-2922kg/ha-7092kg/ha. There were 43 A lines that out yielded NSIC Rc218 (5797kg/ha) by 5.29% to 42.7%, 20 G lines with 7.05% to 53.2% YA over NSIC Rc13 (4576kg/ha), 13 Zn/Fe lines with 7.11% to 60.5% YA over MS13 (4748kg/ha) and 9 P lines with 7.02% to 47.8% YA over NSIC Rc19 (4798kg/ha). The top high yielding entries per specialty types is shown in Figure 44. There were 29 entries (A-22, G-5, P-2) advanced to Preliminary Yield Trial (PYT) and 115 (A-56, Zn/Fe-23, G-23, P-13) were retained for further evaluation.

Table 39. Results of breeding efforts, PhilRice CES, 2016.

Nursery	Number of entries evaluated		Number of entries selected		Remarks
	2016 DS	2016 WS	2016 DS	2016 WS	
Parentals	78 varieties/lines	78 varieties/lines	78 varieties/lines	78 varieties/lines	Most of these entries have the desired quality characteristics, yield enhancing traits and resistance specifically for blast, BLB and tungro
New crosses	-		34 Aromatic (A), 25 Glutinous(G), 30 Pigmented (P), 10 Zn/Fe	29 Aromatic (A), 24 Glutinous(G), 15 Pigmented (P), 35 Zn/Fe	For evaluation 2017 DS
F_1 (crosses)16 DS	11 A, 32 G, 39 P, 2 Zn/Fe	34 A, 23 G, 25 P, 10 Zn/Fe	7 A, 30 G, 27 P and 1 Zn/Fe	18 A, 22 G, 10 P and 5 Zn/Fe	For evaluation 2017 DS
HPN (Hybrid populations for generation advance)	59 A, 16 G, 20 P, 59 Zn/Fe, (154)	43 A, 12 G, 16 P, 47 Zn/Fe	16A, 9G 12Fe and 9P for plant selection 43A, 7G, 11P, 47 Zn/Fe retained for generation advance	12 A, 7 G, 2 P and 7 Zn/Fe	Retained for generation advance. Some of the entries were severely infested by BPH and high lodging incidence because of the whirlwind/heavy rain and typhoon occurred in the area
HPS (Hybrid populations intended for single plant selection)	20 A, 15 G, 7 P, 13 Zn/Fe	19 A, 9 G, 13 P, 11 Zn/Fe	Field selection resulted to 2956 individual plants which was reduced to 1054 (298 A, 232 G, 228 P and 296 Zn/Fe) after kernel evaluation	1651 individual plants were selected from the field and was reduced to 867 (364 A, 210 G, 218 P and 75 Zn/Fe) after kernel evaluation	Plant selection was done in all populations
Pedigree Nursery (PNG)	4304 pedigree lines (2483 A, 846 G, 658 P 317 Zn/Fe)	2621 A, 686 G, 548 P, 449 Fe/Zn.	1988 A, 843 G, 315 P, 161 Fe/Zn. Of these, 112A, 52G, 19P and 10 Zn/Fe uniform lines were elevated to AON for 2016 WS planting	860 A, 321 G, 228 P, 203 Fe/Zn selected from the field. Of these, 37 A, 5 G, 6 P and 4 Zn/Fe uniform lines were elevated to AON for 2017 DS planting	In the field, majority of the lines were discarded owing to poor plant type and susceptibility to BPH, blast, and high lodging incidence because of the whirlwind/heavy rain and typhoon occurred in the area, while in the laboratory, high chalky/translucent grains, discolored and not uniform grain size and shape limited the selection

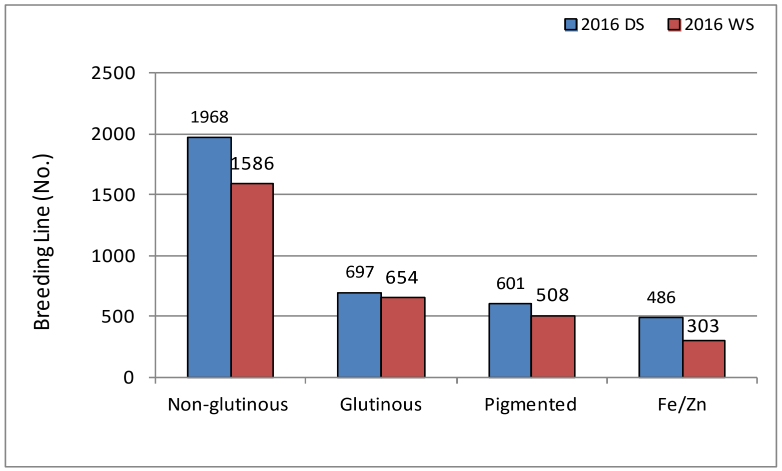


Figure. 43. Selected plants in the hybrid populations (HP) and pedigree nursery (PN) classified based on specialty types, 2016 DS and WS.

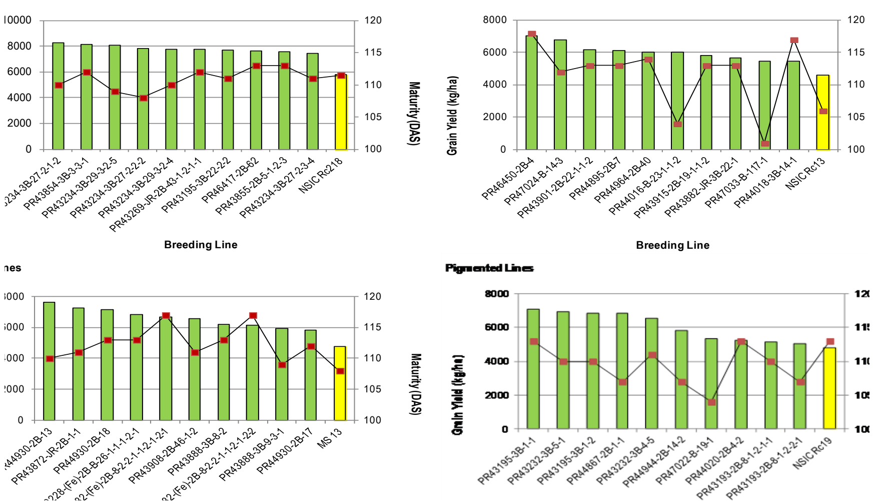


Figure 44. Yield performance and maturity of the top yielding entries per specialty types in the AON, 2016 DS.

- In the Preliminary Yield Trial (PYT) DS trial, out of the 78 (40A, 6G, 15P, 17Zn/Fe) entries evaluated, 14 A lines outyielded NSIC Rc218 by 5.7% to 19%, 14 Zn/Fe lines with 15.8% to 66.6% YA over MS 13 and 7 P lines with 11.8% to 47.0%YA over NSIC Rc19. Fifty-eight (28A, 4G, 14P, 12Zn/Fe) lines were retained for further evaluation in 2016 WS and 4 lines awaiting slots in the MYT. The top ten high yielding entries per specialty types is shown in Figure 45.

- During the WS, 366 AON and 84 PYT entries including checks were evaluated. However, whirlwind/heavy rain (booting/heading stage) and typhoon Karen (heading/soft dough stage) caused severe lodging incidence. Hence, no yield data was obtained. However, survived plants within the plot were harvested for seed purposes.

- In the MYT, there were 34 lines evaluated. During the DS in Group I under Maligaya condition, NSIC Rc298, produced the highest yield of 9630kg/ha. However, PR40228-2B-B-42-1-1 (8927kg/ha) which ranked 2nd and PR38036-2B-5-1-2-2-2-1 (8652kg/ha) ranked 3rd. In Bicol, PR40207-JR-2B-3-2-1 (5068kg/ha) was the top yielder while in CMU, PR40241(Fe)-4B-12-2-1-1 (3716kg/ha) was the best performer. In Negros, PR43966-B-17-1-1. In Group II, there were three 7-tonner entries. PR41621-B-B-19-3-2-1 (7403kg/ha) which ranked 2nd and PR 43985-B-4-1-1 (7091kg/ha) ranked 3rd under Maligaya condition, In Bicol, none of the test entries outyielded the check varieties, NSIC Rc 240 (4514kg/ha) and PSB Rc18 (4041kg/ha) ranked 1st and 2nd respectively. However, ranked 3rd was PR41621-B-B-19-3-2-1 (3595kg/ha) and the highest yielder among test entries. In CMU, PR41050-B-B-29-2-2(3708kg/ha) was the top yielder. In Negros, four test entries were eight tonner with yields ranged from 8054kg/ha to 8567kg/ha).

- Across four locations in Group I, PR40240-2B-B-16 produced the highest mean yield of 6481kg/ha with 7.4%YA over PSB Rc82 (6034kg/ha). It showed adaptability in the three locations. In Group II, PR38982-(Fe)-5B-5-1-1-1-1 (5527kg/ha) was the top yielder with 5.5% YA over NSIC Rc240 (5236kg/ha). It showed good performance in all test locations. Five other test entries with yields ranged from 5270kg/ha to 5468kg/ha with 0.6% to 4.4% YA over NSIC Rc240. (Table 40).

- During the WS at CES, the trial was affected by whirlwind/heavy rain and typhoon Karen which caused severe lodging incidence at booting to soft dough stage. Very low yield was obtained, hence all entries were retained for evaluation.

- In MET, 4 advanced lines completed the trial requirements awaiting NCT slots.

- Two aromatic, and 2 Zinc–dense lines were nominated to NCT SP 2016WS. The two aromatic lines, PR35342-B-B-1-3-1-3-1-5 and PR39878-B-B-B-7-3-2-1-2-1 had yields of 7500 kg/ha with good eating quality while the two zinc-dense PR35015-1-1-1-3-1 and PR38142-B-1 had yields of 6.7tha-1 and 7.2tha-1, respectively with 22.0 and 29.0 mg/kg grain-Zinc content. From the WS seed increase and purification trial, another three aromatic and 7 glutinous lines were nominated to NCT 2017DS. PR30460-4-3-1-3-2-4-1-1-1-4-9, a black non-glutinous (NG) line and PR35034-B-3-2-1-1-4-1-2-1-1-2-1, red NG line with very good sensory quality were identified suitable for brown rice (Figure 46).

- In the NCT SP, the entries in the aromatic and glutinous group still needs to complete the trial requirements. However, the micronutrient-dense group already completed the trial requiremments, hence, discussed and delibetated during the RVIG 62nd annual meeting held last June 1, 2016 in Cebu City. There were 8 test entries evaluated. IR10M300 was recommended for commercial release as the first zinc-dense rice. Its yield during the dry season was 5579kg/ha, 4246kg/ha during wet season and 4690kg/ha across seasons. It recorded more than 20% YA over NSIC Rc172SR across seasons. This line has higher grain-Zinc content (19.6mg/kg) than that of PSB Rc82 (15.5mg/kg) .

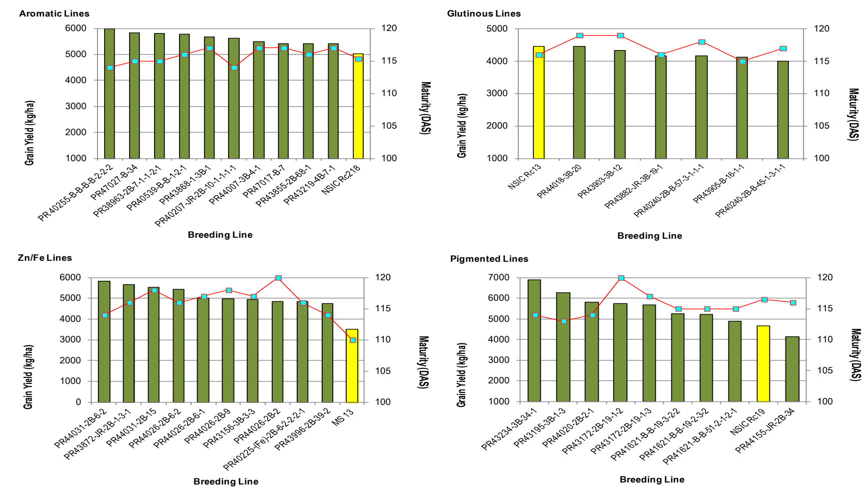


Figure 45. Yield performance and maturity of the top yielding entries per specialty types in the PYT, 2016 DS.

Table 40. Yield performance of the promising test entries which performed best (top ten) in two or three test locations, 2016 DS.

ENTNO	Designation	Mean Yield (kg/ha) - CES	Rank	Mean Yield (kg/ha) - Bicol	Rank	Mean Yield (kg/ha) - CMU	Rank	Mean Yield (kg/ha) - Negros	Rank	Grand Mean Yield (kg/ha)	% over HYC	Rank
Group I												
21	PR40539-B-B-5-1-1-2	6455	4	4888	3	2656	2	7449	11	6114	1.3	2
22	PR40539-B-B-31	5407	19	3784	14	2901	9	8082	6	5297	-12.2	17
23	PR40240-2B-B-16	7709	10		19	3400	6	8004	7	6481	7.4	1
24	PR36970-2B-5	8019	8	5007	2	2821	3	7201	14	5806	-1.6	7
25	PR35491-2B-8	6706	18	3095	17	2743	15	7267	13	4909	-18.2	19
26	PR40207-1R-2B-22-3	8162	6	4514	5	2992	14	7149	15	5677	-5.9	12
27	PR40207-1R-2B-3-2-1	6720	17	5069	1	3460	5	7450	10	5679	-5.9	11
28	PR36405-2B-5-1-22-2-2-1	8622	3	4701	9	3065	12	7877	8	5949	-1.4	5
29	PR36978-2B-73-2-1-2-1	7450	13	4708	8	3105	11	8757	4	5880	-2.6	8
30	PR42865-B-17-1-1	6767	16	3187	18	2911	8	9765	1	5730	-5.0	9
31	PR36960 (Fe)-B-5-5-1	8902	9	2914	11	2600	4	8082	5	5857	-1.4	4
32	PR40226 (Fe)-2B-26-2-2-1-1	8080	5	3999	15	3088	12	7809	16	5557	-8.0	14
33	PR40241 (Fe)-48-122-1-1	8076	7	3845	10	3716	1	6440	17	5544	-8.1	15
34	PR40226 (Fe)-2B-B-45-1-1	8827	2	3900	13	2984	7	7545	9	5806	-1.6	6
35	PR40226 (Fe)-2B-B-11-1	6800	15	3805	12	3132	10	7368	12	5324	-11.8	16
36	PR44031 (Fe)-2B-2	7684	11	3476	16	2489	18	9125	3	5690	-5.8	10
48	PSB Rc82 (Highest Yielding Check-HYC)	7490	12	4850	4	2615	16	9176	2	6034	0.0	3
49	NSIC Rc222	7434	14	4472	6	2596	17	5731	19	5058	-16.2	18
50	NSIC Rc238	9650	1	4430	7	2449	19	5400	18	5505	-7.4	13
	Minimum	5407		3187		2449		5731		4909		
	Maximum	9650		5069		3716		9765		6481		
	Mean	7714		4154		3118		7701		5700		
	Range	2808		1887		1268		4034		1545		
	Stdev	909		577		393		1083		374		
	CV(%)	12.2		13.9		12.6		14.1		6.6		
Group II												
67	PR40226-B-B-BB-10	6210	11	3095	19	2070	6	5787	19	4653	-11.0	19
68	PR36978-2B-152-2-1-2	6671	8	4181	5	2089	10	7312	10	5308	1.3	5
69	PR45160-2B-4	6230	12	3658	13	2715	15	5841	18	4620	-11.5	20
70	PR36978-2B-1-1-2-1-1	5457	19	3872	11	3084	9	7360	9	4947	-5.7	12
71	PR36978-2B-1-1-2-1-2-1	6504	10	3892	10	2976	13	6136	17	4892	-6.6	15
72	PR42865-B-17-1-4	6847	5	3623	14	2680	17	7684	6	5234	-0.1	9
73	PR40226 (Fe)-2B-2-2-1-1-1	6777	13	3517	16	3007	12	6569	15	4967	-7.6	17
74	PR40226 (Fe)-2B-B-2-1-4-4	7824	4	4507	3	2467	4	6272	16	5270	0.6	6
75	PR41024 (Fe)-B-B-14	6164	14	3485	17	2685	16	8024	2	5137	-1.9	10
76	PR36962 (Fe)-5-B-B-1-1-1-1	6773	6	3600	8	2695	7	8117	3	5527	5.5	1
77	PR36957-B-22-3-2	6545	9	2348	20	3084	5	8654	4	5235	-0.1	8
78	PR45123-2B-13-2-1-2	5811	17	3047	18	2629	2	7684	5	5070	-3.2	11
79	PR40240-2B-B-B-2-2-4-4	5454	18	4180	4	2618	3	8567	1	5431	3.7	3
80	PR41050-B-B-22-2-2	6010	16	3818	9	3708	1	7652	7	5357	1.6	4
81	PR42882-B-4-4-1	7081	3	4514	2	2817	14	7651	8	5469	4.4	2
82	PR45208-B-B	5108	20	4166	6	2584	18	7144	11	4753	-9.3	18
83	PR45108-1R-2B-1-1	6145	15	3871	12	2087	8	6797	14	5005	-4.4	13
84	PR41651-B-B-18-3-2-1	7402	2	2686	15	2016	11	5619	20	4399	-6.3	14
99	PSB Rc18	6760	7	4041	7	1713	20	7045	12	4891	-6.6	16
100	NSIC Rc240 (Highest Yielding Check - HYC)	7547	1	4514	1	1681	19	7060	13	5238	0.0	7
	Minimum	5108		2348		1713		5619		4620		
	Maximum	7547		4514		3708		8567		5527		
	Mean	6406		3817		2387		7144		5083		
	Range	2439		1566		1995		2948		884		
	Stdev	666		410		516		867		267		
	CV(%)	10.4		10.7		17.3		12.1		5.3		

Figure 46. Promising pigmented lines with very good sensory quality suitable for brown rice.

Evaluation and utilization of fragrance markers for high-yielding aromatic breeding materials.

TE Mananghaya, ATDC Aradanas, RP Mallari, HT Ticman , MV Chico and EC Arocena

Fragrance (aroma) is considered one of the most important grain quality traits in rice because aromatic rice cultivars command premium prices in the market today. However, the trait is recessive and thus breeding of aromatic rices needs extensive labor and has to involve large numbers of breeding materials to develop and identify a progeny with the target aromatic trait. Thus, molecular markers associated with fragrance trait will assist rice breeders to develop a high yielding variety with excellent grain quality in simple and inexpensive method. This study aims to evaluate a marker system to be used in marker assisted selection for fragrance trait in rice, and thus in aromatic breeding program.

Activities:

- Search and evaluation of new and functional (gene-based markers) and tightly-linked markers for fragrance trait in rice.
- Development of segregating populationGenetic and linkage analyses of fragrance trait and alleles using segregating population.
- Marker assisted selection in aromatic breeding materials.

Results:

- Five new fragrance markers were assembled, optimized using selected parents and rice cultivars checks and to be utilized for marker -assisted selection (MAS) for aromatic rice breeding. These new markers could possibly detect other fragrant loci other than fragrant allele detected by fragrance gene markers (Bradbury markers).

- Fourteen cross combinations were genotyped this year using fragrance and starch synthase markers. Out of 1,885 materials 520 are found positive to homozygous fragrant allele, 790 plants are negative to diagnostic allele and 575 showed heterozygous using Bradbury markers. PR40214-B-9/PR33277-2B-5-2-2-2-3-2-1-1-4-1-1-2-1 cross combination generated the most number of plants that resulted positive to fragrant allele (Table 41).
- DNA polymorphism of selected traditional rice varieties was conducted. Out of 131 samples of selected traditional varieties, 45 (34.4%) of them have the fgr gene, 70 (53.4%) were negative and 16 (9.9%) were heterozygous. Dinorado and Asucena claimed aromatic rice cultivars, showed homozygous non fragrant allele to Bradbury markers. Possibly that there is other loci controlling the fragrant trait of these two known aromatic rice genotypes (Figure 47).

Table 41. Summary of DNA genotyping of F2 segregating plants for detection of fragrant trait using multiplex PCR fragrance markers.

	Fragrance genotyping using FGR markers			
Cross Combinations	Fragrant	Non-Fragrant	Heterozygous	Total
PR40476-3B-1-1/HHZ12-DT10-SAL1-DT1 F5	34	15	26	75
PR37994-B-20-2-2-1/PR34627-B-44-2-1-2-1-1 F5	24	14	12	50
HHZ3-SAL13-Y1-SAL1/PR37343-B-6-3-2-2-2 F5	33	29	38	100
PR40282-(Fe)-2B-8-2-4-3-1-1/NSIC Rc218 SR F4	42	29	29	100
PR40214-B-9/PR33277-2B-5-2-2-2-3-2-1-1-4-1-1-2-1 F4	53	12	35	100
NSIC Rc218 SR / GSR IR1-4-S5-Y2-Y1 (A) F4	21	8	31	60
PR36905-B-1-11-2-1-1-1(A)(NEW)/C9301-B-12-1-1(NEW) (tpr/dsr) F2	59	169	22	250
HHZ6-SAL3-Y1-SUB2 (A) (NEW)/C9354-B-3-1-2 (NEW) (tpr/dsr) F2	15	164	71	250
NSIC Rc218/IRBLz-Fu F2	101	41	108	250
Fermoso/ Aromatic from CMU F2	105	29	116	250
NSIC Rc218/IR04A285 F3	20	51	29	100
NSIC Rc218/IR04A391 F3	1	90	9	100
NSIC Rc218/IR77542-520-1-1-1-1-3 F3	12	68	20	100
GSR IR1-14-Y7-Y1-D2 (A)/BURDAGOL (CHECK) F3	0	71	29	100
Total	520	790	575	**1885**

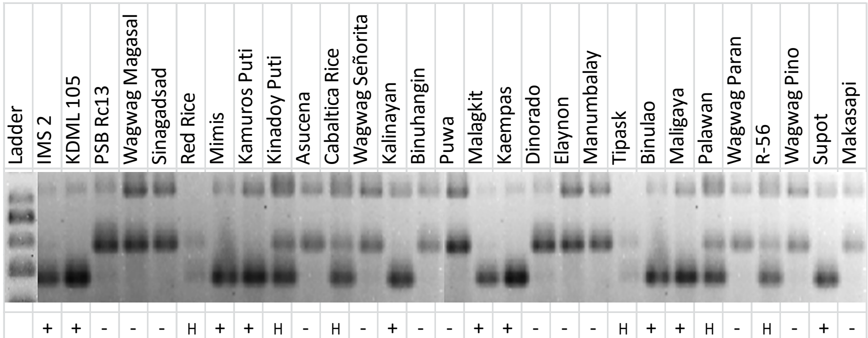


Figure 47. DNA polymorphism of potential parents using fragrance gene markers (Bradbury).

Production of Golden Rice Introgression Lines in the Background of Selected Popular Varieties with Resistance to Tungro and Bacterial Blight
RL Ordonio, RT Miranda, and I Besas

Golden Rice, which is biofortified with beta-carotene, is a potential food-based approach that can complement other sources of Vitamin A in the diet and can help combat the problem of vitamin A deficiency (VAD) which is still on the rise in the Philippines based on recent survey. VAD can weaken the immune system; thereby, increasing the risk of mortality from common diseases, especially among young children and pregnant/lactating women. It can also result in impaired vision and night blindness. Meanwhile, tungro and bacterial leaf blight (BLB) are two of the most important diseases that can severely affect grain yield in irrigated areas. Many varieties possessing resistance to these diseases have been bred and using them to produce a variety with a combination of these traits, plus the ability to produce high beta carotene levels (3-in-1) using marker-assisted breeding as in this study should be a welcome development in rice breeding.

Activities:

- Identification of three GR donors and six recipient varieties with high popularity to farmers and consumers.
- Screened the six identified recipient varieties for tungro and BLB reactions using induced screening.
- Seed increase and generation advance of breeding materials.
- For two seasons in 2016 (dry and wet), we have screened a total of 126 different advanced lines composed of different generations of improved 2-in-1 lines (reciprocal crosses of Line 27 and NSIC Rc120): 19 F1, 10 F2, 81 F3 and 26 F4 , for tungro and BLB resistance.
- Collected leaf samples and extracted DNA of selected plants from the resistance screening and performed PCR for molecular analysis to correlate phenotype with genotype.
- Generated crosses between the new identified recipient parents and line 27.
- Submitted application for Biosafety permit from DOST-BC.

Results:

- Two PSB Rc82-BC5F5-GR2-E lines (IR_112019_ GR_2-E:38-4-27 and IR_112019_GR_2-E:38-4-19) and one BRRI DHAN-GR2E line were selected as candidate GR2E donors. As for the recipient parents to be used, we have identified five varieties popular in areas which are identified to have VAD incidence, namely, PSB Rc82, NSIC Rc222, NSIC Rc160, NSIC Rc238, NSIC Rc300. One elite line with high zinc content (IR10M300) will also be used as a recipient parent.
- In 2016 DS, we seed-increased nine F1 crosses derived from the cross between Line 27 X NSIC Rc 120 F1 and selected resistant Line 27 X NSIC Rc 120 F2 plants with resistance to BLB and tungro. For 2016bWS we have generated 14 new crosses from the identified six recipient parent and line 27.
- For tungro and BLB screening of advanced generation in DS, we have selected 49 individual F3/F4 plants which consist of 23 resistant and 26 plants moderately resistant to tungro. For F2 materials, we have selected 81 individual plants with resistant and intermediate reaction to tungro and 47 plants with resistant (39) and intermediate (8) reaction to BLB. In addition, we have also subjected F1 plants to BLB screening which resulted in the selection of 52 resistant and 11 intermediate plants from eight F1 crosses (Table 42). For WS screening, we have selected a total of 193 F3/F4 individual plants with resistant (178) and intermediate (15) reaction to tungro and all have resistant reaction to BLB (Table 43/Figure -47&48).
- Tungro reaction of the six identified recipient varieties shows that NSIC Rc160 is susceptible, PSB Rc82, NSIC Rc222, NSIC Rc300 and IR10M300 are moderately susceptible and NSIC Rc238 is moderately resistant (I). Rating for their BLB resistance reaction is yet to be determined (Table 43 and

Figure 48).

- Extracted DNA from 400 F2 plants from eight independent F1 reciprocal crosses between Line 27 and NSIC Rc120. Molecular screening for the detection of resistance genes using Xa primers (Xa4 and Xa21) for BLB resistance, RM5495 (tsv1 for tungro resistance) and RM8213 (Glh14 for GLH resistance) is ongoing.

- Project proposal for the biosafety permit from DOST-BC was given a DOST-BC ref no. 2016-0299. Facilitated the inspection of facilities to be used for experimentation by the IBC members as required by the DOST secretariat to obtain the biosafety permit. Currently awaiting the decision from the November meeting of the DOST-BC.

Table 42. Tungro and BLB screening results of different generations of crosses derived from Line 27 and NSIC Rc120.

Entry Description	No. of entries Screened	No. of Selected Plants for Tungro	No. of Selected plants for BLB
F1	9	no Tungro screening for F1	52 (R), 11 (I)
F2	10	81	39 (R), 8 (I)
F3	26	23 (R), 26 (I)	40 (R), 9 (I)

Table 43. Tungro and BLB reaction of control checks, parent checks, advanced lines and new recurrent parents.

Designation	RTV Rating (no. of selected plants)	Lesion Length (cm)	BLB Rating	REMARKS
ARC11154 (Resistant Check-Tungro)	R	6.2	I	
UTRIMERAH(Resistant Check-Tungro)	R	16.7	S	
IR64 (Susceptible Check-Tungro)	S	13	MS	
TN1 (Susceptible Check-Tungro/BLB)	S	30.9	S	
LINE 27 (Parental Check-Tungro(I)/BLB)	I	0.1	R	
NSIC Rc120 (Parental Check-Tungro)	R	31.9	S	
IRBB4 (Check-BLB)	-	11.7	MS	
IRBB5 (Check-BLB)	-	11.9	MS	
IRBB7 (Check-BLB)	-	19.6	S	
IRBB21 (Resistant Check-BLB)	-	11.9	MS	
IRBB61 (Resistant Check-BLB)	-	8.2	I	
IR24 (Susceptible Check-BLB)	-	29.03	S	
21-2n1-F3-1	R(13)/ I(5)	4.12	R	Advanced lines from reciprocal cross between **LINE 27** **x** **NSIC Rc120**
22-2n1-F3-2	R(5) / I(5)	4.64	R	
23-2n1-F3-3	R (17)	1.53	R	
24-2n1-F3-4	R(18)	2.12	R	
25-2n1-F3-5	R(9)	3.04	R	
26-2n1-F3-6	R(39) / I(2)	1.44	R	
27-2n1-F3-7	R (25)	2.62	R	
28-2n1-F3-8	R(52) / I(3)	2.31	R	
PSB Rc82 (Identified recurrent parent)	MS			Identified new Recurrent Parent (Popular Variety in region identified to have high incidence of VAD)
NSIC Rc222 (Identified recurrent parent)	MS			
NSIC Rc160 (Identified recurrent parent)	S			
NSIC Rc300 (Identified recurrent parent)	MS			
NSIC Rc238 (Identified recurrent parent)	I			
IR10M300 (High Zinc) (Identified recurrent parent)	MS			

Legend: RTV Rating: R – resistant; MS – moderately resistant; I – Intermediate; S –Susceptible
Lesion length/BLB Rating: 0-5 cm (R-Resistant); >5-10 cm (I-Intermediate); >10-15cm (MS-Moderately susceptible) >15 cm (S-Susceptible): for future evaluation

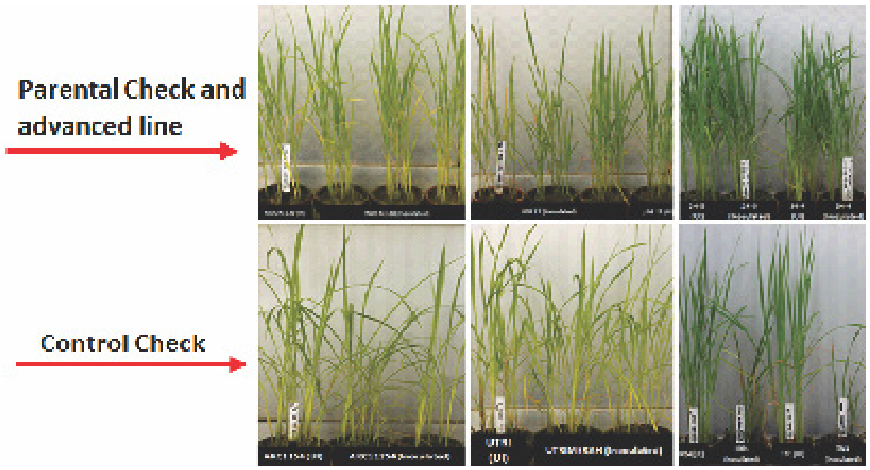


Figure 48. Tungro reaction of parent checks and advanced lines and control checks. Inoculation with tungro resulted in minimal damage in the advanced lines.

Figure 49. Lesion length of advanced lines indicates resistant reaction against PXO 99 (Race 6).

VI. Development of rice varieties adapted to rainfed and stress environments

Project Leader: Dr. Norvie L. Manigbas

Climate change involves long-term shift alteration of the climate system in large scale. Changes in Philippine climate as a whole include increase in rainfall, mean daily temperature, heat-waves intensity, floods, droughts and typhoons. These climate variability and extreme episodes will highly affect rice production. Lasco et al in 2007 reported 82.4% of total rice losses between 1970 and 1990 due to typhoons, floods and drought. Simulation models based on Philippine condition, yield will decline from 6.6-14% for every 10C increase in temperature.

Due to these extreme weather variations that will occur on different regions of the country, there is a need for improvement and development of new rice varieties for rainfed ecosystem and stress environments.

Breeding drought tolerant rice varieties

NV Desamero, CC Cabusora, KRP Balmeo, MAL Tadique, GD Valida, JC Bagarra

Drought is a major restricting factor in rice production under rainfed ecosystem. Developing drought tolerant varieties with high yield potential is one of the challenges in breeding for rainfed lowland rice environment. To cope with this challenge, different breeding strategies, which include classical hybridization and selection, in vitro culture, in vitro mutagenesis and anther culture are employed to generate and develop improved breeding lines for the target ecosystem. This study prioritizes drought tolerance improvement, along with other associated traits. Other traits crucial to adaptation and adoption in the target environments, which include high yield, good grain and eating quality and resistance to prevailing major diseases, are likewise considered in variety development.

Activities:

- Trait Discovery. New sources of genes for drought tolerance by scanning the naturally existing variability in the germplasm and through induced mutation. Selected traditional varieties (TRVs) (Figure 50) were evaluated for drought tolerance. Identified drought tolerant germplasm were further characterized agronomically for economically desirable traits, grain quality traits and traits associated with drought tolerance. The selected high yielding but drought sensitive commercial varieties and drought tolerant traditional varieties lacking the acceptable morphological, agronomical and grain quality traits were mutated via tissue culture to generate somaclones or androclones, or treated with gamma-ray irradiation using either seeds or in vitro generated calli effecting in vitro mutagenesis .

- Breeding line development. Breeding populations were generated through several strategies, viz. conventional/classical hybridization and selection, doubled haploid breeding and mutation breeding. Line development requires a series of trait evaluation, followed by selection towards agronomic uniformity and stabilizing the performance through fixing the genotypes. Parental genotypes with complementary traits were used in making crosses. A target of 30 crosses per year, viz.,single, double, top or three-way and double crosses was made to generate F1 progenies. Breeding lines were generated from F2 or F3 families (pedigree or modified bulk-pedigree) and advanced to succeeding generations until fixed at F5-F7. Line and plant selection (3 plants selected per line) was performed on the basis of phenotypic acceptability.

- Field Performance Evaluation. Fixed lines from the pedigree nursery, as well as, stable doubled haploid lines (DHLs) and mutants were evaluated initially in the observational nursery (ON) for preliminary yield performance under non-stress irrigated and drought stress condition during the dry season (DS) and wet season (WS) and simulated rainfed condition.

Results:

- For trait discovery, 52 TRV's collected from Northwest Luzon were evaluated and characterized from 2015 WS to 2016 DS (Table 44) for agronomic traits, blast resistance, grain quality seedling and reproductive drought stress tolerance to generate novel sources of genes. Days to heading ranged from 71 DAS to 108 DAS, plant stature from 83cm to 176cm, panicle length from 18cm to 36cm, productive tiller from 9 to 16 and grain yield 0.433tha-1 to 5.685tha-1.

- Of the 52 TRV's screened for seedling drought tolerance, 26 (52%) were identified putatively tolerant, and 13 of which were evaluated for reproductive drought stress tolerance. Leaf rolling score ranged from 3 (leaves folding – deep V-shape) to 0 (leaves healthy), grain yield/plant from 0.7g to 17.4 grams. Screening of the remaining 50% (13 TRV's) putatively tolerant TRVs will be done in 2017 DS. Putatively tolerant TRVs will be re-screened in 2017 for validation.

- Of the 50 TRV's evaluated, 19 (38%) were identified resistant,

11 (22%) with intermediate resistance and 20 (40%) were susceptible.

- Grain quality evaluation of 50 TRV's indicated a range of Grade 3 (31.4%) to Grade 1 (55.6%), head rice recovery and Grade 3 (10.6%) to Grade 1 (3.0%) chalkiness. For amylose content (AC), 2 (4%) TRV's were waxy, 11 (22%) with very low AC, 1 (5%) low, 30 (60%) intermediate and 6 (30%) high AC.

- The 435 early generation (M3) mutant lines from 13 genotypes were screened for drought tolerance at seedling stage identifying 68 (15%) lines from 10 genotypes putatively tolerant. Robust plants were retrieved and grown to maturity for seeds to be used in 2017 for uniformity and stability evaluation of agronomic and other traits of interest.

- For breeding line development, 59 and 37 single crosses were made in 2016 DS and WS (Table 45), combining drought tolerance with submergence, saline tolerance and other desirable agronomic traits. Donor parents selected were newly released varieties, high yielding elite inbred lines, elite lines with tolerance to single or multi-abiotic stresses. A total of 3,845 (DS) and 722 (WS) F1 seeds were generated for evaluation and F2 seed production in 2016 WS and 2017 DS.

- Pedigree nursery evaluation of 2,952 breeding lines from 50 crosses at F3 to F7 generation for line selection and generation advance was conducted. A total of 578 lines from 37 crosses were selected in 2016DS, of which 208 (36.7%) lines from 30 crosses were selected for phenotypic acceptability in 2016WS. Selections will be further evaluated for uniformity in 2017 DS.

- Evaluation of 141 breeding lines from 7 crosses at F8 generation in 2016 DS and 216 line from 10 crosses at F8 generation in 2016 WS resulted in the selection of 11 and 32 lines, respectively, based on good phenotypic acceptability, uniformity and kernel quality. Selections will be evaluated for reproductive drought stress tolerance in 2017 DS

- Fast tracking fixed line development was done by culturing anthers from F1 and F2 progenies of single crosses. Seeds of R3 and R4 generation were used for multi-trait evaluation, drought tolerance screen, and multi-location field performance evaluation.

- The 57 R2 DHL from the cross NSIC Rc222/BPI76 were evaluated for uniformity in 2016 DS from which 45 (79%) lines were observed to have agro-morphologically uniform plants and 12 (21%) lines segregating, from which plant selections was made generating sub-lines. The selected 2 lines and 36 plants were evaluated further in 2016 WS, flowering from 86 DAS to 102 DAS. No other agronomic traits and grain yield data were collected as typhoons "Karen" and "Lawin" devastated the experiment. The lines will be re-evaluated in 2017 DS.

- Somaclonal and androclonal variants and gamma-irradiated seed-derived mutants generated from trait discovery activity were developed into breeding lines by subjecting them to multi-trait evaluation which include agronomic and grain quality traits, biotic and abiotic stress tolerance and multi-location field performance.

- The 73 putative seedling drought tolerant mutant lines from 10 genotypes evaluated for yield potential under non-stress irrigated condition in 2016 DS, yielded 50 (68%) lines with grain yield of 5.134tha-1 to 9.918tha-1 (Table 46). Re-evaluation of the lines for yield under non-stress condition and performance under drought stress will be conducted in 2017 DS.

- Evaluation for drought tolerance at reproductive stage of 81 mutant lines derived from 15 genotypes, conducted in 2016 DS, registered leaf rolling scores of 3 to 0 and phenotypic acceptability of 3 to 7. Seed yield per plant ranged from 0 to 29.5g. The identified reproductive drought tolerant 9 (11%) mutant lines will be evaluated for field performance under non-stress irrigated and managed drought stress in 2017 DS.

- The 42 NSIC Rc222-derived mutant lines at M7 evaluated in 2016 WS for agronomic traits and yield flowered from 89 DAS to 91 DAS, comparable to the wildtype. No other valid data was obtained as the experiment was devastated by typhoon "Karen" and "Lawin". Re-evaluation for field performance and validation for rice tungro disease (RTD) resistance will be conducted in 2017 DS.

- A total of 546 (89%) of the 616 SM6 NSIC Rc222-derived lines evaluated for uniformity and agronomic traits in 2016 DS, survived to maturity. Heading ranged from 75 DAS to 87 DAS and plant height from 89 cm to 130 cm. A total of 56 (10%) lines were selected for phenotypic acceptability (Figure 51). Evaluation of the selected lines for amylose content and RTD resistance will be carried out in 2017 DS.

- The field performance of 206 breeding lines from various sources, together with 4 check varieties (IR64, PSB Rc14, NSIC Rc192 and NSIC Rc222) were evaluated for growth and yield performance under non-stress irrigated (ILD) and managed drought (DRD) during the DS, and under irrigated (ILW) and simulated rainfed (RFW) condition during the WS. The trials were laid-out in a Randomized Complete Block Design with three replications. The seeds were sown in a raised seedbed method and transplanted after 21 days from seeding. Seedlings were transplanted in 8.8 m2 plot size.

- Under ILD, the breeding lines yielded 1.006tha-1 to 6.595 tha-1, with PR40887-B-3-1-1-3-3-1 yielding the highest. The yield of 16 (8%) lines ranged from 6.4% (5.466 tha-1) to 28.3% (6.595 tha-1) higher than the highest yielding check, IR64 with 5.139 tha-1 grain yield. Days to heading of the breeding lines ranged from 80 DAS to 102 DAS.

- Under DRD, the breeding lines yielded 0.218tha-1 to 4.062tha-1, identifying PR40871-B-2-1-2-1-1-3 as the highest yielding entry. A total of 20 (10%) lines had yield advantage (YA) of 6.8% (2.800tha-1) to 55.0% (4.062tha-1) over the highest yielding check, NSIC Rc192 which yielded 2.621 tha-1. Heading days of the lines under drought was 74 DAS to 104 DAS.

- Stress tolerance index (STI) of the breeding lines and the check varieties was 0.039 to 1.127 and 0.424 to 0.653, respectively. The lines and check variety with the highest STI was PR41561-B-7-Sal1-1-3 and PSB Rc14, respectively.

- The field performance trial during the 2016 WS was devastated by typhoons "Karen" and "Lawin". Thus, on the basis of the DS performance (yield under irrigated and managed drought, YA and STI) a selection of 19 (9%) lines were made (Table 47). Processing of yield component data from the DS evaluation is in progress.

- The 47 NCT-ready lines were evaluated for grain quality, viz., milling recovery, physical attributes and physico-chemical traits (Table 48). Head rice recovery ranged from Grade 2 (64.1%) to Grade 1 (68.9%) and amylose content were intermediate (19.1% to 22%) to high (22.1% to 24.1%).

Table 44. Evaluation and characterization of the 52 traditional varieties (TRV) for agronomic traits, blast (Bl) resistance and grain quality traits.

No.	Genotype	Agronomic Trait					Bl	Milling Recovery						Physical Attributes						Physico-chemical		
		Days to Heading (DAS)	Plant Height (cm)	Productive Tiller (no.)	Panicle Length (cm)	Grain Yield (t/ha)		Brown Rice		Milled Rice		Head Rice		Chalky		GL		GS		CP	AC	
								%	Cl	%	Cl	%	Cl	%	Cl	mm	Cl	mm	Cl	%	%	Cl
1	Arimuram*	83	153	14	30	1.901	I	79.5	F	72.4	Pr	37.1	G3	7.5	G2	6.3	M	2.6	I	6.2	21.6	I
2	Aringay*	92	134	14	23	5.332	R	78.0	F	71.7	Pr	34.5	G3	4.5	G1	5.5	M	2.3	I	6.4	18.2	I
3	Awan Sapulemon*	90	134	13	23	0.433	R	78.9	F	71.2	Pr	27.4	aa	5.0	G1	6.5	L	2.8	I	6.6	19.1	I
4	Azucena	80	141	13	25	2.903	S	79.9	F	74.3	Pr	32.3	G3	10.6	G3	5.8	M	2.1	I	6.2	19.0	I
5	Baddang*	102	99	13	24	2.901	S	78.6	F	72.5	Pr	33.4	G3	27.8	aa	6.9	L	3.1	S	3.6	26.3	H
6	Ballatinaw (dati)	104	169	15	36	0.523	S	79.8	F	71.1	Pr	48.7	G1	28.7	aa	5.6	M	1.8	B	6.5	19.4	I
7	Ballatinaw (Luna)	80	138	11	25	2.378	S	80.8	G	72.1	Pr	24.3	aa	36.5	aa	5.2	Sh	1.7	B	6.7	19.0	I
8	Ballatinaw (Mt. Province)	78	149	9	28	2.689	R	75.0	F	62.8	G2	20.4	aa	78.4	aa	5.5	M	1.7	B	7.7	9.5	VL
9	Balsamo a*	104	103	15	27	4.709	S	78.7	F	70.1	Pr	18.0	aa	1.0	Pr	6.9	L	3.1	S	7.5	24.0	H
10	Balsamo b	105	141	13	18	2.201	I	80.5	G	73.9	Pr	49.6	G1	9.6	G2	5.5	M	1.9	B	6.2	20.3	I
11	Balud	102	147	11	26	2.534	I	79.7	F	71.2	Pr	48.3	G1	1.5	Pr	7.0	L	3.3	S	6.3	21.6	I
12	Buga	106	147	10	24	2.105	S	78.1	F	71.9	Pr	43.7	G2	11.4	G3	5.9	M	2.1	I	3.7	20.3	I
13	Bukutan	106	156	9	25	2.424	S	79.9	F	73.0	Pr	34.2	G3	48.1	aa	6.1	M	2.0	B	6.8	20.9	I
14	Bulilising*	107	152	10	25	2.459	S	79.2	F	73.3	Pr	14.2	aa	*w*		5.9	M	2.1	I	6.4	3.6	VL
15	Burgis	98	171	11	29	2.297	S	76.1	F	69.9	G1	24.3	aa	*w*		6.5	M	2.6	I	6.7	3.0	VL
16	Dagmuy*	78	168	10	32	2.646	R	80.0	G	72.3	Pr	19.3	aa	54.1	aa	6.7	L	2.6	I	7.1	20.9	I
17	Dinorado	90	156	13	22	3.629	I	78.4	F	70.6	Pr	32.6	G3	20.4	aa	5.4	Sh	2.0	B	6.8	19.5	I
18	FancyRice	90	152	11	25	0.845	S	79.4	F	71.3	Pr	43.6	G2	24.6	aa	6.0	M	2.1	I	7.3	19.6	I
19	Gannal (Batac)	90	154	10	24	3.085	I	79.6	F	72.4	Pr	38.9	G2	30.2	aa	6.1	M	2.0	B	6.9	20.6	I
20	Gannal (Marcos)*	96	156	10	28	1.335	I	77.0	F	71.3	Pr	5.6	aa	10.7	G3	5.8	M	1.9	B	7.2	21.1	I
21	Getbaw	83	83	13	21	5.685	R	80.6	G	73.0	Pr	51.2	G1	5.4	G2	6.1	M	2.7	I	6.7	25.0	H
22	Isic Diket	78	149	13	26	1.335	S	79.6	F	73.2	Pr	13.1	aa	75.5	aa	5.8	M	2.0	B	6.9	8.1	VL
23	Isic Pugot	78	142	11	24	1.335	I	79.6	F	74.0	Pr	31.4	G3	11.4	G3	5.6	M	1.9	B	6.3	19.6	I
24	Kilong	79	154	12	31	1.335	R	77.8	F	70.9	Pr	41.9	G2	*w*		6.4	M	2.5	I	7.3	3.8	VL
25	Langpadan	80	134	13	23	3.937	S	75.0	F	70.1	Pr	23.5	aa	15.0	G3	5.7	M	2.3	I	5.9	22.4	H
26	Lukdit ni Abalayan	80	135	12	24	2.951	R	78.1	F	70.6	Pr	9.2	aa	31.9	aa	6.1	M	2.1	I	5.4	19.3	I
27	Madalia	95	145	12	30	1.659	I	79.6	F	72.9	Pr	34.8	G3	*w*		5.8	M	2.0	B	7.1	2.3	VL
28	Malagkit	87	139	14	26	2.752	I	77.3	F	71.9	Pr	38.4	G3	*w*		5.2	Sh	1.7	B	7.1	1.8	W
29	Malapay	87	149	13	28	0.637	S	76.8	F	69.5	G1	42.6	G2	*w*		5.9	M	2.0	B	6.3	2.2	VL
30	Maliketa	97	155	14	23	1.005	I	78.8	F	73.1	Pr	18.1	aa	11.3	G3	6.1	M	2.0	B	6.9	22.0	I
31	Minama	92	156	14	24	1.113	R	78.6	F	70.7	Pr	7.6	aa	21.2	aa	5.9	M	2.1	I	7.2	19.1	I
32	Mindanao	98	165	13	31	1.889	R	79.6	F	72.1	Pr	33.3	G3	16.2	aa	7.1	L	3.0	I	7.0	19.0	I
33	Mindoro	87	162	14	28	1.336	R	80.4	G	75.0	Pr	33.8	G3	5.9	G2	5.6	M	2.1	I	5.6	20.8	I
34	Nylon*	87	155	14	29	2.712	R	78.1	F	72.8	Pr	43.2	G2	19.9	aa	5.7	M	2.1	I	5.7	21.1	I
35	Palawan a*	87	143	14	26	1.335	R	79.7	F	73.3	Pr	35.5	G3	15.6	aa	5.6	M	2.1	I	6.0	20.7	I
36	Pamplona*	87	155	15	27	4.74	S	80.5	G	74.5	Pr	34.0	G3	5.6	G2	5.6	M	2.1	I	5.8	20.7	I
37	Parina*	79	162	14	27	1.47	R	75.5	F	69.7	G1	6.1	aa	3.0	G1	5.7	M	1.9	B	6.0	5.7	VL
38	Payakan*	78	118	16	30	4.55	I	73.5	P	68.2	G1	9.6	aa	3.4	G1	6.6	L	2.7	I	7.1	2.1	VL
39	Pinal-ug*	78	149	14	23	1.56	R	78.5	F	71.8	Pr	8.9	aa	46.4	aa	5.5	M	1.9	B	6.4	18.7	I
40	Pinyas*	71	161	12	27	3.55	R	76.5	F	67.7	G1	14.6	aa	22.1	aa	5.4	Sh	2.1	I	6.1	23.4	H
41	Purtok*	103	163	11	31	1.51	R	77.5	F	69.0	G1	15.5	aa	24.3	aa	5.3	Sh	2.1	I	6.4	23.2	H
42	Rafinan*	103	153	13	20	3.07		79.6	F	72.9	Pr	14.8	aa	16.5	aa	6.1	M	2.2	I	6.6	20.4	I
43	Saba*	103	167	12	26	2.10	S	77.6	F	70.6	Pr	55.6	G1	70.5	aa	5.4	Sh	1.7	B	6.6	20.4	I
44	Sabadilla*	103	152	14	27	1.37	S	78.2	F	70.8	Pr	35.4	G3	*w*		6.2	M	2.2	I	6.8	2.8	VL
45	Sinelat*	103	152	13	28	0.59	S	76.7	F	69.9	G1	35.4	G3	*w*		6.2	M	2.2	I	6.5	2.0	W
46	Tagaling*	105	165	11	23	2.36	R	78.0	F	71.3	Pr	33.6	G3	55.1	aa	5.3	Sh	1.9	B	3.8	19.8	I
47	Unig*	106	167	13	26	2.87	S	76.7	F	70.4	Pr	18.6	aa	25.8	aa	6.4	M	2.6	I	6.7	7.8	VL
48	Oskil*	108	176	9	27	3.59	S	78.2	F	72.3	Pr	35.7	G3	26.7	aa	5.3	Sh	1.7	B	7.0	19.1	I
49	Zambales	102	125	10	21	1.92	R	75.1	F	68.3	G1	3.8	aa	11.7	G3	5.9	M	2.4	I	7.8	13.2	L
50	Gobyerno B*	83	151	11	29	3.274		77.9	F	67.1	G1	6.2	aa	17.4	aa	6.2	M	2.5	I	6.6	21.6	I
Minimum		*71*	*82.8*	*8.6*	*18.2*	*0.433*		*73.5*		*62.8*		*3.8*		*1.0*		*5.2*		*1.7*		*3.6*	*1.8*	
Maximum		*108*	*175.8*	*15.8*	*35.8*	*5.685*		*80.8*		*75.0*		*55.6*		*78.4*		*7.1*		*3.3*		*7.8*	*26.3*	
Range		*37*	*93*	*7.2*	*17.6*	*5.252*		*7.3*		*12.2*		*51.8*		*77.4*		*1.9*		*1.6*		*4.3*	*24.4*	
Mean		*91.8*	*148.1*	*12.4*	*26.2*	*2.4*		*78.3*		*71.3*		*28.3*		*23.1*		*5.9*		*2.2*		*6.5*	*16.3*	
Standard deviation		*10.7*	*18.1*	*1.7*	*3.3*	*1.2*		*1.7*		*2.1*		*13.9*		*20.0*		*0.5*		*0.4*		*0.9*	*7.6*	
CV		*11.7*	*12.2*	*13.8*	*12.7*	*52.4*		*2.1*		*3.0*		*49.2*		*86.9*		*8.2*		*17.9*		*13.6*	*46.6*	

**putative drought tolerant at seedling stage   aa-beyond range   w-waxy   Cl-class*

Table 45. Generated F1 seeds from single crosses made in 2016 DS and WS, PhilRice CES.

No.	PR No.	Parentage	Target Trait	F_1 seeds
Dry Season				
1	PR48965	DEZO 300/NSIC Rc288	High yielding, grain quality, drought tolerance	78
2	PR48943	NSIC Rc238 /Kinandang Patong	High yielding, drought tolerance, deep root	20
3	PR49495	Kinandang Patong/NSIC Rc238	High yielding, drought tolerance, deep root	20
4	PR49455	Raeline 10/YEY 36 - IR64-NIL 5	drought tolerance, submergence tolerance	268
5	PR49456	Raeline 10/YEY 48 - IR64	drought tolerance, submergence tolerance	235
6	PR49457	DEZO 300/HHZ 1-SAL 9-Y1	High yielding, grain quality, Drought, Submergence and Saline tolerance	40
7	PR49458	DEZO 300/HHZ 5-SAL 9-Y 3-Y 1	High yielding, grain quality, Drought, Submergence and Saline tolerance	8
8	PR49472	PSB Rc68/HHZ 1-SAL 9-Y1	Drought, Submergence and Saline tolerance	17
9	PR49493	FL478/PSB Rc68	Drought, Submergence and Saline tolerance	2
10	PR48968	NSIC 2012 Rc300/Ciherang-Sub1	High yielding, Submergence tolerance	139
11	PR48946	NSIC 2011 Rc240/Ciherang-Sub1	High yielding, Submergence tolerance	61
12	PR48958	NSIC 2013 Rc308/Ciherang-Sub1	High yielding, Submergence tolerance	
13	PR48960	NSIC 2012 Rc298/PSB Rc68	High yielding, Submergence tolerance	100
14	PR48961	NSIC 2012 Rc298/NSIC Rc194	High yielding, Submergence tolerance	177
15	PR48967	DEZO 300/PSB Rc18 Sub1	High yielding, grain quality, Submergence tolerance	21
16	PR48980	NSIC Rc300/NSIC Rc194	High yielding, Submergence tolerance	80
17	PR49475	PSB Rc68/YEY 18 - NSIC Rc158	Submergence tolerance	4
18	PR49476	PSB Rc68/YEY 36 - IR64-NIL 5	Submergence tolerance	26
19	PR49477	PSB Rc68/YEY 48 - IR64	Submergence tolerance	3
20	PR49492	YEY 3 - NSIC Rc158/PSB Rc68	High yielding, Submergence tolerance	88
21	PR49494	Ciherang-Sub1/NSIC 2012 Rc300	High yielding, Submergence tolerance	65
22	PR49496	Ciherang-Sub1/NSIC 2011 Rc240	High yielding, Submergence tolerance	68
23	PR49497	Ciherang-Sub1/NSIC 2013 Rc308	High yielding, Submergence tolerance	97
24	PR49448	NSIC RC 222/NSIC 2013 Rc330	High yielding, Saline tolerance	249
25	PR49459	NSIC 2012 Rc300/NSIC Rc 326	High yielding, Saline tolerance	23
26	PR49460	NSIC 2012 Rc300/NSIC Rc340	High yielding, Saline tolerance	79
27	PR49461	DEZO 300/NSIC Rc340	High yielding, grain quality, Saline tolerance	52
28	PR49462	NSIC 2011 Rc240/NSIC Rc334	High yielding, Saline tolerance	23
29	PR49463	NSIC 2012 Rc298/NSIC Rc334	High yielding, Saline tolerance	12
30	PR49464	NSIC 2012 Rc300/NSIC Rc334	High yielding, Saline tolerance	116
31	PR49465	NSIC 2013 Rc308/NSIC Rc334	High yielding, Saline tolerance	4
32	PR49466	DEZO 300/NSIC Rc334	High yielding, grain quality, Saline tolerance	33
33	PR49467	NSIC 2011 Rc240/NSIC Rc336	High yielding, Saline tolerance	35
34	PR49468	NSIC 2012 Rc298/NSIC Rc336	High yielding, Saline tolerance	96
35	PR49469	NSIC 2012 Rc300/NSIC Rc336	High yielding, Saline tolerance	21
36	PR49470	NSIC 2013 Rc308/NSIC Rc336	High yielding, Saline tolerance	17
37	PR49471	DEZO 300/NSIC Rc336	High yielding, grain quality, Saline tolerance	80
38	PR49478	NSIC 2013 Rc330/NSIC RC 222	High yielding, Saline tolerance	120
39	PR49481	NSIC Rc326/NSIC 2012 Rc300	High yielding, Saline tolerance	20
40	PR49482	NSIC Rc340/NSIC 2011 Rc240	High yielding, Saline tolerance	73
41	PR49483	NSIC Rc340/NSIC 2012 Rc298	High yielding, Saline tolerance	8
42	PR49485	NSIC Rc334/NSIC 2011 Rc240	High yielding, Saline tolerance	27

Table 45. Generated F1 seeds from single crosses made in 2016 DS and WS, PhilRice CES. (Con't...)

43	PR49486	NSIC Rc334/NSIC 2012 Rc298	High yielding, Saline tolerance	89
44	PR49487	NSIC Rc336/NSIC 2011 Rc240	High yielding, Saline tolerance	51
45	PR49488	NSIC Rc336/NSIC 2012 Rc298	High yielding, Saline tolerance	88
46	PR49489	NSIC Rc336/NSIC 2012 Rc300	High yielding, Saline tolerance	17
47	PR49490	NSIC Rc336/NSIC 2013 Rc308	High yielding, Saline tolerance	45
48	PR49491	NSIC Rc336/DEZO 300	High yielding, grain quality, Saline tolerance	91
49	PR48973	DEZO 300/IR86385-38-1-1-B	High yielding, grain quality, Submergence and Saline tolerance	3
50	PR48997	NSIC Rc300/IR86385-38-1-1-B	High yielding, Submergence and Saline tolerance	26
51	PR49449	YEY 36 - IR64-NIL 5/NSIC 2013 Rc330	Submergence and Saline tolerance	125
52	PR49450	YEY 48 - IR64/NSIC 2013 Rc330	Submergence and Saline tolerance	48
53	PR49451	YEY 48 - IR64/CSR 88-IR-13	Submergence and Saline tolerance	48
54	PR49452	NSIC Rc190 /NSIC Rc194	Submergence and Saline tolerance	33
55	PR49453	NSIC Rc190 /PSB Rc68	Submergence and Saline tolerance	4
56	PR49454	NSIC Rc190 /PSB Rc18 Sub1	Submergence and Saline tolerance	12
57	PR49479	NSIC 2013 Rc330/YEY 36 - IR64-NIL 5	Submergence and Saline tolerance	303
58	PR49480	NSIC 2013 Rc330/YEY 48 - IR64	Submergence and Saline tolerance	136
59	PR49498	IR86385-38-1-1-B/NSIC Rc300	High yielding, Submergence and Saline tolerance	21
Total				3,845
Wet Season				
1		NSIC Rc330 /Ciherang Sub-1	Saline and Submergence Tolerance	26
2		NSIC Rc338 /Ciherang Sub-1	Saline and Submergence Tolerance	18
3		Ciherang Sub-1/NSIC Rc330	Submergence and Saline Tolerance	7
4		Ciherang Sub-1/NSIC Rc338	Submergence and Saline Tolerance	48
5		PSB Rc68 /NSIC Rc330	Saline and Submergence Tolerance	
6		DEZO 300/PR40858-NSIC Rc9-M4R-383	Drought Tolerance and High Yielding	14
7		DEZO 300/PR41395-NSIC Rc9-IVM2009DS 1-11-4	Drought Tolerance and High Yielding	80
8		NSIC Rc308/PR38560-1-Azucena-Coll. No. 1528- M5R-1 DrS111	Drought Tolerance and High Yielding	17
9		NSIC Rc308/PR40858-NSIC Rc9-M4R-383	Drought Tolerance and High Yielding	6
10		NSIC Rc308 /PR40858-NSIC Rc9-M4R-310	Drought Tolerance and High Yielding	28
11		NSIC Rc308 /PR41395-NSIC Rc9-IVM2009DS 1-11-4	Drought Tolerance and High Yielding	2
12		NSIC Rc352 /PR38560-1-Azucena-Coll. No. 1528- M5R-1 DrS111	Drought Tolerance and High Yielding	18
13		NSIC Rc352 /PR40858-NSIC Rc9-M4R-383	Drought Tolerance and High Yielding	49
14		NSIC Rc352 /PR40858-NSIC Rc9-M4R-310	Drought Tolerance and High Yielding	45
15		NSIC Rc352 /PR41395-NSIC Rc9-IVM2009DS 1-11-4	Drought Tolerance and High Yielding	7
16		NSIC Rc354 /PR38560-1-Azucena-Coll. No. 1528- M5R-1 DrS111	Drought Tolerance and High Yielding	
17		NSIC Rc354 /PR40858-NSIC Rc9-M4R-383	Drought Tolerance and High Yielding	7
18		NSIC Rc354 /PR40858-NSIC Rc9-M4R-310	Drought Tolerance and High Yielding	1
19		NSIC Rc358 /PR40858-NSIC Rc9-M4R-383	Drought Tolerance and High Yielding	23
20		NSIC Rc358 /PR40858-NSIC Rc9-M4R-310	Drought Tolerance and High Yielding	9
21		NSIC Rc358/PR41395-NSIC Rc9-IVM2009DS 1-11-4	Drought Tolerance and High Yielding	47
22		PR40858-NSIC Rc9-M4R-383/DEZO 300	Drought Tolerance and High Yielding	13
23		PR41395-NSIC Rc9-IVM2009DS 1-11-4/DEZO 300	Drought Tolerance and High Yielding	5
24		PR38560-1-Azucena-Coll. No. 1528- M5R-1 DrS111/NSIC Rc308	Drought Tolerance and High Yielding	105

Table 45. Generated F1 seeds from single crosses made in 2016 DS and WS, PhilRice CES. (Con't...)

25		PR40858-NSIC Rc9-M4R-383/NSIC Rc308	Drought Tolerance and High Yielding	10
26		PR40858-NSIC Rc9-M4R-310/NSIC Rc308	Drought Tolerance and High Yielding	1
27		PR41395-NSIC Rc9-IVM2009DS 1-11-4/NSIC Rc308	Drought Tolerance and High Yielding	6
28		PR38560-1-Azucena-Coll. No. 1528- M5R-1 DrS111/NSIC Rc352	Drought Tolerance and High Yielding	11
29		PR40858-NSIC Rc9-M4R-383/NSIC Rc352	Drought Tolerance and High Yielding	
30		PR40858-NSIC Rc9-M4R-310/NSIC Rc352	Drought Tolerance and High Yielding	12
31		PR41395-NSIC Rc9-IVM2009DS 1-11-4/NSIC Rc352	Drought Tolerance and High Yielding	4
32		PR38560-1-Azucena-Coll. No. 1528- M5R-1 DrS111/NSIC Rc354	Drought Tolerance and High Yielding	9
33		PR40858-NSIC Rc9-M4R-383/NSIC Rc354	Drought Tolerance and High Yielding	45
34		PR40858-NSIC Rc9-M4R-310/NSIC Rc354	Drought Tolerance and High Yielding	2
35		PR38560-1-Azucena-Coll. No. 1528- M5R-1 DrS111/NSIC Rc358	Drought Tolerance and High Yielding	3
36		PR40858-NSIC Rc9-M4R-383/NSIC Rc358	Drought Tolerance and High Yielding	2
37		PR41395-NSIC Rc9-IVM2009DS 1-11-4/NSIC Rc358	Drought Tolerance and High Yielding	42
Total				722

Table 46. Selected stable (M5) mutant lines, 2016 DS, PhilRice, CES.

RL2016DS_SI
Seeding Date: December 18, 2015 — Planting Distance: 20 cm
No. of Rows x Hills: 3 rows x 21 hills — Replication: Unreplicated

No.	Field Code	Line Designation	Grain Yield (t/ha)	Days to Heading	Plant height (cm)	Panicle Length (cm)	Productive Tiller (no.)
1	MUT-16DS_SI-1	PR45713-Salumpikit-IVM2011WS 1-3-2-4	6.576	75	100	21	15
2	MUT-16DS_SI-2	PR45713-Salumpikit-IVM2011WS 1-6-3-1	9.805	75	98	25	17
3	MUT-16DS_SI-4*	PR37443-13/PR33382-25-1-1(MES) (Raeline 3) 4-3-4-1	9.310	87	99	22	16
4	MUT-16DS_SI-5*	PR37443-13/PR33382-25-1-1(MES) (Raeline 3) 4-3-4-2	6.724	84	121	28	13
5	MUT-16DS_SI-6*	FL378/PSB Rc18-Sub1//PSB Rc18-Sub1 1-2-1	6.103	83	109	24	16
6	MUT-16DS_SI-7	Tanggiling Mutant	4.486	87	73	20	15
7	MUT-16DS_SI-8	Tanggiling	6.256	80	156	23	13
8	MUT-16DS_SI-10	PR40060-Y Dam Do-IVC2008DS 1-2-2	8.353	87	104	22	18
9	MUT-16DS_SI-12	PR40060-Y Dam Do-IVC2008DS 2-3-1	5.134	77	105	21	17
10	MUT-16DS_SI-13	PR40060-Y Dam Do-IVC2008DS 2-3-2	6.360	87	102	21	17
11	MUT-16DS_SI-14	PR40060-Y Dam Do-IVC2008DS 2-4	7.429	87	106	23	16
12	MUT-16DS_SI-15	PR40060-Y Dam Do-IVC2008DS 2-5	5.913	87	102	23	17
13	MUT-16DS_SI-16	PR40060-Y Dam Do-IVC2008DS 3-3	5.608	87	105	21	18
14	MUT-16DS_SI-17	PR40060-Y Dam Do-IVC2008DS 4-5	6.522	87	108	22	16
15	MUT-16DS_SI-19	PR40060-Y Dam Do-IVC2008DS 6-4	5.794	87	108	22	21
16	MUT-16DS_SI-20	PR40060-Y Dam Do-IVC2008DS 7-3-1	6.074	87	103	21	19
17	MUT-16DS_SI-21	PR40060-Y Dam Do-IVC2008DS 7-3-2	9.918	84	113	26	15
18	MUT-16DS_SI-22	PR40060-Y Dam Do-IVC2008DS 7-4	9.908	87	101	23	16
19	MUT-16DS_SI-23	PR40060-Y Dam Do-IVC2008DS 10-1	11.397	87	104	23	18
20	MUT-16DS_SI-24	PR40060-Y Dam Do-IVC2008DS 10-2-1	13.349	92	295	25	18
21	MUT-16DS_SI-25	PR40060-Y Dam Do-IVC2008DS 10-2-2	8.317	87	109	23	18
22	MUT-16DS_SI-26	PR40060-Y Dam Do-IVC2008DS 13-1	9.219	83	119	24	16
23	MUT-16DS_SI-28	PR40060-Y Dam Do-IVC2008DS 14-6	6.236	87	111	24	17
24	MUT-16DS_SI-29	PR40060-Y Dam Do-IVC2008DS 15-1	6.942	87	109	22	17
25	MUT-16DS_SI-30	PR40060-Y Dam Do-IVC2008DS 15-2-1	8.173	80	97	23	15
26	MUT-16DS_SI-31	PR40060-Y Dam Do-IVC2008DS 15-2-2	5.577	87	114	22	17
27	MUT-16DS_SI-33	PR40060-Y Dam Do-IVC2008DS 22-5-1	7.609	87	109	22	18
28	MUT-16DS_SI-34	PR40060-Y Dam Do-IVC2008DS 22-5-2	8.431	87	107	22	18
29	MUT-16DS_SI-35	PR40060-Y Dam Do-IVC2008DS 23-4	8.457	87	111	23	17
30	MUT-16DS_SI-36	PR40060-Y Dam Do-IVC2008DS 7-1-1	6.337	90	112	27	19
31	MUT-16DS_SI-37	PR40060-Y Dam Do-IVC2008DS 7-1-3	6.720	91	113	25	15
32	MUT-16DS_SI-39	PR40060-Y Dam Do-IVC2008DS 15-3	6.574	87	113	23	17
33	MUT-16DS_SI-40	PR40060-Y Dam Do-IVC2008DS 15-4	6.312	85	116	25	19
34	MUT-16DS_SI-41	PR40060-Y Dam Do-IVC2008DS 17-2	6.588	90	125	27	16
35	MUT-16DS_SI-43	PR40060-Y Dam Do-IVC2008DS 6-5	6.410	80	115	25	19
36	MUT-16DS_SI-44	PR40063-SCRL2008DS 8-1	7.468	85	110	23	19
37	MUT-16DS_SI-45	PR40063-SCRL2008DS 14-3	6.420	87	91	20	18
38	MUT-16DS_SI-48	FR13A-IVM2012DS 101-1	7.563	80	105	25	14
39	MUT-16DS_SI-49	FR13A-IVM2012DS 101-10	7.199	80	94	23	17
40	MUT-16DS_SI-50	PR41907-Vandana-IVC2010DS 1-9	5.577	75	109	26	13
41	MUT-16DS_SI-54*	NSIC Rc240/NSIC Rc194-ACRL-2014WS 2-1-1	7.170	75	91	23	14
42	MUT-16DS_SI-56*	NSIC Rc240/NSIC Rc194-ACRL-2014WS 2-1-3	5.008	83	97	22	14
43	MUT-16DS_SI-59*	NSIC Rc240/NSIC Rc194-ACRL-2014WS 2-1-9	5.745	83	93	21	15
44	MUT-16DS_SI-61	PR40060-Y Dam Do-IVC2008DS 5-4 (tall)	5.526	90	108	28	16
45	MUT-16DS_SI-66	PR40060-Y Dam Do-IVC2008DS 8-1	7.535	87	105	17	14
46	MUT-16DS_SI-72	Salumpikit 1-3-24	6.318	75	99	20	13
47	MUT-16DS_SI-73	Salumpikit 1-6-10	5.407	75	95	23	14
48	MUT-16DS_SI-74	Salumpikit 1-6-10	5.423	75	23	24	15
49	MUT-16DS_SI-91	PR45719-KDML 105-SM2012DS-94-13-DRT1	5.508	80	107	25	18
50	MUT-16DS_SI-92	PR45719-KDML 105-SM2012DS-94-13-DRT2	6.591	83	102	23	15
Minimum			*4.486*	*75*	*23*	*17*	*13*
Maximum			*13.349*	*92*	*295*	*28*	*21*
Range			*8.863*	*17*	*272*	*11*	*8*
Mean			*7.068*	*84*	*108*	*23*	*16*
Standard Deviation			*1.719*	*4.8*	*31.5*	*2.1*	*1.9*
CV			*24.3*	*5.7*	*29.0*	*9.1*	*11.8*

**doubled haploid lines*

Table 47. Selected lines based on yield under ILD and DRD and STI, 2016 DS PhilRice CES.

No.	Field Code	Genotype	Days to Heading (DAS)		Grain Yield (tha^{-1})		STI
			IL	MDR	IL	MDR	
1	IR64		86	89	5.139	1.426	0.424
2	NSIC Rc192		81	89	4.096	2.621	0.621
3	NSIC Rc222		84	73	**4.832**	1.940	0.542
4	PSB Rc14		87	81	4.381	**2.58**	0.653
5	RFL_2016DS -170	PR42271-1-1-6-40	86	97	5.931	0.462	0.159
6	RFL_2016DS -156	PR40872-B-1-2-3-3-2-1	85	87	5.568	0.904	0.291
7	RFL_2016DS -169	PR42271-1-1-6-40	84	88	5.557	1.103	0.354
8	RFL_2016DS -78	PR41566-B-13-1-BCg-2	82	82	5.469	1.549	0.490
9	RFL_2016DS -51	PR42156-B-6-2-1-2-1	85	87	5.718	1.502	0.496
10	RFL_2016DS -147	PR40887-B-4-2-3-2-2-1	85	92	5.782	1.734	0.579
11	RFL_2016DS -137	PR40871-B-96-1-1-1-1-2	85	92	4.133	2.534	0.605
12	RFL_2016DS -67	PR42167-B-B-16-1-3-1	87	87	5.877	1.941	0.659
13	RFL_2016DS -168	PR40887-B-3-1-1-3-3-1	87	87	6.595	1.930	0.736
14	RFL_2016DS -144	PR40873-B-1-1-2-2-1-1	85	80	5.523	2.338	0.747
15	RFL_2016DS -62	PR42167-B-B-27-1-2-1	87	86	6.152	2.329	0.828
16	RFL_2016DS -143	PR40893-B-29-1-1-3-1-1	85	82	5.701	2.728	0.899
17	RFL_2016DS -136	PR40871-B-3-1-3-1-1-2	93	94	5.830	2.680	0.903
18	RFL_2016DS -7	PR42156-B-4-1-1-1-1	93	98	5.298	3.063	0.938
19	RFL_2016DS -129	PR40871-B-37-1-3-2-1-2	84	87	5.466	3.021	0.954
20	RFL_2016DS -138	PR40871-B-102-2-3-2-1-1	83	88	5.206	3.224	0.970
21	RFL_2016DS -94	PR41561-B-10-Sal4-1-1	86	87	5.672	3.034	0.995
22	RFL_2016DS -189	PR45713-Salumpikit-IVM2011WS 1-3-2-DRT3	84	84	6.001	2.950	1.023
23	RFL_2016DS -82	PR41561-B-7-Sal1-1-3	86	88	5.472	3.563	1.127
Minimum			*82*	*80*	*4.133*	*0.462*	*0.159*
Maximum			*93*	*98*	*6.595*	*3.563*	*1.127*
Range			*11*	*18*	*2.461*	*3.101*	*0.968*
Mean			*86*	*88*	*5.629*	*2.242*	*0.724*
Standard Deviation			*2.8*	*4.7*	*0.483*	*0.862*	*0.274*
Coefficient of Variation			*3.3*	*5.3*	*8.579*	*38.463*	*37.817*

Table 48. Grain quality evaluation of 47 NCT-Ready lines, 2016 WS, PhilRice, CES.

NO	Line Designation	BR (%)		MR (%)		HR (%)		%Chalky		GL		GS		%CP	%AC		GT	
		%	CL	%	CL	%	CL	%	CL	mm	CL	mm	CL		%	CL	ASV	Class
1	PR41395-NSIC Rc9-IVM2009DS 3-1-1	73.0	P	66.4	G1	43.3	G2	12.6	G3	6.7	L	2.8	I	8.1	19.1	I	3.6	HI
2	PR42837-NSIC Rc222-SM-DR-10	72.7	F	64.1	G2	37.1	G3	9.7	G2	6.6	L	3.0	I	8.2	20.1	I	4.1	I
3	PR42837-NSIC Rc222-SM-DR-12	75.4	F	65.9	G1	50.8	G1	15.4	G3	7.0	L	3.2	S	8.2	20.1	I	3.7	HI
4	PR39950-B-15-B-7-2	75.0	F	66.2	G1	48.5	G1	14.1	G3	7.1	L	3.3	S	7.9	20.7	I	3.7	HI
5	PR42837-NSIC Rc222-SM-DR-1	76.5	F	67.8	G1	48.1	G1	10.4	G3	7.1	L	3.4	S	8.3	22.3	I	4.7	I
6	PR42837-NSIC Rc222-SM-DR-15	75.0	F	67.4	G1	44.0	G2	13.1	G3	7.0	L	3.2	S	8.6	21.0	I	3.8	HI
7	PR42837-NSIC Rc222-SM-DR-7	76.4	F	67.9	G1	45.9	G2	15.4	G3	6.5	M	2.8	I	8.5	20.1	I	3.5	HI
8	PR42837-NSIC Rc222-SM-DR-9	75.2	F	68.5	G1	51.9	G1	17.4	G3	6.1	M	2.6	I	8.9	21.5	I	5.0	I
9	PR39919-B-10-B-4-2	75.8	F	68.9	G1	43.5	G2	22.2	G3	6.3	M	2.6	I	8.2	22.2	H	5.7	I
10	PR39955-B-8-1-3-1	75.5	F	68.0	G1	43.6	G2	20.7	G3	6.7	L	3.0	I	7.4	20.2	I	3.3	HI
11	PR42837-NSIC Rc222-SM-DR-11	74.7	P	65.7	G1	40.4	G2	14.7	G3	6.6	L	2.8	I	7.9	20.2	I	3.5	HI
12	PR42837-NSIC Rc222-SM-DR-41	74.8	P	65.9	G1	56.7	G1	15.6	G3	7.0	L	3.4	S	7.1	21.5	I	3.9	HI
13	PR42837-NSIC Rc222-SM-DR-35	74.7	P	65.4	G1	51.0	G1	13.9	G3	6.8	L	3.1	S	7.4	22.3	H	4.0	I
14	PR39165-B-32-B-B-1	73.9	P	68.9	G1	60.0	Pr	10.2	G3	5.9	M	2.7	I	6.9	21.9	I	6.9	L
15	PR39955-B-5-2-4-2	74.3	P	66.3	G1	47.1	G2	24.5	G3	6.6	L	2.9	I	7.3	20.9	I	3.0	HI
16	PR39923-B-3-B-1-1	73.1	P	67.6	G1	50.1	G1	17.5	G3	6.4	M	2.9	I	7.4	21.5	I	3.9	HI
17	PR39923-B-1-B-2-2	76.4	F	67.3	G1	43.9	G2	34.0	G3	6.4	M	2.7	I	7.4	22.6	H	5.5	I
18	PR42837-NSIC Rc222-SM-DR-18	75.3	F	68.2	G1	39.5	G2	29.3	G3	6.9	L	3.0	I	7.0	23.4	H	4.1	I
19	PR39949-B-6-2-1-1	74.8	P	65.0	G2	33.6	G3	21.0	G3	6.5	M	2.7	I	8.0	21.6	I	4.8	I
20	PR39955-B-4-2-2-2	76.4	F	65.3	G1	38.0	G3	17.2	G3	6.7	L	3.1	S	7.4	23.0	H	4.2	I
21	PR39950-B-11-B-1-2	76.5	F	67.8	G1	35.0	G3	19.6	G3	6.5	M	3.0	I	8.2	19.4	I	3.0	HI
22	PR39242-B-4-2-2-2	75.6	F	66.6	G1	37.8	G3	11.4	G3	6.6	L	2.9	I	7.7	20.8	I	4.3	I
23	PR42837-NSIC Rc222-SM-DR-16	75.8	F	63.8	G2	46.2	G2	11.6	G3	6.7	L	3.2	S	8.1	21.6	I	4.2	I
24	PR38869-17-1-3-1-B	74.3	P	66.7	G1	32.7	G3	12.7	G3	6.7	L	2.9	I	7.6	20.1	I	3.9	HI
25	PSB Rc4-IVM2011WS 1-1-5	76.3	F	66.7	G1	40.9	G2	11.9	G3	6.8	L	3.1	S	8.1	21.6	I	5.2	I
26	PR39954-B-15-2-4-1-1	75.6	F	66.7	G1	42.3	G2	19.8	G3	6.6	L	2.7	I	8.0	22.0	I	5.3	I
27	PR39954-B-15-2-4-1-2	74.2	P	66.5	G1	36.1	G3	14.9	G3	6.4	M	2.7	I	8.2	21.0	I	6.2	L
28	PR39954-B-15-2-4-2-1	75.7	F	67.3	G1	46.7	G2	20.8	G3	6.5	M	2.8	I	8.0	20.5	I	6.1	L
29	PR39954-B-15-2-4-2-3	76.1	F	67.7	G1	43.5	G2	13.7	G3	6.4	M	2.9	I	8.0	19.9	I	5.6	I
30	PR39955-B-5-1-2-3-1	76.0	F	67.3	G1	39.8	G2	17.9	G3	6.5	M	2.8	I	8.1	21.3	I	4.8	I
31	PR39955-B-5-1-2-3-5	75.8	F	65.7	G1	41.8	G2	15.7	G3	6.9	L	3.3	S	8.1	19.6	I	3.2	HI
32	PR40029-B-15-1-3-3-3	74.6	P	64.5	G2	34.6	G3	31.7	G3	6.8	L	3.2	S	8.1	19.1	I	3.1	HI
33	PR40029-B-14-B-2-2-5	74.5	P	64.8	G2	27.7	G3	51.2	G3	6.8	L	3.1	S	8.5	19.8	I	3.3	HI
34	PR40029-B-3-B-5-2-4	76.7	F	66.5	G1	25.7	G3	56.8	G3	6.9	L	3.1	S	8.4	19.5	I	3.8	HI
35	PR40029-B-3-B-1-2-3	76.0	F	65.3	G1	31.0	G3	34.6	G3	6.8	L	3.2	S	8.1	21.8	I	3.3	HI
36	PR40029-B-16-2-3-1-3	80.0	G	65.5	G1	39.2	G2	12.8	G3	6.9	L	3.3	S	8.0	24.1	H	5.1	I
37	PR40029-B-16-2-3-2-1	70.8	P	63.0	G2	32.0	G3	43.0	G3	6.6	L	3.0	I	8.3	19.9	I	4.2	I
38	PR40029-B-20-1-2-2-1	74.7	P	64.4	G2	32.8	G3	29.0	G3	6.8	L	3.1	S	8.0	19.8	I	3.6	HI
39	PR40028-B-6-B-5-1-3	75.3	F	66.4	G1	35.7	G3	22.9	G3	6.7	L	3.0	I	7.9	19.9	I	3.7	HI
40	PR39289-B-8-B-1-1-3	75.8	F	66.7	G1	37.4	G3	14.7	G3	6.5	M	3.0	I	8.0	20.7	I	3.5	HI
41	PR39950-B-15-B-5-2	79.4	F	65.2	G1	39.8	G2	10.6	G3	6.7	L	3.3	S	7.6	22.3	H	4.2	I
42	PR39172-B-19-B-B-3	76.4	F	64.8	G2	43.5	G2	15.8	G3	6.7	L	3.2	S	7.7	20.8	I	4.6	I
43	PR39954-B-15-1-2-1	76.4	F	65.7	G1	41.5	G2	16.3	G3	6.6	L	2.9	I	7.4	22.1	H	4.7	I
44	PR39965-B-15-B-4-1	76.6	F	66.8	G1	42.3	G2	17.1	G3	6.4	M	2.6	I	7.8	22.7	H	5.4	H/I
45	PR40029-B-16-2-3-3	75.8	F	64.6	G2	32.3	G3	22.4	G3	6.6	L	3.0	I	8.2	20.0	I	3.4	HI
46	PR39269-B-3-B-1-3	76.1	F	64.8	G2	36.9	G3	27.2	G3	6.7	L	3.0	I	8.0	19.5	I	3.6	HI
47	PR39923-B-3-B-2-1	75.8	F	66.5	G1	39.3	G2	19.8	G3	6.8	L	2.9	I	7.8	19.4	I	3.4	HI

Figure 50. Plant morphology of tolerant TRV's Payakan, Pinyas and C-1.

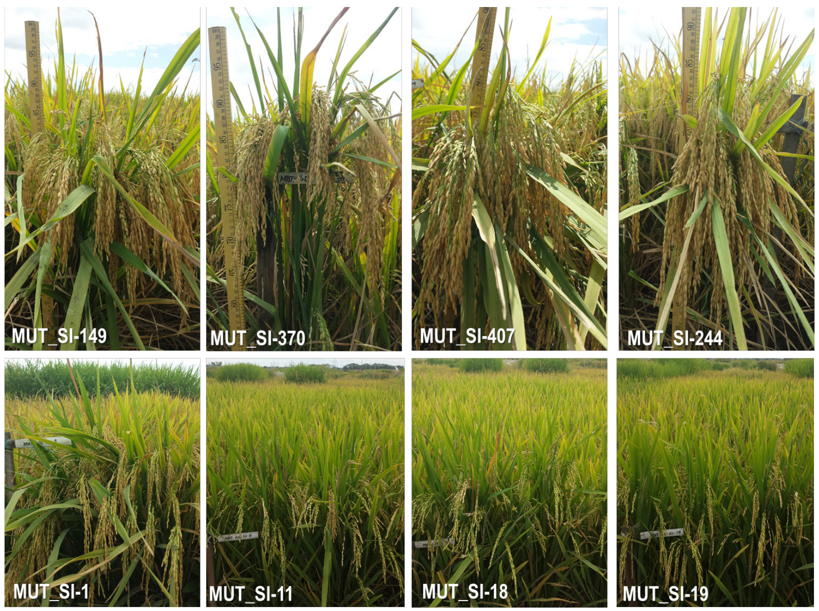


Figure 51. Mutant line selection for observational nursery evaluation in 2017 DS.

Mass Screening for Salinity, Submergence and Seedling Stage Drought Tolerance

NV Desamero, GD Valida, RD Buluran, CC Cabusora, KRP Balmeo, and JS Concepcion

Mass screen facilities for drought, submergence and salt stress tolerance were established for routine evaluation of segregating populations, fixed lines and germplasm accessions/introductions. It is a key component and a must requirement for a successful rice breeding program for addressing developing and improving varieties with tolerance to multiple abiotic stresses. Pre-selection of breeding materials under controlled or managed condition increases selection efficiency in the target environment where the breeding lines are bred for.

Activities:

- Drought tolerance mass screen at seedling to early vegetative stage. Fifty pre-germinated seeds per test entry, including the check tolerant variety PSB Rc14 and susceptible IR64, were drilled along 1-m row in GI-based boxes containing soil mix medium. Drought was imposed by water withdrawal 14 days after sowing. Re-watering was done when IR64 reached the leaf drying (LeD) score of 7. The entries were scored for green plant recovery and vigor at 10 days after re-watering. Leaf rolling (LeR) and LeD score as a measure of response to drought was based on IRRI's Standard Evaluation System (SES) for Rice. The recovered plants were retrieved, transplanted and grown to maturity for seed harvest.

- Salinity tolerance mass screen at seedling stage. Segregating populations, traditional rice varieties (TRVs), and seed mutation (SM), in vitro culture and in vitro mutagenesis (IVM) derived mutant lines were screened for salt tolerance at seedling stage using salinized Yoshida hydroponic solution with electrical conductivity (EC) adjusted to 6 to16 dSm-1. FL478 and IR29 were used as the tolerant and susceptible check, respectively. First scoring was done at 10 days and 16 days after the first salinization for final scoring.

- Submergence tolerance mass screen at seedling stage. Thirty pre-germinated seeds per test entry, including the check tolerant variety FR13A and IR42, were drilled along 60-cm row in plastic trays containing paddy soil. The seedlings were submerged for 14 days in cemented tank with clear water. Seedlings in pots of the susceptible check IR42 cultivars were taken out of the tank 10 to 14 days after submergence, and observed for the degree of tissue decay and foul odor. Data collected include survival, done by counting the numbers of hills with at least one green leaf regenerated after 7, 14 and 21 days from desubmergence.

Results:

- A total of 433 test genotypes and 11 F2 populations (≅9,071 plants) were evaluated in the glasshouse for drought stress tolerance at seedling stage (Table 49).

- Of the 294 seed mutation (SM)-derived NSIC Rc222 lines, 43 (15%) exhibited some degree of tolerance to drought stress manifested in plant recovery from stress. Of these putatively tolerant mutants, 17 (6%) were putatively tolerant with 7%-81% recovery advantage over the tolerant check, PSB Rc14 having 43% recovery (Figure 52).

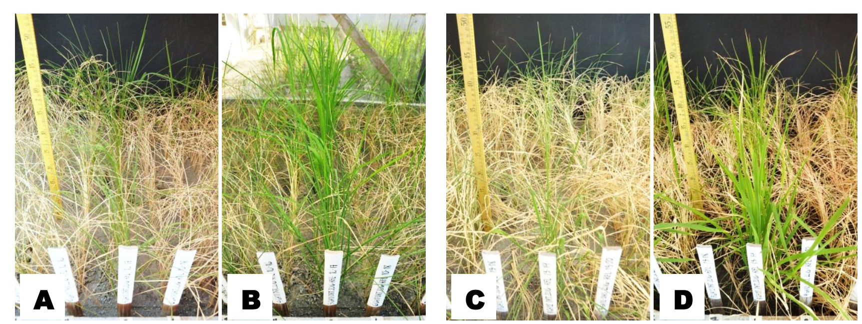
- Seven (70%) out of the 10 progenitors and 47 (33%) lines from the 141 stable mutant lines were identified putatively tolerant to drought stress. Of these tolerant mutants, 36 (77%) were more than 5% recovery advantage (7-94%) over the tolerant check, PSB Rc14 with 51% plant recovery.

- For the 11 F2 segregating populations, a total of 4,183 (46%) out of 9,071 plants recovered from drought stress and currently were grown to maturity for seed produce. Lastly, for the 116 rainfed rice breeding elite lines, experiment is still on-going.

Table 49. Drought recovery response of TRVs, early generation putative and stable mutant line selections at seedling to early vegetative stage, PhilRice-CES, 2016.

No.	ENTRY	Total No. of Lines	HT		T		MT		S		HS	
			n	%	n	%	n	%	n	%	n	%
1	Traditional varieties	3	0	0	1	33	2	67	0	0	0	0
2	Progenitors	10	1	10	1	10	5	50	3	30	1	10
3	NSIC Rc222 (SM)	294	0	0	2	1	41	14	109	37	142	48
Stable mutant line selections												
4	Salumpikit *(IVM)*	2	0	0	0	0	1	50	0	0	1	50
5	PR37443-13/Raeline 3 *(AC)*	2	0	0	0	0	0	0	2	100	0	0
6	FL378/PSB Rc18-Sub1//PSB Rc18-Sub1 *(DH)*	1	0	0	0	0	0	0	1	100	0	0
7	Y Dam Do *(IVC)*	27	1	4	3	11	6	22	13	48	4	15
8	Jepun *(IVC)*	3	0	0	2	67	0	0	1	33	0	0
9	Vandana *(IVC)*	2	0	0	0	0	2	100	0	0	0	0
10	NSIC Rc240/NSIC Rc194 *(AC)*	6	0	0	1	17	3	50	1	17	1	17
11	NSIC Rc194/NSIC Rc182 *(AC)*	1	1	100	0	0	0	0	0	0	0	0
12	NSIC Rc222 (SM)	56	0	0	1	2	12	21	17	30	26	46
13	NSIC Rc222/BPI 76 *(AC)*	36	0	0	3	8	7	19	22	61	4	11
	TOTAL	**443**	**3**	**0.7**	**14**	**3**	**79**	**18**	**169**	**38**	**179**	**40**

***HT, highly tolerant (score 1)** = 90-100% plants recovered; **T, tolerant (3)** = 70-89%; **MT, moderately tolerant (5)** = 40-69%; **S, susceptible (7)** = 20-39%; **HS, highly susceptible (9)** = 0-19%.*



PR42837-NSIC Rc222-47-B-RTD-2-17 PR42837-NSIC Rc222-48-B-RTD-4-19

Figure 52. Response of two identified putatively tolerant (T) IVM-derived NSIC Rc222 mutant lines before (A & C) and 10 days after rewatering (B & D).

- For saline screen, a total of 217 breeding materials composed of 75 TRVs, 135 NSIC Rc222 SM and 7 FR13A IVM-derived lines, and a total of 6,779 plants from 5 F2 and 1 F2:3 segregating populations were evaluated in saline hydroponic solution for salt stress tolerance at seedling stage. Of these materials, 98 (45%) exhibited tolerance to salt stress distributed as follows: 22 T and 76 MT and 4,069 (60%) plants survived in the segregating populations (Table 50).

Table 50. Summary response segregating populations, traditional rice varieties (TRVs), and seed mutation (SM), in vitro culture and in vitro mutagenesis (IVM) derived mutant lines to salt stress at seedling stage, PhilRice-CES, 2016.

No.	ENTRY	Total No. of Lines	HT		T		MT		S		HS	
			n	%	n	%	n	%	n	%	n	%
1	Traditional Varieties	75	0	0	8	11	31	41	32	43	4	5
2	NSIC Rc222 (IVM)	135	0	0	10	7	41	30	64	47	20	15
3	FR13A (IVM)	7	0	0	4	57	4	57	0	0	0	0
	Total	**217**	**0**	**0**	**22**	**10**	**76**	**35**	**96**	**44**	**24**	**11**
$F_{2:3}$ generation												
4	PSB Rc50/NSIC Rc298 (PR47486)	**1,272**	**114**	**9**	**265**	**21**	**340**	**27**	**206**	**16**	**347**	**27**
F_2 generation												
5	PSB Rc68 (Sacobia)/FL478 (PR48972)	1,147	80	7	159	14	395	34	384	33	129	11
6	NSIC Rc194/NSIC Rc182 (PR48981)	1,320	189	14	237	18	364	28	398	30	132	10
7	NSIC Rc120/DrS 111 (PR48992)	900	79	9	320	36	241	27	197	22	63	7
8	NSIC Rc182/FL478 (PR48993)	1,405	185	13	353	25	364	26	342	24	161	11
9	IR86385-38-1-1-B/DEZO 300 (PR49000)	735	88	12	141	19	155	21	235	32	116	16
	Total	**6,779**	**735**	**11**	**1,475**	**22**	**1,859**	**27**	**1,762**	**26**	**948**	**14**

HT, highly tolerant (score 1) *= normal growth, no leaf symptoms;* ***T, tolerant, (3)*** *= nearly normal growth, but leaf tips or few leaves whitish and rolled;* ***MT, moderately tolerant (5)*** *= growth severely retarded, most leaves rolled, only a few are elongating;* ***S, susceptible (7)*** *= complete cessation of growth, most leaves dry, some plants dying;* ***HS, highly susceptible (9)*** *= almost all plants dead or dying.*

- A total of 8,244 plants from 5 segregating F2 populations were evaluated in concrete tank for submergence tolerance (Table 51). Of these plants, 3,436 (42%) were recovered and selected as putatively submergence tolerant. Leaf sampling was done for genotyping to confirm the presence of sub1 gene. The recovered plants were grown to maturity and the F3 seeds harvested will be established in the pedigree nursery for line development (Figure 53).

- Of the 223 breeding materials composed of 71 traditional varieties and 58 and 94 IVC-derived Jepun and Y Dam Do lines, respectively, were identified to exhibit some degree of tolerance (4 T, 20 MT) to submergence stress (Table 52).

Table 51. Summary of submergence tolerance mass screening of 5 F2 populations, PhilRice-CES.

No.	Source Code	PR Number	Parentage	Initial No. of Seedlings	No. of Plants Survived	
					n	%
1	RL15WS_F_{1-2}	PR47483	HHZ5-SAL8-DT3-SUB1/SHZ-2	2,162	318	15
2	RL15WS_F_{1-4}	PR47479	NSIC Rc194/ NSIC Rc182	1,867	319	17
3	RL16DS_F_{1-2}	PR48938	DEZO 300/PSB Rc18-Sub1	2,473	1,721	70
4	RL16DS_F_{1-6}	PR48942	NSIC 2012 Rc298/PSB Rc18-Sub1	1,001	709	71
5	RL16DS_F_{1-15}	PR48951	DEZO 300/NSIC Rc194 (Submarino 1)	741	369	50
			Total	**8,244**	**3,436**	**42**

Table 52. Summary of submergence tolerance mass screening of mutant lines and traditional varieties, PhilRice-CES.

No.	ENTRY	Total No. of Lines	HT		T		MT		S		HS	
			n	%	n	%	n	%	n	%	n	%
1	Jepun *(IVC)*	58	0	0	0	0	0	0	1	2	57	98
2	Y Dam Do *(IVC)*	94	0	0	0	0	0	0	2	2	92	98
3	Traditional varieties	71	0	0	4	6	20	28	11	15	36	51
	Total	**223**	**0**	**0**	**4**	**2**	**20**	**9**	**14**	**6**	**185**	**83**

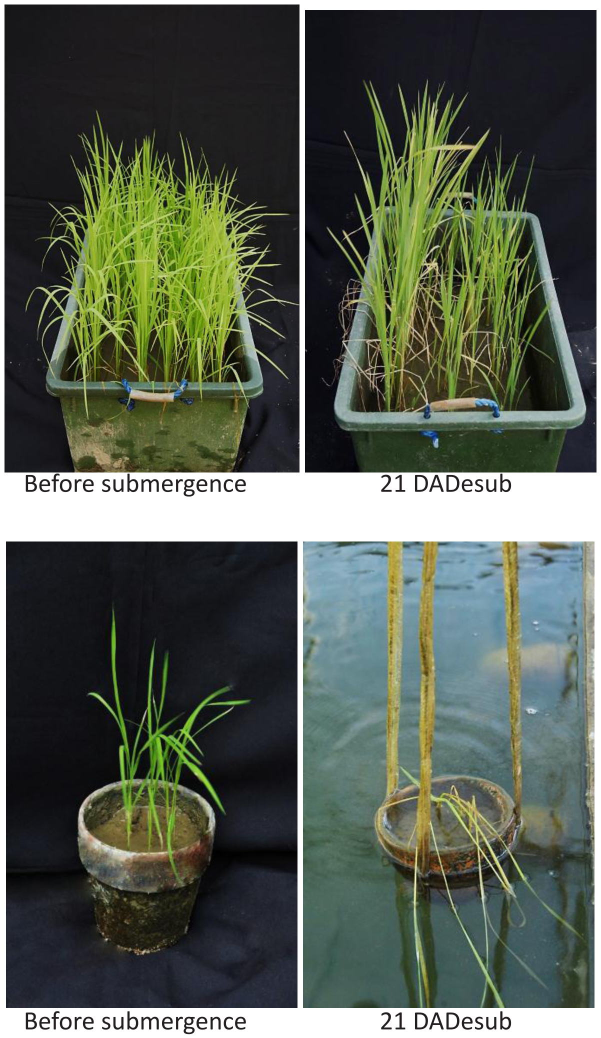


Figure 53. Submergence tolerance mass screen setup, 2016DS, PhilRice-CES.

Mass Screening for Reproductive Stage Drought Tolerance

JM Niones, VAC Marcelo, MAR Orbase and NV Desamero

Drought stress causes drastic yield reduction in rice especially at the reproductive stage. Efficiency of selection not only depends on yield but its combination of high yield combined with putative secondary traits adapted to drought stress in the rainfed lowlands. Traits of correlated value combined with the selection of yield per se, can improve the plant breeding process either in parental selection or in the screening of segregating populations (Fischer et al., 2002). In this study, reproductive drought screening and selection focused on selection for yield along with highly correlated traits to delineate promising drought tolerant varieties to be advanced to observational nurseries under drought and irrigated conditions.

Activities:

- Screen and phenotype 1352 entries and checks for agro-morphological characteristics, drought response, yield and its yield component under reproductive drought during the dry season.

- Select 150 reproductive drought tolerant lines with yield of ≥10 g plant-1 and leaf rolling score of healthy leaves (0) to leaf folding in deep V shape by 2016.

- During drought, soil moisture content (SMC, %) was measured gravimetrically or through a data logger ECH20, water table depth (WTD) and rainfall were also monitored and recorded. The following parameters leaf rolling and leaf drying score, days to 50% heading, plant height, frequency of productive and unproductive tillers and yield were measured in response to drought stress. Yield component data were also gathered in the form of frequency of filled and unfilled grains, % spikelet fertility and 100 grain weight.

- Agro-morphological characterization and seed increase of 156 lines for utilization on the 2017 dry season observational nurseries under rainfed and irrigated conditions.

Results:

- A total of 1352 advanced breeding lines, traditional varieties along with 5 checks (IR64, Rc14, Rc68, NSIC192 and NSIC222) were evaluated under managed reproductive drought in an augmented design.

- Drought was initiated 21 days after transplanting. Three cycles of drought and re-watering were imposed that lasted for 17, 16 and 16 days (Figure 54). The onset of drought started at water below soil surface from (6cm to 13cm) to (68cm to 98cm) during drought cycles. Also, % soil moisture content (%, SMC) at 30 cm depth lowered from the initial (56 % to 58 %) to (10 % to 36 %) prior re-watering (Figure 54).

- In terms of agro – morphological characters, heading ranged from 69 to 123 days after sowing (DAS), plant height ranged from 51cm to 126cm, productive tiller numbers ranged from 0 to 22 per plant, and unproductive tiller number ranged from 1 to 17 per plant. The grain yield of entries ranged from 0 to 33.56g/ plant with an average of 7.88g/ plant whereas the mean yield of check varieties ranged from 6.11g/plant (IR64) to 12.28g/ plant (Rc68).

- Leaf rolling scores at the 1st cycle of drought ranged from 0 to 7, whereas scores of 0 to 9 were observed under succeeding cycles. Furthermore, leaf canopy temperature (CT) at the cycles of drought ranged from 24.4˚C to 37.5˚C. (Figure 55).

- Yield/ plant was positively significant with plant height, no. of productive and total tillers, frequency of filled grains, % spikelet fertility and 100 grain weight. Negatively significant correlation was observed for heading, leaf canopy temperature, leaf rolling scores, phenotypic acceptability (PAcp) and frequency of unproductive tillers.

- Based on yield and its significant medium to high correlation to PAcp, leaf rolling score at the 2nd cycle, productive and unproductive tillers and number of filled grains under reproductive drought, a total of 156 (11.54 %) of the entries were selected to be advanced for observational nurseries under drought and irrigated conditions through the sequential use of correlation and cluster analyses (Figures 56 to 58) based on yield and its significant correlation to other traits.

- One - hundred thirty-six seed packets for observational nurseries under drought and irrigated conditions were prepared the 2017 dry season. On the 156 lines, high diversity (0.78 to 0.93) were observed for plot yield, heading, 100 grain weight, weight of filled grains per plant, % spikelet fertility, no of filled and unfilled grains, plant height, culm length, number of tillers and panicles, ligule length, leaf blade length, leaf blade width, flag leaf length and width; moderate diversity was recorded for panicle length; no diversity were observed for basal leaf sheath color, leaf sheath anthocyanin coloration, leaf blade anthocyanin coloration, altitude of penultimate leaf, ligule shape, flag leaf altitude, culm habit angle, culm kneeing ability, culm internode anthocyanin and flag leaf altitude of blade.

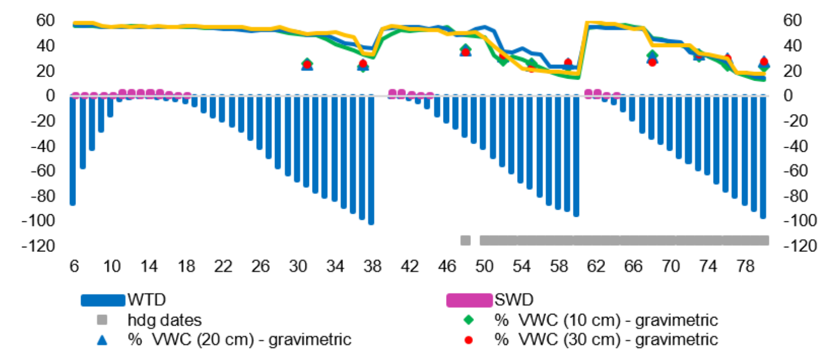


Figure 54. Soil hydrology during the 2016 DS under managed reproductive drought.

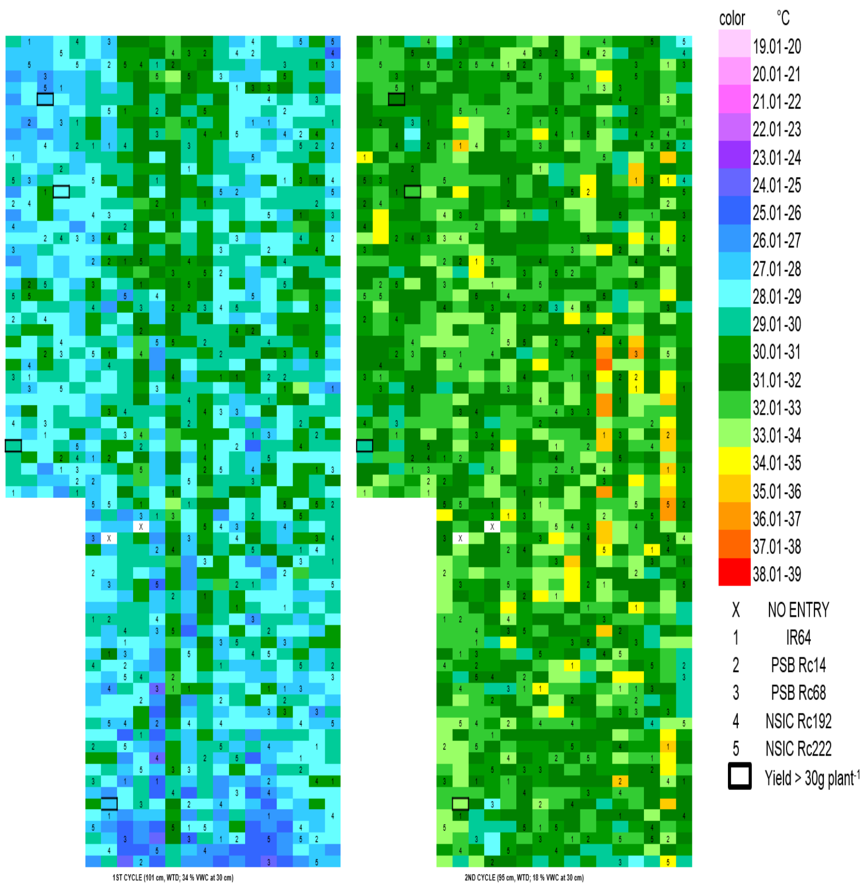


Figure 55. Leaf canopy temperatures under managed reproductive stage drought, 2016 DS.

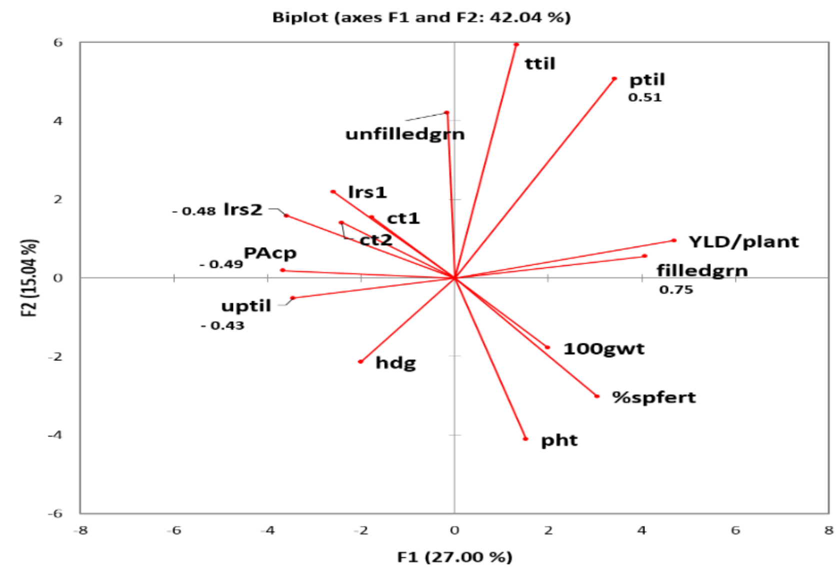


Figure 56. Biplot of yield, agro-morphological traits, drought scores and yield components with significant medium to high Pearson correlation and r values in relation to yield/ plant under 2016 reproductive drought.

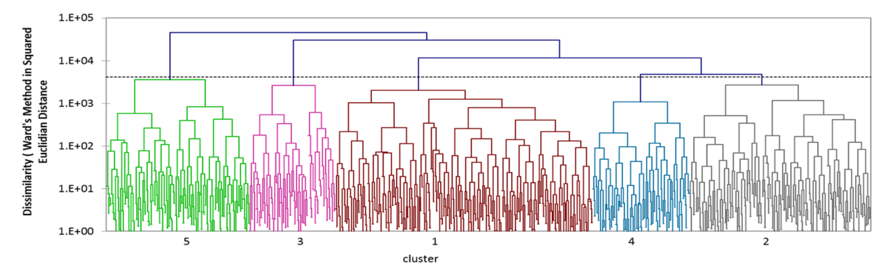


Figure 57. Dendogram of 1001 test entries based on yield, plus correlated traits (leaf rolling score – 2nd cycle, PAcp, productive and unproductive tillers and frequency of filled grains.

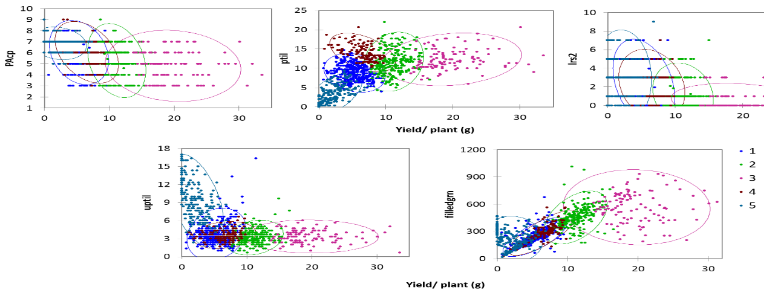


Figure 58. Scatterplots of chosen secondary traits for selection: phenotypic acceptability (PAcp), productive tiller (ptil), leaf rolling score – 2nd cycle (lrs2), unproductive tillers and number of filled grains (filledgrn) in relation to yield per plant (Clusters 2 and 3 were selected).

Multi-environment and adaptability tests of breeding lines in drought-prone rainfed lowland

JM Niones, MAR Orbase, NV Desamero, VAC Marcelo, CC Cabusora, SJE Labarosa, AY Alibuyog, JM Solero, FM Ramos, DB Rebong, VC Lapitan, MJT Mercado, CU Seville, JD Tangog, EA Sana, and NL Manigbas

High and stable yield is importance for sustainable rice production under rainfed rice area. In these areas, several varieties grown provide shown good yield under normal water condition but suffer high losses in the event of drought stress. However, selection for such stable varieties was not successful due to high genotype by environment (G×E) interactions for grain yield. Therefore, there is a need to evaluate genotypes in several environments to determine their yield potential and wide adaptability. Multi-environment trial of advanced breeding lines is one of the best strategies in the identifying and development of wide adapted and location-specific adapted varieties and genotypes. This study aims to evaluate advanced breeding lines with drought tolerance in multi-environment trials prior National Cooperative Test advancement.

Activities:

- Fifty (50) test entries and 20 reference varieties were evaluated under non-stress (irrigated) and managed drought stress condition. The test entries were dry-direct seeded and laid-out in RCBD with three replications. Agro-morphological characteristics, pest and disease incidence, phenotypic acceptability, yield components and yield were measured.

- The same set entries were evaluated in 8 sites (CES, Batac, Isabela, Nueva Vizcaya, Los Baños, Negros, Agusan and Midsayap) in 2016 wet season.

Results:

- In 2016DS, four cycles of drought and re-watering was implemented. The first cycle was imposed 35 days after sowing (DAS). Water was withheld for 13 days after drought imposition (DADI) or until the leaf of IR64 (susceptible check) rolled or the sol moisture content (SMC) is 10%, prior to re-watering (Figure 59A). Water table depth (WTD) was 86.3cm below soil surface with SMC 9% at 15 cm and 11% at 30 cm soil depth. Furthermore, 2nd to 4th cycles of drought imposition lasted ranged from 18 to 22 days. WTD reached 95 cm with SMC of 17 at 15 cm and 22 at 30cm prior to re-watering. Leaf rolling score of test entries by the end of the 4th cycle ranges from 1 to 9 (SES).

- Yield of test entries ranges from 155 to 3098kgha-1 (Figure 61), days to flowering ranges from 81 to 99 DAS, plant height from 58 to 87cm, number of tiller (LM) ranges from 97 to 269 and number of productive tiller (LM) ranges from 44 to 127 as compared to check varieties where yield ranges from 525 to 2265kg/ha, days to flowering from 80 to 94 DAS, plant height from 60-107 cm, number of tillers (LM) from 121 to 283 and number of productive tillers (LM) ranges from 56 to111 while under full irrigation yields of these entries ranged from 2920 to 7746kgha-1.

- Yield under stress showed high significant correlation to harvest index (HI), % filled grains, no. of spikelet per panicle and moderate significant correlation to plant height and 1000 grain weight. In contrast with the correlation to days to heading and phenotypic acceptability was observed.

- Based on drought indices such as STI, HM, MP and GMP showed positive significant correlations with yield under stress and non-stress and were suggested as desirable indices to identify drought tolerant genotypes.
- Out of 50 genotypes, 4 (8%) entries (PR39950-B-15-B-5-2, PR39269-B-3-B-1-3, PR39965-B-15-B-4-1 and PR39955-B-3-2-2-2-6) were selected based on correlated drought indices and 5% yield advantage over the best performing check, yield reduction (40 to 80%) and yield under stress and non-stress as compared with PSB Rc14 (1999kg.ha-1), best performing check (Table 53).

- In 2016 WS, frequent heavy rains and typhoon during rice crop growth were observed. In Philrice CES, high frequency of rainfall was observed during vegetative stage until reproductive stage with recorded total rainfall of 1035.7mm and water table depth from 0 to 48cm below soil surface (Figure 59B).

- Yield of entries ranges from 2177 to 5784 kg.ha-1, while yield of checks ranges from 2768 to 5784 kg.ha-1 (Figure 61).

- Maturity of entries ranged from 104 to 133 DAS, plant height from 81 to 123cm, no of productive tiller from 34 to 114 L/M, harvest index from 0.22 to 0.56, % filled grains from 54 to 90, no. of spikelet per panicle from 19 to 92 and 1000 grain weight from 15 to 32. Among these traits, no. of productive tillers, harvest index, % filled grains and no. of spikelet per panicle were significantly correlated to yield.

- Out of 50 entries, 12 (24%) out-performed the best performing check with 5% yield advantage over NSIC Rc222 (4544kg. ha-1). The lines yielded 4826 to 5613kg.ha-1, with maturity of 106 to 132 DAS and stood at 87 to 114cm.

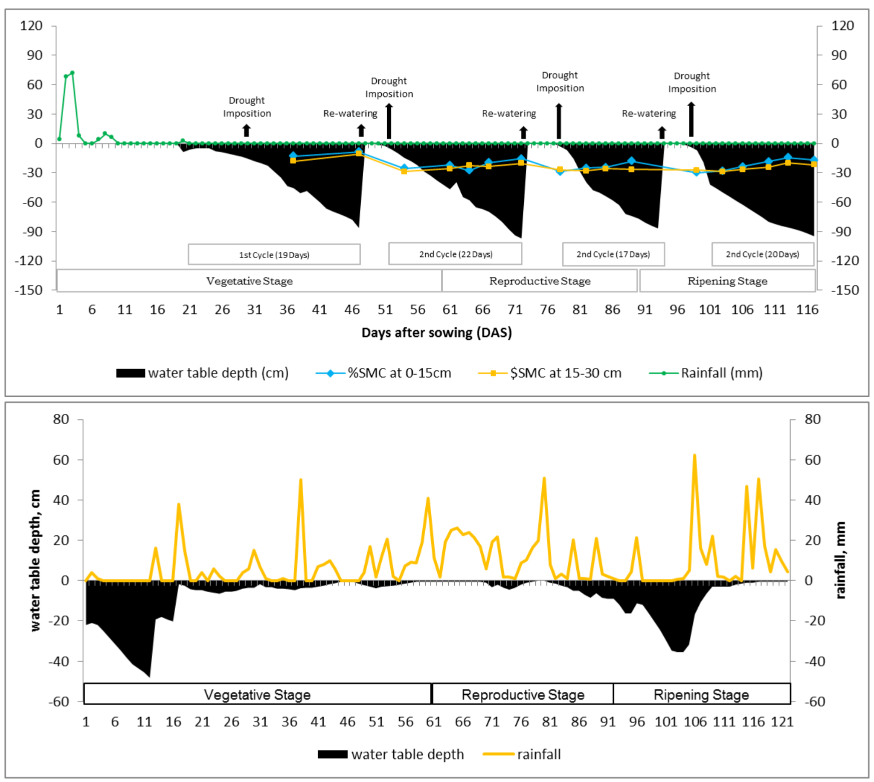


Figure 59. Water table depth, height of surface water and soil surface tension of MET experimental set-up in PhilRice CES on 2016DS (A) and 2016WS (B).

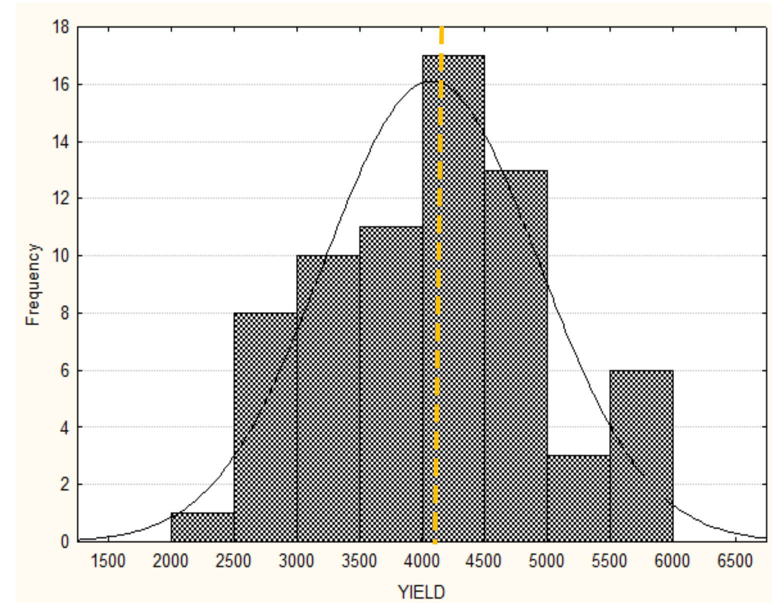


Figure 60. Frequency distribution for yield of MET breeding lines, PhilRice CES, 2016WS.

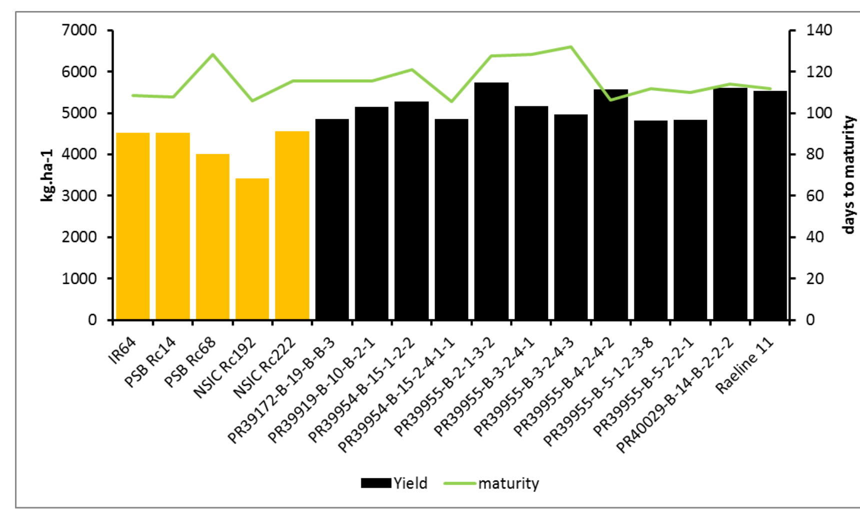


Figure 61. Mean yield and maturity of selected breeding lines, MET 2016WS.

Table 53. Yield, agro-morphological traits and drought indices of four selected breeding lines, MET 2016DS.

Genotype	Parentage	Yield-IL ($kgha^{-1}$)	Yield-DR ($kgha^{-1}$)	Days to Heading (DAS	Plant Height (cm)	Tiller Number (LM)	YA	LRS (1-9)	STI	MP	GMP	HM	YR
IR64		5655	1746	90	69	123	-12.68	7	0.30	3700	3142	2668	69
PSB Rc14		5778	1999	86	68	183	-	5	0.35	3889	3399	2971	65
PSB Rc68		5827	1724	88	92	173	-13.75	5	0.30	3776	3170	2661	70
NSIC Rc192		5736	633	85	70	180	-68.32	5	0.11	3185	1906	1141	89
NSIC Rc222		5058	567	94	67	121	-71.64	7	0.09	2813	1694	1020	89
PR39950-B-15-B-5-2	PR25769-B-9-1/PSB Rc82	6317	2878	91	72	220	43.97	3	0.55	4598	4264	3955	54
PR39269-B-3-B-1-3	PSB Rc10/NSIC Rc138	6795	2375	81	77	207	18.78	1	0.49	4585	4017	3519	65
PR39965-B-15-B-4-1	PR36711-B-6-3/PSB Rc40//PSB Rc14	5984	3098	86	72	186	54.97	1	0.56	4541	4306	4083	48
PR39955-B-3-2-2-2-6	PSB Rc14/PSB Rc82	6130	2376	86	81	269	18.87	1	0.44	4253	3817	3425	61

**YA=yield advantage, LRS=leaf rolling score, STI=Stress tolerance index, MP=Mean productivity, GMP-Geometric mean productivity, HM-Harmonic mean, YR=yield reduction.*

Pyramiding Salinity and Submergence Tolerance in High Yielding Rice Varieties

NV Desamero, JS Concepcion, JC Baggara, GD Valida, and KRP Balmeo

Too much precipitation and rise in sea water level are among the projected ill-effects of climate change, resulting potentially in flooding and salinization of rice paddies along the coastal areas. The use of rice varieties with tolerance to submergence and salt stress is a viable climate-resilient adaptation measure for our rice farmers in marginal areas. Fast tracking and enhancing selection efficiency in climate resilient variety development is targeted by integrating molecular markers with classical breeding approach to combine salinity and submergence tolerance into high yielding cultivars. To achieve the objective, three activities were implemented, viz., (1) trait discovery for trait of interest, (2) introgress SalTol QTL into high yielding variety or breeding line, and (3) combine salinity and submergence (Sal-Sub) tolerance into candidate genotype.

Activities:

- Trait discovery. Traditional varieties (TRVs) were utilized in discovering possible new sources of genes for complete submergence stress tolerance. Induced mutation with the use of gamma irradiation and tissue culture was also resorted to enhance the frequency of inducing genetic variation in traits with agronomic and economic value. Selected TRVs and commercially released varieties were subjected to mutation to generate plants with improved or new desirable traits for utilization in breeding line development. Generated mutant lines were evaluated for submergence and/or salinity stress tolerance imposed at seedling and early vegetative stage.

- Introgress SalTol QTL into high yielding variety or breeding line. Crosses between salt tolerant genotypes which are sources of SalTol QTL and high yielding varieties or breeding lines were made. F2 populations of identified crosses were screened for salinity tolerance at seedling stage, resulting in the selection of tolerant plants for use in line development. Advanced generation breeding lines were established in the non-stress pedigree nursery for selection on the basis of phenotypic acceptability and agronomic traits, and for genetically fixing the lines.

- Combine salinity and submergence (sal-sub) tolerance. Crosses between varieties possessing the genes conferring tolerance to salinity and submergence tolerance were made. Advanced generation breeding lines from identified crosses were established in the pedigree nursery. Phenotypically acceptable lines with desired agronomic traits were identified and selected for further evaluation and genotype fixing.

Results:

- In 2016 DS, 52 TRVs (Table 54) were screened for seedling stage submergence stress in the cemented tank resulting in the identification of 24 (46.15%) moderately tolerant to tolerant TRVs with 75% to 98% survival. Tolerance of the identified TRVs has to be revalidated both in the cemented tank for seedling tolerance and field tank for early vegetative tolerance and yield performance under stress in 2017.

- Similarly, in 2016 DS, 19 TRVs (Table 55) were evaluated for field performance under early vegetative submergence stress 6 days in the field tank, exhibiting 2 to 63 % survival, averaging 19 ±18% 21 DAD (Figure 63). Getbaw survived the highest at 63%. Re-validation of identified putative tolerant TRVs has to be done in 2017 using the seeds harvested from individual plants that survived.

- In 2016 WS, 57 advanced mutant lines (M5) together with their progenitors were evaluated under early vegetative submergence stress. Performance was significantly affected by the quality of the flood water with an average EC reading of 216.75 μ/cm, pH of 8.14, total dissolved solids (TDS) of 152.14 μS, 7.53 mg/l dissolved oxygen and temperature of 31.74^{o}C. The increase in TDS and EC, with decrease in dissolved oxygen affected the survival of the entries. Interestingly FR13A had 83.68% survival indicating its tolerance to the extremely unfavorable growing condition, other than complete submergence. Surviving plants from these entries will be harvested separately, and will be subjected to seed increase in 2017 DS before re-validation and re-evaluation.

- A total of 261 NSIC Rc222-derived mutant surviving entries subjected to salinity stress at seedling stage genotyped for presence of SalTol QTL using 5 SSR markers. Of which, 221 (84.67%) entries amplified alleles similar to FL478.

- Seedling stage salt tolerance screen of 1272 F2 plants from PSB Rc50/NSIC Rc298(PR47486) yielded 714 (56%) surviving plants, of which 208 (29%) amplified alleles with least 4 of the 5 SSR markers (viz. RM7075, RM6711, RM1287, RM8094, and RM10793) similar to FL478, the tolerant check and source of the SalTol QTL (Figure 62). Surviving entries were evaluated under pedigree nursery for phenotypic acceptability and stability evaluation.

- Of the 25 crosses (Table 57) made to introgress SalTol from 5 salt tolerant varieties (NSIC Rc326, NSIC Rc330, NSIC Rc334, NSIC Rc336 and NSIC Rc340) into high yielding varieties (NSIC Rc222, NSIC Rc240, NSIC Rc298, NSIC Rc300, NSIC Rc308 and DEZO 300), 20 (80%) had at least 20 F1 naked seeds. Harvested F1 seeds will be planted in 2017 DS to generate F2 and F 2:3 populations, which will be screened for salt tolerance at seedling stage.

- Of the 5507 F2 plants from 5 crosses (PSB Rc68 (Sacobia)/FL478; NSIC Rc194/NSIC Rc182; NSIC Rc120/DrS 111; NSIC Rc182/FL478; IR86385-38-1-1-B/DEZO 300) screened for salt tolerance at seedling stage, 621 (11.28%), 1210 (21.97%) and 1519 (27.58%) were identified as highly tolerant, tolerant, and moderately tolerant, respectively. Tolerant plants were grown to maturity and the seeds harvested are to be used for generation advance in the pedigree nursery (PN). As applicable, in a cross with submergence tolerant parent (PSB Rc68 (Sacobia)/FL478, NSIC Rc194/NSIC Rc182) salt stress tolerant plants are genotyped with sub1 markers and phenotyped for submergence tolerance for selection before fixing for agronomic trait in the PN.

- In 2016 WS, 1112 lines were selected for phenotypic acceptability at F4 to F8 generations from 16 crosses incorporating salt tolerance into high yielding genotypes. Selections were composed of 800 F4 lines from 3 crosses, 264 F7 from 5 crosses and 48 F8 from 8 crosses. F2 bulked populations from 2 crosses were generated.

- Of the 213 lines developed from 9 crosses and fixed for observed agronomic traits at F8 generation, 28 (13%) were selected and will be evaluated for field performance under non-saline and saline condition and for grain quality and pest resistance in 2017.The remaining fixed lines will likewise be evaluated for stress tolerance.

- In 2016 WS, F2 population from 2 crosses bulked. A total of 800 F4 entries from 3 crosses, 264 F7 entries from 5 crosses, 48 F8 entries from 8 crosses, selected based on phenotypic acceptability from pedigree nursery

- Of the 12 crosses made in 2016 DS to combine salt and submergence tolerance, 5 (42%) yielded at least 20 F1 naked seeds (Table 56). The 200 F1 seeds obtained from the crosses were planted in 2016 WS, generating the F2 populations, which will be subjected to plant selection under stress. F2:3 bulk populations will be generated to obtain more recombinants. Crosses with less than 20 F1 seeds will be re-generated in 2017 DS.

- In 2006 WS, 637 lines were selected for observed agronomic traits at F4 to F8 generations from 15 crosses made combining salt and submergence tolerance. Selections were composed of 169 F4lines from 8 crosses, 180 F5 from 3 crosses, 285 F6 from 3 crosses, and 3 F8 lines from 1 cross. The lines are subject to selection under stress for further development

- F2 population from 4 crosses bulked. A total of 169 F4 entries from 8 crosses, 180 F5 entries from 3 crosses, 285 F6 entries from 3 crosses, 3 F8 lines from 1 cross selected based on phenotypic acceptability selected based on phenotypic acceptability.

- Of the 199 lines developed from 5 crosses and fixed for observed agronomic traits at F8 generation, 21 (14%) were selected and will be evaluated for field performance under non-saline and saline condition and for grain quality and pest resistance in 2017. The remaining fixed lines will likewise be evaluated for stress tolerance.

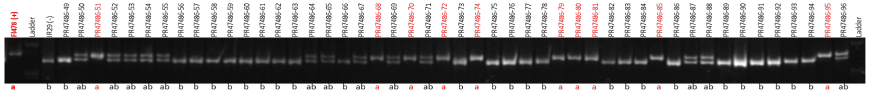


Figure 62. PCR Amplification profile of surviving lines from PR47486 using RM7076 primer (Highlighted entries amplified similar band with FL478); a = amplified band similar to FL478, b = amplified band similar to IR29, ab = heterozygous.

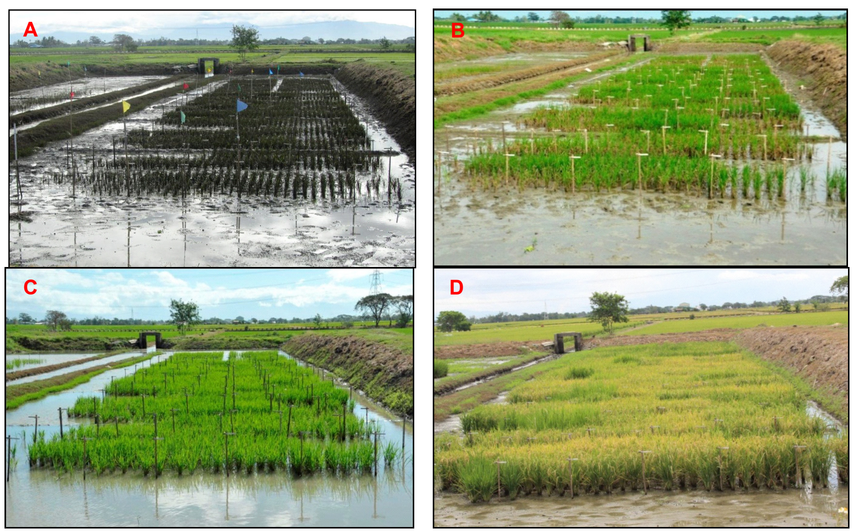


Figure 63. Response of test entries, including 19 traditional rice varieties to 10 days of complete submergence stress; (a) 3 days after de-submergence (DAD), (b) 14 days DAD, (c) 21 DAD and (d) maturity stage.

Table 54. Seedling stage submergence stage response of 52 traditional rice varieties (TRVs), Cemented Tank, PhilRice CES, 2016 DS.

No.	ENTRY	Number of Plants		% Survival	Tolerance	Plant Height (cm)	
		Initial	21 DAD			Initial	21 DAD
	FR13A	30	30	**98**	**T**	45	67
	IR42	28	16	**55**	**S**	40.5	38
1	Palawan	38	28	73	S	36.85	33.5
2	Arimuram	39	28	73	S	33.75	37.5
3	Aringay	40	17	43	HS	47.2	38.8
4	Awan Sapulemon (b)	27	3	10	HS	50.4	31.6
5	**Azucena**	37	28	75	**MT**	35.55	37.9
6	**Baddang**	38	36	95	**T**	39.9	42.9
7	**Ballatinaw (dati)**	37	31	84	**MT**	33.91	37.1
8	Ballatinaw (Luna)	39	0	0	HS	51.3	
9	Ballatinaw (Mt. Province)	38	17	46	S	40.5	33.5
10	**Balsamo a**	41	31	75	**MT**	33.1	32.5
11	**Balsamo b**	40	34	85	**MT**	37.35	38.6
12	Balud	21	0	0	HS	45.5	
13	Buga	31	2	7	HS	49.55	42.3
14	Bukutan	37	0	0	HS	52.25	
15	Bulilising	37	0	0	HS	48.85	
16	Burgis	36	1	2	HS	49.6	52.5
17	**Dagmuy**	39	36	92	**MT**	37.45	42.6
18	Dinorado	38	2	4	HS	51.7	40.7
19	**FancyRice**	36	33	92	**MT**	40.4	38.1
20	**Gannal (Batac)**	38	32	83	**MT**	37.4	42
21	**Gannal (Marcos)**	39	35	89	**MT**	41.4	39.1
22	**Getbaw**	40	39	96	**T**	34	36.3
23	**Purple Rice**	40	34	84	**MT**	37.8	34.7
24	**IsicDiket**	40	39	98	**T**	34.7	40.5
25	**IsicPugot**	40	31	76	**MT**	39.55	44.5
26	Kilong	36	18	48	HS	40.95	43.8
27	Langpadan	39	2	4	HS	53.4	30.7
28	Lukdit ni Abalayan	29	0	0	HS	51.45	
29	Madalia	25	1	2	HS	47.4	40
30	Malapay	25	5	20	HS	42.65	29.3
31	Maliketa	33	6	16	HS	40.6	32.6
32	Minama	32	0	0	HS	45.6	
33	Mindanao	34	19	60	S	42.1	33.7
34	Mindoro	39	24	60	S	45.4	36.8
35	**Nylon**	37	32	86	**MT**	38.35	34.2
36	Palawan a	36	23	64	S	44.7	40.8
37	**Pamplona**	35	27	80	**MT**	40.3	40.2
38	**Parina**	40	34	85	**MT**	40.45	45.8
39	**Payakan**	40	38	96	**T**	40.5	40.4
40	**Pinal-ug**	35	32	91	**MT**	39.15	42.1
41	**Pinyas**	37	31	83	**MT**	72.7	37.7
42	**Purtok**	37	29	77	**MT**	41.1	46.8
43	**Rafinan**	38	30	79	**MT**	38.1	41.6
44	**Saba**	39	31	78	**MT**	36.95	37.9
45	Sabadilla	40	18	45	HS	56.65	39.6
46	Sinelat	38	18	46	HS	42	30.8
47	Tagaling	39	21	54	S	40.8	33.8
48	Unig	40	29	74	S	36.1	38.6
49	**Oskil**	37	34	94	**MT**	42.9	39.1
50	Zambales	37	18	49	HS	40.8	36.7
51	Gudoy	38	21	56	S	40.85	35.9
52	**Purtok**	35	27	77	**MT**	43.6	50.4

Table 55. Vegetative stage submergence stress response of 19 traditional rice varieties (TRVs), Field Tank, PhilRice CES, 2016 DS.

No.	Field Code	Entry Name	Plant Survival (%)		% Comparative Survival
			AD	21DAD	
	FR13A	FR13A	89	95	
	IR42	IR42	22	45	
1	Aringay	Aringay	6	39	41.05
2	Awan Sapulemon (b)	Awan Sapulemon (b)	9	23	24.21
3	Ballatinaw (Mt. Province)	Ballatinaw (Mt. Province)	0	0	0
4	Dagmuy	Dagmuy	0	7	7.36
5	Getbaw	Getbaw	25	63	66.31
6	Purple Rice	Purple Rice	0	37	38.95
7	Kilong	Kilong	0	2	2.11
8	LukditniAbalayan	LukditniAbalayan	0	2	2.11
9	Minama	Minama	8	47	49.47
10	Mindanao	Mindanao	3	8	8.42
11	Mindoro	Mindoro	6	13	13.68
12	Nylon	Nylon	6	17	17.89
13	Palawan a	Palawan a	1	4	4.21
14	Parina	Parina	1	7	7.37
15	Pinal-ug	Pinal-ug	3	15	15.79
16	Pinyas	Pinyas	0	0	0
17	Purtok	Purtok	0	14	14.74
18	Tagaling	Tagaling	9	26	27.36
19	Zambales	Zambales	5	37	38.95
		MINIMUM	0	0	
		MAXIMUM	25	63	
		RANGE	25	63	
		AVERAGE	4	19	
		STANDARD DEVIATION	5.983606	18.04429	
		VARIANCE	35.80354	325.5966	
		COEFFICIENT OF VARIATION	137.6114	94.87477	

*Highlighted are selected lines based on percent survival

Table 56. Crosses generated to combine salinity and submergence tolerance, PhilRice CES.

No.	Parentage	No. of F1 Seeds
1	FL478/PSB Rc68	2
2	DEZO 300/IR86385-38-1-1-B	3
3	NSIC Rc300/IR86385-38-1-1-B	26
4	NSIC Rc190 /NSIC Rc194	33
5	NSIC Rc190 /PSB Rc68	4
6	NSIC Rc190 /PSB Rc18 Sub1	12
7	IR86385-38-1-1-B/NSIC Rc300	21
8	NSIC Rc330 /Ciherang Sub-1	26
9	NSIC Rc338 /Ciherang Sub-1	18
10	Ciherang Sub-1/NSIC Rc330	7
11	Ciherang Sub-1/NSIC Rc338	48
12	PSB Rc68 /NSIC Rc330	0
	Total	200

Table 57. F1 progenies generated to introgress SalTolQTL into high yielding varieties, PhilRice-CES 2016.

No.	PR Number	Parentage	No. of F_1 Seeds
	PR49478	NSIC 2013 Rc330/NSIC RC 222	120
2	PR49481	NSIC Rc326/NSIC 2012 Rc300	20
3	PR49482	NSIC Rc340/NSIC 2011 Rc240	73
4	PR49483	NSIC Rc340/NSIC 2012 Rc298	8
5	PR49485	NSIC Rc334/NSIC 2011 Rc240	27
6	PR49486	NSIC Rc334/NSIC 2012 Rc298	89
7	PR49487	NSIC Rc336/NSIC 2011 Rc240	51
8	PR49488	NSIC Rc336/NSIC 2012 Rc298	88
9	PR49489	NSIC Rc336/NSIC 2012 Rc300	17
10	PR49490	NSIC Rc336/NSIC 2013 Rc308	45
11	PR49491	NSIC Rc336/DEZO 300	91
12	PR49448	NSIC RC 222/NSIC 2013 Rc330	249
13	PR49459	NSIC 2012 Rc300/NSIC Rc 326	23
14	PR49460	NSIC 2012 Rc300/NSIC Rc340	79
15	PR49461	DEZO 300/NSIC Rc340	52
16	PR49462	NSIC 2011 Rc240/NSIC Rc334	23
17	PR49463	NSIC 2012 Rc298/NSIC Rc334	12
18	PR49464	NSIC 2012 Rc300/NSIC Rc334	116
19	PR49465	NSIC 2013 Rc308/NSIC Rc334	4
20	PR49466	DEZO 300/NSIC Rc334	33
21	PR49467	NSIC 2011 Rc240/NSIC Rc336	35
22	PR49468	NSIC 2012 Rc298/NSIC Rc336	96
23	PR49469	NSIC 2012 Rc300/NSIC Rc336	21
24	PR49470	NSIC 2013 Rc308/NSIC Rc336	17
25	PR49471	DEZO 300/NSIC Rc336	80
		Total F1 seeds generated	**1469**

*Highlighted successful crosses generating at least 45 F_1 seeds

Breeding Heat-tolerant Rice in the Philippines

NL Manigbas and LB Madrid

Rice grows optimally between 20oC to 35oC and becomes increasingly sensitive to increasing temperatures especially during flowering which can eventually reduce yields (Redona, et al 2007). Rice yields could be affected as climate change may give a significant addition to future stresses and maybe beyond the capability of the existing rice cultivars to adapt to the conditions (Manigbas and Sebastian 2007). Therefore, there is a need to breed rice varieties that can tolerate higher temperatures or can avoid exposure to high temperatures by having shorter growing seasons or flowering that occurs during cooler periods of the day (Redona et al 2007). Selected rice breeding populations were established in the field and glashouse nurseries in Southern Cagayan Research Center, Iguig, Cagayan and at PhilRice Experiment station in Nueva Ecija. Daily temperature and RH were gathered with the use of MINCERs (Micrometeorological Instrument for Near Canopy Environment of Rice) and thermometers installed in the field and glashouse nurseries especially flowering period of the rice crop. Selected samples will be evaluated based on percent sterility and other morphological traits important to variety development. The study aimed to: (1) develop rice genotypes that can tolerate and adapt heat; (2) determine QTLs for heat tolerance of selected backcross populations; (3) conduct preliminary, observational, and replicated yield trials of selected heat-tolerant rice breeding lines in 'hot spots' areas in Luzon; and (3) nominate elite lines to NCT (National Cooperative Test) for heat tolerance test.

Activities:

- Five hundred seventy-eight breeding lines of different generations were planted for heat-tolerance screening in 2016 dry season (Table 58). Plants were selected based on important agro-morphological traits and percent spikelet sterility. Heat-tolerance was determined based on spikelet sterility. Panicles with <17.5% sterility are classified tolerant, 18-39% are intermediates, and >40% are intolerants.

- One hundred eighty-one advance lines were established for evaluation of uniformity and yield performance under heat stressed condition.

- Seed increase and purification of 415 uniform lines were established in dry and wet season.

- Three populations composed of 250 plants each were planted in glasshouse. Leaf samples were collected and DNA was extracted for QTL analysis.

- Temperature and relative humidity were monitored from the start of heading up to ripening using MINCER.

- Four populations were advanced three times since January 2016 using Rapid Generation Advance (RGA).

Results:

- High temperature condition occurred in Philrice-CES on April 16-May 19, 2016 (Figure 64). Data were obtained from automatic data loggers which were set to record every two minutes at day and night. Data showed that high temperature happened every day and went as high as 38.4°C, a condition suitable for screening and selecting heat-tolerant rice lines. Tolerant lines have high spikelet fertility even if their reproductive growth stage is exposed to temperature higher than 35°C.

- Out of 587 breeding lines planted, 471 lines were selected based of plant type Table 58. One hundred twenty-two had percent sterility data and it revealed 27 tolerant lines, 71 intermediate and 24 intolerant (Table 59).

- Due to stemborer infestation, advance lines were not evaluated for uniformity and only few seeds were produced. However, heat-tolerance of 156 lines was assessed using primary panicles that were not affected by stemborer. Panicles of 156 lines were taken and it revealed 19 tolerant lines, 86 intermediate and 51 susceptible.

- Panicle selections were employed in uniform lines due to severe stemborer infestations. Panicles from 303 lines were collected and verified 19 tolerant lines, 188 intermediates and 54 susceptible. Seed increase and purification completed in 2016 wet season.

- Three populations for QTL analysis established in glasshouse were already phenotyped. DNAs were extracted from these plants and 71 samples will be sent to IRRI before the end of December 2016.

- Four populations had four generation advance using Rapid Generation Advance (RGA) facility. These populations will be screened and selected under field condition in 2017 dry season.

- Six elite lines were submitted to NCT for 2016 and 2017 DS evaluation (Table 60).

- HTVN-1-1-4-1-3-3-B passed MET 1 and will be advance to MET 2 in 2017 (Table 60).

- Four were submitted in AYT or MET and one line, PR 42073-7-3-1-2-3-B was selected and will be advanced to MET 1 (Table 60).
- Seven new entries for 2017 AYT were submitted for 2017 evaluation (Table 60).

- Ninety-five lines were submitted to Preliminary Environmental Yield Trial.

Table 58. Lists of entries planted and selected on 2016 dry season.

Generation	Lines Planted	
	2016 DS	2016 WS
F1	44	44
F2	30	98
F3	372	157
F4	105	163
F5	27	9
Advance Lines (ON)	181	164
Uniform Lines (HT-SI)	415	405
SI (ELITE LINES)	100	96

Table 59. Summary of lines selected based on spikelet sterility 2016 dry season.

TRIAL/NURSERY	TOLERANT	INTERMEDIATE	INTOLERANT
Breeding Lines	27	71	24
Advanced Lines	61	188	54
Uniform Lines	19	86	51
	<17.5% STERILITY	**18-39% STERILITY**	**>40% STERILITY**

Table 60. Entries currently in NCT, MET 1, MET 2, AYT.

DESIGNATION	Maturity	Sterility	Yield	Blast	BLB	Amylose	Chalkiness	Remarks
PR42026-34-1-3-B-2	129	66.0	6.8			I	Pr	NCT
PR42130-M-1-B-6-2-B-7	116	70.1	6.4	I		L	G1	
PR44500-A3-3-2-2	124	62.2	6.2			I	G1	
HTVN-13-9-2-1-1-B	121	75.0	6.0	I		VL	Pr	
PR 40330-4-2-7-1-2-1	122	50.7	5.8			L	G3	
PR42132-M(I)-1-B-8-B-B-6	118	71.8	5.5		I	L	Pr	
PR42073-7-3-1-2-3	120	70.0	7.5			L	G2	AYT-MET 1
HTVN-1-1-4-1-3-3-B	124	85.0	7.0	I				MET1-MET 2
HTVN-1-4-8-4-2-3-B	122		8.9					AYT
PR 37464-31-3-2-2-2-3-1-B-6-1-1	122		8.2					
PR 37541-43-3-2-2-2-1-1-2-3-B-2-1-1	126		9.34					
PR 37605-9-2-2-2-3-1-B-1-1-1	122		8.96					
PR37056-19-1-1-1-2-3-2-B-1-1-1	128		9.93					
PR42032-26-6-1-B-2	123		8.5					
PR42116-1-1-1-3-2	122		8.4					

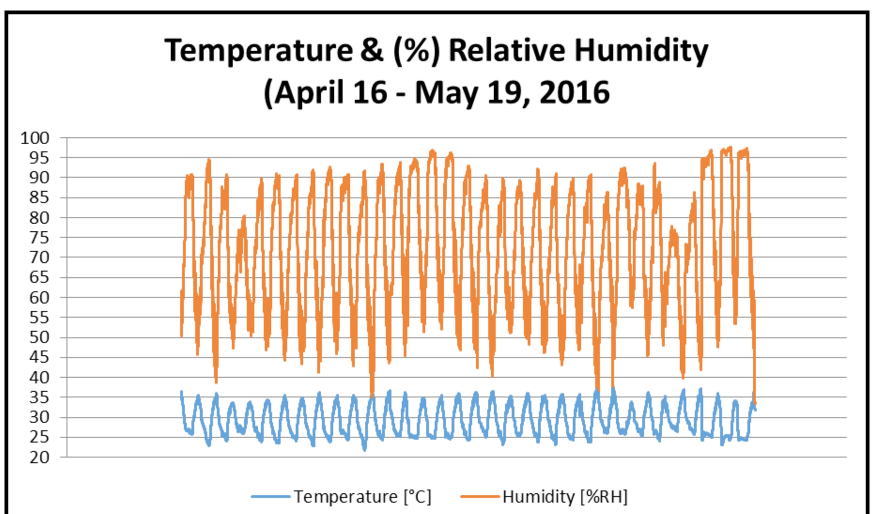


Figure 64. Temperature and relative humidity under field conditions at PhilRice, Nueva Ecija from April 16-May 19, 2016.

Genetic improvement of locally-adapted rice cultivars and elite lines for upland and drought-prone rainfed lowland environments

VC Lapitan and MJT Mercado

Lower productivity in rainfed lowland and upland areas are caused by the frequent occurrence of drought due to a failure of rain or long spell between two rains. It was predicted that due to climate change water shortage will be further experienced in years to come (Wassmann et al., 2009) and therefore the effects of drought in agriculture particularly in rice farming are predicted to become worse (Bates et al., 2008). Damage from drought may occur at the seedling stage and tillering stages, and on some occasions the damage is also severe at the reproductive stage. Several approaches such as integrated management technologies and irrigation enhancements can be employed to mitigate drought stress due to climate change; however, drought tolerant varieties developed through plant breeding are more accessible to farmers than these interventions that might require large investments by farmers. The continued application of conventional breeding and the recent developments in non-conventional approaches offer significant potential for improving yield growth and adaptation to drought in upland and drought-prone rainfed lowland environments.

Activities:

- Screening and identification of tolerant rice varieties and donor parentals for breeding.
- Generate elite lines that are suitable and locally adapted for upland and drought prone rainfed environment.

Results:

- A total of 12 donor parents were identified and selected possessing good seedling vigor, ability to recover from drought stress, resistance to pest and diseases and with good grain quality. Donor parentals were crossed with popular high yielding modern varieties such as NSIC Rc18, NSIC Rc222, NSIC Rc238 and PSB Rc82.
- Table 61 shows the total number of entries evaluated and selected during the 2016 WS (Figure 65) under rainfed lowland condition. The selected entries will be advanced to next generations in 2017 DS.
- Selected BC2F5 that performed well and shows line uniformity during the trial are advanced to next season trial as ON entries.

- Due to strong wind caused by typhoon Karen and Lawin that hit the field, natural selection for lodge tolerance was employed. Entries severely lodged were rejected in the selection process.
- For field pest screening for stemborer infestation, out of the total 774 advance lines, 768 lines were found to be resistant (R), 5 entries were moderately resistant (MR) and 1 entry to be moderately susceptible (MS).
- Brown Plant Hopper (BPH) and Green Leaf Hopper (GLH) screening tests were performed under the greenhouse condition by the Entomology Department, Crop Protection Cluster (CPC-CA), UP Los Banos.
- Out of the 100 entries screened for BPH, 49 entries were found to be intermediate (I); 41 entries moderately resistant (MR) and 10 entries were moderately susceptible (MS).
- For GLH screening, out of 100 entries, 53 were found to be intermediate (I); 26 entries moderately resistant (MR); 20 entries were moderately susceptible (MS) and one entry was susceptible (S).
- Continuous rain during the late reproductive to harvesting stage caused difficulty in harvesting and data gathering.
- A total of selected 14 advance breeding lines that performed well at normal rainfed condition will be submitted for MET trial. Yield during the trials ranged from 6.24 to 7.23 tons/hec.
- Initial selection of entries based on the ability to recover after the onset of drought was collected at the upland condition even if the trial is still on-going (Table 61).

Table 61. Number of entries selected during the 2016 WS and for evaluation in 2017 DS under rainfed condition. Numbers in parenthesis are entries evaluated in 2016 WS.

Generation	No. of entries selected in 2016 WS	No. of entries for evaluation in 2017 DS	Remarks
Rainfed condition			
F1		13	
F2	19		
F3	251 (86)	888	
F4		258	86 entries were selected X 3 plants collected per entry.
F5	39 (21)		
ON	273	246	21 entries from F5, 57 entries from BC2F5 and 168 re-ON due to lodging.
PYT	285	363	285 existing entries + new 105 entries from ON
BC2F5	255	57	Forwarded to ON
Upland condition			*Initial selection (Trial still on-going)
F5	72	23	
ON	3*		
BC2F5	537	167	

Figure 65. Established fields at harvesting stage during 2016 WS trial.

Breeding of Resilient and Productive Rice Genotypes Adapted to Water Stress Environment in Mindanao

JM Niones, SJE Labarosa, VAC Marcelo, MAR Orbase, RR Suralta, LM Perez, and SE Abdulla

Soil moisture deficit at varying degree is a recurring stress that affects rice production. Rice plants in rainfed rice areas are usually exposed to soil moisture fluctuation due to erratic rainfall. Rice areas in Mindanao particularly in Regions 9, 10, 11 and 12 are highly dependent on the availability of rainfall for irrigation source. In addition to water deficit stress, problems on RTV and BLB diseases often arise. Thus, this study aimed to develop rainfed lowland rice advanced breeding lines with BLB and RTV resistance and identify cultivars adapted to areas prone to soil moisture fluctuations. A series of identification of cultivars with plastic root system, development of breeding lines, screening for drought and disease tolerance, yield and multi-location trials will be conducted from 2014 to 2019 to achieve these objectives.

Activities:

- Promising advanced breeding lines were evaluated for general (GYT) and preliminary (PYT) yield performance at PhilRice Midsayap.
- These entries were laid out in a randomized complete block design with three replications in a 15 sq. m plot for PYT and 20 sq. m for GYT with 20 cm x 20 cm planting distance.
- Experiment areas were drained 14 days after transplanting to simulate rainfed condition.
- Data gathered includes heading date (DAS), flowering date (DAS), maturity date (DAS) phenotypic acceptability (SES), plant height (cm), number of tillers (cm), plot yield (g), moisture content (%), number of filled and unfilled grains, weight of 100 seeds (g), panicle length (cm) and above ground biomass (g),
- 10 successful crosses from drought tolerance and root plasticity donors generated.
- Performance of 10 high yielding (≥3.5 tha-1) breeding lines with acceptable PAcp (1-5) selected and evaluated under soil moisture fluctuation.

- 7 elite lines advanced to MET and 3 advanced elite lines nominated to NCT in Dec. 2016.

Results:

- Nine breeding lines and three check varieties were evaluated in general yield trial (GYT) and 17 breeding lines and three check varieties in preliminary yield trials under simulated rainfed conditions in PhilRice Midsayap.
- For the general yield trial, estimated yield ranges from 122kg/ha (Dinorado) to 2,556kg/ha [IR83142-4-4 (IR07G 104)] with yield advantage of 84.34% (Table 62) for all check varieties under simulated rainfed condition. In addition, days to maturity ranges from 96 DAS (Dinorado) to 114 DAS (NSIC Rc226) (Figure 66).
- For the preliminary yield trial, estimated yield ranges from 527 kg/ha (PR33608-15-B-B-B-5-4-B) to 1,748 kg/ha (Raeline 6) with yield advantage of 28.84% (Table 63) for all check varieties under simulated rainfed condition. Furthermore, days to maturity ranges from 98 DAS (101 NCI) to 115 DAS (PR33608-15-B-B-B-5-4-B) (Figure 67).
- 17 successful crosses were generated from drought tolerance and root plasticity donors, 65 plant selections in F2; 324 in F3; 129 in F5 and 993 in the F6.
- Five breeding lines with a yield of (3612kg/ha to 3986kg/ha) and PAcp of 3 to 5 (Table 64) were advanced to GYT.
- Raeline 5, Raeline 7, and Raeline 11 were nominated in NCT. Moreover, six breeding lines, Raeline 5, Raeline 6, Raeline 9, PR39954-B-15-2-4-2-1, PR39954-B-15-1-2-2, PR39954-B-15-2-4-1-1, were elevated to MET rainfed.
- Data collection for the advanced breeding lines evaluated for general (GYT) and preliminary (PYT) yield performance at PhilRice Midsayap during the 2016 wet season is still on-going.

Table 62. Some agronomic characteristics of 9 GYT entries and 3 check varieties under simulated rainfed condition in 2016DS.

Genotype	Grain Yield (kg/ha)	Yield Advantage (%)	Maturity (DAS)	Spikelet Fertility (%)	Above Ground Biomass (g)
DRS 768 (Raeline 7)	2533.23	82.67	109	58.9	34.23
DRS 14 (Raeline 3)	2023.73	45.93	105.67	77.66	41.93
BP1976B-2-3-7-TB-1-1	676.34	-51.23	105.33	59.18	40.7
B11598C-TB-2-1-B-7	163.02	-88.24	108	63.64	39.78
B11577E-MR-B-12-1-1	814.44	-41.27	107.67	68.48	37.47
IR83142-4-4 (IR07G 104)	2556.35	84.34	108	68.19	42.53
IR82912-B-B-16	835.08	-39.78	107.67	66.09	47.67
DINORADO	121.97	-91.21	96.33	62.94	38.15
RAELINE 3	768.12	-44.61	105	58.86	36.17
NSIC Rc226	1845.88	-	113.67	53.68	45.43
NSIC Rc298	1378.73	-	110	66.52	30.13
NSIC Rc222	935.72	-	107	53.72	40.77

Table 63. Some agronomic characteristics of 17 PYT entries and 3 check varieties under simulated rainfed condition in 2016DS.

Genotype	Grain Yield (kg/ha)	Yield Advantage (%)	Maturity (DAS)	Spikelet Fertility (%)	Above Ground Biomass (g)
Kawilan	861.67	-36.82	104.33	53.92	35.23
101 NCI	548.33	-59.11	98	39.15	43.87
Jasmin 1	1116.67	-17.28	102.67	52.37	37.93
Raeline 6	1748.33	28.84	107.67	44.6	36.33
Raeline 7	606.67	-55.21	105	65.48	34.57
Raeline 8	701.67	-48.07	107.67	64.11	42.23
PR33608-13-B-B-B-16-5-B	690	-49.13	111.67	53	42.43
PR33608-14-B-B-B-13-1-B	1421.67	5.06	107.33	58.77	39.1
PR22608-14-B-B-B-13-2-B	925	-32.07	103.67	47.39	36.6
PR33608-15-B-B-B-5-2-B	788.33	-41.81	109.33	47.04	31.3
PR33608-15-B-B-B-5-4-B	526.67	-61.16	115	60.23	32.67
PR33608-16-B-B-B-19-4-B	1550	13.32	111	50.51	34.97
PR33608-19-B-B-B-12-5-B	998.33	-26.64	106.33	57.46	41.57
PR33608-26-B-B-B-7-2-B	638.33	-53.07	108	53.32	41.73
PR33608-30-B-B-B-17-3-B	1651.67	20.69	110.33	68.16	29.83
PR33642-72-B-B-B-7-3-6	560	-58.81	113	65.98	41.33
PR33642-72-B-B-B-7-3-10	883.33	-34.96	111	62.29	35.13
NSIC Rc226	1646.67	-	110	40.76	35.2
NSIC Rc298	1015	-	108.67	63.48	41.7
NSIC Rc222	1437	-	111	70.53	34.07

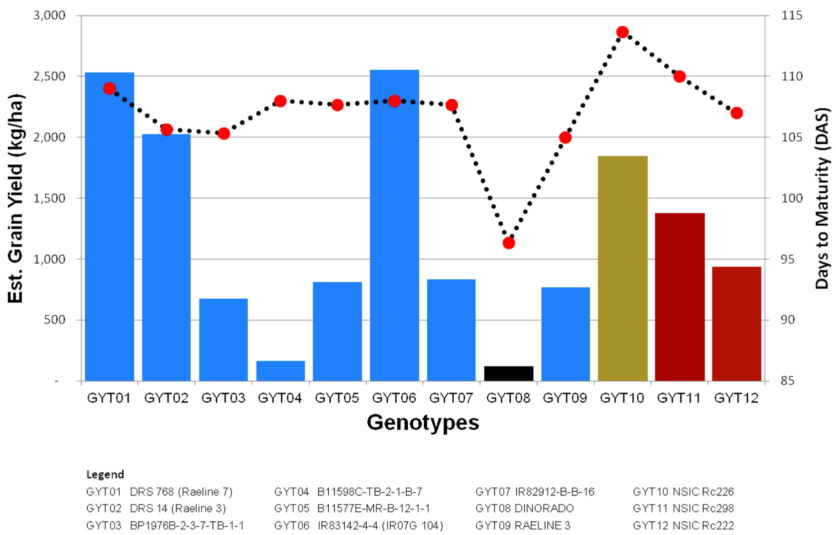


Figure 66. Estimated yield (kg/ha) and maturity (DAS) of GYT entries in 2016 DS.

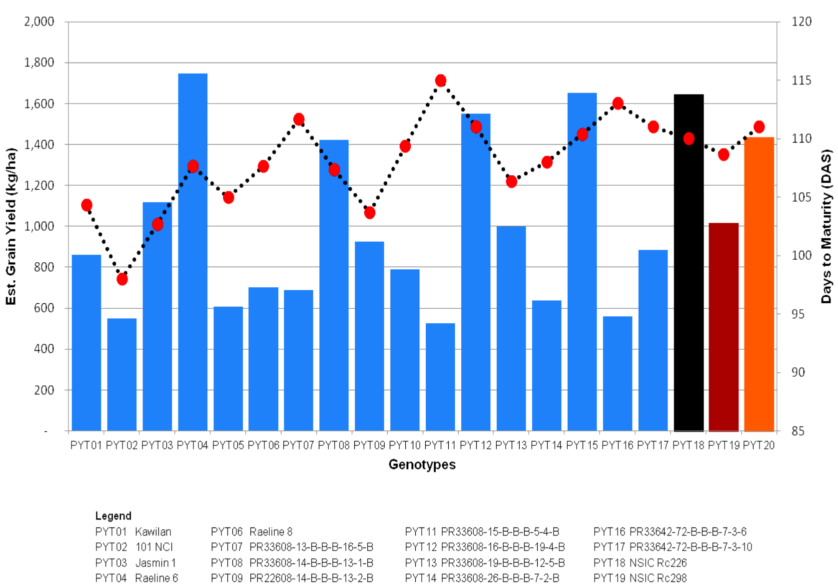


Figure 67. Estimated yield (kg/ha) and maturity (DASD) of PYT entries in 2016 DS.

Table 64. Some agronomic characteristics of 5 BR-ON entries and 5 check varieties under simulated rainfed condition in 2016WS.

Designation	yield (kg/ha)	YA (%)	50% heading	PAcp	plant height (cm)	no. of panicles	no. of tillers
PR33608-1-53-B-1	3814.15	106.87	66	3	124	13	14
PR33608-14-B-B-B-13-1-B	3612.08	95.91	66	5	127	13	14
PR33608-15-B-B-B-5-2-B	3986.72	116.23	62	5	120	12	13
PR33608-19-B-B-B-12-5-B	3712.13	101.33	65	5	130	15	16
PR33642-72-B-B-B-7-3-4	3683.69	99.79	61	5	118	13	14
IR64	1639.38	-11.08	56	6	113	12	13
PSB Rc14	1617.26	-12.29	59	6	111	15	13
PSB Rc68	1164.10	-36.86	72	5	129	12	13
NSIC Rc192	1688.59	-8.42	63	6	125	14	14
NSIC Rc222	1843.77	0	62	6	114	14	16

Identification of High-value traits (grain quality and nutrition) and Population Improvement of Upland Rice Cultivars in Mindanao

AY Cantila, SE Abdula, and JL Balos

Traditional cultivars far exist in the upland; these traditional cultivars were known thru the years to stand biotic and abiotic stress and are believed to be of higher quality than lowland rice. In population improvement, selection method is an important step. Recurrent selection (RS) is a cyclic breeding system aiming at a gradual increase in frequency of desirable alleles for a particular quantitative characteristic without a marked loss of genetic variability. In Mindanao, farmers cultivated significant hectares of popular traditional and indigenous varieties. Farmers' adoptions of new varieties were greatly influenced by grain quality traits. Different characteristics of 'grain quality' in rice largely determine the product's market price and acceptability. Thus, it is important to improve farmers' preferred variety and identify the nutritional value of upland rice to help Filipino households benefit from high-quality and nutrient rich rice, thus helping address the productivity, profitability and malnutrition problem.

Activities:
Activity 1: Population improvement of preferred upland rice varieties in Mindanao.

Population improvement through recurrent selection.

- Generated base population was improved using recurrent selection. All entries were crossed to CMS line. Progenies was then evaluated and compared to the parents.

Developed and evaluated lines obtained from the sources against biotic and abiotic stresses.

- Lines with superior performance compared to their parents was evaluated against biotic and abiotic stresses like disease and insect screening and screening for drought and submergence.

Activity 2: Identification of High-Value Traits (Grain Quality and Nutrition) of Upland Rice Cultivars in Mindanao.

Collection of traditional, improved and elite breeding lines from different places in Mindanao.

- Materials was collected from Mindanao using the PhilRice collaborating stations/Universities. In addition, tradvar from Philrice genebank may be collected (non-evaluated lines) and evaluated the same way the other collections. Subsequently, collected materials were seed increased. All collected tradvar/entries were screened for zinc and iron tolerance as well as analyzed their iron and zinc concentration. The same set of entries was also evaluated in terms of their grain quality (physical evaluation). Entries with high concentration of Fe and Zn were selected and further functional/molecular analysis was conducted.

Results:

- Eight cultivars such as Milbuen 3, Pinursigi, C22, Aritao Cagayan, Ranan, Awot, Salimboa and Kulu were found to be tolerant in Zn deficiency test.

- New collected lines from Senator Ninoy Aquino, Sultan Kudarat.
  - Hinumay and Kasagpi pigmented grains
  - Malido and Intramis-aromatic

- From Norallah, South Cotabato
  - Masbate-extra-long grain (Figure 68)

- Awot, Azucena, Dinorado, Dukpayon, Hinumay, Kasagpi, Kutibos, Malan, Minurugon, Palawan, Putotan and Wagwag were among the preferred varieties had undergone recurrent selection for population improvement.

- Only Palawan, Hinumay, Minarugon, Wagwag and Dukpayon had better yields with 3.14, 3.09, 3.05, 3.03 and 3.00 t/ha among the 12 improved population (at 3rd generation)

Figure 68. Masbate-extra-long grain collected from Norallah, South Cotabato.

Utilization of Wild Rice Species as Gene Sources for Drought Tolerance and other Traits

CFSTe, RTMiranda, and NRLSevilla

Drought is the single most important abiotic factor that hinders productivity in rainfed areas. Increasing production in the vast rainfed areas in the country is crucial in achieving rice self-sufficiency and can only be achieved by developing technologies such as appropriate rice varieties and water-saving technologies that will address water-related stresses that become more and more severe due to changing climate patterns.

Wild relatives of rice and landraces are rich source of agronomically important traits such as resistance/tolerance to biotic and abiotic stresses, that can be transferred into cultivated varieties through wide hybridization. This study aimed to: (1) acquire wild rice accessions and evaluate them for tolerance to drought and other important traits; (2) transfer drought tolerance and other important traits from wild rice donors into elite background through wide hybridization and; (3) evaluate the comparative performance of derived elite breeding lines under field condition.

Activities:

- Screening for drought tolerance (Figure 69) of 446 elite breeding lines was composed of 63 lines replicated under Preliminary Yield Trial and 257 lines under Advance Observational Nursery under field conditions. Drought stress was imposed during the reproductive stage (50 DAS) of the materials and lasted for 45 days.

- Drought screening of five wild rice accessions under screen house conditions was conducted to evaluate drought tolerance.

- All entries from the dry season screening were forwarded for wet season yield performance evaluation and for generation advance.

- Performed hybridization between O. meridionalis and available recipient parent.

Results:

- Yield components of all the materials under stressed/ unfavorable condition during the season were not evaluated due to severe drought stress and followed by heavy rains during the recovery phase of the plants, resulting to unfilled grains if not lodged and very low recovery. Hence, trait confirmation will be done the following drought screening.

- Grain yield under favorable conditions identified four entries with >4tha-1 yield, including drought tolerant check NSIC Rc276 with 4.33tha-1 (Figure 70). Performance of these lines under drought stress will be further evaluated the next season.

- Data on soil moisture content (SMC) under drought-stressed conditions at 45 days after drought imposition in 15 cm and 30 cm soil depth were 11.5% and 12.2% respectively with 99 cm water table depth.

- Among the breeding lines under PYT, three (Figure 71.) obtained leaf drying (LD) score of 3 while the susceptible check IR64 obtained LD of 7. Drought tolerant checks PSB Rc14 and NSIC Rc276 obtained scores of 5 and 7 respectively. These elite lines were derived from crosses of land races, wild rice derivative and drought tolerant varieties.

- Eleven lines under AON showed promising drought response with leaf drying score of 3.

- The ability to maintain leaf water status may allow greater transpiration and photosynthetic activity, and thus would be helpful in grain filling stage of rice under drought stress.

- Five wild rice accessions (Oryza australiensis) were screened for drought tolerance (Figure 72) and regenerated another ten wild rice accessions for seed increase.

- Initial analysis identified two accessions with promising response to drought with leaf drying score of 3 while the susceptible check, IR64, scored 9.

- Four accessions of the said wild rice were initially characterized were identified with purple sheath/base and one exhibited bending at the node area (Figure 72).

- Evaluation and further analysis of wild rice accessions are currently being done, including molecular characterization using primers linked to known disease resistance genes in rice.

- Produced 3 F1 seeds from cross between O.meridionalis and PRUP 101 and is now awaiting response from embryo rescue.

- For WS, 63 advanced lines were evaluated for preliminary yield trial and 257 for advanced observational nursery. Data generation is on-going.

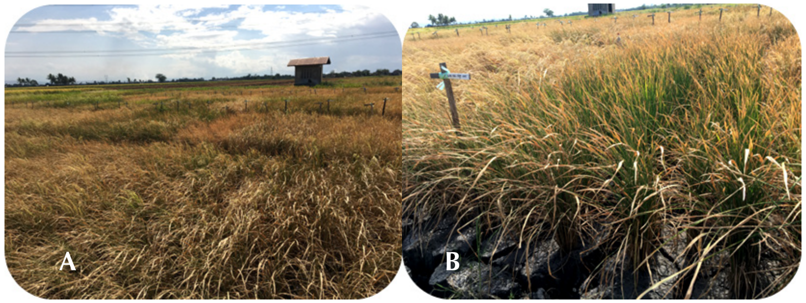


Figure 69. Field set-up (a.) under severe drought stress condition and (b.) a promising line with green leaf retention.

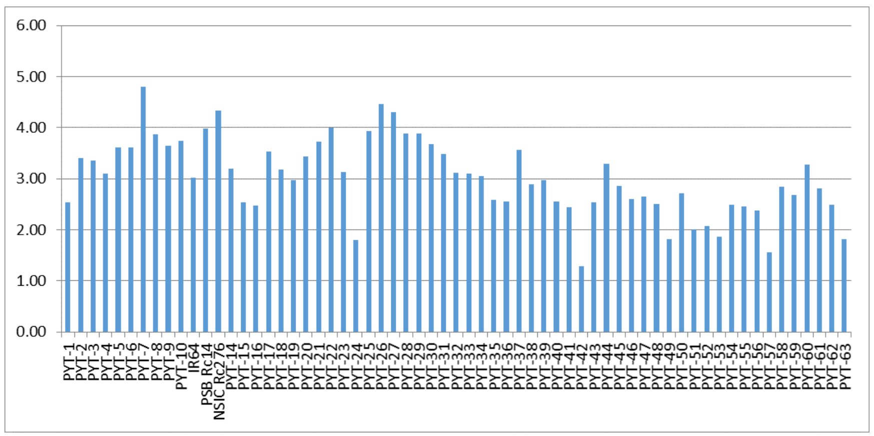


Figure 70. Grain yield of 63 elite breeding lines under favorable conditions, 2016DS.

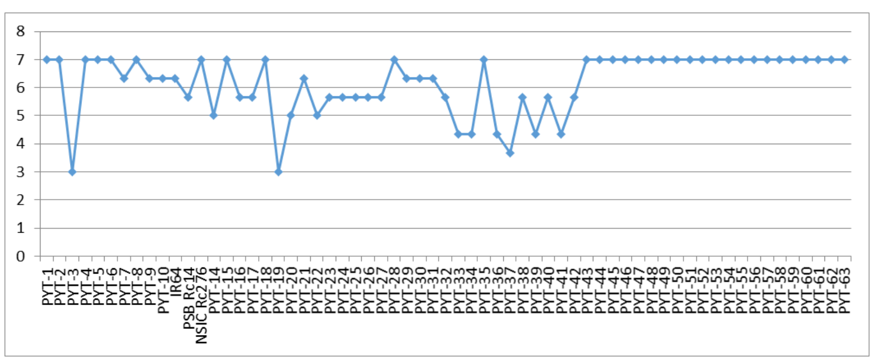


Figure 71. Leaf drying (LD) scores of 63 PYT entries screened for drought tolerance.

Figure 72. Drought tolerance screening of wild rice accessions at screenhouse condition. Set-up (a.) before drought imposition, (b.) after drought imposition and (c.) initial characterization of wild rice accession.

Pilot testing the KeyChecks for the Drought-prone Rainfed Lowland PalayCheck System

Nenita V. Desamero, Rolando T. Cruz, Wilfredo B. Collado, Reynaldo C. Castro, Genaro S. Rillon, Sandro D. Cañete, Daisy D. Pablero, Alex J. Espiritu, Ailon Oliver V. Capistrano, and RJ D. Buluran

The use of PalayCheck System as a monitoring guide in cultivating rice has been very successful in enhancing rice production in the irrigated lowland ecosystem. The system, however, does not perfectly fit in the rainfed rice ecosystem, considering its complexity and heterogeneity, warranting location-specific technologies and management systems for sustained rice productivity. Interventions and best farmers' practices associated with rice production in the rainfed lowland are incorporated in PalayCheck System. The system needs to undergo multi-location adaptation to validate different keychecks and the tailored associated production technologies. The required adaptability cum validation trials will, likewise, identify other best practices from each pilot site for further development and refinement of the system. Location-specific recommendation(s) to achieve a keycheck for enhanced production is necessary to address the complex and heterogeneous nature of the rainfed areas. The study aimed to evaluate and adapt in-field water harvesting system (IWHS) as a means of ensuring water availability during critical crop growth stage, one of the proposed KeyChecks for drought-prone rainfed lowland.

Activities:

- KeyCheck to ensure water availability during critical crop growth stage is addressed by adapting two in-field water harvesting systems (IWHS) in two farmers' field, one in Sta. Maria and the other in Casilan, Pangasinan. The modular drum-type (IWHS) was installed in Sta. Maria for demonstration.

- Crop suitability analysis of the pilot site was done. Corn as second crop was tried for the first time in Sta. Maria pilot site, which was provided with water harvesting systems, small farm reservoir (SFR) supported by the local government unit and modular drum-type IWHS, with materials supported by PhilRice and labor for construction provided by the farmers as their counterpart.

- The cemented tank-type IWHS was targeted to be constructed by May of 2016 in the Casilan pilot site, but did not materialize due to delayed supply procurement and on-set of rainy season.

Results:

- One modular type IWHS was constructed in Sta. Maria, Pangasinan in 04 November 2015. The system consists of three-200 Li capacity plastic drums per module, and with four modules. Target date of construction was May 2015. Procurement and delivery of supplies was delayed hence the IWHS was established very late in 04 November 2015, after the 2015 WS rice crop was harvested. With this scenario, it was targeted to demonstrate the feasibility of having a second crop using the rain water collected in the IWHS from November to December and in the SFR.

- Crop suitability analysis was conducted identifying corn, sorghum, squash, sweet potato, ground nuts, mungbean, and mango as moderately suitable crops for cultivation in the pilot sites. Growing short duration rice and non-rice crops can make use of residual soil moisture and the amount of water harvested when these crops are planted in relay to wet season rice.

- The rain water harvested in November-December 2015 in modular (PhilRice technology) and SFR (LGU-funded technology) was used to grow corn as second crop after rice and to maintain the rice crop established from drop seeds. The water in SFR dried up by end of February 2016.

- Employing farmers' practice in Umingan, a hybrid yellow corn "LVN 10" was established in 613 m2 paddy area in 05 January 2016 by sowing 2-3 seeds per hill, spaced at 20 cm x 50 cm within and between rows. The crop was fertilized with 189-44-44 (NPK), with split application of 14-14-14 and 46-0-0, at 3rd (3.3 bags each) and 8th (3.0 bags each) leaf stage (20 January and 03 February 2016, respectively). No pesticide was applied, and weeds were managed manually. The experimental area was irrigated four times: during 2nd harrowing (04 Jan), 1st (20 Jan) and 2nd (03 Feb) fertilizer application and flowering stage (28 Feb 2016) at 12 hours per irrigation (6 AM to 6 PM) using the harvested water.

- The corn plants stood from 204 to 225cm, measured from 10 sample plants. The crop yielded 200kg (~3.262 t/ha) kernels, with an average of 51 hills and 68 ears harvest from 5.0 m2. The corn kernel was sold at Php 10.60 per kg. Within 98 days from sowing, the crop was at its physiological maturity. This activity has demonstrated the feasibility of growing a second crop with corn in the area provided rainwater is harvested, conserved and utilized appropriately. (Note: The first corn planting was done in 02 December 2015 using the waxy corn "Lagkitan", a hybrid from Allied botanical company, maturing in 75 to 80 days. With heavy rains caused by typhoon, the paddy was flooded two days after sowing resulting in very low germination. The crop was plowed under, harrowed in 04 January, and a day after replanted with "LVN 10" corn variety, with two kg seeds)

- Growing short maturing rice as second crop was also demonstrated as the farmer-partner was able to harvest 1.056 t/ha, equivalent harvest from 610 m2 paddy beside the corn area. The rice crop was established from drop seeds of NSIC Rc222 cultivated in the previous cropping (2015 WS). Late harvesting in 2015 WS, due to unavailability of hired labor, resulted in seed shattering and significant amount of drop seeds in the paddy. With residual soil moisture, and after cultivation, the drop seeds germinated and with supplemental irrigation from IWHS grew into maturity.

- Ocular inspection of the site for the construction of cemented tank-type IWHS in Casilan, Pangasinan was done in 12 April 2016. The target date for construction was May 2016, which did not materialize as supply procurement was again delayed. The first batch of materials for use in the construction of IWHS was delivered in August 3, 2016, two months past the regular crop establishment in the pilot area. The other construction materials like sand, gravel, cement and hollow blocks are to be delivered on-site once the construction started, targeted the soonest when there will be no prolonged rainy days in the last quarter of 2016, hopefully by November 2016.

- The farmer-partner, Mr Ernesto Tobias, from Casilan, Umingan, Pangasinan owns 9,544m2 rainfed rice area. In 2016 WS, he grew NSIC Rc308 rice variety with 111 days maturity, transplanted in 14 July 2016 and harvested in 15 October 2016. The crop yielded 72 cavans with an average grain weight of 60kg/cavan (4.320t/ha), with pure rain as source of irrigation water. Rain gauge and piezometer were installed in the pilot area to monitor rainfall and below ground water availability. Crop-cut and samples for yield and yield components were harvested. Sample processing and data determination are still in progress.

VII. Development of Selection Criteria and Strategies for Organic Rice Breeding

Project Leader: Alvin D. Palanog

The breeding goals and objectives of conventional and organic rice systems are much alike. Basically, the breeding is directed to achieve desired traits such as high grain yield, resistance to biotic and abiotic stresses, and grain qualities acceptable to consumers. The main differences are the selection environment and the expression of these traits on these environments. Some of the important traits to be considered in organic rice breeding system are not often addressed in conventional breeding systems particularly on traits such as nutrient uptake efficiency, weed competitiveness, high total biomass yield, tolerance to mechanical weed control, and others. These traits are agronomic important traits and are highly cultural management dependent and different traits demands for different selection parameters and criteria in order to achieve maximum genetic gain. The basic requirement for the breeding program to commence is to test different genotypes under organic condition, identify the genotypes that will perform well under this condition, and characterize the traits of the adaptable genotype(s). From these, phenotypic characteristics ideal for adaptation under could be identified and could be the set as phenotypic parameters in selection for ideal genotypes.

Under conventional rice breeding system, it takes 10 years or more from hybridization or crossing of two parents to develop a new variety. To realize varietal improvement for organic farming systems, it is imperative that screening and crossing of ideal genotypes have to make as early as possible (Lammerts van Bueren et al. 2011). To develop an effective strategy of variety, development, the breeder must understand the alternative method that could be utilized and evaluate the genetic improvement that could be realized using this method (Fehr). Selection has always been an integral tool in plant breeding. The efficiency of selection largely depends on the accuracy and precision of selection criteria to the particular target trait and most importantly the ability of the breeder to effectively employ the selection criteria set. Selection criteria and parameter discriminate traits between desirable traits that should be advanced and undesirable traits that should be discarded. Their ultimate goal is to develop variety(ies) that address the criteria and suited to the target environment.

Evaluation of genotypes under low-external input system
CU Seville, AD Palanog, and LT Sta.Ines

In support to the declaration of Negros as an organic island, PhilRice Negros Station started its organic rice production and research in the six (6) hectares research and seed production area during the dry season of 2012. Various researches are needed to know the appropriate varieties or rice plant type suitable for organic rice production. It is also essential to know if there is need to have a separate varietal development intended for organic rice production, thus this study. The study aims to assess the performance of genotypes under conventional and organic rice production systems. It also aims to identify ideal plant type suitable for organic rice production. In this study, 30 genotypes were evaluated under three different production practices: organic, zero, and conventional system. Responses of different genotypes in terms of agronomic characters were recorded and variation of responses under various system were also noted to measure the indirect selection efficiency of traits particularly grain yield and biomass yield.

Activities:

- A field trial was conducted using 30 genotypes (modern and special rice) established in three different production systems: organic, zero, and conventional input systems (Table 65).

- Agronomic data were gathered and analyzed using STAR and PBTools.

Results:

- During the wet season 2015 establishment, days to heading, plant height, number of productive tillers, panicle length, average spikelet, percent fertility seed weight and yield per ha were significantly affected by the production systems. Conventional system had longer days to heading, taller in height, more productive tiller, longer panicle length more spikelets per panicle, heavier seed weight and higher yield than organic and zero input production system. No significant differences were observed on harvest index (Table 66).

- During the DS 2016 establishment, most of the parameters are significantly affected by the production systems (Figure 73) except for the seed weight and harvest index. Longer days to heading, taller in height, more productive tillers, longer panicle, more spikelet per panicle and higher yield were observed in conventional production system. Higher percent fertility and seed weight were observed in organic and zero input, respectively (Table 66).

- Under organic production system, mean yield ranges from 2.3 to 4.7t/ha during the wet season. Hybrid and modern released varieties performed well under the low input system. NSIC Rc120, Rc222, Rc214 and Rc280 were consistent to perform in succeeding seasons. Pigmented Corocan had also a promising performance under the system. During the DS2016, where El Niño phenomenon was experienced, mean yield ranges only from 0.8 to 3.2t/ha (Table 67).

Table 65. List of varieties established during WS 2015 and DS 2016.

VARIETY		VARIETY		VARIETY	
1	PSB Rc10	11	NSIC Rc282	21	BR261
2	PSB Rc36	12	NSIC Rc308	22	Calatrava
3	NSIC Rc19	13	NSIC Rc342	23	Corocan
4	NSIC Rc120	14	NSIC Rc344	24	Masipag 10-1-1
5	NSIC Rc214	15	NSIC Rc346	25	Raeline 6
6	NSIC Rc218	16	NSIC Rc348	26	Raeline 7
7	NSIC Rc222	17	NSIC Rc352	27	Raeline 8
8	NSIC Rc224	18	NSIC Rc354	28	Raeline 9
9	NSIC Rc240	19	NSIC Rc356	29	Raeline 10
10	NSIC Rc280	20	NSIC Rc358	30	NSIC Rc204H

Table 66. Mean yield and performance of 30 genotypes under three production systems during WS 2015 and DS 2016 at PhilRice Negros, Cansilayan, Murcia, Negros Occidental.

	Days to heading	Plant height (cm)	No. of productive tillers	Panicle length (cm)	Ave. spikelet/ panicle	Percent fertility (%)	Seed weight (g)	Harvest index	Yield (t/ha)
WS 2015									
Organic	82	102	8	26	142	68	32	0.31	3.3
Zero input	81	97	8	25	130	72	31	0.37	2.6
Conventional	84	114	12	27	148	66	32	0.22	3.9
Con	**	**	**	**	*	*	*	ns	*
Con x gen	ns	*	ns	ns	ns	ns	**	ns	*
DS 2016									
Organic	79	81	9	21	102	83	29	0.39	2.2
Zero input	78	74	8	20	78	81	30	0.40	1.5
Conventional	80	87	12	23	106	78	29	0.39	3.1
con	**	**	**	**	**	*	ns	ns	**
Con x gen	**	**	**	ns	**	ns	ns	ns	**

Table 67. Top 10 best performer varieties under organic production system at Philrice Negros, Cansilayan, Murcia, Negros Occidental WS 2015.

	WS 2015	Yield (t/ha)	DS 2016	Yield (t/ha)
1	Corocan	4.7	NSIC Rc204H	3.2
2	Raeline 7	4.1	NSIC Rc358	2.9
3	NSIC Rc204H	4.0	NSIC Rc360	2.9
4	NSIC Rc222	3.8	NSIC Rc342	2.9
5	NSIC Rc358	3.8	NSIC Rc222	2.8
6	NSIC Rc120	3.7	NSIC Rc214	2.7
7	NSIC Rc280	3.5	Corocan	2.7
8	NSIC Rc214	3.4	NSIC Rc19	2.6
9	NSIC Rc19	3.4	NSIC Rc282	2.5
10	NSIC Rc218	3.4	NSIC Rc280	2.4
Mean Yield (t/ha)		**3.3**		**2.2**

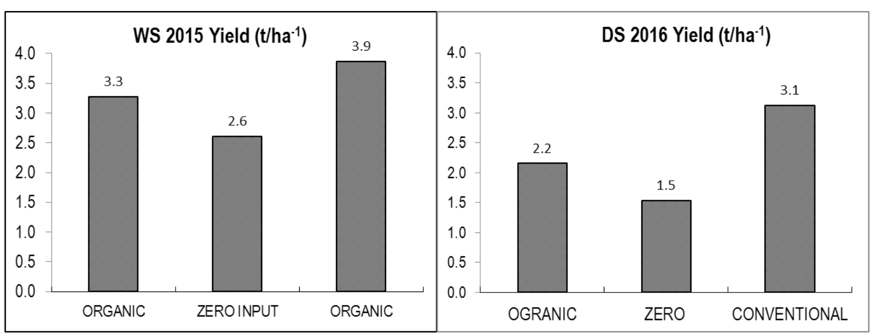


Figure 73. Yield trend of three production systems during WS2015 and DS2016 at PhilRice Negros, Cansilayan, Murcia, Negros Occidental.

The role of GxE in breeding for superior genotypes under low-external input system

AD Palanog, CU Seville, LG Dogeno, and LT Sta.Ines

The response of varieties to conventional rice production system will be more likely differ to their response to organic rice system which apparently due to the difference on level of inputs applied. Genotype x inputs (environment) interaction contributes largely to the variation of responses. Previous study showed significant genotype-by-fertilizer interaction when modern cultivars and advance lines were used. The genotypes with greater yield potential under fertilizer condition do not yield usually do not yield more than other genotypes high under low fertilizer/ no fertilizer condition (Wonprasaid et al.,1996; Romyen et al., 1998; Inthapanya et al., 2000). High genotype x input interaction exhibited would mean that cultivars selected under research station will not perform well in low-input farmer's field. Thus, indirect selection of varieties with higher grain yield under conventional system intended for organic system may not be effective. Study aims to (a) examine the effect of genotype x environment (input) interaction on grain yield and other agronomic traits; (b) identify genotypes generally- and specifically-adapted to low external input systems; and (c) Investigate the need for breeding for genotypes with general or specific adaptability to low-external input systems. A field trial was conducted in farmers' field using their indigenous organic cultural management and practices and evaluated the responses of 30 genotypes to various management practices.

Activities:

- Conducted field trials in farmers' field: a) Tabunan, Bago City, and b) Taloc, Bago City; and on-station trial at PhilRice Negros. Farmers practices and cultural management were followed all throughout the growing season of crop.

- Agronomic data were gathered and analyzed using STAR and PBTools. Combined analysis of variance across location was measured to determine the Genotype by managements (GXE) effects.

Results:

- In Taloc, Bago City, grain yield of 30 genotypes ranges from 1477 to 3940kg/ha with an average yield of 2541kg/ha. NSIC Rc354 out-yielded other entries while NSIC Rc218 obtained the lowest yield. The top ten high-yielding genotypes is presented in Figure 74. Meanwhile, in Tabunan, Bago City, grain yield ranges from 435 to 3808kg/ha with an average yield of 1300 kg/ha. Corocan- a traditional variety obtained the highest while PSB Rc36 had the lowest yield (Figure 75). Grain yield of genotypes evaluated at PhilRice Negros ranges from 1325 to 2723kg/ha with an average yield of 2148kg/ha (Figure 76). NSIC Rc224 out-yielded other entries while Raeline 8, an elite line for rainfed ecosystem had the least yield. Analysis of variance (ANOVA) for each location revealed a significant genotype variation indicating the diversity of grain yield response of genotypes under each organic practice. Taloc, Bago City is the highest yielding site (2541kg/ha mean yield) followed by PhilRice Negros (2148kg/ha) and Tabunan, Bago City as the least yielding site (1300kg/ha).

- Top ten high yielding rice genotypes across locations is presented in Figure 77. To determine, the stable and consistent genotype across locations/management systems, grain yield was plotted against their respective percent coefficient of variation (Figure 77) since the statistical tools would allow for GxE analysis only if there are ≥5 locations/sites. NSIC Rc224, NSIC Rc356, NSIC Rc360 were one of the genotypes considered as stable and high-yielding genotypes during the dry season 2016 trial.

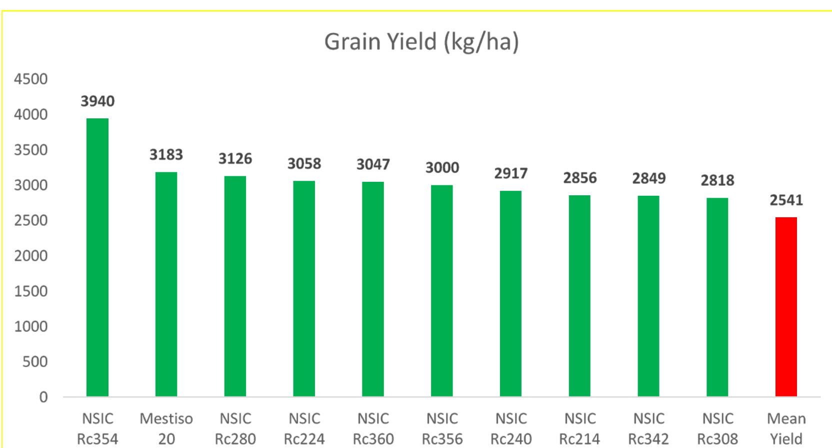


Figure 74. Top ten high-yielding genotypes in Taloc, Bago City with an average site grain yield mean of 2541kg/ha during the dry season of 2016 trial.

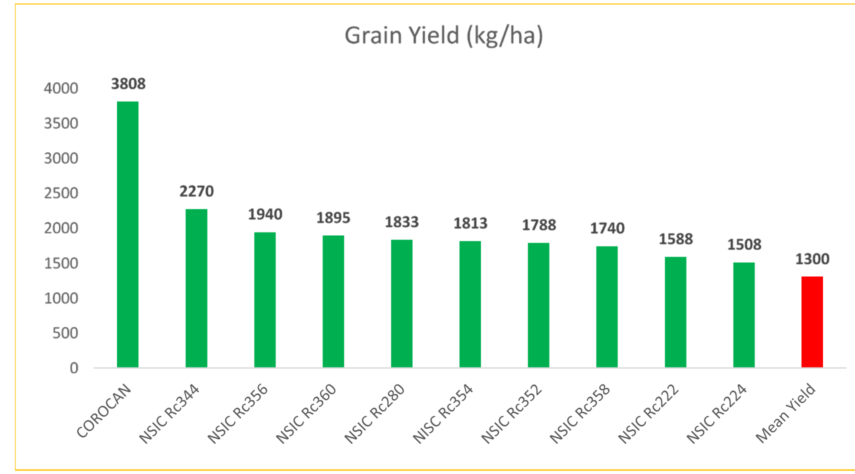


Figure 75. Top ten high-yielding genotypes in Tabunan, Bago City with an average site grain yield mean of 1300kg/ha during the dry season of 2016 trial.

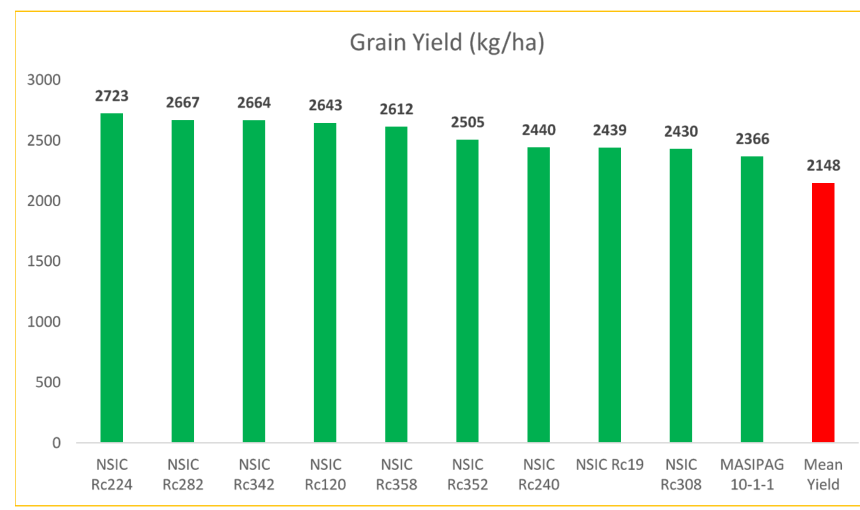


Figure 76. Top ten high-yielding genotypes at PhilRice with an average site grain yield mean of 2148kg/ha during the dry season of 2016 trial.

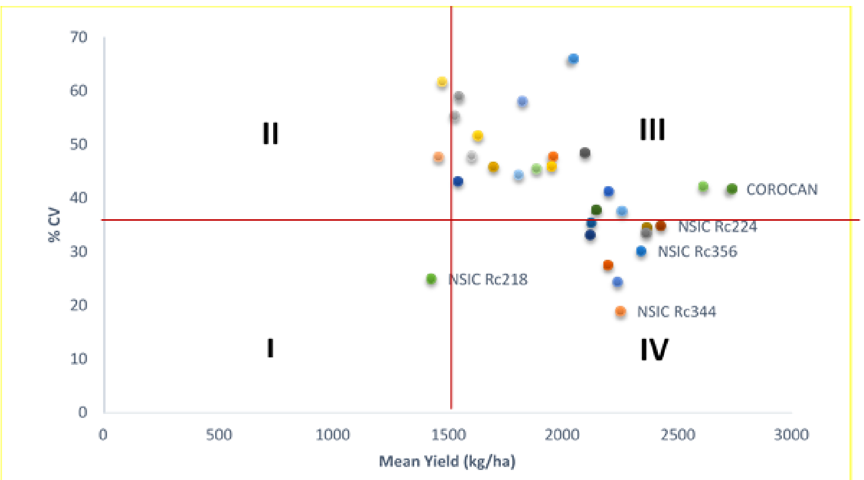


Figure 77. Stable genotypes identified by plotting the mean yield and coefficient of variation of the genotypes. Stable high-yielding genotypes are found in quadrant IV.

Abbreviations and acronymns

ABA – Abscicic acid
Ac – anther culture
AC – amylose content
AESA – Agro-ecosystems Analysis
AEW – agricultural extension workers
AG – anaerobic germination
AIS – Agricultural Information System
ANOVA – analysis of variance
AON – advance observation nursery
AT – agricultural technologist
AYT – advanced yield trial
BCA – biological control agent
BLB – bacterial leaf blight
BLS – bacterial leaf streak
BPH – brown planthopper
Bo - boron
BR – brown rice
BSWM – Bureau of Soils and Water Management
Ca - Calcium
CARP – Comprehensive Agrarian Reform Program
cav – cavan, usually 50 kg
CBFM – community-based forestry management
CLSU – Central Luzon State University
cm – centimeter
CMS – cystoplasmic male sterile
CP – protein content
CRH – carbonized rice hull
CTRHC – continuous-type rice hull carbonizer
CT – conventional tillage
Cu – copper
DA – Department of Agriculture
DA-RFU – Department of Agriculture-Regional Field Units
DAE – days after emergence
DAS – days after seeding
DAT – days after transplanting
DBMS – database management system
DDTK – disease diagnostic tool kit
DENR – Department of Environment and Natural Resources
DH L– double haploid lines
DRR – drought recovery rate
DS – dry season
DSA - diversity and stress adaptation
DSR – direct seeded rice
DUST – distinctness, uniformity and stability trial
DWSR – direct wet-seeded rice
EGS – early generation screening
EH – early heading
EMBI – effective microorganism-based inoculant
EPI – early panicle initiation
ET – early tillering
FAO – Food and Agriculture Organization
Fe – Iron
FFA – free fatty acid
FFP – farmer's fertilizer practice
FFS – farmers' field school
FGD – focus group discussion
FI – farmer innovator
FSSP – Food Staples Self-sufficiency Plan
g – gram
GAS – golden apple snail
GC – gel consistency
GIS – geographic information system
GHG – greenhouse gas
GLH – green leafhopper
GPS – global positioning system
GQ – grain quality
GUI – graphical user interface
GWS – genomwide selection
GYT – general yield trial
h – hour
ha – hectare
HIP - high inorganic phosphate
HPL – hybrid parental line
I - intermediate
ICIS – International Crop Information System
ICT – information and communication technology
IMO – indigenous microorganism
IF – inorganic fertilizer
INGER - International Network for Genetic Evaluation of Rice
IP – insect pest
IPDTK – insect pest diagnostic tool kit
IPM – Integrated Pest Management
IRRI – International Rice Research Institute
IVC – in vitro culture
IVM – in vitro mutagenesis
IWM – integrated weed management
JICA – Japan International Cooperation Agency
K – potassium
kg – kilogram
KP – knowledge product
KSL – knowledge sharing and learning
LCC – leaf color chart
LDIS – low-cost drip irrigation system
LeD – leaf drying
LeR – leaf rolling
lpa – low phytic acid
LGU – local government unit
LSTD – location specific technology development
m – meter
MAS – marker-assisted selection
MAT – Multi-Adaption Trial
MC – moisture content
MDDST – modified dry direct seeding technique
MET – multi-environment trial
MFE – male fertile environment
MLM – mixed-effects linear model
Mg – magnesium
Mn – Manganese
MDDST – Modified Dry Direct Seeding Technique
MOET – minus one element technique
MR – moderately resistant
MRT – Mobile Rice TeknoKlinik
MSE – male-sterile environment
MT – minimum tillage
mtha^{-1} - metric ton per hectare
MYT – multi-location yield trials
N – nitrogen
NAFC – National Agricultural and Fishery Council
NBS – narrow brown spot
NCT – National Cooperative Testing
NFA – National Food Authority
NGO – non-government organization
NE – natural enemies
NIL – near isogenic line
NM – Nutrient Manager
NOPT – Nutrient Omission Plot Technique
NR – new reagent
NSIC – National Seed Industry Council
NSQCS – National Seed Quality Control Services
OF – organic fertilizer
OFT – on-farm trial
OM – organic matter
ON – observational nursery
OPAg – Office of Provincial Agriculturist
OpAPA – Open Academy for Philippine Agriculture
P – phosphorus
PA – phytic acid
PCR – Polymerase chain reaction
PDW – plant dry weight
PF – participating farmer
PFS – PalayCheck field school
PhilRice – Philippine Rice Research Institute
PhilSCAT – Philippine-Sino Center for Agricultural Technology
PHilMech – Philippine Center for Postharvest Development and Mechanization
PCA – principal component analysis
PI – panicle initiation
PN – pedigree nursery
PRKB – Pinoy Rice Knowledge Bank
PTD – participatory technology development
PYT – preliminary yield trial
QTL – quantitative trait loci
R - resistant
RBB – rice black bug
RCBD – randomized complete block design
RDI – regulated deficit irrigation
RF – rainfed
RP – resource person
RPM – revolution per minute
RQCS – Rice Quality Classification Software
RS4D – Rice Science for Development
RSO – rice sufficiency officer
RFL – Rainfed lowland
RTV – rice tungro virus
RTWG – Rice Technical Working Group
S – sulfur
SACLOB – Sealed Storage Enclosure for Rice Seeds
SALT – Sloping Agricultural Land Technology
SB – sheath blight
SFR – small farm reservoir
SME – small-medium enterprise
SMS – short message service
SN – source nursery
SSNM – site-specific nutrient management
SSR – simple sequence repeat
STK – soil test kit
STR – sequence tandem repeat
SV – seedling vigor
t – ton
TCN – testcross nursery
TCP – technical cooperation project
TGMS – thermo-sensitive genetic male sterile
TN – testcross nursery
TOT – training of trainers
TPR – transplanted rice
TRV – traditional variety
TSS – total soluble solid
UEM – ultra-early maturing
UPLB – University of the Philippines Los Baños
VSU – Visayas State University
WBPH – white-backed planthopper
WEPP – water erosion prediction project
WHC – water holding capacity
WHO – World Health Organization
WS – wet season
WT – weed tolerance
YA – yield advantage
Zn – zinc
ZT – zero tillage

List of Tables

List of Tables

List of Tables

List of Tables

List of Tables

List of Figures

List of Figures

List of Figures

List of Figures

List of Figures

List of Figures

Department of Agriculture
Philippine Rice Research Institute

PhilRice Central Experiment Station; Maligaya, Science City of Muñoz, 3119 Nueva Ecija
Tel: (44) 456-0277 • Direct line/Telefax: (44) 456-0112 • Email: prri.mail@philrice.gov.ph
PhilRice Text Center: 0920-911-1398 • Websites: www.philrice.gov.ph; www.pinoyrice.com

BRANCH STATIONS:

PhilRice Agusan, Basilisa, RTRomualdez, 8611 Agusan del Norte;
Telefax: (85) 343-0768; Tel: 343-0534; 343-0778; Email: agusan.station@philrice.gov.ph
PhilRice Batac, MMSU Campus, Batac City, 2906 Ilocos Norte;
Telefax: (77) 772- 0654; 670-1867; Tel: 667-1508; Email: batac.station@philrice.gov.ph
PhilRice Bicol, Batang, Ligao City, 4504 Albay; Tel: (52) 284-4860; Mobile: 0918-946-7439 ;
Email: bicol.station@philrice.gov.ph
PhilRice Isabela, Malasin, San Mateo, 3318 Isabela; Mobile: 0908-895-7796; 0915-765-2105;
Email: isabela.station@philrice.gov.ph
PhilRice Los Baños, UPLB Campus, Los Baños, 4030 Laguna; Tel: (49) 536-8620; 501-1917;
Mobile: 0920-911-1420; Email: losbanos@philrice.gov.ph
PhilRice Midsayap, Bual Norte, Midsayap, 9410 North Cotabato;
Tel: (64) 229-8178; 229-7241 to 43; Email: midsayap.station@philrice.gov.ph
PhilRice Negros, Cansilayan, Murcia, 6129 Negros Occidental;
Mobile: 0932-850-1531; 0915-349-0142; Email: negros.station@philrice.gov.ph
PhilRice Field Office, CMU Campus, Maramag, 8714 Bukidnon;
Mobile: 0916-367-6086; 0909-822-9813
Liaison Office, 3rd Floor, ATI Bldg, Elliptical Road, Diliman, Quezon City; Tel: (02) 920-5129

SATELLITE STATIONS:

Mindoro Satellite Station, Alacaak, Sta. Cruz, 5105 Occidental Mindoro; Mobile: 0908-104-0855
Samar Satellite Station, UEP Campus, Catarman, 6400 Northern Samar; Mobile: 0948-800-5284