Quality Rice. Quality Life.

2017
National Rice R&D
Highlights

PLANT BREEDING AND BIOTECHNOLOGY DIVISION

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Plant Breeding and Biotechnology Division

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Executive Summary

The demand for rice is continuously increasing with the growing human population. Hence, it is vital to improve the traits of the existing varieties, which will lead to higher yield. Essentially, breeding activities at Plant Breeding and Biotechnology Division (PBBD) aimed to achieve desired traits such as high grain yield, resistance to abiotic and biotic stresses, and good grain qualities acceptable to consumers.

Restricting factors such as biotic and abiotic stresses affect rice growth and development under different environmental conditions. These factors greatly affect yield which in turn affect 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 in unfavorable environments (rainfed-drought, submergence, high temperature, and low temperature conditions). To address these constraints and challenges, breeding strategies including integrated management technologies, Marker-Assisted Selection (MAS), classical hybridization and biotechnology, in-vitro culture, in-vitro mutagenesis, anther culture, root plasticity development, and introgression of rice tungro virus and bacterial blight disease resistance genes were 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. Breeding lines, existing varieties, and wild relatives were screened for particular traits in search for genes and donors useful in breeding. Four projects in the development of elite lines for the stressed and unstressed environments were hosted in the Division. These projects contributed to the development of rice varieties for different ecosystem by incorporating desirable traits to selected lines and modern varieties.

The Division released two rice varieties. PBBD researchers conducted, monitored, and evaluated 15 national and international collaborative researches.

The Division also accommodated 32 international and national students, on the job trainees, and research interns, which created and enhanced knowledge sharing among local and international researchers.

I. Pre-breeding and Germplasm Enhancement

Arlen A. dela Cruz

This project aimed to broaden the genetic base of germplasm for rice breeding. To increase the efficiency of rice breeding programs and accelerate rice varietal improvement, it is necessary to identify promising sources of genes/QTLs and new sources of agronomically important traits must be available and accessible to breeders.

Three studies under this project utilized induced mutation to improve yield or other agronomic traits of selected traditional and modern rice varieties. In 2017, 18 putative mutant lines derived from Dinorado, Ballatinaw, and Azucena (traditional varieties) and MS 16, PSB Rc 10, NSIC Rc 150, and NSIC Rc 152 (modern varieties) were improved with waxy trait or intermediate amylose contents (AC). Eleven of these rice lines, which have intermediate AC, were also improved with higher yield and resistance to bacterial leaf blight. Two Ballatinaw putative mutant lines improved with high anti-oxidants and antocyanin contents were also selected. A mutant of Nipponbare, which was nominated in the National Cooperative Tests, was approved as NSIC Rc 482SR or Japonica 5 in the special rice category for commercial release in 2017.

Moreover, promising putative mutant lines of Gal-ong with improved yield and potential resistance to stemborer were also developed. Despite stemborer infestation in DS 2017, the estimated yield of the most promising rice line went as high as about 7.2 t/ha while it recorded 6.7 t/ha yield in WS 2017. Stemborer significantly reduced the yield of wild type Gal-ong (WTGO) to only 1.2 t/ha. WTGO was included in the field evaluation as check variety. The apparent stemborer resistance will be further verified. Other promising Gal-ong mutants with reduced number of maturity days or with shorter stature but had retained excellent and good kernel qualities were also generated.

For the development of early maturing rice, two elite mutant lines maturing in less than 100 days after sowing were selected. Their yield were comparable with PSB Rc 10.

The project also worked on finding new sources of traits and resistance genes/QTLs against rice pests and diseases. Eight putative QTLs (two in chromosome 3; three, chromosome 4; and 3, chromosome 12) associated to rice blast resistance were identified for further validation. On exploring natural allelic variations in PhilRice genetic resources, the physico-chemical properties of eight founder lines to be used in development of multi-parent advanced genetic inter-crosses (MAGIC) populations were determined: NSIC Rc 218 and NSIC Rc 298 had low AC (15- 15.5%); NSIC Rc 346 and PR37951-3B-37-1-2, NSIC Rc 226, PR34358-5-POKKALI-AC-37-M5R-15-Dr93, NSIC Rc 342 had intermediate AC (19.0%- 21.7%); and NSIC Rc 354 with high AC (23.5%).

New cytoplasmic male sterility (CMS) source is also being developed using three nucleus substitution approach. This may lead to creation of the first PhilRice-bred CMS source in the background of our own Philippine germplasm. Among the 202 BC1F4 and BC1F3 materials evaluated in 2017, plants with highest pollen sterility of 98% were identified among inter-subspecific crosses of modern variety and Javanica.

Crossing block or the parentals needed in breeding programs are also being managed and maintained in this project. At least 500 rice accessions were established every cropping season in two staggered batches with 13 new entries in WS. Among these, 118 and 146 rice accessions were characterized for major yield-enhancing traits in DS and WS, respectively. Data gathered on grain length/shape/weight, grains per panicle, percent filled spikelets, and maturity were provided to breeders for reference.

Induced Mutations for Quality Improvement in Rice

Rustum C. Braceros, LR Pautin, T Padolina

In this study, mutation in the rice seed was induced through exposure to physical agent such as gamma radiation from radioactive cobalt (60Co); causing changes on special traits relating to grain quality, yield, and resistance to various stresses. Although the development of new cultivars has been the primary objective of mutation breeding, the genetic stocks that will be developed can be used as a donor parent in conventional breeding or as a parent in hybrid breeding programs. Traditional cultivars such as Azucena, Dinorado, and Ballatinaw were used as parent varieties and were mutated to improve yield and other agronomic traits while retaining good grain quality. A second set of high yielding modern varieties such as PSB Rc 10, NSIC Rc 152, NSIC Rc 150, and MS16 will be improved to increase the acceptability and competitiveness of cereal products both in national and international markets.

Selected advanced mutant lines from traditional and modern backgrounds were generated from 2014 to 2017. Potential donor parents with unique traits were developed and nominated to the PBBD crossing block for use in the breeding programs. The lines had improved morpho-agronomic and improved quality traits in terms of physical and milling potentials, physico-chemical traits, sensory properties, and other value-added traits like higher nutrient content and anti-oxidant properties. Higher productivity and resistance over their parent stock were ensured while improving the rice lines. As a result, high generation of mutants as new pool of genetic stocks were achieved: 1) two of the 4 high yielding and shorter

mutants DinoradoSusi-5kR-38-3-2-3 and DinoradoSusi-5kR-8-1-4 exhibited improvement in terms of head rice recovery, chalky traits, grain size, and shape; 2) among 6 Ballatinaw mutants, PR39490-Ballatinaw-30kR-8-3-1-2 had longer grain size with intermediate amylose content than the extra-long and waxy parent. This mutant also possessed significant anthocyanin content at 40% higher than the original in the unpolished form but was reduced to 29% in the polished form. Two other mutants, PR39490-Ballatinaw-30kR-30-12-1-1 and PR39490-Ballatinaw-30kR-14-1-4-1, had higher anthocyanin level by 54.6% and 89,1%, in the unpolished form respectively, but was reduced to -5.0-76.9%, respectively; 3) two stable Azucena mutants, PR39843-Azucena-30kR-4-4-1 and 30kR-37-38-1, had higher yield by more than 100% with better head rice recovery and less chalky trait. They also mutated in grain size from medium intermediate to short/intermediate and long/slender grains. Among the five selected PSB Rc 10 mutants, none mutated to early maturity but yields were higher ranging from 34% to 74% and achieved the intermediate amylose content from 17.3% to 19.3% as compared with the parent stock with high level of 23.1%.

The following results were also gathered:

- Mutant PR 39487-NSIC Rc150-30kR-2-21 retained its high yielding ability but with improved amylose content of 18.8% as compared with 23.4% of the original;

- For the NSIC Rc 152 mutants, PR39488-NSIC Rc 152-25Kr-19, was comparable with the parent stock in terms of grain quality traits except for mutated intermediate amylose of 17.7% versus 22.1% of the original. Both have extra-long and slender grains.

- For the transgressive segregants of Mestizo 1(PSB Rc72H), 7 mutant lines were identified. Yield, maturity, plant height, tillering ability, and quality traits were improved. The top yielder PR37913-PSB Rc72H-20kR-6-1-1-1(A) with 8119 kg/ha had similar quality traits with the Mestizo 1 including its aroma.

- Among notable achievement was the direct use of the mutant PR39494-Nipponbare-25kR-AC-29-1-1-1-1, induced initially by gamma irradiation followed by anther-culture induction. Evaluated from 2014 to 2016 in the NCT Specialty Rice, Japonica category, it is now registered as NSIC Rc482SR of Japonica 5 for commercial cultivation.

Breeding of Very Early Maturing Rice Varieties with High Yield

Thelma F. Padolina and Lenie R. Pautin

Farmers in the irrigated or rainfed lowland usually prefer varieties maturing in less than 100 days. Very-early maturing varieties with high yield offer sustainable breakthrough interventions not only to increase total productivity under favorable conditions but also under the less favorable environments. Development of these varieties are crucial with the increasing 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 study aimed to develop populations with maturity of less than 100 days with yield potential of at least 5 t/ha using gamma rays and ion beam and conventional breeding. Conventional crosses generated 9 pre-breeding lines with the desired earliness and yield during the dry season but the yield levels were not consistent across seasons. Under WS evaluation, five of these materials were selected but maturities were not consistent. Three pre-breeding lines: PR40366-2-2-1, PR40350-1-3-2, and PR40401-7-2-2 consistently showed the maturity of 92 to 99 DAS across seasons but still fall short of the yield target. These pre-breeding lines were nominated as donor germplasm for earliness. Thirteen other higher yielding lines and mutants (>5.4 to 7.8t/ha) with maturity from 102 to 115 days were further tested in replicated yield trials.

The pre-breeding materials will be further improved using complex parents and screened thoroughly for complementary yield-enhancing and stabilizing traits to attain a cumulative gene action for yield.

Finding Durable and Novel Blast Resistance Genes Effective against Philippine's Magnaporthe Grisea Pathogen Population

Jonathan Niones, TE Mananghaya, TF Padolina, JT Niones, JP Rillon, RP Mallari, JBM Alvariño

Rice blast (Magnaporthe oryzae anomorph Pyricularia oryzae) is one of the most devastating rice diseases. Studies have shown that plant's mode of resistance against the pathogen can either be complete or partial. Complete resistance, which is controlled by major genes, breakdown within specific years while partial resistance gene, which is controlled by minor genes, is more durable.

The study aimed to identify novel blast resistance genes in selected rice germplasm (traditional/landraces and improved varieties). Malay-2, an improved rice variety, showed strong resistance towards leaf blast; however,

no resistance gene has been identified. A genotype-phenotype linkage was conducted using three mapping software to identify putative Quantitative Trait Loci (QTLs) of Malay 2. Using 273BC1F2 individual derived plants from US2 and Malay-2 crosses and by using 65 identified polymorphic Simple Sequence Repeats (SSR), eight consistent candidate QTLs located in chromosome 3, chromosome 4, and chromosome 12 were identified with logarithm of the odds (LOD) threshold value of 3.00 and IM (R2) of 0.004-0.96 and CIM (R2) of 0.002-0.78. Morpho-agronomical characterization was conducted in segregating population of US2/Malay2 using 56 qualitative and quantitative traits in vegetative, reproductive, and maturity stages of rice.

General Evaluation of Donor Germplasm

Arlen A. dela Cruz, TF Padolina, OE Manangkil, EC Arocena, PAC Canilang

The availability of a wide variation among rice genetic resources is the keystone for successful varietal improvement. Thus, in the development of economically high-yielding rice with desirable agronomic and phenotypic traits, finding unique donor parents with good combining abilities at the pre-breeding phase is very important. In this study, suitable donors of target traits useful for various hybridization activities were identified among available rice germplasm.

In 2017, 1,166 rice accessions (575 in DS and 591 in WS) composed of modern and traditional rice varieties, elite and mutant breeding lines, derivatives of wide hybrids, and introductions were established in the crossing block. To allow greater chances of synchronized flowering, materials were established in two staggered batches. The characterization of 264 entries (118 in DS and 146 in WS) for major yield-enhancing traits resulted in the identification of potential sources of traits such as extra-long and long grains, slender grain shape, and early maturity. Characterized materials were also ranked based on 1000-grain weight, number of grains per panicle, and percentage of filled spikelets. The summary of materials that qualified based on the standard basis of selection were presented to rice breeders to serve as accessible reference for selecting superior sources of agronomically important traits.

Increasing the Yield of Gal-ong, a Traditional Rice Variety (Special Rice), through Induced Mutation

Eleanor S. Avellanoza, RT Miranda, AA dela Cruz, EC Arocena

This study aimed to produce a Gal-ong mutant line with improved yield and has maintained the variety's original excellent kernel quality and aroma through induced-mutation. In DS 2017, 21 putative Gal-ong mutant lines (19 M5 and 2 M3) were evaluated for yield in the field under PhilRice

CES condition. Nine M4 putative mutants observed with moderate to resistant reactions to stemborer (SB) were also included in the yield DS 2016 trial. The overall agro-morphological performance evaluation of 14 promising putative mutant lines showed that GXB-208 recorded the highest yield in WS 2017 (7.2 tons/ha) and it ranked third in terms of yield in DS 2017 (6.7 tons/ha). This was followed by GXB-319 with 6.1 and 5.7 tons/ha yield during WS and DS, respectively. GXB-310 recorded 5.5 t/ha in WS 2017. The remaining mutant lines yielded 5-5.3 t/ha in DS 2017 and 2.5-4.7 tons/ha in WS 2017. The yield of wild-type Gal-ong (WTGO) during the dry season was very low (1.2 t/ha) due to severe stemborer infestation. The putative mutant lines exhibited significant improvement on resistance to pest and disease in addition to improvement of various yield-enhancing traits. The selected mutant lines were also early maturing like the WTGO, which can be harvested in 20-44 days during DS and 22-40 days in WS. Some rice lines were shorter than WTGO during DS. Notable reduction in plant height were observed in 12 rice lines in DS and in 6 rice lines in WS. Majority of the evaluated putative mutant lines also had excellent and good kernel quality ratings. Among the identified rice lines with good eating quality, five were already included in the preliminary yield trial.

Additional 79 Gal-ong putative mutant lines with improved plant type have other interesting traits: early to medium maturity, reduced plant height, long-slender to long-semi bold grains, more tillers, long-dense panicles, and colored grain and pericarp. Meanwhile, 8 highly-segregating M5 and M6 putative mutant lines were observed with 2-12 types of variants per line differing in terms of, among others, apiculus and sterile lemma color, grain shapes and straw and pericarp color, plant height, and awn.

To address the issues of admixtures among the selected putative high-yielding mutant lines with good eating quality and aroma, quality control measure such as molecular characterization will be employed to assure the true-to-type identity of the Gal-ong mutants and to compare the degree of relatedness of these rice lines with WTGO.

MAGIC (Multiparent Advanced Generation Inter Crosses) in PhilRice Genetic Resources

Jess Bryan M. Alvariño, XGI Caguiat, TE Mananghaya, RP Mallari

Using MAGIC (Multi- advanced generation inter crosses) method in breeding mines natural allelic variants that can be sources of novel quantitative trait loci (QTL). IRRI successfully designed MAGIC populations for the Indica and Japonica groups through breeder-selected founder lines with unique agronomic characteristics. This study aimed to develop MAGIC populations that would serve as genetic resource for scientists and breeders interested in genetic mapping studies, and as associate QTLs for candidate

gene identification and gene discovery in rice by intermating 8 parental inbred strains, followed by repeated selfing or sibling mating. Eight donor lines were identified with important traits such as aromatic; high yielding; intermediate amylose content; and resistance to major rice insects/pest and diseases (bacterial leaf blight, green leaf hopper, stemborer, rice tungro, blast, brown planthopper, sheath blight); and saline tolerance. The selected founder lines are elite and PhilRice-released rice cultivars. Phenotyping and DNA analysis using functional markers of selected founder lines were conducted to validate the introgressed traits. Based on physiochemical properties evaluation of parental, NSIC Rc 218 and NSIC Rc 298 has low amylose content of 15% and 15.5% respectively. Five parental lines had intermediate amylose: NSIC Rc 346 and PR37951-3B-37-1-2 (19.7%), NSIC Rc 226 (19.5%), PR34358-5-POKKALI-AC-37-M5R-15-Dr93 (21.7%), NSIC Rc 342 (19.0%), and NSIC Rc 354 (23.5%).

Development of New Cytoplasmic Male Sterile Source Using Nucleus Substitution Approach

Imeldalyn G. Pacada, CC Ringor, MB Dela Cruz, OKS Acac

Most of the developed three-line hybrids and hybrids in the pipeline are based on one cytoplasmic source, the wild abortive (WA) cytoplasm. Extensive use of one type of cytoplasm narrows the cytoplasmic diversity and may also be prone to vulnerability of diseases. This study identified new cytoplasmic source using Philippine germplasm and modern varieties. Three nucleus substitution approaches were used including: inter-varietal (primitive landraces/traditional cultivars x modern varieties), inter-specific (wild rice derived lines x modern varieties), and inter-subspecific (primitive indica varieties x japonica/javanica varieties). Among the three nucleus substitution approaches, the inter-subspecific provided higher pollen sterility from BC3F1 progeny exhibiting 98% pollen sterility. Obtaining higher sterility depends on the genetic similarity and dissimilarity of parent used. The more diverse the parents, the more successive backcrossing is needed. Initial result of this study indicates that breeding of new cytoplasmic source is possible. However, to understand the genetics of traits and possible existence of chromosomal and female sterility among generated BC progeny from three approaches, the establishment of more basic research is highly recommended.

Development of Irrigated Lowland Rice Varieties

Emily C. Arocena

Success of variety development either for transplanted or direct wet seeded depends on how rigid the evaluation and selection process based on the breeding objectives. This project aimed to develop appropriate rice varieties with high and stable yield averaging 8-10 t/ha or ≥ 5% yield advantage over the check varieties, resistant to major biotic and abiotic stresses, good grain quality, and has better resiliency to changing climate and shifting production constraints in highly intensive production systems. It also aimed to implement a systematic approach for early generation screening and selection and for performance testing suitable to transplanting and/or direct seeding method of establishments and multi-location yield trial.

The project implemented six studies: the hybridization and pedigree nurseries, which generated new crosses and line development for both transplanted and direct wet seed method of establishment; the evaluation of early seedling vigor, anaerobic tolerance and lodging resistance, which identified lines suitable for direct seeding; and the marker-assisted selection for pest and disease resistance genes, which identified lines with BLB and tungro resistance. Promising lines identified in these line development studies were forwarded to the three performance trials; the international irrigated rice observation nursery, which included diverse germplasm from other countries; the Advanced Observation Nursery (AON) and Preliminary Yield Trial (PYT), which considered the yielding ability and other agronomic traits under transplanted and/or direct wet seeded on-station; and the Multi-location Yield Trial (MYT) under different test locations to initially identify elite lines with location-specificity or with wide adaptability.

Next generation rice plant type and improved inbred rice lines were also developed to break yield plateau. These new rices will have a yield advantage of 50-100% relative to the check varieties and with resistance to diseases. Hybrids or traditional cultivars with higher yields and other agronomic traits were subjected to gamma ray irradiation. Selection of promising mutant lines was based on yield performance. Selected mutant lines were evaluated in six environments and were also screened for disease resistance. Promising entries that performed better than the check varieties will be nominated to Multi-environment Trial (MET) and/or to the National Cooperative Trial (NCT).

Breeding efforts resulted in 225 new crosses generated, 156 true F1 hybrids identified, 171 F2 populations selected for single plant selection, 1,761 F3 plants selected with phenotypes based on the breeding objectives, and 7,971 lines from F3 to F10 generations were evaluated under direct seeded and transplanted methods. Selection among and within lines based on phenotypes, maturity, uniformity, and reactions to abiotic and

biotic stresses was done. Five hundred forty-one individual plants from hybrid populations and 2,684 lines were selected for further evaluation in the pedigree nursery. Moreover, 257 uniform lines were nominated to Advanced Observation Nursery in DS 2018.

The effect of submergence during crop establishment and lodging at flowering to maturity limit the adoption of direct-seeding especially during rainy season. Thus, these traits were screened. One hundred twenty-six F2 populations and 170 lines were submerged in wet bed to screen for early seedling vigor, anaerobic tolerance, and lodging resistance. Of these, 10 populations and 6 breeding lines exhibited excellent early seeding vigor and anaerobic tolerance while 16 populations and 7 breeding lines had good rating. Five advanced breeding lines had intermediate anaerobic germination/seedling tolerance under controlled condition. Ten advanced breeding lines were lodging resistant. Populations and breeding lines with excellent to good early seeding vigor, anaerobic tolerance, lodging resistance, and other important traits were advanced to pedigree nursery, performance trial, or hybridization block as donor parent.

Marker-assisted selection (MAS) was used to facilitate introgression and pyramiding of various BB and RTD resistance genes in the breeding lines. Resistance genes against BB (Xa4, xa5, Xa7, and Xa21) and RTD (Glh14 and tsv1) were pyramided into breeding lines in various combinations. One hundred sixty-five lines were successfully introgressed with 2-4 BB resistance genes plus Gh14 and/or tsv1. The selected MAS-bred rice lines were evaluated at PhilRice Negros in WS 2017 under natural condition to confirm the effectiveness of Glh14 and/or tsv1 against dual infection of RTSV and RTBV. To ensure presence of Glh14 and/or tsv1, the selected individual test plants were genotyped using the reported SSR markers RM8213 and RM5495, respectively. All rice lines introgressed with Glh14+tsv1 exhibited moderate tungro resistance based on the computed % plant height reduction, % number of leaves with discoloration, and presence of interveinal chlorosis on young leaves. The combined effects of RTD resistance genes apparently prevented the development of severe stunting and leaf discoloration, reduction in number of tillers, delayed flowering, and severe reduction in yield. MAS-205-3 (7686 kg/ha) recorded the highest extrapolated yield followed by MAS-169-1 and MAS-207-2 with 6366 and 6283 kg/ha, respectively. These new breeding lines identified with promising resistance against BB and/or tungro if found superior will be used as donor parents and for further evaluation in the performance trial.

In the field performance test for transplanted culture, three activities were conducted: the International Irrigated Rice Observational Nursery (IIRON), the AON, and the Preliminary Yield Trial (PYT). The IIRON was conducted during WS only, and 9 top yielders were identified. TP 30615 and TP 30757 were identified as potential donor for shorter stature and slow senescence. The DS trials for AON and PYT were severely infested by stemborer (SB) from 25% to 95% at reproductive stage; hence, yielding ability was affected. However, under such condition in the AON, 9 uniform lines produced more than 7 t/ha (7.2-7.8 t/ha) with yield advantage of 18-21% over NSIC Rc308 (6.1 t/ha). These were advanced to PYT for WS evaluation. Twenty entries were nominated to PYT during WS. Ten of these entries had yields ranging from 5.4 t/ha to 6.2 t/ha. Ten PYT entries recorded 5-6.4 t/ha yield. These were nominated to multi-location yield trial (MYT) for further field performance evaluation.

In the MYT, 47 test entries together with seven check varieties were evaluated in four PhilRice stations in the DS and WS. Overall yield performance across four test locations in the DS showed that 8 test entries yielded 7.0 t/ha to 7.8 t/ha across two favorable locations (CES, Bicol). Of the 8 entries identified, PR43790-B-30-1-1 (7.8 t/ha) is the only entry with a yield average of 8.3% over the highest yielding check, NSIC Rc222 (7.2 t/ha).

Exploiting the GxE interactions using AMMI stability value (ASV) and yield stability index (YSI), potential lines with such characteristics was confidently selected. PR43790-B-30-1-1 and PR40525-4 demonstrated the most stable and high yield based on ASV and YSI. PR39497-4-2-16 performed best in four locations while eight entries performed best in three locations. In the WS, none of the test entries numerically outyielded NSIC Rc 222 (3.5 t/ha). PR41804-3B-71 was identified among the top ten high-yielding entries in all test locations. This test entry together with PR43872-JR-2B-16-1 4 demonstrated the most stable and high yield based on ASV and YSI. Potential entries with stable and high yield and with wide adaptation for nomination to MET and or NCT were selected. Five advanced lines with 7.1-7.8 t/ha yield were nominated to MET and four promising lines with 7-7.2 t/ha yield during the DS were nominated to NCT.

In the wet and dry seasons, 23 hybrid mutants were selected and evaluated across six environments in Midsayap, Negros, and Bukidnon PhilRice Stations. Combined ANOVA identified significant variation in environment (E), genotype (G), and G by E.

E explained 25.5% variance in the yield, which contributed the GxE of 52.9%. GxE in yield of check varieties ranged from 4.74 to 7.15 t/ha with overall mean of 6.12 t/ha. Yields of inbred check variety ranged from 3.56 to 7.47 t/ha with overall mean of 6.14 t/ha in six environments.

For Midsayap, G2, G3, G5, G9, G11, and G17 had ≥50% yield advantage over the check varieties (YAcv) and inbred check variety (YAiv) for DS but only G8 had ≥50% YAcv and YAiv in WS. For Negros, G9 and G10 had ≥50% YAcv and YAiv only in DS. In Bukidnon, G2 had ≥50% YAcv and YAiv while G22 in WS had ≥50% YAiv.

Meanwhile, disease screening showed that 20 mutants were resistant to BLB; 30 mutants, ShB; 27, RB; and 11, tungro virus. These hybrid mutant lines are potential for MET or NCT.

Hybridization and Pedigree Nurseries

Wilhelmina V. Barroga, EC Arocena, OE Manangkil, JM Niones, TF Padolina, RC Braceros, SB Estrada, GM Osoteo, PNM Marcelo

Philippine food security is challenged with increase food demand and is threatened by declining rice production area and water availability. There are 79 million ha of irrigated lowlands providing 75% of the world's rice production and is the most reliable environment of developing new intensive–culture rice crops.

Variety development for this ecosystem includes trait discovery for use as donor parents, line development, and performance trials to select desirable plants for further evaluation. This study aimed to generate crosses and develop breeding populations and lines with high yield, resistance to major insect pests and diseases, and good grain quality characteristics suitable to transplanting and/or direct seeding method of establishments. Breeding efforts resulted in 225 new crosses generated with backgrounds of high yield, biotic and abiotic tolerance using released varieties and breeding lines. One hundred fifty-six true hybrids were also identified from the F1 nursery. In the pedigree nurseries, 171 F2 populations were established and 1,761 F3 plants with phenotype based on the breeding objectives were selected. From F3 to F10 generations, 7,971 lines were established and evaluated both under direct seeded and transplanted methods. Selection among and within lines based on phenotypes, maturity, uniformity, and reactions to abiotic and biotic stresses was also conducted. Five hundred forty-one individual plants from hybrid populations and 2,684 lines were selected for further evaluation in the pedigree nursery. Two hundred fifty-seven uniform lines were selected for evaluation in the Advanced Observation Nursery this DS 2018.

Performance Evaluation of Transplanted Rice Breeding Lines

Emily C. Arocena, TF Padolina, PAC Canilang, GM Osoteo, LR Pautin, RC Braceros

The study initially evaluated the field performance of the breeding lines, which were developed from the pedigree nursery in addition to access to diverse germplasm pool from the international nursery. The study aimed to evaluate the uniformity, yield, and other agronomic characteristics of the advanced irrigated lowland rice selections for possible advancement to multi-location evaluation. Top-yielding test entries with good agronomic

characteristics were identified from the different activities. Two top yielding IIRON entries with intermediate stature and slow senescence were identified for use as parents in crossing. The DS trials for AON and PYT were severely infested by SB from 25% to 95% at reproductive stage; hence, yielding ability was affected. However, under such condition, nine AON uniform lines produced more than 7 t/ha (7.2-7.8 t/ha) with yield average of 18-21% over NSIC Rc308 (6.1 t/ha).

During WS, 225 AON test entries including maturity checks were evaluated for yield and other agronomic characteristics. There were 20 entries elevated to PYT owing to their comparable or better yield performance than the maturity check, good phenotypic acceptability, moderate resistance to BLB and blast, and good to excellent kernel qualities. There were 13 test entries that passed the 5 t/ha yield target for WS elevated to PYT. Among the 84 test entries evaluated including maturity checks in the PYT, 10 promising test entries with yields ranging from 5 to 6.4 t/ha were identified for elevation to MYT. These promising AON and PYT entries will be further evaluated for yield, resistance to insect pests and diseases, and grain quality characteristics in DS 2018.

Performance Evaluation of Direct-seeded Rice Breeding Lines

Oliver E. Manangkil, WV Barroga, PNlM Marcelo, AB Rafael

Direct seeding (DS) system in farmers' field is a promising option to increase profits in rice production. Farmers practicing DS benefit from reduced labor cost and water use. However, problems associated with the method such as poor seedling establishment, heavy weed infestation, and lodging limit the wide adoption of direct seeding. The release of high yielding DS variety with good seedling vigor, anaerobic tolerance, lodging resistance, good grain quality, and tolerance to biotic stress might increase adoption of direct-seeding in the country.

Breeding lines were evaluated in performance trials for yield, reactions to biotic and abiotic stress, and grain quality to identify promising lines for direct seeding method. In observational nursery, top five breeding lines had yields ranging from 4.4 t/ha to 5.2 t/ha. Promising line PR45297-42-2-3-B had the highest yield of 5.2 t/ha and out yielded six checks with 5% to 114% yield advantage. It was early maturing with intermediate reactions to anaerobic stress, lodging, BLB, blast, and amylose content. During DS 2017 in general yield trial (GYT), four breeding lines had yields ranging from 7.17 t/ha to 7.46 t/ha and were better than check varieties with ≥5% yield advantage. Lines had early to medium maturity and intermediate pushing resistance. In GYT wet season, top five high yielding entries had yields ranging from 6.10 t/ha to 6.82 t/ha with ≥5% yield advantage over the check PSB Rc 18. Promising lines were nominated to multi-environment trial and hybridization block as donor parents.

Multi-location Yield Trial

Emily C. Arocena, Henry T. Ticman, AD Palanog, GC Nuñez, D Dela Cruz

The new stratified multi-environments testing in the early generation significantly improved the quality of materials prior to NCT. This led to the release of inbred varieties with stable and higher yielding ability, better resistance to biotic stresses, and enhanced adaptation to different environments. Along with improved performance, there are ways to breed varieties with wide adaptation and genotypes with superior location-specific performance. The study aimed to evaluate and identify rice breeding lines with stable yield and with wide or location-specific adaptation. Forty-seven rice breeding lines together with seven check varieties were evaluated in four PhilRice stations in DS 2017 and WS. These were grouped based on days of maturity. Group 1 was composed of early- maturing lines while Group II was composed of medium to late-maturing lines. In the DS, overall yield performance across four locations in Group 1 showed that only PR39497-4-2-16 (6 t/ha) numerically outyielded NSIC Rc 222 (5.9 t/ha). This entry was consistently included among the top ten high-yielding entries in all the test locations. In Group II, six test entries performed better than NSIC Rc 308 (5.4 t/ha) with yields of 5.7 -6.1t/ha and with yield average of 5-13.8%. Three of these entries performed best in three locations while the other two performed best in two locations. Across two favorable test locations (CES and Bicol), there were ten test entries that yielded 7-7.8 t/ha. Additive Main Effects and Multiplicative Interaction Models (AMMI) biplot analysis and yield stability index (YSI) incorporating AMMI stability value (ASV) showed that PR40525-4 and PR43790-B-30-1-1 demonstrated the most stable and high yield across all test locations. These are potential entries for Multi-Environment Yield Trial (MET) or NCT.

In the WS at PhilRice-CES, three advanced breeding lines were identified with yields ranged from 5.7 t/ha to 6 t/ha with yield advantage ranging from 5.4% to 11.5% over the highest yielding check variety, NSIC Rc 160 (5362 kg/ha).

Seven elite lines completed the required number of season evaluation in MAT for deliberation of the RTWG. There were 8 new entries nominated to MAT; 3 for both TPR and DSR; 3, TPR; and 2, DSR only. Five advanced lines with 7.1- 7.8 t/ha yield were nominated to MET and 4 promising lines were nominated to NCT, WS 2017 with 7-7.2t/ha yield during the DS.

Early Seedling Vigor, Anaerobic Tolerance, and Lodging Resistance Evaluation

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

Early seedling vigor, anaerobic tolerance, and lodging resistance are important traits in direct seeding. During crop establishment, germination or seedling survival is affected by flood when sowing coincides with the rainy period or when field is not well-leveled. When there is strong wind, lodged varieties decrease its grain quality due to increased coloring of brown rice and/or decreased flavor. The effects of flooding during crop establishment and lodging at flowering to maturity limit farmers in the adoption of direct-seeding especially during rainy season. Thus, these important traits are incorporated in the development of direct-seeded rice variety. The study aimed to develop breeding lines with high seedling vigor, anaerobic tolerance, and lodging resistance, which are pre-requisite for a direct-seeded variety and identify promising lines as potential donor parent or entry for multi-location trials. During line development, F2 populations and advanced breeding lines were screened for these traits.

One hundred twenty-six F2 populations and 170 breeding lines were submerged in wet bed, which resulted in 10 populations and 6 breeding lines with excellent early seeding vigor and anaerobic tolerance while 16 populations and 7 breeding lines had good rating. Five advanced breeding lines had intermediate anaerobic tolerance under controlled condition. Ten breeding lines were lodging resistant. Populations and breeding lines with early seeding vigor, anaerobic tolerance, lodging resistance, and other traits based on breeding objectives were advanced to pedigree nursery, performance trial, and as donor parent in hybridization.

Marker-assisted Selection for Pest and Disease Resistance Genes in Inbred Variety Development

Arlen dela Cruz, RBraceros, J Duque, 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. In this study, the resistance genes against BB (Xa4, xa5, Xa7 and Xa21), and RTD (Glh14 and tsv1) were pyramided into rice breeding lines in various combinations to hasten the development of l of BB and RTD-resistant rice varieties and to help improve rice productivity in disease hot spot areas. Out of 274, 190 were selected among the introgressed rice lines with various combinations of BB and tungro resistance genes through marker-assisted selection. Among these, 13 representative

MAS-bred F4-F5 rice lines (11 with Xa4+xa5+Glh14+tsv1 and 2 with Xa4+xa5_Xa7+tsv1) exhibited improved resistance against BB and tungro under controlled conditions. The presence of the BB and tungro resistance genes in individual plants were verified using specific or tightly linked markers. Results showed that rice lines introgressed with at least Xa4+xa5 were resistant against the most virulent Philippine Xoo races (Pxo-99). Meanwhile, Glh14 and tsv1 showed better effectiveness in preventing further development of tungro symptoms such as stunting and leaf discoloration than tsv1 alone. Tungro virus accumulation in plants introgressed with at least tsv1; however, were found relatively lower than in TN1 susceptible check based on ELISA at 21 days post inoculation. Under natural field condition at PhilRice Negros Experiment Station, 12 advanced MAS-bred rice lines introgressed with both Glh14 and tsv1 exhibited improved tungro resistance/tolerance based on tungro disease intensity scores and ELISA. Even when tungro disease was so widespread in the field, the highest extrapolated yield computed based on crop cut data from 25 plants was recorded in MAS-205-3 with 7686 kg/ha, followed by MAS-169-1 and MAS-207-2 with 6366 and 6283 kg/ha, respectively. These promising rice lines will be forwarded for preliminary yield trial and will also be shared in the crossing block for use in breeding as common donors of BB and tungro resistance. This had proven the effectiveness of MAS in combining multiple resistance genes into a plant, which allowed enhancement of rice resistance against BB and/or tungro.

Development of Next Generation Rice Plant Type to Break Yield Plateau

Aldrin Y. Cantila, SE Abdula, JL Balos, AJR Quitel

Hybrid varieties were mutated to develop rice lines that could break yield plateau in irrigated lowland with yield advantage of 50-100% relative to the check varieties. Out of 720 entries for selection from F4 (filial lines at fourth generation), 23 mutants were selected until F7 and evaluated across six environments. They were evaluated during the wet and dry seasons in Midsayap, Negros, and Bukidnon, PhilRice Stations. Combined ANOVA identified significant variation in environment (E), genotype (G) and G by E. E explained 25.5% variance in the yield, which contributed the GxE of 52.9%. GxE interaction in yield was significant with yields of check varieties ranging from 4.74 to 7.15 t/ha with overall mean of 6.12 t/ha. Yields of inbred check variety ranged from 3.56 to 7.47 t/ha with overall mean of 6.14 t/ha in six environments.

For Midsayap, G2, G3, G5, G9, G11, and G17 had ≥50% yield advantage over the check varieties (YAcv) and inbred check variety (YAiv) for DS. However, only G8 had ≥50% YAcv and YAiv in WS. For Negros, G9 and G10 had ≥50% YAcv and YAiv only in DS. In Bukidnon, G2 had ≥50% YAcv and YAiv while G22 in WS had ≥50% YAiv. Disease screening also showed that 20 mutants were resistant to BLB; 30 mutants, ShB; 27, RB; and 11, tungro virus. Therefore, mutant lines can be submitted to NCT trial and later be released as location specific varietal technology.

II. Breeding of Specialty Rice

Emily C. Arocena

Enhanced micronutrient content of rice in polished form provide better nutrition especially in the rural areas where the program of the government on supplementation and fortification is of limited access. Hence, there is a need to develop high-yielding specialty type rice to attract the farmers to expand its cultivation. This project aimed to develop rice varieties with specialty traits that are acceptable to the farmers, have higher farm productivity, and can provide additional nutrition. The project had two studies, which focused on the development of improved glutinous, aromatic, pigmented and iron/zinc dense varieties through conventional breeding and on the use of fragrance gene molecular markers, which will be used in the selection of aromatic progenies in the early segregating generation.

Breeding efforts identified 179 parentals with the desired yield enhancing and pests resistance traits were utilized and generated 230 new crosses. Four hundred twenty-three hybrid populations were identified for selection and 4,516 breeding lines were selected based on good to excellent kernel quality. These breeding lines will be further evaluated in the Pedigree Nursery. One hundred sixty two uniform lines with excellent to good kernel qualities with the specialty traits were elevated to AON. Best performing 25 AON lines were elevated to PYT while 23 promising PYT advanced lines were elevated to MYT. From the MYT, three aromatic, one glutinous, two zinc-dense, and one pigmented advanced lines were nominated to Multi-Environment Trial. Three aromatic, two glutinous, and two zinc-dense lines were nominated to NCT. Six promising pigmented lines were identified suitable to brown rice to be included for plant variety protection application.

The use of marker aided selection (MAS) for aroma during the DS resulted in 485 lines with positive allelle to fragrant trait using the Bradbury fragrance markers, 1,055 lines using FMbadh2-E4-5 and 166 lines using INS3. Out of the 2,000 plants evaluated, 271 showed positive allele to two of the fragrance markers while 10 were positive to three functional fragrance markers. During WS, 631 plants were identified with homozygous allele for aromatic trait using Bradbury fragrance markers. These identified breeding lines with aroma through MAS will undergo selection for yield, resistance to insect pests and diseases, and grain quality traits in the pedigree and field performance trial.

NSIC Rc31SR, a new glutinous variety, was approved for commercial release by the National Seed Industry Council.

Development of Aromatic, Glutinous, Pigmented, and Iron/Zinc-dense Rice Varieties

Emily C. Arocena, MV Chico, GM Osoteo, RC Braceros

Parental selection, hybridization, identification of hybrid populations for single plant selection and generation advance, selection of desirable plants in the segregating generations and performance trials to identify promising lines for multi-location testing were conducted. One hundred seventy-nine parentals with different desirable traits were selected for crossing, which resulted in 230 new crosses. Of the 202 true F1 crosses selected, 122 were advanced to the Hybrid Population for Non-Selection. One hundred twenty hybrid populations were identified for single plant selection and 89 populations were retained for further generation advancement.

From the segregating populations, 2,531 desirable individual plants were selected in the field and were reduced to 1,284 plants after kernel evaluation. Field selection from the 6,094 breeding lines evaluated in the pedigree nursery resulted in 2,054 lines with 3 plants per line selected. After kernel evaluation, 3,232 plants were selected with good to excellent kernel quality for further line selection. From the pedigree nursery, 162 uniform lines with excellent to good kernel quality were nominated to AON. From the performance trials, 25 promising AON advanced lines were nominated to PYT, of which 23 were nominated to MYT. From the MYT, three aromatic, one glutinous, two zinc-dense, and one pigmented advanced lines were nominated to MET. Three aromatic, two glutinous, and two zinc-dense lines were nominated to NCT. Six promising pigmented lines were identified suitable to brown rice to be included for plant variety protection application. NSIC Rc31SR, a new glutinous variety, was approved for commercial release by the National Seed Industry Council.

Evaluation and Utilization of Fragrance Markers for High-Yielding Aromatic Breeding Materials

Teodora E. Mananghaya, ATDC Aradanas, EC Arocena, HT Ticman, MV Chico, BO Juliano

Aromatic trait is an essential factor affecting market price of rice and is routinely evaluated in rice breeding programs. This study determined the aroma of segregating populations in aromatic rice breeding in PhilRice through marker-aided selection. In DS 2017, 6 populations of F3 plants were evaluated. Out of 200 plants, 485 showed positive allele to fragrant trait using fragrance markers (Bradbury). The results were validated by checking the phenotype thru KOH test. New deletion site of fragrant gene was reported (Shao, 2010) and developed FMbadh2-E4-5 fragrance marker. One thousand fifty-five (52.7%) test entries were identified positive to fragrant allele, in which 943 have homozygous non-fragrant trait and 2 entries were heterozygous. Using INS3, results showed that 166 (9.7%) materials have fragrant trait while 1,531 were detected negative of fragrant allele. Out of 2,000 entries, 271 (13.5%) possess fragrant allele to either two of the fragrance markers and 10 (0.5%) to three functional fragrance markers for rice. In WS 2017, the cross combination between NSIC Rc 218/ IR65482-4-136-2-2 recorded 125 F2 plants positive to fragrant trait. Of 1,483 plants evaluated, 506 showed a homozygous allele for aromatic trait.

III. Development of Rice Varieties Adapted to Rainfed and Stress Environments

Norvie L. Manigbas

The project aimed to address the challenges of coping with global climate change and significantly contributes in addressing poverty alleviation in the marginal areas at the local and national levels. With the availability of multi-stress tolerant varieties, farmers are provided with viable options for coping mechanisms under different stressed conditions.

For breeding drought tolerance using conventional method, 77 lines with acceptable phenotype for generation advance and 17 fixed lines for multi-trait evaluation were identified and selected. Utilization of induced mutation have generated improved drought tolerant breeding lines with grain yield comparable with IR64, the highest-yielding check, under irrigated, managed drought stress, and simulated rainfed condition. Nineteen lines were selected from field performance of promising breeding lines under observational nursery. Selection was based on yield potential, yield under stress, and yield under rainfed condition. New putative drought tolerant lines as source of novel genes for tolerance were identified with acceptable agronomic characteristics and grain yield. Screening of mutant lines of Y Dam Do, Jepun, and NSIC Rc 222 identified 239 improved new lines. In WS 2017, two elite lines were approved as new varieties by the National Seed Industry Council.

Screening for salinity at seedling stage resulted in the identification of 6 FR13A-derived lines and 8 TRVs as new sources of genes for tolerance. Four mutant lines and 7 TRVs were putatively tolerant to submergence stress tolerance and will be evaluated in DS 2018 to confirm the presence of tolerant gene. Five hundred fifty stable breeding lines were evaluated at seedling stage for drought tolerance and 254 (46.2%) showed tolerance. Evaluation for salinity have resulted in identification of 1,444 plants tolerant to salinity. Submergence evaluation resulted in 78 breeding lines and 3,794 plants from 8 populations with tolerance. One hundred seventy-six lines were identified to have drought and salinity tolerance while five can withstand drought, salinity, and submergence.

Under reproductive stage drought, 150 entries were selected to advance in observational nurseries under drought and irrigated conditions with yield greater than susceptible check, 3 g/plant, acceptable phenotypic acceptability of 3-5 and leaf rolling scores of 0 - 3 through the sequential use of correlation, principal component, and cluster analyses.

Through multiple testing under rainfed environments and managed drought conditions, promising lines, which are adaptable to the target environments and highly acceptable to the farmers, were selected. Multi-environment trials were conducted to identify both stable and high yielding genotypes in a wide range of environments. However, environmental changes affect crop yield due to significant genotype and environment interactions. For the multi-environment trials, 20 released varieties in 6 test locations were selected and evaluated in 2016 at the Central Experiment Station in Nueva Ecija and at stations in Batac, Isabela, Los Baños, Negros Occidental, Agusan, and Midsayap. Fifty elite breeding lines were screened in DS 2017. Based on the computed yield stability index (YSI), the most stable and high-yielding genotype was PR45719-KDML105-SM2012DS-400-5 (1.91-4.33 tha-1) followed by PR41398-ICRL2008WS-PSB Rc68 11-4-1 (1.67-4.29 t/ha), Raeline 7 (1.91-4.19 t/ha), and PR39269-B-3-B-1-3 (1.89-7.74 t/ha). These lines will be nominated for NCT. Data showed that NSIC Rc 222 has specific adaptation to Negros while NSIC Rc 354 showed good performance at CES and in Batac during 2015. In 2016, NSIC Rc 282 yielded good harvest in Batac and Midsayap; NSIC Rc 354 in Agusan; and NSIC Rc 346 at CES.

Pyramiding submergence and salinity tolerance have identified six pyramided promising lines with acceptable yield under stress and irrigated condition and with confirmed genes for tolerance to both stresses. FR13A-derived mutant lines (21) and 138 TRV-derived lines were identified to be moderately to highly tolerant to salinity at seedling stage.

On breeding heat-tolerant rice, 1,390 breeding lines were selected based on phenotypic acceptability and reaction to pests and diseases. These lines had yield range of 4-6 t/ha and spikelet fertility of 70-95%. Heat-tolerance evaluation under field condition showed 24.6% of the breeding lines are tolerant while 47%, intermediate tolerant. Using DNA markers, six elite heat-tolerant lines also have tolerance to submergence, BLB, and rice tungro virus. PR40330-42-7-12-1 had the highest and most stable yield across environments in the NCT. This elite line was genotyped to have tolerant gene for submergence and tungro.

For upland and drought-prone rainfed environment genetic improvement, several breeding lines of 540 F4, 504 F5, 183 F6, 80 ON, and 290 lines were screened for yield performance. Seven lines were nominated to National MET at UPLB for further evaluation.

Twenty F1 populations were generated in DS and WS 2017 as starting materials for developing elite lines adapted to water limiting environments in Mindanao. Results showed that from the 280 advanced lines, 57 had yields greater than 3.5 t/ha with 3-5 phenotypic acceptability under fluctuating soil moisture conditions. The selected lines will be further evaluated in the PYT in Midsayap.

On improving grain quality and nutrition of upland varieties in Mindanao, 13 of the 57 upland rice varieties (URVs) were improved using recurrent selection method for four seasons. URVs with their base and improved population were compared in yield performance in simulated (on-station) and natural environments (upland condition). URVs from base to improved population found a mean yield increment (YI) of 38.9% in simulated environment while 39.2% in natural environment. Improved Malan, Wagwag, Kutivos, Awot, Dinorado, Dinorado CES, and Pututan with a yield ranging from 2 to 4.86 t/ha had ≥40% YI in simulated environment. With a yield ranging from 2.83 to 3.83 t/ha, these varieties had ≥40% YI in natural environment. In average, Awot, Malan, Kutivos, Dinorado CES, and Pututan populations were improved with ≥40% YI from a mean of 1.95 t/ha of base population.

An experiment was conducted in a farmer-collaborator's field in Pangasinan to determine the effectiveness of PalayCheck System on water management in drought-prone rainfed lowland. After the consultation meetings with the local government unit of Umingan, Pangasinan, in-field rain water harvesting system (IWHS) was constructed. Its efficiency in collecting rain water and as irrigation source was tested in 2017. The IWHS was fully constructed in WS 2016, but rain water was only collected in May 2017 due to intermittent rainfall. The collected water was used to irrigate the established rice crops in WS 2017 when water scarcity occurred 15 days after transplanting.

Breeding Drought Tolerant Rice Varieties

Nenita V. Desamero, JM Niones, CC Cabusora, KR Balmeo, MDM Banting, JOP Orpilla, RJD Buluran, JS Concepcion

Breeding drought tolerant rice varieties is essential for the crops to survive harsh phenomena brought about by changing climate. At PhilRice, conventional breeding, mutation breeding, and doubled haploid breeding are used to generate and develop climate resilient rice varieties.

The study identified new putative drought tolerant lines as novel source of genes for tolerance and generated tolerant promising lines with acceptable agronomic characters and grain yield. To date, 19 lines from different breeding strategies were identified and selected for multi-

environment trial in different rainfed-drought prone locations in 2018 WS. In WS 2017, two promising lines were approved by the National Seed Industry Council (NSIC) as new varieties for commercialization and cultivation.

Mass Screening for Salinity, Submergence and Seedling Stage Drought Stress Tolerance

Norvie L. Manigbas, NV Desamero, RJ D. Buluran, RM Sumabat

Breeding lines generated from conventional breeding, mutation breeding, double haploid breeding, and molecular assisted breeding (MAB) were screened for tolerance to abiotic stresses namely drought, submergence, and salinity at seedling to early vegetative stage. Established screening protocols for abiotic stresses were employed to screen and/or evaluate the breeding lines. Five hundred fifty stable and advanced breeding lines were evaluated to validate their drought tolerance at seedling stage. The evaluation resulted in the identification of 254 (46.2%) lines with validated tolerance. Screening of 149 sublines from xx TRVs for salinity tolerance to identify new novel gene source identified xx TRVs tolerant. Screening of segregating population composed of 2,044 plants had identified 1,444 (70.6%) plants that are putatively tolerant. Evaluation of stable advanced lines for submergence stress identified 78 lines tolerant, and screening of 5,190 F2 plants from 8 segregating population had identified 3,794 (78%) plants that are putatively tolerant. The screening and evaluation identified 176 lines with tolerance to drought and salinity and 5 lines with multiple tolerance (drought, salinity, submergence). Tolerant lines from early generation breeding lines will be evaluated further for uniformity, agronomic traits, yield and other trials, while advanced lines with validated tolerance will be used as novel gene source or as candidate for NCT for varietal release. Identified lines with multiple tolerance will be further evaluated.

Mass Screening for Reproductive Stage Drought Tolerance

Jonathan M. Niones, NV Desamero, VAC Marcelo, MDM Banting

Drought is a major abiotic constraint in the rainfed lowlands. Development of a drought tolerant variety is a strategy to mitigate the negative effects of drought. Efficiency of selection does not only depend on yield but also on the combination of high yield and correlated traits. This study aimed to screen and phenotype 1134 F6 to F8 test entries and checks for agro-morphological characteristics, drought response, yield and its yield component under reproductive drought during DS and agro-morphological characterization of 150 selected lines during WS seed increase.

During DS, four cycles of drought and re-watering were imposed lasting for 18, 15, and 17 days with water below soil surface onset from

0.5-2 cm to 93.75-96 cm during drought cycles. Based on yield/plants' positive significant association with plant height, culm length, panicle length, frequency of productive tillers and negatively significant correlation for 3rd cycle leaf rolling score and leaf canopy temperatures (1st and 2nd cycles). One hundred fifty entries were selected through the sequential use of correlation, principal components, and cluster analyses. Mean yield per plant of selected entries averages at 7.2 g with leaf rolling scores ranging from 0 to 5 and Phenotypic Acceptability (PAcp) from 3 to 5. Diversity analysis showed that majority of the qualitative traits were monomorphic except collar and auricle colors. Moderate to high diversity (h= 0.72 – 0.88) were recorded for agronomic traits. Germplasm seed source (300 g) for rainfed observational nurseries under divergent trials were prepared for DS 2018 planting.

Multi-environment and Adaptability Tests of Breeding Lines in Drought-prone Rainfed Lowland

Jonathan M. Niones, NV Desamero, VAC Marcelo, MDM Banting

Multi-environment trials are conducted to identify stable and high yielding genotypes in a wide range of environments. However, environmental changes affect crop yield due to significant genotype and environment interactions. This study aimed to improve rice productivity in the target environments of drought-prone rainfed lowlands through more efficient and accelerated selection procedures of highly adaptable and acceptable rice lines for location-specific recommendations. Breeding lines and check entries were established at PhilRice Central Experiment Station during DS under managed drought condition. Another set of test entry were established in 5 on-station sites (CES, Batac, Isabela, Negros, and Midsayap) under rainfed condition, both in factorial Randomized Complete Block Design (RCBD) with 3 replications in at least 10 m2 plots, together with check varieties that were high yielding and locally adapted. Data for yield, yield components, and other agro-morphological traits were gathered. In DS 2017, 50 elite breeding lines were screened while 20 check entries were evaluated in 2016. Results showed that PR39269-B-3-B-1-3 (1044 kg/ha) and PR45719-KDML105-SM2012DS-400-5 (1200 kg/ha), outyielded the highest yielding check IR64 (1020 kg/ha) with 2.31 and 17.60 yield advantage, respectively. Thirty-six entries were evaluated across 5 sites (CES, Batac, Isabela, Negros, and Midsayap). At CES, four of the 31 breeding lines outperformed the best check with 5-26% yield advantage over NSIC Rc 222 (3771 kg/ha): PR38537-B-8-3-1(3970 kg/ha), PR39315-ACDS2007 44-1-2 (4329 kg/ha), PR39950-B-15-B-3-1 (4384 kg/ha), and PR30025-99ACWSAL-1087/SHZ-2-ACRL 2012WS 1-1-9-3 (4785 kg/ha). However, data from other sites must be consolidated and analyzed to verify their field performance across sites.

Pyramiding Submergence and Salinity Tolerance into High Yielding Varieties

Norvie L. Manigbas, NV Desamero, JS Concepcion, RJD Buluran, KRP Balmeo, CC Cabusora, JOV Orpilla

Increasing severity of abiotic stresses affecting coastal rainfed ecosystems requires the development and utilization of salinity and submergence stress tolerant rice varieties as adaptive mechanism. The study aimed to develop rice varieties and identify novel gene sources with salinity and submergence stress tolerance through combined phenotypic and genotypic evaluations. Five mutant lines and three TRVs were identified to be moderately-highly tolerant to submergence stress while 138 TRV-derived lines and 21 FR13A-derived mutant lines were identified to be moderately-highly tolerant to salinity stress at seedling stage. Pedigree nursery evaluation for SalTol QTL introgressed lines resulted in the selection of 102 (22.76%) lines from 4 (50%) crosses at F3 - F8 generations.

Breeding Heat-tolerant Rice in the Philippines

Norvie L. Manigbas, JL Grospe, LB Madrid, ES Ladia, FB Enriquez

Breeding for heat-tolerant lines in the Philippines was conducted to develop rice genotypes that can tolerate and adapt heat, determine QTLs for heat-tolerance of selected population, and screen promising and advanced heat-tolerant lines for abiotic and biotic stresses using DNA markers. The project also aimed to conduct preliminary, observational, and replicated yield trials of selected heat-tolerant rice breeding lines in 'hot spots' areas in Luzon and to nominate lines to MET and NCT for heat tolerance test. Breeding lines were screened, evaluated, and selected in Cagayan and Nueva Ecija where temperature reached >35oC. These lines were planted in staggered months so that flowering will all coincide with the hottest period of the year, which is between April and May. Thousands of breeding lines were screened under high temperature conditions in Nueva Ecija and Cagayan. Out of these lines, 24.6% and 47% had tolerance and intermediate tolerance to heat stress, respectively. Advance lines developed had yield range of 4-6 t/ha and spikelet sterility (%) of 5.5-30.1%. Six elite lines were already in NCT for further and more advance testing.

Genotype by environment interaction was also studied in four municipalities of Cagayan. From the study conducted, GxE was found significant ($P<0.01$) for both genotypes and environment and for their interaction ($P<0.05$). Environment contributed the greatest proportion 43.1% of the total variance while genotype contributed 35.5% and GxE 21.5%. The significant effects indicated that environmental conditions had major effects in selecting rice for high grain yield. High genotypic effect also showed that genotypes could be selected for specific environments.

Genotype plus genotype by environment (GGE) biplot showed Iguig as the most discriminating and representative environment making it more suitable for screening adapted high-yielding genotypes under high temperature conditions. PR40330-42-7-12-1 was selected as the best genotype because it is stable across environments and high yielding. It is an elite line currently tested in NCT under heat-tolerance category.

Genetic Improvement of Locally-adapted Rice Cultivars and Elite Lines for Upland and Drought-prone Rainfed Lowland Environments

Victoria C. Lapitan and Mark Joseph T. Mercado

Rice cultivation in the Philippines caters a very dynamic and diverse ecosystem- ranging from irrigated to rainfed lowland to rainfed upland ecosystems. The rapid land conversion of favorable rice lowland areas to human settlements places the rainfed lowland and upland areas as important potential systems for food production. However, this ecosystem is threatened with low crop productivity due to delayed occurrence of rain, prolonged dry spell between two rains, and marginal zone locations. Another challenge is the current effect of climate change that causes drought, which severely affect yield during anthesis and seedling stage.

Crop improvement through conventional breeding is one of the several interventions to improve crop yield. Screening was conducted to identify tolerant rice varieties and potential sources of tolerance. Breeding population was developed from the screened parental stocks. The populations were screened in the field for drought tolerance, tolerance to soil problem, and potential yielding ability. The study generated 540 F4 lines, 504 F5 lines, 183 F6 lines, 80 observational nursery (ON) lines, and 290 lines screened for potential yield. Seven lines were also forwarded for National Multi-Environment trial at UPLB for evaluation.

Breeding of Resilient and Productive Genotypes Adapted to Water-limiting Environments

Jonathan M. Niones, RR Suralta, SB Estrada, VAC Marcelo

Rice plants in rainfed 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. Thus, this study aimed to develop rainfed lowland rice advanced breeding lines with BLB and RTV resistance and to identify cultivars adapted to areas prone to soil moisture fluctuations. Twenty F1 populations were generated during the 2017 dry and set cropping seasons. Segregating populations were also selected phenotypically from F2 to F6 populations. Fifty-seven of 280 advanced lines in the observational obtained

yield greater than 3.5 t/ha with 3- 5 phenotypic acceptability under soil moisture fluctuation. The selected lines will be further evaluated under preliminary and yield trials under Midsayap setting.

Pilot-testing the Key Checks for the Drought-prone Rainfed Lowland PalayCheck System

Norvie L. Manigbas, NV Desamero, RT Cruz, RC Castro, WB Collado, AJ Espiritu, AOV Capistrano, GS Rillon, RJD Buluran, RGM Castelo

The study focused on validating and adapting the proposed KeyCheck on water management in the drought-prone rainfed lowland. The proposed KeyCheck under study was "Drought stress avoided at key crop growth and development stages." A technology to harvest/collect, conserve and utilize rainwater as needed shall ensure availability of water during critical stages in rice production. Hence, the crop is not predisposed to stress resulting from water deficit. Specifically, the study aimed to establish IWHS appropriate for small-scale farming in the pilot site, demonstrate effectivess of the IWHS in ensuring availability of water at critical stages of rice growth and development, and determine the feasibility of a second crop after rice in the pilot site. IWHS was constructed and its efficiency in collecting rain water and its irrigation use was tested in 2017. The collected water was used to irrigate the established rice crops in WS 2017, when water scarcity occurred 15 days after transplanting.

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

Aldrin Y Cantila, SE Abdula, JL Balos, AR Quitel

The study aimed to improve URVs and identify important upland traits. Among 57 URVs, 13 were improved using recurrent selection for four seasons. URVs with their base and improved population were compared in terms of yield performance in simulated (on-station) and natural environments (upland condition). URVs from base to improved population found a mean yield increment (YI) of 38.9% in simulated environment while 39.2% in natural environment.

Improved Malan, Wagwag, Kutivos, Awot, Dinorado, Dinorado CES, and Pututan with a yield ranging from 2 to 4.86 t/ha had ≥40% YI in simulated environment. With a yield ranging from 2.83 to 3.83 t/ha, the varieties had ≥40% YI in natural environment. Awot, Malan, Kutivos, Dinorado CES, and Pututan populations improved by ≥40% YI from a mean of 1.95 t/ha of base population. For traits, only flag leaf width, grain length, grain width, and 1000 grain weight were positively correlated to yield.

Azucena and Kutivos had wider flag leaves with ≥1.7 cm; Kutivos, Kasagpi, Milbuen 3, and Hinomay had the longest grains with ≥9.1 cm; Awot had the widest grains with 3.2 cm; while Azucena and Milbuen 3 had the heaviest grains with ≥24.6 g. Binatang, Binernal White, C2, Chumi-I-tinawon, Dalagang Bukid, Maligaya 2, Milbuen 3, Milpal 18, Parirutong, Pinalwa, Kalinayin, and Karutak showed tolerance to iron toxicity. Milbuen 3, Pinursigi, C22, Aritao Cagayan, Ranan, Awot, Salimboa, and Kulu showed tolerance to zinc deficiency. Binatang, Gos, Kutivos, Kasagpi, Hinumay, Malagkit (IND), Maliket, Murado, Mangguraman, Palawan, Pokkali, Parirutong, and Pututan had pigmented/ colored grains. Therefore, it is possible to improve upland yield and identify good traits in upland varietal development.

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

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We are a government corporate entity (Classification E) under the Department of Agriculture. We were created through Executive Order 1061 on 5 November 1985 (as amended) to help develop high-yielding and cost-reducing technologies so farmers can produce enough rice for all Filipinos.

With a "Rice-Secure Philippines" vision, we want the Filipino rice farmers and the Philippine rice industry to be competitive through research for development in our central and seven branch stations, coordinating with a network that comprises 59 agencies strategically located nationwide.

We have the following certifications: ISO 9001:2008 (Quality Management), ISO 14001:2004 (Environmental Management), and OHSAS 18001:2007 (Occupational Health and Safety Assessment Series).

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