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National Rice R&D
Highlights

HIGH-VALUE PRODUCTS FROM RICE AND IT'S ENVIRONMENT PROGRAM

Philippine Rice Research Institute
Central Experiment Station
Maligaya, Science City of Muñoz, 3119 Nueva Ecija

TABLE OF CONTENTS

High-value Products from Rice and its Environment Program

Marissa V. Romero

Executive Summary

The Program explored rice, other crops, and beneficial organisms in the rice environment to help increase the income and improve the nutritional status of the rice farming community members. It developed value-adding systems to enhance quality, nutrition, shelf-life, market value, profitability, and availability of rice, other crops, and products from organisms in the rice environment for benefit of the rice farmers and industry stakeholders.

The Program implemented three projects: 1) High-Value Rice Grain; 2) High-Value Products from the Rice Grain and other Parts of the Rice Plant; and 3) Beneficial Organisms in the Rice Environment. The first project developed healthy and nutritious gamma-aminobutyric acid (GABA) rice from Philippine rice cultivars for potential applications to food and pharmaceutical industries. It also explored the potential of other crops in the preparation of nutrient-rich rice blends with high consumer acceptability; developed/verified pre-harvest and post-harvest management options for aromatic and organic rice; and optimized the process parameters and evaluated the quality of low-protein rice.

The second project developed high-value products (HVP) from various parts of the rice plant such as grain and cell/organ cultures, biomass, and by-products. Experiments involved the use of the rice grain and rice milling fractions as material sources to aid in the screening and characterization of beneficial compounds found in the grain but could also be extracted from the other rice plant parts. Optimized harvesting time of these parts at certain growth stages ensured no detrimental effects on rice productivity. The project surveyed, screened, and characterized rice cultivars (modern, traditional, and wild rices) and their plant parts to determine the best sources of the compounds of interest. Innovations from existing HVP prototypes, processes, and technologies, and characterizations of the materials involved were included in the process. It also developed production protocols for HVP and evaluated their bio-efficacy, clinical and toxicological properties, and marketability for eventual demonstration and deployment with partner agencies, industries, and manufacturers. Specifically, the project developed encapsulated antioxidants, proteins, and dietary fiber (DF) from bran; resistant starch (RS) from the rice grain; and nanotechnology-based industrial products from hull and straw.

Lastly, the third project determined the applications of beneficial microorganisms present in the rice environment either as biofertilizer or as food; and evaluated the effectiveness of plant growth promoting bacteria for improving rice productivity.

I. High-value Rice Grain

Marissa V. Romero

In the Philippines, rice is the most important part of the diet because it is the staple food of its population. Thus, rice serves as the primary source of calories needed for the daily energy requirement of Filipinos. It also provides a significant amount of protein to those who cannot afford to buy protein-rich foods such as meat and fish. Majority of Filipinos prefer to eat cooked milled or polished rice because of its excellent eating quality. Unfortunately, milled rice contains mostly carbohydrates and protein as most of the micronutrients are removed during the milling process.

There are other forms and types of rice with added value and health benefits. Brown rice or the unpolished form of rice has more health benefits than milled rice because of higher amounts of dietary fiber, fat, vitamins, minerals, and antioxidants. There is also germinated or sprouted brown rice, which contains gamma-aminobutyric acid (GABA). This form of rice is more nutritious, softer, sweeter, and tastier compared to brown rice. The persistent problem of micronutrient deficiency in the country has prompted interventions such as commercial fortification and biofortification to enhance the amounts of iron and zinc in rice. As the Philippines is rich in nutrient-dense crops, they can also serve as alternative staple foods. Efforts are being made to incorporate other staples in the regular diet by substituting them to rice as the main item of the meal. As most consumers are yet to be accustomed eating them as total replacement to table rice, alternative staples may be mixed with rice in certain proportions that would satisfy consumer requirements on eating quality, nutritional improvement, and hunger mitigation. Aromatic and organic rice, which command higher market value, are also becoming popular nowadays.

This project evaluated germinated brown rice, micronutrient-dense rice, nutrient-rich rice blends, aromatic rice, and organic rice which have added value and/or health benefits compared to the regularly milled rice. The general objectives were: (1) development of healthy and nutritious GABA rice from Philippine rice cultivars and identification of their potential applications to food and pharmaceutical industries; (2) exploration of the potential of corn and adlai in the preparation of nutrient-rich rice blends with high consumer acceptability; (3) development/verification of pre-harvest and post-harvest management for aromatic and organic rice; and (4) optimization of process parameters and evaluation of low-protein rice.

Healthy and Nutritious GABA Rice for Functional Food and Pharmaceutical Industries

RM Bulatao, MB Castillo, JPA Samin, and MV Romero

Germinating brown rice results in the production of GABA, which is known to have energy-boosting, health-promoting, and mental-enhancing properties. Recognizing these benefits, this study developed and characterized germinated brown or GABA rice from our local cultivars. GABA rice was characterized for its nutritional composition, microbial load, and functional quality characteristics. The consumer acceptability and shelf-life were also assessed.

Results showed that the dried GABA rice is a good source of GABA (15.56mg/100g), protein (8.4 mg/100g), dietary fiber (4.1 mg/100g), carbohydrates (71.1 mg/100g), calcium (31.7 mg/100g), iron (4.3 mg/100g), and sodium (13.0 mg/100g). It also had high consumer acceptability in both raw (67.5%) and cooked (72.5%) forms. Shelf-life evaluation indicated that GABA rice stored in plastic and aluminum foil at room (25-27°C) and refrigerated (4°C) temperatures can still be consumed after two months as shown by its acceptable pH (6.07-6.83), titratable acidity (0.16-0.19), water activity (0.94-0.96), and safe microbial load (<2.0x104 CFU/mL total plate count and 3.5x102 CFU/mL coliform count). Due to its ideal functional quality, GABA rice was used as base ingredients in the development of instant GABA rice congee and instant chocolate GABA rice drink. These two products were found to be a good source of nutrients, had high consumer acceptability, and are safe for consumption.

Development of Nutrient-Rich Rice Blends Using Local Food Crops

HF Mamucod, RV Manaois, AV Morales, PR Beligica, and MV Romero

The Department of Agriculture promotes the utilization of other energy-dense local food crops such as adlai (Coix lacryma-jobi L. var. ma-yuen) and corn (Zea mays) as rice complements to enhance food security in the Philippines. This study evaluated the suitability of adlai and corn in complementing rice through the development of ready-to-eat (RTE) rice-adlai and rice:corn meals, and rice:adlai and rice:corn blend products. One RTE meal and three blend products were developed and characterized per rice:adlai and rice:corn combinations. Results of the optimization process showed that both transparent polypropylene (TPP) and aluminum-coated pouches (ACP) were able to stand the temperature and pressure during the retort-processing of meals. The packaging materials did not impart any residual off-odor and off-taste to the products. Addition of 0.1% malic acid was found suitable as antimicrobial agent due to its subtle acidity.

The rice:adlai energy bar had a shelf-life of eight weeks at room temperature, either packed in TPP or ACP without the addition of preservative. For the rice:adlai and rice:corn hopia, samples with mungbean and adlai flour, and mungbean and corn grits fillings had good sensory characteristics, and obtained consumer acceptability of 90 and 94%, respectively; indicating high market potential. Substituting all-purpose flour with mungbean combined with rice, adlai, and corn in the preparation of hopia also provided the same nutritional value of the product. Results of the sensory evaluation showed that rice:adlai and rice:corn soft cookies were generally comparable with the control. In terms of consumer acceptability, rice:adlai and rice:corn soft cookies obtained high acceptability of 94 and 93%, respectively. Both products were also preferred by the consumers over the control, which also indicates good potential in product marketability.

Post-harvest Management of Aromatic and Organic Rice
MAU Baradi, JM Solero, CT Dangcil (PhilRice Batac); MV Romero, GA Corpuz, RT Cruz, and MJC Regalado (PhilRice CES)

Lost in quantity and quality of rice grains occur during postharvest operations. As such, this study evaluated the effects of various conditions during harvesting, drying, and milling on the yield and quality of aromatic and organic rice.

Initial results showed that season, harvesting time, variety, and their interactions significantly affected the yield during both dry and wet seasons. Yields were higher in wet season than dry season when Burdagol-Laguna Type was harvested at 25 and 30 days after flowering (DAF); Gal-ong, 25 DAF; and PSB Rc82, 25 and 35 DAF. During dry season, highest yields were obtained when Burdagol was harvested at 35 DAF; Gal-ong, 30 DAF; and PSB Rc82, 25 DAF. Meanwhile, highest yields during wet season were obtained when Burdagol was harvested at 30; Gal-ong, 35 DAF; and PSB Rc82, 25 DAF. PhilRice-recommended postharvest technology resulted in positive effects on moisture content, drying time, and milling recoveries compared with Farmers' Practices. Moisture content of Gal-ong was reduced to 13.27-13.47% when recommended sundrying technology (PhilRice) was followed. Drying was significantly reduced to 7 hr compared with the Farmers' Practices (1 and 2) of 13 hr . Grains from Farmers' Practices were overdried (7.83−8.80 % MC), resulting in reduced final weight. Drying of Gal-ong was more uniform using PhilRice technology. In pre-milling drying, moisture content and brown rice and milled rice recoveries of PSB Rc82 were significantly affected by drying method. The 2-hr drying (with every 30-min stirring) had removed the least amount of moisture from the grains, and gave the highest brown rice and milled rice recoveries, followed by the 4-hr and 6-hr drying. Lowest brown rice and milled rice recoveries were obtained from Farmer's Practice and Control. Milling recoveries of rice was significantly affected by the kind of milling machines used.

Optimization of Process Parameters and Evaluation of Low-Protein Rice
MV Romero, MJC Regalado, HF Mamucod, AV Morales, MB Castillo, and PR Belgica

Low-protein rice is a pre-cooked, protein-reduced rice intended for individuals who want to continue consuming rice on a low-protein diet. As rice is the Filipino's staple food, reducing its protein content is an excellent strategy to help patients with chronic kidney disease who have restricted protein diet. This study screened suitable Philippine rice varieties for making low-protein rice; optimized several process parameters involved in its preparation; and established its shelf-life using the method developed by Biotech Japan (BTJ) Corporation.

Result showed that low-protein rice produced from both Japonica-type varieties (NSIC Rc304 and NSIC Rc242) were very soft and cohesive with corresponding lower Instron hardness values. Both varieties also produced unpleasant yellowish color as manifested by their lower L and higher b values. The Indica-type NSIC Rc160, NSIC Rc222, and NSIC Rc152 produced whiter products as showed by their significantly higher L and lower b values accompanied by higher sensory score for color. However, due to their hard Instron classification, NSIC Rc222 and NSIC Rc152 had high tendency to become harder and separated at room temperature. The samples were also described as less glossy, separated, hard, and rough by the panelists. With its good sensory attributes and cooked rice texture, the low-AC rice variety NSIC Rc160 was found suitable for the development of low-protein rice. Protein content reduction from 0.25 to 1.55% was achieved. Addition of 60 mL of 0.05% malic acid before sterilization resulted in a product with good textural and eating quality. Using the BTJ method, low-protein rice had shelf-life of 19 weeks at room temperature and remained acceptable on the 28th week at refrigerated temperature with minor changes in Instron harness, moisture content, and Aw. The microbial count was also within the safe limit without E. coli.

II. High-Value Products from the Rice Grain and Other Parts of the Rice Plant

Rosaly V. Manaois

This project with three studies investigated the potential of the rice grain and other parts of the rice plant for the development of high-value products, particularly encapsulated antioxidants and proteins and dietary fiber (DF) from bran, resistant starch (RS) from the rice grain, and nanotechnology-based industrial products from hull and straw. It focused on the rice plant parts, rice production biomass, and rice processing by-products as material sources of the compounds of interest. These can be harvested at certain optimized periods ensuring that harvesting will have no detrimental effects on crop growth and rice productivity. The project also looked at processes, methodologies, and technologies necessary for the development of production systems and product prototypes of marketable high-value products from abovementioned sources for eventual demonstration and deployment in collaboration with partner agencies, industries, and manufacturers.

Project outputs such as the functional foods/beverages and food supplements industries, pharmaceutical companies and/or agricultural products industries can be directly utilized by stakeholders. Rice farmers and village-level farmer organizations, being the source of rice biomass in the large-scale production of high-value products, can be key players in the supply chain and may also be involved in the initial preparation and processing of raw materials from rice. Thus, improving their profitability from rice farming and processing through these in-demand high-value products from the rice grain and rice plant parts.

In the study on the extraction and encapsulation of antioxidants and proteins from rice bran, 45 pigmented rice samples were screened as potential sources for use in functional food, pharmaceutical and biomedical applications. The red variety Malagkit Kapa had the highest total phenolic content and antioxidant capacities using the three widely used methods, namely 2,2-diphenyl-1-picrylhydrazyl (DPPH), ferric reducing antioxidant power (FRAP), and 2,2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS). Ratan and Tib Bak had the highest total anthocyanin and flavonoid contents, respectively. Anthocyanin was extracted from Ominio bran and encapsulated by polyelectrolyte complex formation of alginate and chitosan polymers. The process was optimized using Response Surface Methodology. The encapsulated anthocyanin from Ominio bran can be further tested for use in various applications.

The second study looked into the potentials of rice and the bran as sources of prebiotic components called RS and DF, respectively, and their

possible utilization in food products. Pigmented and non-pigmented rice varieties were screened for these properties. Rice samples with relatively high RS were subjected to parboiling to further improve the RS content. It was also tested in the development of food products. Results showed that varieties with higher amylose content (AC) formed higher levels of RS3 or retrograded starch upon parboiling. Parboiling increased hardness of the cooked rice but the parboiled rice, could not improve the RS in pretzel and noodles. Other methods of inducing RS in rice (i.e., chemical treatments) could be tested in the future for use in food products. To test bran for high DF, bran of different varieties were screened for DF and then tested as supplementing ingredient in fresh noodles. Rice and its parts (i.e., bran) can therefore be used as sources of the prebiotic substances RS and DF in foods.

The third study explored the production of cellulose acetate (CA) and nanosilica from rice straw and rice hull ash, respectively, through nanotechnology. Rice straw samples were screened for their pulp yield and further acetylated through ionic liquid, sulfuric acid, and their combinations to obtain high quality CA. The CA was then converted to electrospun nanofiber composite (ENC) to be used as membrane for nano-remediation of regulated heavy metals and pesticide residues in the soil. Fourier transform infrared spectroscopy analysis confirmed the compositional resemblance of rice straw CA with commercial standard. The developed electrospun nanofiber composite membrane was also found effective in the removal of heavy metals (Pb, Cr, and Hg) and organochlorine pesticide residues in soil. This study concluded that CA from rice straw can be an excellent and cheap source of membranes for nano-remediation of heavy metals and pesticide residue in the soil.

Extraction and Encapsulation of Antioxidants and Proteins from Rice Bran for Functional Foods and Biomedical Applications

RM Bulatao, JPA Samin, RP Tubera, RV Manaois (PhilRice CES); JJ Monserate (CLSU); MM Cayanan, and GC Sanchez (Pampanga State Agricultural University)

This study extracted and optimized the encapsulation of anthocyanins and proteins from rice bran for biomedical and pharmaceutical applications. Forty-five pigmented rice samples were collected with promising phytochemical properties in terms of total phenolic, anthocyanin and flavonoid contents, and antioxidant activities using DPPH, FRAP, and ABTS assay. Among the collected varieties, Malagkit Kapa, a red rice, had the most total phenolic content and highest antioxidant activities (DPPH, FRAP and ABTS). While Ratan and Tib Bak had the highest total anthocyanin and flavonoid contents, respectively. The extraction of protein using alkali method showed that defatting process had low percent yield but had higher protein content as compared to the undefatted samples. Furthermore, encapsulation of anthocyanin from Ominio bran by polyelectrolyte complex formation of alginate and chitosan polymers was successfully optimized using response surface methodology. The best combination of variables for the process was 6.3 mg/mL chitosan, pH 5.5 and 36 mM CaCl2 with a theoretical efficiency of 51.4% per 30 mg of crude anthocyanin extract. Experimental validation was done with 0.02% relative error to the predicted value of the model. Evaluation of the phytochemical properties of the encapsulated anthocyanin showed 0.34 mg gallic acid eq./g (total phenolic content) and 5.69 mg trolox eq./g encapsulate (DPPH). Encapsulated anthocyanin also exhibited good encapsulation using chitosan-alginate polymeric complex as seen in the FTIR spectra, smooth surface texture using scanning electron microscopy with an average nanoparticle diameter size of 118.83 nm.

Prebiotics from Rice: Dietary Fiber and Resistant Starch

RV Manaois, JEI Zapater, and ESA Labargan

Prebiotics are food components not digested and absorbed in the small intestines. As a result, they exert hypoglycemic effects and are fermented and metabolized by beneficial microorganisms in the gut, improving the overall health of the host. RS and DF are among the known prebiotics. This study looked into the potentials of rice and its parts as sources of RS and DF with prebiotic properties and their possible utilization in food products. Pigmented and non-pigmented rice varieties were screened for their RS. They were subjected to parboiling to further improve the RS content and tested in the development of food products. Bran of different varieties were also screened for their DF levels and then tested as supplementing ingredient in a food product (i.e., noodles). Results showed that varieties with higher AC, particularly Minaangan (red, intermediate-AC) and NSIC Rc222 (non-pigmented, high-AC), formed higher levels of RS3 or retrograded starch upon parboiling. RS levels of cooked parboiled NSIC Rc222 and Minaangan were 32% and 49% higher than those of their non-parboiled counterparts. Parboiling further increased hardness of the cooked forms of these types of rice, but adjusting the amount of cooking water to 2.5x that of rice improved its texture while enhancing the RS content. The parboiled rice, however, could not improve the RS in pretzel and noodles. Other methods of inducing RS in rice (i.e., chemical treatments) could be tested in the future for use in food products. DF of the tested bran samples were generally >35%. When NSIC Rc298 and Minaangan bran were used in fresh noodles at 10% supplementation, they improved the DF level of the product by 42% and 80%, respectively, without affecting the overall acceptability of noodles. Rice and its parts (i.e., bran) can therefore be used as sources of the prebiotic substances RS and DF in foods.

Production Nanotechnology of Rice Straw and Rice Hull for Industrial Applications

JJ Monserate, RM Bulatao, MV Romero, and JR Salazar

Farmers often burn rice straw in an open field but this imposes environmental threat as tons of unwanted greenhouse gases are produced. Given the appropriate technology, this agricultural waste can be a potential source of income for Filipino farmers. More environmental and agricultural applications for rice straw have actually been established lately. In this study, CA production CA through nanotechnology was explored. Rice straw samples were screened for their pulp yield and further acetylated through ionic liquid, sulfuric acid, and their combinations to obtain high quality CA. The CA was then converted to ENC to be used as membrane for nano-remediation of regulated heavy metals and pesticide residues in the soil. Among the samples, rice straw from NSIC Rc222 had the highest pulp yield (35.7%), which consequently produced the highest CA yield (93%). Among different solvent systems, higher CA yield was obtained from the combination of ionic liquid and sulfuric acid compared with their individual treatment. Fourier transform infrared spectroscopy analysis confirmed the compositional resemblance of CA from rice straw with commercial standard. The developed ENC membrane was also found effective in the removal of heavy metals (Pb, Cr, and Hg) and organochlorine pesticide residues in soil. This study concluded that CA from rice straw can be an excellent and cheap source of membranes for nano-remediation of heavy metals and pesticide residue in the soil. Synthesized Nanosilica from rice hull ash, XRD analysis in this study revealed a gentle peak at 2Θ=22.5o, which proves to be non-crystalline; thus, safe for the human body.

III. Beneficial Organisms in the Rice Environment

Evelyn H. Bandonill

Intensive rice production through planting of modern rice varieties with heavy dependence on commercial fertilizers and pesticides affects soil productivity. There are beneficial organisms in the rice environment that can be utilized to possibly address this challenge. The project studied three organisms: 1) blue-green algae (BGA); 2) drought-tolerant bacteria; and 3) nitrogen-fixing BGA – Nostoc commune. BGA thrives in the rice environment and can fix nitrogen (N) in flooded soils leading to its use as biofertilizer for rice. Meanwhile, drought-tolerant bacteria plays a major role in enhancing the growth of upland rice especially in drought conditions. Enhancing the availability of beneficial microorganisms to mineralize organic matters in addition to the application of inorganic fertilizer and increasing water holding capacity to support the growth of rice are very important. The project also studied large scale-production of nitrogen-fixing BGA that has been originally explored as a nitrogen source in rice fields and was considered as good source of valuable products such as phycobiliprotein and polysaccharides. One of these BGA is Nostoc commune which is already being consumed as traditional food by the Ilocanos. However, its population has dwindled over the years; thus, there is a need to restore its production level in rice paddies.

This project determined the applications of beneficial microorganisms present in the rice environment either as biofertilizer or as food and evaluated the effectiveness of plant growth-promoting bacteria for enhancing rice growth and improve its productivity. The first study determined the effect of BGA, Anabaena variabilis, on the agronomic characteristics, yield, and N content of rice during 2017 dry and wet season. The treatment 50% BGA + 50% NPK produced comparable yield with 100% NPK in 2017 dry season. The second study examined the potential of five bacteria as microbial inoculant for improving the yield of NSIC Rc192 through screenhouse experiments. Significant increase in plant height, tiller number, shoot oven dry weight, and grain yield by bacterial isolates demonstrated the potential of the bacteria as plant growth-promoting inoculants for upland rice. However, field assessment is recommended to determine the effect of biotic and abiotic stresses in the performance of promising bacteria. The third study documented the presence of N. commune in Ilocos Norte, Nueva Ecija, and Cagayan Region and discovered that there was no significant difference in the morphological structures of the algae collected from different locations. Moreover, no particular soil and floodwater properties was found to be associated with the persistence of N. commune in rice paddies and other bodies of water. Rice paddies found to be dominated by N. commune were generally shallowly tilled, applied with minimal amount of chemical farm inputs, and situated nearby a water source that is believed to be favoring its presence. It is concluded that introduction of sufficient amount of N. commune in any soil type, possessing the above-mentioned conditions will support its growth for possible mass production and become a possible source of food. The outputs generated by the studies under the project thus enhanced the availability of either biofertilizer, plant growth-promoting bacteria, or food from beneficial organisms thriving in the rice environment.

Algalization of Rice Paddies

EH Bandonill, MD Malayabayabas, JCA Cacerez, and MR Martinez-Goss

To utilize BGA as cheap and renewable source of biofertilizer for rice cultivation, the algae strain Anabaena variabilis (Ns71Ph) was used in pot experiment during 2017 dry and wet season. The effect of 100% BGA biofertilizer or in combination with commercial inorganic fertilizer on the growth, yield, and N content of PSB Rc82 rice variety was determined. Treatments include the control (no fertilizer), 100% recommended rate of NPK (120-40-40 kg/ha), 50% BGA (50 kg/ha) + 50% recommended rate of NPK (60-20-20 kg/ha), and 100% BGA (100 kg/ha). Rice growth was monitored at 39, 53, 83, and 97 days after sowing (DAS) during the dry season and 41, 54, 83, and 96 DAS during the wet season, while the yield and yield components were gathered at maturity. During the dry season, plants applied with BGA had comparable heights with those treated with 100% NPK at 53 and 97 DAS. Those treated with 50%BGA + 50%NPK produced comparable tiller count with those applied with 100%NPK. At 83 DAS, leaf greenness of plants applied with NPK and BGA did not significantly differ. During the wet season, plants applied with BGA had comparable heights with those treated with 100% NPK at 41, 54, and 83 DAS. Plants treated with 50%BGA + 50% NPK had significantly more tiller count than the untreated control at 54 and 83 DAS. Leaf greenness of plants applied with 100% NPK f was comparable with 50%BGA + 50%NPK at 83 DAS. All plants from the four treatments had comparable panicle, harvest index and spikelet count during dry season. Treatment with 100% NPK produced the highest grain yield (468.0 g/m2) followed by treatment with 50% BGA+50% NPK (305.8 g/m2). Better growth and yield was observed during the dry season than during the wet season.

Isolation and Screening of Plant Growth-Promoting Bacteria as Potential for Enhancing Drought Tolerance of Upland Rice

JA Cruz, AA Dela Cruz, TC Fernando, RL Ordonio, EV Evangelista, AR Agpaoa, JMR Bautista, and AJC Santos

Screenhouse experiments examined the potential of five bacteria as microbial inoculant to improve the yield of NSIC Rc192. The five isolates were also subjected to biochemical analysis to establish isolate identity. Based on biochemical analysis (BiOLOG GEN III Microbial ID System), majority of the selected isolates are Bacillus sp. In the carbon source utilization assays, selected bacterial isolates were positive for potassium tellurite, sodium bromate, aztreonam, and lithium chloride. These were commonly used as a carbon source of selective media for soil bacteria. Carbon source (aztreonam) was commonly used by researchers as an antibacterial agent. Some organic acids were also produced by the selected bacteria. In the screenhouse, percent increases on plant height was observed at half fertilizer treatment + IS8-9 (24.75%, vegetative stage; 18.63%, reproductive stage; ripening stage, 11.26%) relative to uninoculated control. Similarly, inoculation of rhizobacteria significantly increased the tiller number of NSIC Rc192. Isolate IS8-9 + 1/2 RRF increased tiller number by 66.67% relative to uninoculated control. On the other hand, isolate MB3-279 + 1/2 RRF and isolate MB1-263+1/2 RRF had the least effect, which only increases tiller number by 33.33% relative to uninoculated control. This result is correlated with the data presented in plant height, in which isolate IS8-9 + ½ RRF had the most effective result and isolate MB3-279 + 1/2 RRF had the least favorable finding. Inoculation also increased shoot oven dry weight of NSIC Rc192. Percent increase of 4.20% on shoot oven dry weight was obtained at half fertilizer treatment in combination with MB3-279 isolate relative to ½ RRF. Compared with full rate fertilizer, highest grain yield was obtained at MB3-279 + ½ RRF and at AP-3-7 + ½ RRF with an increase of 58% and 15% respectively. Meanwhile, IS-8-9 + RRF did not significantly increase grain yield relative to RRF. The significant increase in plant height, tiller number, shoot oven dry weight, and grain yield by bacterial isolates demonstrate the potential of these bacteria as plant growth-promoting inoculants for upland rice. However, field assessment is recommended to determine the effect of biotic and abiotic stresses in the performance of promising bacteria.

Ecological Basis for Persistence and Production of N. commune in the Rice Paddies

AA dela Cruz, TC Fernando, ES Avellanoza, and JC Yabes

N. commune, locally known as tabtaba, is an edible BGA that is also capable of fixing atmospheric N into the soil. Thriving in hilly areas and rice paddies, it is being consumed in the Philippines, particularly in the Ilocos Region, as food or used as feed for small farm animals. Its population was dense in the rice paddies in Regions 1 and 2 during the 1980s until early 2000s. However, it disappeared recently or the areas inhabited had significantly decreased. As potential beneficial organisms in rice ecosystem, its ecological factors affecting its survival and production are determined. This study also aimed to design a system for its scalable on-farm production using low-cost farm resources.

Survey showed that N. commune are abundant in eleven municipalities in Ilocos Norte and in rice paddies and along a river in Nueva

Vizcaya. They are sold in local markets in the Cagayan Region, in fresh and dried forms. Microscopic examinations of specimens revealed no significant morphological differences. Short-long chains of vegetative cells and intercalating heterocysts, the site of N fixation, were consistently observed. Rice paddies aplenty of N. commune were generally shallowly tilled, applied with minimal amount of chemical farm inputs, and situated near a water source. In comparing the chemical properties of soil and floodwater samples collected from areas with- and without- N. commune, however, there were no particular properties found to be associated to its presence. Therefore, the introduction of sufficient amount of inoculum in any soil type, as long as it is possessing the characteristics mentioned above, may potentially support N. commune growth.

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

Philippine Rice Research Institute
Central Experiment Station
Maligaya, Science City of Muñoz, 3119 Nueva Ecija

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).

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: 0917 111 7423;
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@philric
PhilRice Batac, MMSU Campus, Batac City, 2906 Ilocos Norte; Telefax: (77) 772- 0654; 670-1867; Tel: 677-1508; Email: batac.station@philrice.gov.
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.p
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