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2017
National Rice R&D
Highlights

RICE ENGINEERING and MECHANIZATION DIVISION

Philippine Rice Research Institute
Central Experiment Station
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Rice Engineering and Mechanization Division

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Executive Summary

The Rice Engineering and Mechanization Division (REMD) helps improve the national level of farm modernization and modernize rice production and postharvest operations. There are two projects under the division: 1) Development of production and postproduction machinery that aims to develop machinery and protocols that reduce production cost and minimize postharvest losses; and 2) Commercialization of matured engineering technologies that aimed to jumpstart their commercialization.

REMD developed the following technologies: reversible dryer, seed cleaner, flourmill, micromill, village type brown rice machine, microtiller, plastic drum seeder, and gasifier stove, which are still in demand in the local market. Reversible dryer is one of this year's most popular technologies in the market; registering the most number of queries received from the internet, cellphone, and during office visit to get information on price, capacity, and drawing.

Matured engineering technologies (flourmill, micromill, village model brown rice machine, microtiller, rototiller, riding leveler attachment) were deployed to the branch stations for promotion to the intended end-users. Brochures and leaflets were produced and distributed during exhibits. REMD Machinery book was drafted including the rice production manual using plastic drum seeder, which was funded by INCA plastics. A technology bulletin on brown rice machine (village model) was released in October 2017 for sharing and promotion. Three new manufacturers were accredited and one license to manufacture was renewed.

Five engineering technologies: ricehull gasifier engine pump system, riding type transplanter, and infrared dryer (PCAARRD funded); brown rice machines (village model and pedal-type); MP Seeder (BAR funded); and reduced-till planter were pilot-tested. These technologies will be commercialized in 2019.

Three machine prototypes (stripper combine harvester, riding boat tiller, and motor driven brown rice machine) under research category were developed, which showed promising performance. Pilot testing will be conducted in 2019.

Three series of training/workshop titled, "Strengthening the Capacity to Design Agricultural Machines: Finite Element Analysis (Structural analysis, Heat transfer, Fatigue analysis, and Computational Fluid Dynamics),"

were conducted. Thirteen REMD engineers, who are mostly junior staff, completed a training/workshop series with Dr. Christian Della from University of Glascow, Singapore. A potential collaboration will be expected between PhilRice and University of Glascow in 2018 on improving the development of Agricultural Machinery for rice crop using simulation program.

I. Development of Production and Postproduction Machinery

Caesar Joventino M. Tado

The project has three studies, which focused on land preparation, harvesting, and postharvest development of engineering technologies. Riding boat tiller was intended to be developed for deep muddy fields to reduce the operation cost per hectare during land preparation. Stripper combine harvester is being developed to reduce harvesting costs and prevent harvesting losses. Brown rice machines were also developed to help ensure availability of fresh brown rice in the market and increase its milling recovery.

The stripper combine harvester prototype was field tested and showed promising performance with an average actual field capacity of 1.02 ha/day. The pedal type brown rice machine prototype also showed promising performance with capacity of 2.3 kg of brown rice after two passes in 1 hour of operation. Brown rice recovery registered 72%. Riding boat tiller prototype was tested with promising performance, but needs further improvement to work well in deep muddy fields. Motor-driven brown rice machine prototype is almost completed and will be tested in 2018 first quarter.

The project output contributed to Outcome 1: Increased productivity, cost-effectiveness, and profitability of rice farming in a sustainable manner; Outcome 2: Improved rice trade through efficient postproduction, better product quality, and reliable supply and distribution system; and Outcome 3: Enhanced value, availability, and utilization of rice, diversified rice-based farming products, and by-products for better quality, safety, health, nutrition, and income.

Development and Pilot Testing of Ride-on Stripper Combine

Joel A. Ramos, CJM Tado, MJC Regalado, AS Juliano, EG Bautista, EB Sibayan, RS De Gracia Jr, PR Castillo

A study was implemented to develop a ride-on stripper combine prototype and to investigate on its performance and grain losses. Stripping is a harvesting principle, which involves detaching the grain from the panicle leaving the straw still uncut. A crawler type ride-on stripper combine prototype was developed and initially tested in a demonstration farm at PhilRice CES where PSB Rc 10 and NSIC Rc 396 rice varieties were planted. Appropriate mechanization and postharvest technologies can contribute significantly in improving production and postproduction efficiencies, reduction of costs, and increasing farmers' income. To contribute to these targets, a machine prototype that harvests grains from the panicle through stripping was developed. The prototype has a rotor head, which detaches the grains from the panicle without cutting the straw. It is a crawler-type combine harvester for enhanced mobility in wet field condition. The prototype was initially tested by harvesting an area of 2,000 m2 (PSB Rc 10 and NSIC Rc 396) during WS 2017 following existing standard procedure for rice combine harvester (PAES 225:2015). After two field tests, the prototype recorded an average actual field capacity of 1 ha/day at an average travelling speed of 1.8 kph. The average field efficiency of the prototype was at 54.14% while total grain loss was recorded at 7.8%. The recorded values were notably beyond the acceptable values prescribed in Philippine Agricultural Engineering Standard (PAES). However, this can be reduced by improving the stripping, separating, and cleaning efficiencies. With the ongoing refinements and succeeding field tests, these constraints in efficiency and losses would be properly addressed. It is suggested to improve the width of cut and the prototype's cleaning and separation assembly to reduce the total grain losses. Improvement in the conveying assembly is also necessary to avoid damaged grains such as husked grains and broken grains.

Performance Evaluation of a Hydraulic Ram Pump for Irrigating Rice and Rice-based Crops in Ilocos

Noel D. Ganotisi, JA Calapit, JMM Bumanglag, and CJM Tado

High irrigation cost remains one of the farmers' challenges. To help reduce this overbearing problem, this study validated and promoted the use of hydraulic ram pump (HRP). It aims to aid farmers gain high profit from rice and rice-based farming.

HRP was profiled and characterized to identify improvements to make the pump suitable for Northwest Luzon. Six sites from Ilocos Norte, Ilocos Sur, and Abra were surveyed for installing the HRP. Performance of two sizes of HRP, 2" and 3", were tested and evaluated in terms of their volumetric efficiency and pumping efficiency. Results showed that all the testing sites are suitable in installing HRP with respect to their high pumping efficiency. The higher the vertical fall of water from the drive pipe, the higher it can be lifted. Maximum vertical lift of HRP is five times its vertical fall. HRP was also sensitive to small debris that can clog the waste valve. Strainer at the intake of the drive pipe must be installed to prevent malfunctioning. Ensuring stability is highly recommended in this technology.

Adaptability Test and Improvement of the Manually-operated Rice Transplanter
Lex C. Taguda , DP Dal-uyen , MU Baradi , MG Galera, CJM Tado

Rice production is labor and cost-intensive that it remains a subsistence activity. Hired farm labor decreasing owing to preference of labor employment in the urban centers and abroad. Mechanization can play an important role; however, it has always been associated with big or engine-powered machinery, which is not appropriate in areas with small farm holdings.

China had developed a manually-operated two-row rice transplanter that has promising performance for small farm holdings. Hence, this study was conceptualized to test and evaluate the technical performance of the China's manually-operated two-row rice transplanter at PhilRice Batac and to modify the machine to suit the local condition. One unit was procured from China through online purchasing. The transplanter was tested and evaluated at the station using two methods of seedling establishment (modified dapog and ordinary seed bed). Transplanting modified dapog established seedlings using the machine had less missing hills (25% to 35%) and few seedlings per hill (4-7 seedlings). Transplanting ordinary seedbed-established seedlings recorded high number of missing hills (30% to 40%) and more seedlings per hill (5-8 seedlings). However, the machine's transplanting performance is not good enough for successful transplanting. A modified prototype with improved picking mechanism, seedling tray, and operation mode was developed for testing and evaluation based on the result of testing and evaluation of the Chinese model.

Design and Development of a Lightweight Riding Boat Tiller Using Molded Tough Virgin Polyethylene (MDPE) Plastic for Global Market
Arnold S. Juliano, JA Ramos, EG Bautista, MJC Regalado, KC Villota, PR Castillo

The development of a boat tiller for soft and deep-muddy fields aimed to reduce the land production cost and improve farmers' operating condition. A plastic material for the boat tiller's body was explored in this study to address the problem on frequent bog downs encountered on the previous prototypes and ensure buoyancy. However before subjecting into a plastic body, the existing prototype must be optimized to ensure efficient operation on "laboy" field.

Numerous effort on field testing, modifications, and adjustments had been made as attempt to achieve the desired performance. The following were the improvements considered on the current prototype: a metal outrigger was formed on both sides that improves the stability during operation and the outer-end of the puddler was provided with cross paddle to improve traction. The front wheel, which is being used for maneuvering at corners and headlands, was provided with floater so as not to get stuck in the mud. The control lever for clutch and for depth of cut was also extended on the side-front of operator for easy access. It is recommended that weight reduction should be considered as this factor significantly contributes to the difficulty on forward movement of the machine during operation.

Development of Portable Brown Rice Machine for Household Use
Phoebe R. Castillo, AS Juliano, JA Ramos, JP Miano

The study aimed to develop a gender-friendly brown rice machine intended for the households. The output capacity of portable brown rice machine was designed for the daily requirement of an average family of 5 members. The design was conceptualized for most household members that even a 10-year-old can operate the machine. Two prototypes of brown rice machine, a pedal-type and a motor-driven prototypes, were developed. The pedal-type featured a rubber roll huller and mounted on a bicycle frame while the first prototype of a motor-driven had a centrifugal-type huller. The pedal-type prototype produced 1.33 kg of brown rice per hour of operation with dehulling recovery of 72% after two passes.

Carbonized Rice Hull (CRH)-Insulated Rice Silo: A Solution to Rice Storage Losses
Lex C. Taguda, DP Dal-uyen, MAU Baradi, BM Catudan, CJM Tado, SR Brena, RM Ramos

In the Ilocos region, it is a common practice for farmers to store their rice seeds in a wooden storage, woven basket, or bagged seeds. These practices often result in fluctuating temperature and relative humidity and high incidence of weevils that cause storage losses (e.g., low germination rate) by as much as 36-43%. This study developed a 1-ton capacity rice silo insulated with carbonized rice hull (CRH) to reduce grain storage losses. The CRH-insulated silo was also compared with the hermetic storage bag (saclob). Registered seeds of NSIC Rc 216 were stored in the silo for one year. Results showed that the silo maintained the viability of the stored seeds for 10 months. During the 10-month storage period, germination rate and moisture content (wet basis) ranged from 89.7–97.3% and 10.6–12.5%, respectively. Average weevil population in three representative sampling sites was 166 per 750 g of grains, while the percent damaged grain was recorded at 1.2% during the 10-month storage period. Initial results in another experimental set-up showed that the saclob maintained the germination of stored seeds above 85% during the 7-month storage period. The germination rate and moisture content of the stored seeds in the saclob ranged from 96.58 to 97.5% and 11.07¬-12.24, respectively. In the CRH-insulated silo, germination rate and moisture content ranged from 97.42 to 96.08% and 11.31-11.7, respectively, during the 7-month storage period. In the control (jute sack), germination rate and moisture content of the bagged seeds ranged from 97.42 to 65.58% and 10.92-14.09, respectively, during the same storage period. Germination rate of the control dropped below 85% on the fifth month.

Pilot Testing of Improved Mini Combine Rice Harvester
Caesar Joventino M. Tado

The rice combine harvester makes harvesting efficient as it can cut, thresh, clean, and bag simultaneously in one operation. The technology has been introduced throughout the country in the previous years; however, the level of adaptation has been low due to various reasons, one of these is the inefficiency of the machine due to irregular shaped fields and small plot sizes in the country. The study was conducted to improve the existing PhilRice-designed 1.3-meter rice combine harvester with emphasis on the ground drive system and hydraulic lifting mechanism. The fabrication of first prototype was completed in 2016. The prototype has been tested in the field in DS 2017. However, the operation was stopped due to failure in the grain conveying assembly. The assembly was modified and clogging at the screw conveyor was addressed. The prototype was also tested to determine its forward speed under actual field conditions. Results of the test showed that the machine can operate at the maximum speed of 3.47 kph. However, turning at this speed in both directions was not possible. Therefore, further improvement in the ground drive system of the prototype is needed to address the problem.

II. Commercialization of Matured Engineering Technologies
Eden C. Gagelonia

PhilRice, through REMD, has been at the forefront in the development of production machinery and postharvest equipment for rice production. A vigorous technology transfer strategy is therefore needed for the technologies to be adopted by farmers. Linkage with the manufacturers are also necessary in the promotion and technology commercialization.

Among the strategies implemented in the promotion of matured engineering technologies were information dissemination through distribution of leaflets, brochure, and machine catalog to farmers and stakeholders. Machines were demostrated during field days and exhibits for farmers and stakeholders to be aware of the technologies developed by PhilRice. The branch stations were also provided with demonstration units for demonstration in the station during field days. Machine gallery were improved to include displays of miniature machine models and their descriptions. A book on matured engineering technologies was also drafted.

Continuous-type rice hull carbonizer was introduced and installed as source of heat in the production of coco sugar. Two units of CtRH were installed in two barangays in Alabat, which is Bacong and Villa Hesus Weste. Biomass assessment and load profiling were also conducted to determine the available biomass and electricity consumption in the community, which is needed in determining the capacity of the power plant. Other baseline data needed in the preparation of feasibility study for the establishment of biomass power plant was provided by the municipal agricultural office and planning office. The feasibility study on the establishment of hybrid energy power plant using biomass and solar energy was prepared because available biomass is not enough for the determined capacity of the power plant.

Two models (RHGEPS-1 and RHGEPS-2) of rice hull gasifier engine pump system completed pilot testing in the dry season. Three gasifier engine-pump system units were fabricated by the accredited manufacturer. RHGEPS-2 was pilot-tested at PhilRice Mindoro while RHGEPS-1 was tested at PhilRice-Batac and PhilRice CES Future Rice Farm. The design of the rice hull gasifier engine-pump system was standard in all units pilot-tested.

The RHGEPS-1 performed well with an average discharge of 1 l/sec and 4 kg/hr ricehull consumption at 3.5 m pumping depth. The machine was used to irrigate crops (eggplant, tomatoes, and chili) with a total area of 1200m^2.The RHGEPS-2 also performed well with an average discharge of 9 l/sec and 8 kg/h ricehull consumption at 1.1 m pumping depth. The machine was used to irrigate rice crop in 1.3 hectare.

Promotion of Matured Engineering Technologies
Eden C. Gagelonia

With the approval of AFMech Law, rice production gradually shifted to mechanization. Since PhilRice was established, REMD had been developing rice farm machinery suitable to local conditions. At present, PhilRice had developed around 20 farm machinery that can be promoted to our farmers and stakeholders. Promotion is needed for the farmers and other stakeholders to be aware of the available technologies that can be adopted in rice farming.

Matured engineering technologies were promoted through: 1) information dissemination by distribution of leaflets, brochure, and machine catalogue of developed farm machinery; 2) accreditation of private manufacturers for the transfer of technologies for mass production and promotion; 3) improvement of the machine gallery area; and 4) provision of demonstration units of the matured engineering technologies to the branch stations.

Pilot-testing of Ricehull Gasifier Engine-Pump System for Philippine Rainfed Lowland Farm
Arnold S. Juliano, JA Ramos, JP Miano

Pumping water from underground or from open sources such as lakes, rivers, and streams could be very costly, especially with increasing cost of fuel. To lower the high cost of pumping water, PhilRice developed two models of rice hull gasifier engine-pump system (RHGEPS), which uses rice hull as fuel (instead of gasoline fuel) to pump water from a source with features that are compact, light-weight, mobile, and affordable for the small farmers.

Prior to full commercialization, pilot-testing is necessary to identify potential problem and deficiencies of the machine. This study pilot-tested the machine in farmer's fields near PhilRice branch stations, specifically in rainfed lowland condition with abundant rice hull biomass.

The RHGEPS units was pilot-tested during dry season. Three RHGEPS were procured from accredited manufacturer. RHGEPS-2 was pilot tested at PhilRice-Mindoro while RHGEPS-1 was tested at PhilRice Batac and PhilRice CES Future Rice Farm. RHGEPS-1 performed well with an average discharge of 1 l/sec and 4 kg/hr ricehull consumption at 3.5m pumping depth to irrigate crops (eggplant, tomatoes, and chili) in 1200 m^2. RHGEPS-2 also performed well with an average discharge of 9 l/sec and 8 kg/hr ricehull consumption at 1.1 m pumping depth to irrigate rice crop in 1.3 hectare.

Comments and suggestions from farmer/cooperator were collected such as longer time of operation per batch (8 hrs) and automation of fuel switching from gasoline to producer gas. RHGEPS-1 were modified to improve its performance and usability. Additional two units RHGEPS-2 was procured, which will be used as pilot test units for North Cotabato and Negros Occidental.

Feedback showed that RHGEPS-1 system can help farmers save on fuel cost by almost 50% using rice hull as fuel. However, P70,000 per unit is costly for farmers. Farmer-association may buy the machine if the design is improved. Feedback also showed dissatisfaction on the performance of RHGEPS as bigger reactor is needed for longer and continuous operation of the system. SDesign of the machine also needs adjustment.

A continuation, pilot testing, and automation of the rice hull gasifier system was recommended to determine and incorporate further improvements that will increase acceptability of the machine.

Sustainable and Energy Self-sufficient Community in Small Island of the Philippines
Eden C. Gagelonia, AS Juliano, EG Bautista, JA Ramos, MJC Regalado, BD Tadeo

The study aimed to develop energy self-sufficient and sustainable communities using renewable energy sources and sustainable rice-based technologies. A continuous-type rice hull carbonizer was introduced in the household processor of the municipality as source of heat for coco sugar production. Two units of carbonizer was installed in Barangay Bacong and Villa Hesus Weste. These units are now being used by the household processor for the coco sugar industry.

Biomass assessment survey was conducted to determine the available biomass resources in the municipality. The load profile (including the time on utilization of electricity for each appliances and the kw rating of incandescent bulb and fluorescent) of each household was also determined. These data will determine the potential power that can be generated from the available biomass and the electricity consumption of each household.

Feasibility study was prepared for the hybrid energy using biomass and solar energy that can be established in the municipality. Financial analysis showed that the pre-tax project IRR is 12.8% per annum, which is higher than the discount rate of 7.0%. This will yield in a positive NPV of P 10.05 million. The equity IRR is 23.6% and the payback period is 7.1 years.

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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