2015 National Rice R&D Highlights

Farming Without Fossil Energy Program

Department of Agriculture
PHILRICE
PHILIPPINE RICE RESEARCH INSTITUTE

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FARMING WITHOUT FOSSIL ENERGY PROGRAM

Program Leader: EC Gagelonia

Executive Summary

The Program aims to substantially or entirely remove use of fossil fuels as energy source in rice and rice-based farming by developing alternative energy sources and inputs to come up with sustainable and cost-effective rice and rice-based farming systems. It will explore the use of biomass waste, wind, sun, water and plants to develop processes and technologies that would help reduce dependence on fossil fuels in rice and rice-based farming operations. In addition, the program will identify available rice production technologies that are resource use-efficient.

The program is composed of three projects, with Project 1: Information, Knowledge Generation on Energy Profile in Rice and Rice-based Farming System completed in 2014. The two other ongoing projects are as follows: 1) Development of Renewable, Alternative, Diversified and Decentralized Energy Resource Systems for and from Rice-Based Agriculture – these are technologies that will provide sustainable energy and fuel for farming activities as well as for electricity generation and 2) Adaptation of Low External Energy Input Technologies in Rice-Based Farming – these are generated technologies that will contribute in reducing dependence from fossil energy use and resource use-efficient in rice-based farming system.

Evaluation of the instant steam generator (ISG) prototype as replacement for boiler to drive reciprocating piston-type engines was done. An old 3hp gasoline engine was fabricated as steam engine. Results of test showed that the ISG could run the fabricated steam engine, however, the steam generated is not enough, thus a new design of ISG different from the existing was fabricated.

The developed rice husk gasifier for 100 KVA generator was improved for efficient performance. Series of tests were done for evaluation of performance at continuous operation.

PhilRice designed and developed distillers to produce crude and hydrous bioethanol from fermented nipa sap. The bioethanol distilling facility was deployed in Infanta, Quezon for pilot testing. The hydrous bioethanol distiller was installed at the cooperating user farm and operated for one season to evaluate the performance and quality of the ethanol produce. Tests have proven that a simple distillation facility can be functional to a regionalized and farm–based production system and can be operated by one operator for each unit of distiller.

PhilRice developed a fuel feeding device that allows spark-ignition engine which one of the power sources of rice farming equipment to be operated solely using hydrous bioethanol instead of gasoline fuel. Farming implements such as water pump (1), grass cutter (2), and pump boat (3) were installed with retrofitted engine and subject for long-season operation and testing.

A moving-bed downdraft rice husk gasifier for shallow-tube well pumping of water was designed and fabricated. Based on inital testing conducted, the gasifier unit performs with a fuel consumption rate of 12.5kg of rice husk per hour. The quality of gas entering the engine was monitored using syngas analyzer.

Among the PhilRice developed technologies that can be adapted in the rice-based farming system to increased farm productivity are the continuous flow rice husk gasifier for mechanical drying application, use of wind and solar energy sources for crop irrigation, azolla spore production as biofertilizer, the rice hull gasifier engine-pump system for optimum application in rainfed lowland farms, and utilization of alternative and potential non-fossil fuel based nitrogen nutrition in rice farming.

I. Development of Renewable, Alternative, Diversified and Decentralized Energy Resource System for and from Rice-Based Agriculture

Project Leader: EC Gagelonia

Biomass, which can be derived from plant materials like rice and other crops including farm wastes, is a potential source of energy for rice mechanization. This energy source can be considered as carbon-neutral since the CO2 emitted by this material when burned is counterbalanced by consuming an equivalent amount of CO2 during their growth stage. Biomass includes rice plant itself and its by-products such as rice husk, straw, and its surrounding weeds in the farming environment. They are usually considered as nuisance in the community due to the large volume and spaces they occupy in the field and in rice mills which makes it necessary for them to be eradicated to take advantage of other farming and business opportunities. Tapping these wastes for beneficial use can provide the energy and power needed to fuel both stationary and agricultural machines used in the farm.

Currently, biomass can be converted into different forms of fuel either solid, liquid, gas, or their combination. Heat can be derived directly by burning biomass with excess air. It can also be burned with limited amount of air to produce char which can be used as soil amendment materials and the heat generated can be utilized to produce steam to provide mechanical power. When burning biomass with limited amount of air, combustible gases such as carbon monoxide (CO), hydrogen (H2), and methane (CH4) are produced. On the other hand, sugar-rich biomass materials such as those living in rice environment like nipa, coconut, sugar, and many others can be processed through fermentation and distillation to extract the bioethanol content which can be used as replacement or supplementary fuel for spark-ignition engines; whereas, oil-based biomass like coconut, jatropha, and others can be converted into biodiesel through methyl esterification that can be used as replacement for diesel as fuel for compression-ignition engines.

Currently, PhilRice is engaged in the research and development of alternative, renewable, diversified, and decentralized energy sources and fuel from rice and non-rice biomass. It is contemplated that the fuel and energy that can be derived from rice wastes and its by-products can be used to fuel varieties of sizes and kind of internal combustion engines that will power stationary and mobile machines for land preparation, irrigation, harvesting, threshing, drying, transport, and milling. With this idea, farmers can be encouraged to produce fuel from their farm which they can subsequently use for their farming activities and they can even sell some for their livelihood. Once this is realized, a sustainable and cost-effective rice farming can be achieved.

Evaluation of instant steam generation concept (steam on demand) as replacement for boiler to drive reciprocating piston-type engines
RF Orge and JEO Abon

The development of the continuous rice hull (CtRH) carbonizer by PhilRice has opened a lot of opportunities for enhancing farmers' productivity and income. While producing the carbonized rice hull, the heat generated during the operation of the CtRH carbonizer is recovered for various uses in the farm. Heat recovery attachments to utilize the heat for cooking, baking, and drying had been developed as a way of providing farmers opportunities to generate additional sources of income. Another application of the carbonizer-generated heat which is explored in this study, is to make use of the heat to generate steam for household power generation. New and unconventional method of generating steam are explored to do away with the use of the conventional boilers which are potentially dangerous. Specifically, this study aims to design and develop an instant steam generator (ISG) that, as its name implies, converts a regulated amount of water into steam right at the time of application, eliminating the possibility of hazardous explosion as in the case of the conventional boilers.

Highlights:

- The working prototype of the ISG (Figure 1) was further improved and tested to determine its optimum operating condition. This prototype makes use of 5mm (I.D.) x 2.4m long copper tube as heat transfer medium where water passes through and exposed to heat before coming out through the nozzle. It has a total heated surface area of 3,710cm2 and volume of 464cm^3.

- Results of tests showed that the prototype woks best at water intake rate of 47L/h. At this rate, the highest steam pressure of 77psi was observed (Figure 2). As intake rate increases, the generated steam tends to become so misty. In contrast, a drier steam was observed at lower water intake rates.

- Because of limited budget and the experienced difficulty of acquiring new equipment, the steam engine needed in the study was fabricated from an old 3hp gasoline engine. Modifications had been done on the cam that controls the engine's intake and exhaust valves. Moreover, the cooling fins were insulated so as to prevent the steam from condensing as it enters the cylinder head.

- Results of the conducted test trials (Figure 3) showed that the ISG could run the fabricated steam engine. However, its shaft could not rotate fast when resistance is applied at its output pulley. As analyzed, the following were the possible causes:

  a. Although the cooling fins of the engine was insulated, it was found out that the insulation was not sufficient since most of the steam had condensed (as seen from the watery exhaust) thus significantly lowering the pressure at the cylinder head;
  b. The steam pressure created by the ISG may not be enough;

- A new ISG was designed and fabricated with a different concept from that of the existing one (Figure 4). It features coils of 5mm dia. copper tubes provided with brass ball valves so as to effect a one-way flow of water and prevent backflow as water enters these heated coils. Provisions are made in such a way that part of the generated steam is diverted back so as to help force water to enter into the series of coils. With this design, it is hypothesized that the prototype can operate even without the use of pump thus lowering the parasitic load of the ISG. The prototype however still needs to undergo series of tests to fully evaluate its performance. Performance data were not gathered yet since leaks were observed during the conduct of the preliminary test runs which were currently being addressed.

Figure 1. The working prototype of the ISG.

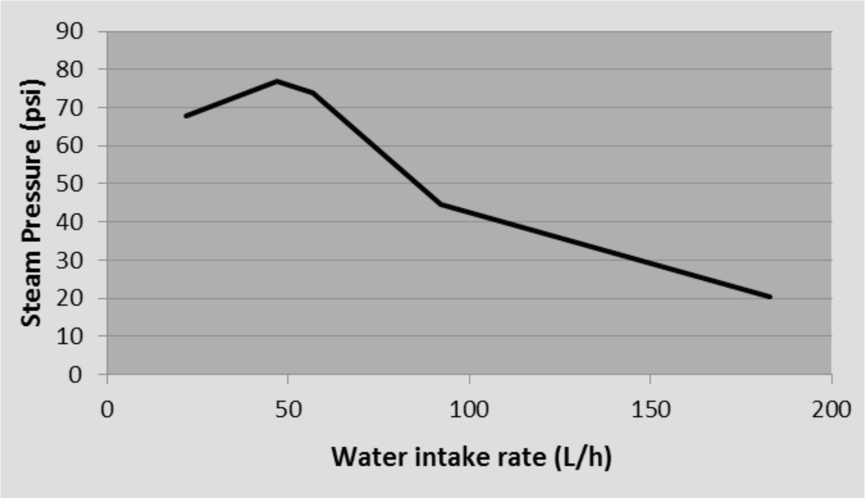

Figure 2. Performance of the ISG prototype as affected by water intake rate.

Figure 3. The ISG prototype coupled to a steam engine.

Figure 4. The new prototype.

Pilot Testing of PhilRice crude and hydrous bioethanol distiller using nipa as feedstock
ML Rafael, KC Villota, PR Castillo, AT Belonio, and MJC Regalado

PhilRice designed and developed distillers to produce crude and hydrous bioethanol from fermented nipa sap. The main goal of the study is to produce alternative fuel from nipa sap which can be used to power small gasoline engines of rice farmers and fisher folks. Two proto-types of 200 liter-capacity distillers to produce crude and hydrous bioethanol were fabricated and tested. Both distillers comprises of an internally heated boiler/ steamer, rice husk fuelled heating unit, trickling- type water condenser, and feedstock feeding bin. The crude bioethanol distiller uses a conical grate rice husk furnace as heat source while the hydrous bioethanol distiller uses a rice husk gasifier and a water heated column to purify alcohol to a higher level.

Two distillers were tested at Binonoan, Infanta, Quezon. The crude bioethanol distiller was conducted on the last quarter of 2014 while hydrous bioethanol distiller was on 2015. The hydrous bioethanol distiller was installed at the cooperating user farm and operated for one season to evaluate the performance and quality of the ethanol produce.

Highlights:

- The crude bioethanol distiller can process 160 to 180 liters of fermented nipa sap and able to produce 34 to 45 liters with 30 to 39% alcohol concentration within 2 to 3 hours with distillation rate of 19 to 28 li/hr with rice husk consumption rate of 18 to 20kg/hr.

- The hydrous bioethanol distiller with 200li capacity is capable of producing 10 to 15.6 liters of fuel grade alcohol with alcohol concentration of 92.5 to 95% within 6.2 to 6.8 hours with distillation rate of 2.3 to 4 liters per hour using nipa sap as feedstock with initial alcohol content of 6.5 to 7.6%.

- The capacity of the distiller increased using pre-processed feedstock with higher concentration as based on the result of testing using 145 liters of crude bioethanol diluted to obtain 15% alcohol content. With this feedstock, the distiller capacity increased to 18.3 to 20.2 liters fuel-grade bioethanol with 92% within 5.3 hours with distillation rate of 4.9 to 5.0 liters per hour. The unit has rice husk consumption rate of 17 to 27.8kg/hr (Table 1).

- Maintain 50 to 600C temperature of water being recirculated at the upper portion of the column to obtain hydrous bioethanol with 90 to 95% alcohol which was the proven effective concentration as fuel for spark-ignition engine.

- The accumulation of char at the burner and flying CRH from the chimney are some of the major problems encountered. These were addressed by increasing the hole-diameter of the burner and providing a 1m extension for chimney.

- Tests were completed and have proven that a simple distillation facility can be functional to a regionalized and farm–based production system and can be operated by one operator for each unit of distiller.

- The product hydrous bioethanol have been initially tested and proven effective as fuel for operations like water pumping, grass cutting and hauling (pump boat).

- The PhilRice HBED-250 has an investment cost of Php180,000.0 per unit. With PhilRice Hydrous Bioethanol Distiller, the farmers can produce their own fuel for their farm equipments with a production cost of PhP32/li. With the prevailing market price of Php65.0/li of Bioethanol, the investment cost of the unit will return after 1.5 years.

- The LGU-Camarines Norte signified their interest on acquiring ten (10) units of crude bioethanol distiller and one (1) unit of Hydrous Bioethanol distiller as based on the request letter forwarded to Philrice by the Province Gorvenor

- The cooperating user suggested to use quality materials and equipment to ensure durability of the unit and quality products (crude and hydrous bioethanol).

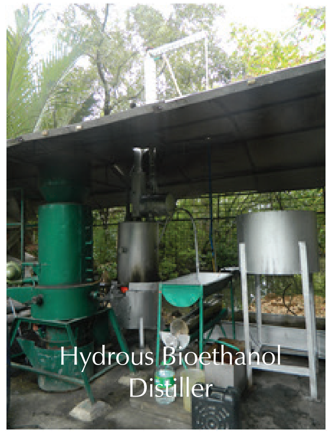

Figure 5. Two proto-types of 200 liter-capacity distillers.

Table 1. Performance test of hydrous bioethanol distiller (HBED-200L).

Parameters	HBED-200	HBED-145
Feedstock	fermented nipa sap	Crude + water Solution
Volume of Feedstock(li)	200	145
Initial Alcohol Content (%)	6.5 -7.6	15
Alcohol Content of the Distillate(%)	92.5 to 95	92
Distillation rate (li/hr)	2.3 -4.0	4.9-5.0
Start of distillate Collection time (hr)	2.3-2.68	1.2-1.7
Total period of collection(hr)	3.85-4.33	4.1-3.6
Total period of test (hr)	6.2- 6.8	5.3
Rice Husk Consumption rate(kg/hr)	17- 23.7	24.7-27.8

Performance Evaluation of 100-KW Rice Husk Gasifier

JA dela Cruz, AT Belonio, JA Ramos, MJC Regalado, and EC Gagelonia

REMD started its research and development on rice husk gasifier in the early 2000. And in 2013, the 100kWe rated capacity rice husk gasifier for electricity generation was designed and developed. The gasifier system comprised of a 1.20m diameter moving-bed downdraft gasifier reactor, a 30cm diameter by 3m long counter-flow impact-type wet scrubber, two (2) 60cm diameter by 50cm thick horizontal-type packed-bed filter as the primary filter device using wood fiber as filter material, a 50 x 50 x 10cm thick foam as the secondary filter device, and a 75cm diameter by 245cm long holding tank for storing the gas. A 3hp single-phase, high-pressure ring blower located between the secondary filter and the engine gas manifold is used in pulling the gas from the reactor. The engine used to drive the generator is an 8 cylinder spark-ignition engine running at around 2000rpm rated speed. The engine is cooled with circulating water from a 1.73m^3 cooling tank. The generator is a brushless 3-phase synchronous generator with 100 kW, 220 volt, 328 A 60 Hz rated power running at 1800rpm. Rice husk is fed into the reactor with the use of a 5in cup by 15cm spacing bucket elevator with 227kg per hour capacity. It is driven by a 2hp, 220 single phase electric motor capable of filling the reactor with rice husk within 30 minutes. Char is removed from the water-filled bin using a ½hp screw conveyor with 50kg of wet char per hour throughput rate. Gradual removal of char is done by manually scraping burnt rice husk with a rotating sweeper to ensure continuous operation of the gasifier. The gasifier, which was previously planned to be installed at PhilRice Negros for pumping water and for supplementary supply of electricity in the farm, was decided to remain at REMD to be able to carry out series of tests and evaluations in order to optimize its operation and performance. The usual problems on excessive wear-and-tear of engine-belt drives and on overheating of the engine were successfully addressed.

Highlights:

- The engine at present was found to operate optimally at 4th gear transmission setting with 1800rpm generator speed. The engine speed is on idle condition giving a voltage output of 220 volts at 60Hz. Previously, the engine runs at 3rd gear transmission setting and was found too excessive for the engine when it ran continuously for 2 hours.

- The temperature monitoring test using thermocouple wires and digital thermometer showed that the temperature at the reactor ranges from 600 to 710^{o}C. The temperature of the gas leaving the reactor measured at the gas outlet ranges from

349 to 429°C. After the scrubber, the temperature measured ranges from 38.5 to 44.5°C; whereas, after the filter, the temperature ranges from 31.5 to 39.9°C. The temperature of the gas entering the engine was measured at the range of 32 to 39.9°C.

- The temperature of water in the cooling tank ranges from 39.2 to 56.9°C during the tests which is safe enough to run the engine continuously without overheating.

- Gas analysis revealed that the gas produced from the gasifier contains the following in average: 9.47 to 12.23% carbon monoxide (CO), 2.64 to 3.46% methane (CH_4), and 7.64 to 9.62% hydrogen (H_2). Furthermore, the heating value of the gas produced ranges from 722 to 930kcal/m3. The other compositions of gases are shown in Table 2 below.

- Measurement of the sound level of the engine at 4th gear which was taken 1 m away averaged to 89db. The result is slightly lower compared with that of gasoline-fueled gasifier.

- Tests so far have shown that the system can operate continuously for even 12 hours and is expected to be longer with the setting where the engine is in idle condition. Rice husk consumption ranges from 48kg of rice husk per hour with 12kW power out.

- There is a need to provide additional load to the generator to determine the maximum electrical output of the system.

The 100-KW Rice Husk Gasifier

Table 2. Performance of the Gasifier at 4th Gear Transmission Drive.

Gear Setting	4th
Operating Time	4 hours
Throughput Capacity	46 kg of rice husk per hour
Load	12 pcs 1 kW bulb
Reactor Temperature (°C)	600 - 710
Gas Temperature (°C)	
After the Reactor	346 - 429
After the Scrubber	38 – 45
After the Filter	32 – 43
Before the Engine	32 – 40
Water Temperature (°C)	
Bottom Tank	34 – 48
Top Tank	36 – 48
Engine Water Cooling Tank (°C)	39 – 57
Engine Sound Level at 1 m	87 db

Table 3. Compositions of Gases from the Rice Husk Gasifier with Engine Operating in 4th Gear Transmission Drive.

Sampling	CO (%)	CH_4 (%)	H_2 (%)	CO_2 (%)	CnHm (%)	O_2 (%)	Heating Value (kcal/m^3)
1	12.23	3.46	9.62	13.58	0.15	3.91	930
2	10.47	3.09	8.98	12.47	0.16	5.67	834
3	9.47	2.64	7.64	10.43	0.13	7.66	722
4	9.74	2.86	7.83	10.29	0.16	7.92	761

Pilot Testing of Retrofitted Engine for Mechanized Rice Farming Operation

KCVillota, ATBelonio, MLRafael, PRCastillo, EC Gagelonia and MJCRegalado

PhilRice developed a fuel feeding device that allows spark-ignition engine which one of the power sources of rice farming equipment to be operated solely using hydrous bioethanol instead of gasoline fuel. However, long-term effects of this fuel to the engine and machine performance are lacking. Therefore, further evaluation is needed, hence, this study. Farming implements such as water pump (1), grass cutter (2), and pump boat (3) were installed with retrofitted engine and subject for long-season operation and testing. Presently, pump boat is being used by the identified cooperating user at Infanta, Quezon for hauling nipa sap. Water pump and grass cutter, on the other hand, are being tested at Future Rice. The water pump is supplying the water requirement of 500m2 rice area.

Highlights:

- The 3.5hp retrofitted engine coupled to 2-inch diameter water pump was observed running stable at 2800 to 3000rpm. At this speed, the engine consumed hydrous bioethanol at a mean rate of 1.6L/hr and the pump discharged water at an average rate of 13m3/hr.

- Weld beads that might have corroded from the bioethanol tank was observed on the fuel line of the engine (b).

- Initial testing of grass cutter powered by ~1.1hp retrofitted engine showed that the unit consumed hydrous bioethanol at a mean rate of 0.6L/hr.

- The 6.5hp retrofitted engine as power source of pump boat with propeller shaft running at 1600rpm and with ~250kg load consumed hydrous bioethanol at 0.9L/hr rate.

- The noise level of retrofitted engines as power source of different machines ranged from 76 to 101dB. As cited by Durgut and Celen (2004), 2 to 8 hours exposure on these levels especially 90 to 100dB is harmful to operator.

Development of a moving-bed downdraft rice husk gasifier for shallow-tube well pumping of water
PR Castillo, AT Belonio, JA Ramos, EC Gagelonia and MJC Regalado

One of the major problems in rice production and postharvest operations is the cost of energy to provide power for various agricultural mechanization tasks. During the cropping season, usually farmers needed irrigation water the most for their field for 2 to 3 days period. Failure to provide the water required during crop maintenance often results in reduced rice yield which is translated to low income for farmers. As reported in the Asia Rice Forum Seminar (Belonio, et.al.2013), it requires around 0.8 to 1.0 liter per hour of diesel just to pump water to irrigate a hectare of rice fields. This is more so during dry cropping season when the period of irrigating the field is longer and the amount of water needed by the rice plants is more.

It is envisioned that with the use of the rice husk gasifier technology for pumping water, rice farmers will be able to cope with the problem on the high cost of fuel for their farm machine. Farmers can make use of the rice husks from their harvested paddy as fuel for pumping rather than just burning them in the field or throwing them along roadsides. As the technology developer for rice machineries, PhilRice can introduce to farmers that alternative to conventional fuel is now available. Testing the technology and making it available to farmers on-site can hasten its adoptability, hence reducing farmers' dependency on imported fossil fuel and consequently minimizing the country's dollar outflow associated with fossil fuel importation.

Highlights:

- A moving-bed downdraft rice husk gasifier for shallow-tube well pumping of water was designed and fabricated with the following components: a conical reactor having a diameter of 40cm, gas conditioning component adopted from the existing 10kWe gasifier, 16hp B&S gasoline engine where clean gas fed, 2kW electric generator and 4" self-priming water pump.

- Based on inital testing conducted, the gasifier unit performs with a fuel consumption rate of 12.5kg of rice husk per hour with a moisture content of 11%, a gas flow rate of 2.445x10-4 m/s and a pumping rate of 48m3/hr.

- Carbon monoxide (CO) was measured with an average of 17ppm.

- The quality of gas entering the engine was monitored using syngas analyzer. The following data were gathered:

Sampling	Gas Reading, %						Heating Value, Kcal/m^3
	CO	CH_4	H_2	CO_2	C_nH_m	O_2	
1	15.87	03.81	5.41	14.26	0.25	0.72	985
2	17.56	4.53	5.80	14.11	0.31	1.46	1111
3	13.8	3.46	3.72	11.02	0.27	5.47	846

II. Adaptation of Low External Energy Input in Rice-Based Farming

Project Leader: JA Ramos

Conventional farming system is energy-intensive and consumes higher energy input than organic farming system which is basically coming from fossil fuel-based inputs. However, most farmers are practicing this system because of relatively higher yields even the additional cost is higher to obtain that yield. Adaptation of low external energy input technologies in rice based farming operations can help reduce the utilization of fossil fuel-based inputs since it make use of the available resources found within the farming system. This will promote a sustainable source of inputs and environment-friendly farming operations.

This project aims to promote technologies and techniques that focus on lowering the input of energy from the fossil fuel that is use in the farm operations. The ultimate goal is to contribute to reducing dependence from fossil energy use in the rice based farming. In the process, technologies are generated and rice based farming is improved.

With six studies implemented, the project attempts to test gasifier technologies for water pumping and grain drying, develop wind-solar hybrid system for irrigation, produce stable species of azolla, identify the best non fossil fuel-based source from green manures, and optimize production of vermicast from farm wastes. These activities have been undertaken in the hope to reduce input of energy in a particular operation this technology is adopted.

Harnessing Wind and Solar Energy for Crop Irrigation in Ilocos Region
MG Galera, ND Ganotisi, MLO Quigao, MU Baradi, MJC Regalado, and AT Belonio

The study aimed to harness wind and solar energy to pump water for irrigating rice and rice-based crops. Solar radiation and wind speed were gathered from the Weather Station (PhilRice Batac FMON1) installed at the back of the PhilRice Batac to determine the available wind and solar energy in the area. The harnessed wind-solar energy was used to drive an electric pump to draw water for irrigation.

Highlights:

- A hybrid wind-solar pump system was installed and evaluated on its capacity to harness the available wind and solar energy, and water pumping capacity.

- The pump has a capacity of 30 to 35 Ampere (A) to discharge the battery. The battery capacity of the system has 600 Ampere-hour (AH) and allowed battery discharge should only up to 50% of its full capacity. In full charge condition, the battery could drive the pump in approximately 8 to 10 hrs. On the other hand, the solar panel (300 W) has an average of 5.5 A charging capacity (Table 4). For a day of charging from 7AM to 5 PM, a total of 55A would charge the battery which could run the pump in approximately 1.5 hrs.

- Wind occurs drastically and often unpredictable. A 0.02 Vhr-1 of charging from the wind with a 2.5 hrs average of wind per day gave a total of 0.05 V (Table 4). This could give an additional 20 mins of pumping. Combining the wind and solar charging system will yield to a total of 1 hr and 50 mins (1.83 hrs) of pumping per day.

- Average water table during the dry season (DS) had reached 6.2m below ground surface while 1.0m during the wet season (WS). Using a 0.5hp submersible pump, an average discharge of 0.72lps during DS while 1.57lps during the WS was recorded. This could be attributed to the water table difference between DS and WS as shown in Table 5.

- Running the pump in 1.83 hrs will draw an approximately 4.7 m3 and 10.3m^3 for DS and WS, respectively. This can irrigate roughly 700m^2 of vegetables like tomato and eggplant for DS or 1000m2 of rice during WS. For a 4-month crop duration, the wind-solar pump system could save about 100L of diesel fuel or around PhP2,500.00.

- The turbine tower was reinstalled and made taller 1.5m GI pipe to have a total height of 7.5m (Figure 6). A 10-unit street light powered by the wind-solar to light some portions of the experimental farm of the station was also installed (Figure 7).

- The turbine blade was damaged due to typhoon "Egay" last July 2015 but was replaced with a new one (Figure 8).

- For 2016, a direct current (DC) pump will be purchased to get rid of using an inverter to drive the pump and also has lower ampere rating. This could also be used for pumping during sunshine hours without the aid of a battery. During 2015, the AC pump was used to address the shallow tube well (STW) pumping while the DC pump may be used for open wells.

Table 4. Parameters of the wind-solar pump system.

PARAMETERS	
Battery capacity, AH	600.00
Ampere usage of the pump, A	30.00
Start-up wind speed, mps	2.50
Average charging of the solar panel (300W) during day time, A	5.50
Average additional voltage from wind, V	0.05

Table 5. Performance of the wind-solar pump.

PARAMETERS	DS 2015	WS 2015
Average pump discharge, lps	0.72	1.57
Average water table, m	6.20	1.00
Average well recharge, lps	0.17	1.43
Ampere usage of the pump, A	30.00	30.00
Voltage drop using the pump, V/hr	0.13	0.13

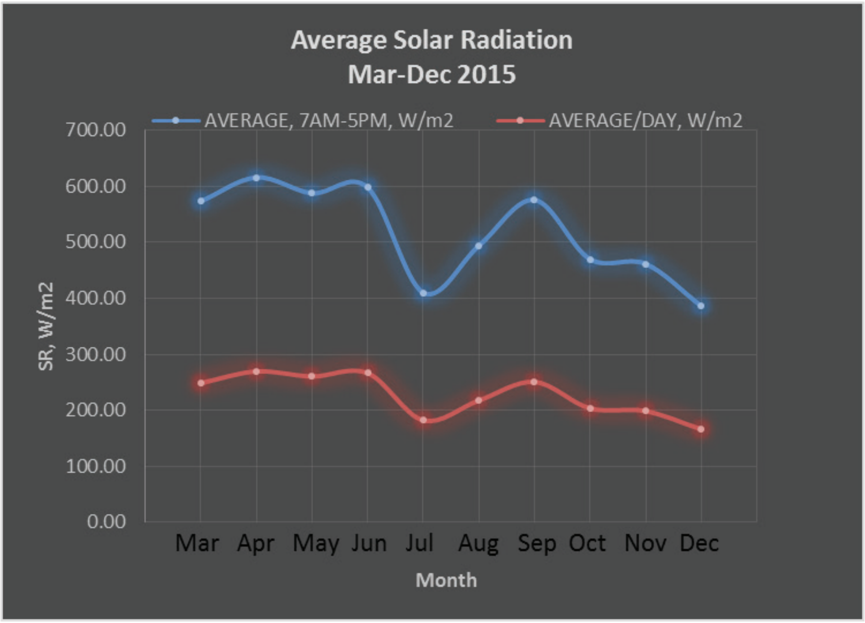

Figure 6. Mean Solar Radiation from March to December, 2015.

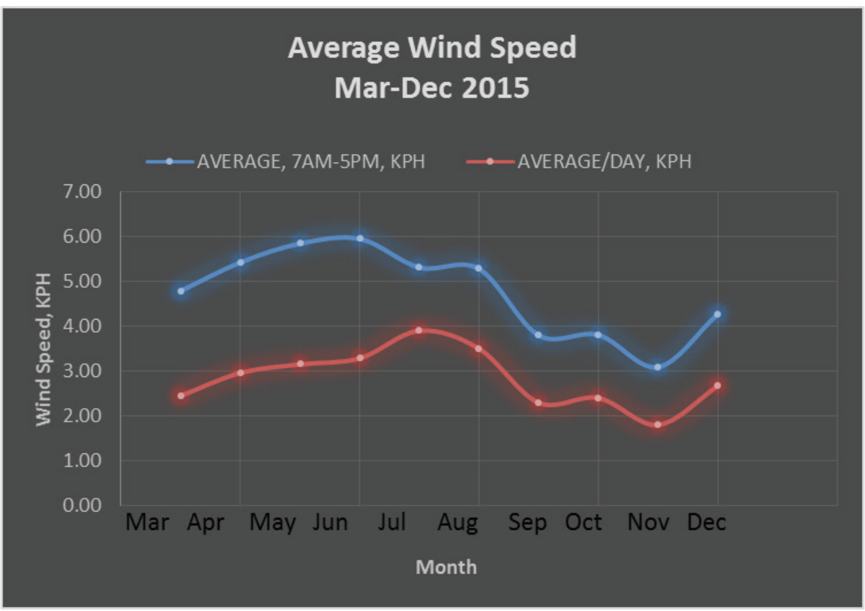

Figure 7. Average wind speed from March to December, 2015.

Figure 8. Installation of the 7.5 m high wind turbine tower.

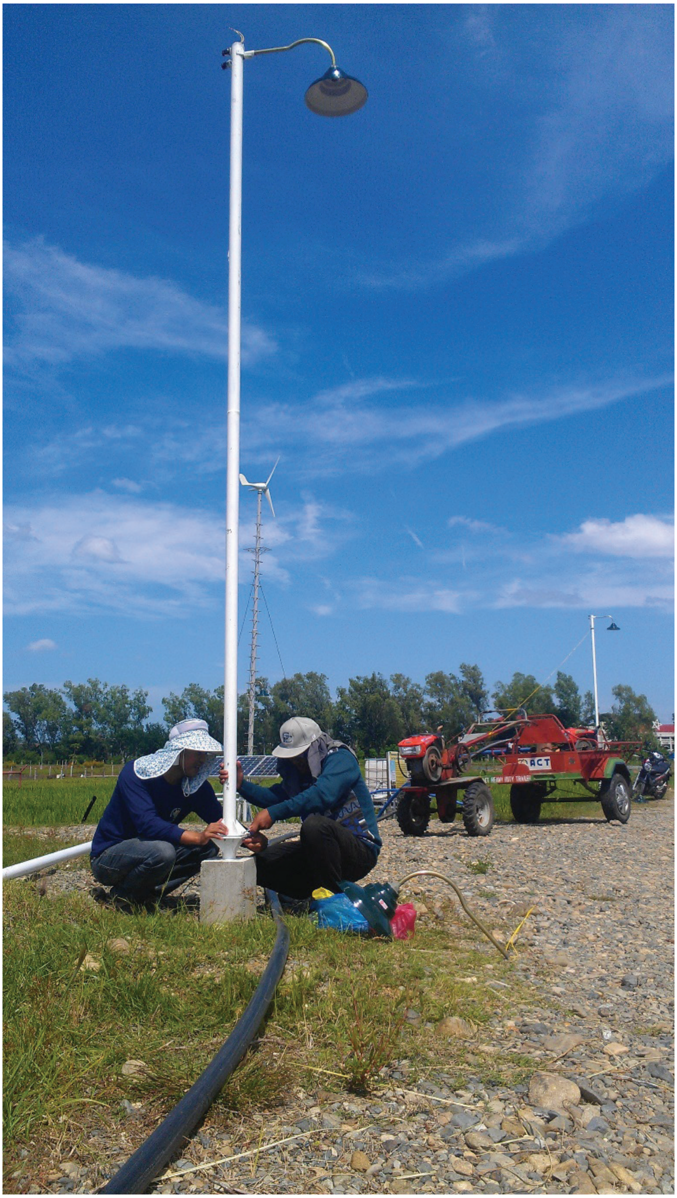

Figure 9. Installation of the 10-street lights for the experimental farm.

Figure 10. The turbine blade after typhoon “Egay”, July 2015.

Figure 11. The set-up of the study, December 2015.

Optimizing Water Utilization from a Developed Ricehull Gasifier Engine-Pump System for Rainfed Lowland Farm

AS Juliano, RB Gavino, and MJC Regalado

Water is certainly one of the major resources in farming. Crops cannot thrive without water. Unfortunately, water is increasingly becoming more expensive especially with the effects of the El Niño phenomenon in the rainfed areas. Pumping water from underground or from open sources such as lakes, rivers, and streams could be very costly, especially with the increasing cost of fuel. One possible solution for lowering the high cost of pumping water is the efficient and reliable gasifier engine-pump system where ricehull biomass is used as fuel (instead of gasoline fuel) to pump water from a source.

The study focused on the optimization of water utilization from a developed ricehull gasifier engine pump system for rice, onion, and squash crops in a rainfed lowland farm at Baloc, Sto. Domingo, Nueva Ecija where shallow tube well (STW) was the source of irrigation. Using the developed ricehull gasifier engine-pump system running continuously for 2 hours operation, it consumed an average ricehull of 17 kilograms with an average water discharge of 9.37 lps from a 4" diameter water pump. The system was powered by a 16 hp gasoline engine.

Highlights:

- Characterization of ricehull biomass was done in Nueva Ecija. In 2008, the total rice production in Nueva Ecija produced 77, 507 tons of ricehull biomass using the 515 units of single pass ricemill (accessible to the farmers). For the whole country, the total population of single pass ricemill is 24,980 units with the capacity of producing 3,759,490 tons of ricehull biomass in one year. Ricehull biomass stored for a month or more when used in the gasifier system as fuel resulted to stoppage of operation. Fresh ricehull biomass from the ricemill provided continuous water pumping operation of the system (Figure 12).

Figure 12. Ricehull Gasifier Engine-Pump system operation at PhilRice Baloc farm, DS 2015.

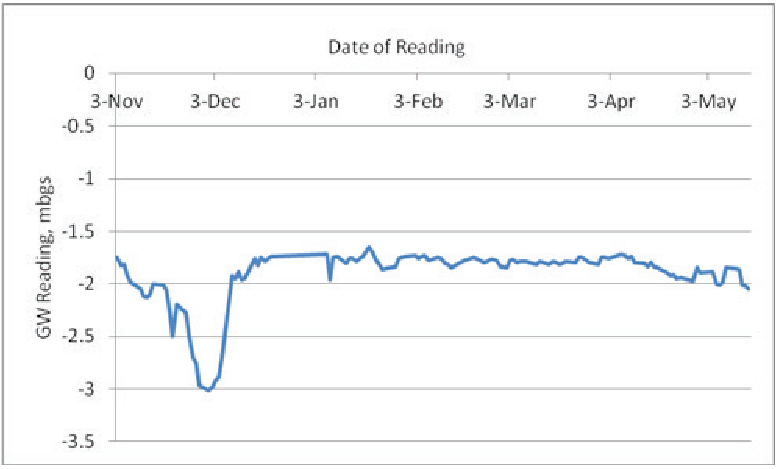

Figure 13. Groundwater table reading at Baloc, Sto. Domingo, Nueva Ecija, DS 2015.

- Validated the optimization scheme developed (3 crops; rice, squash, and onion) for obtaining maximum benefits in using the developed ricehull gasifier engine-pump system. Actual field experiment of rice, squash and onion crops production were established at Baloc (Figure 14) with an area of 0.31, 0.31ha, and 0.25ha, respectively (following the existing plots layout). Rice crop yielded 2,009 kilograms (25% mc) using 5,206 m^3 of pumped water in 0.31ha area. Harvested Onion crop was 2,703 kilograms from 0.25ha with 1,723m^3 irrigation water applied for the whole cropping season. Squash crop fruited 2,270 kilograms from an area of 0.31ha with a total water application of 1,156m^3.

Figure 14. Three crops were considered in the optimization study; rice (a & d), bulb onion (b & e), and squash (c & f). DS 2015

- The total actual net benefits was P45,175 (broken down as rice – P13,095; onion – P25,716; squash – P6,364) using the prevailing price of each crop (P16/kg, P19/kg, and P8/kg of rice, onion, and squash crops, respectively)as shown in Table 6. Higher total net benefit was observed in the actual experiment than the potential net benefit, mainly because of the higher yield of onion and rice crop also higher prevailing in the market. Low actual squash yield was observed that gave lower benefits compared to the potential consideration. This was probably affected greatly by farmer expertise (no experience in squash farming) and the timing of planting. Total water requirement of the three crops was 8,085 m3 for the whole dry season which was lower than the total potential water requirements (9,146 m3).

Table 6. Comparison of actual and potential yield, water requirement, and benefits of crops planted. DS 2015.

Crop	Actual Area,ha	Actual Yield,kg	Water Reqt, m^3	Actual Net Benefits, P	Actual Yield,t/ha	Potential Yield,t/ha	Potential WR, m^3	Potential NB, P
Rice	0.31	2,009	5,206	13,095	6.49	5	5,409	8,270
Onion	0.25	2,703	1,723	25,716	10.65	12	1,565	9,675
Squash	0.31	2,270	1,156	6,364	7.4	20	2,174	19,915
Total	***0.87***		***8,085***	***45,175***			***9,146***	***37,860***

- Considering the actual yields of the three crops in one hectare area and the standardized market prices, the best cropping combination was taken as 0.8ha for onion, 0.1ha for squash, and 0.1ha for rice crops (considering limiting area of each crop is 0.1 ha for diversification) with total net benefits of PhP86,253ha^{-1}season^{-1} and required irrigation water of 66m^{3}d^{-1} (Figure 15). Given the 0.87ha (actual experimental area) used in the validation experiment, the net benefit attained was PhP44,863season^{-1} using only 71m^{3}d^{-1} of water drawn from the improved gasifier engine-pump system.

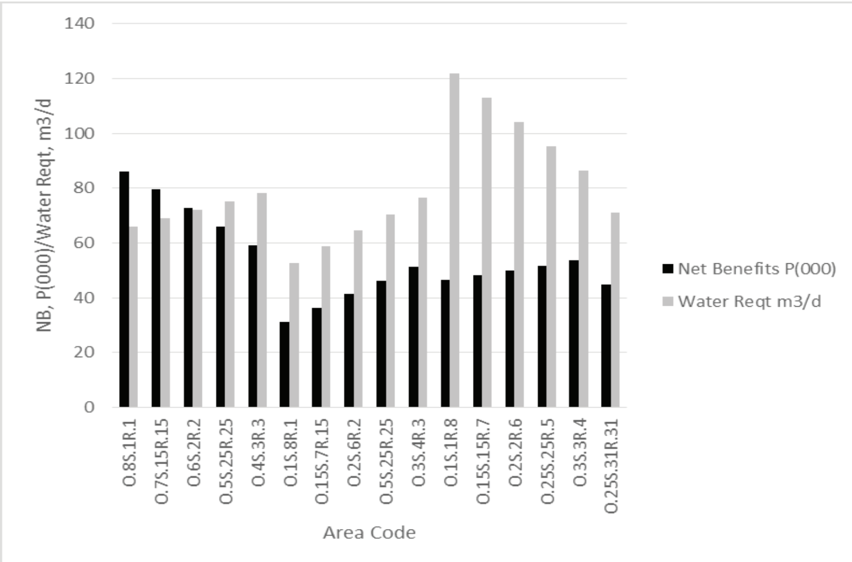

Figure 15. Projected optimization chart of three crops for the 1 ha rainfed lowland area.

- Considering the gasifier cost (PhP54,331.00) and other cost determinants, the increasing income of PhP67,258.44yr^{-1} (fuel difference and carbonized ricehull or CRH cost) and decreasing income of PhP46,553.39yr^{-1} (operational cost of the gasifier, oil difference, labor difference, ricehull cost, and maintenance cost) were derived per year with savings of PhP20,705.00 in using the system compared with using water pump powered by 16hp gasoline engine (Table 2). Investment in procuring the gasifier system can be returned in 2.62 years (4.6 years when not considering the CRH benefit) of pumping operation in the field for irrigation application. The ricehull gasifier system had a pumping water cost of PhP1.23m^{-3}. For the maximum area of 2.9ha that can be irrigated by the improved system and the total cost of the system (PhP86,331.00), the irrigation development cost is about PhP30,000.00ha^{-1}.

Table 7. Partial budget analysis.

PARAMETER	GASOLINE ENGINE + PUMP	RHGEP SYSTEM
A. Increasing Income, Pyr^{-1}		67,258.44
Fuel Difference (gasoline), Pyr^{-1}		58,358.12
Total Fuel cost/yr,Pyr^{-1}	65,019.65	6,661.52
Total CRH cost, Pyr^{-1}		8,900.31
B. Decreasing Income, Pyr^{-1}		46,553.39
Operational Cost of gasifier, Pyr^{-1}		24,735.87
Oil (difference), Pyr^{-1}		3,224.31
Total cost (Pyr^{-1})	365.74	3,590.04
Labor (difference), Pyr^{-1}		2,269.75
Total labor cost (Pyr^{-1})	846.61	3,116.36
Yearly cost of ricehull fuel, Pyr^{-1}		8,476.49
Maintenance Cost, Pyr^{-1}		7,846.98
Savings/(Loss), Pyr^{-1}		
Savings without CRH cost, Pyr^{-1}		20,705.05 11,804.73
Payback Period, years		2.62
Payback Period without CRH cost, years		4.6
Pumping Water Cost, Pm^{-3}		1.23

Evaluation of Azolla-Rice System: Spore Production
CLC Mondejar and GO San Valentin

Azolla is a freshwater fern which has the ability to fix nitrogen (N) through its symbiotic relationship with Anabaena azollae. Numerous studies conducted have demonstrated its effectiveness as biofertilizer in rice production. Despite the effort of the Philippine government to promote azolla as biofertilizer in rice production in the 1980s, only very few rice fields where azolla could be found nowadays. The environmental conditions and growth characteristics such as growth rates, sporulation index and germination rate contributing to the continuous existence of azolla in specific location is the subject of the present study at PhilRice particularly on the reasons for the persistent of azolla in some surveyed sites in CALABARZON and Bicol region. Field observations indicate the persistence of certain species of azolla in some areas alternately flooded and drained during the year-round cropping cycle. The persistence of azolla appears to be associated with production of spores and favourable environmental condition to induce the sporulation of azolla.

Azolla is a biofertilizer which could supply nitrogen to the rice crop in amount proportional to the biomass produced and incorporated in the paddies during cropping. The ecology and biology of azolla, its symbiotic relationship with the blue-green algae, the agronomy of its utilization as biofertilizer in rice production, and as feedstuff have been studied in the Philippines by scientists in University of the Philippines Los Baños (UPLB) and collaborating institutions during the implementation of the National Azolla Action Program (NAAP). Some studies have been focused on environmental factors affecting its growth in the paddies and effects on growth and yield of rice. Several species and strains of azolla have been collected and studied and recommended for use by rice farmers in the Philippines. The use of sporocarps for seeding azolla in ponds and rice paddies will help overcome several limitations to the use of azolla as biofertilizer. The vegetative means of multiplying azolla possess a great problem to farmers when they need to inoculate due to limited supply of water during summer, outbreaks of pest and diseases and natural calamities like floods and droughts.

The general objective of the study is to make azolla and other green manuring technologies a stable component of the rice-based farming systems. Specifically, the study aims to:

1. Select suitable species or strains of azolla as biofertilizer in the Philippines.
2. Produce fresh biomass or sporocarps of the best performing varieties of azolla.
3. Evaluate the performance of selected species or strains of azolla in rice-based farming systems.
4. Develop efficient azolla sporocarp production system.

5. Identify range of rice farming environmental conditions favourable to sustainable biomass and spore production of azolla.
6. Develop an integrated management for rice-azolla system using sporocarps.

Highlights:

- Areas in CALABARZON and Bicol Region where azolla are still thriving were surveyed. Azolla were likewise collected and evaluated at PhilRice Los Baños. Among places surveyed, the sites where azolla were observed are in (1) Brgy. Taytay, Majayjay, Laguna, (2) Brgy. Tinamnan, Lucban, Quezon, (3) Brgy. 4, Tugawe-Site, Malilipot, Albay, (4) Brgy. 4, Paete, Laguna, (5) Brgy. Maahas, Los Baños, Laguna and (6) Talavera St., Pakil, Laguna. Field observations indicate the persistence of azolla in these rice areas alternately flooded and drained during the year-round cropping cycle. The persistence of azolla appears to be associated with production of spores and favourable environment condition which induce the sporulation of azolla. Sample werelikewise collected from these sites. The azolla from Lucban and Majayjay sporulated at PhilRice Azolla Nursery in Los Baños.

- PRRI-AZ-001-005 is the first hybrid azolla (UPLB-1) developed by UPLB. It is a cross between Azolla microphylla # 4018 (MI 4018) and Azolla mexicana # 2001 (ME 2001). UPLB-1 hybrid is not temperature dependent to sporulate thus it is capable of producing microspores and megaspores all year round. Figure 16 shows the sporulation of UPLB-1 in Los Baños for a period of one year.

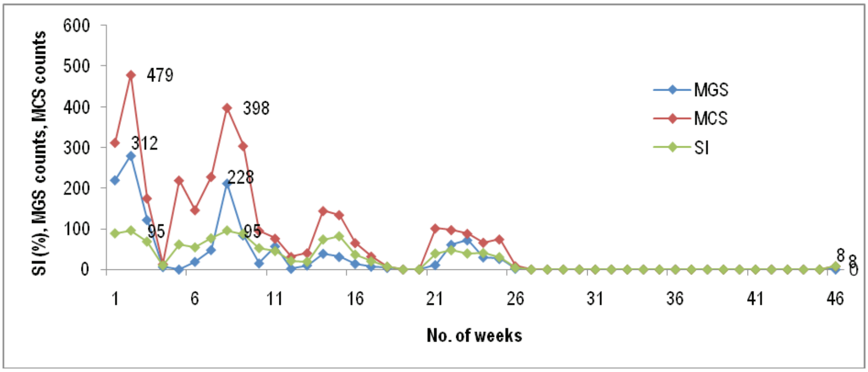

Figure 16. Sporulation of UPLB Hybrid 1 for a period of one year (September 1, 2014 to September 1 2015) in PhilRice Azolla Nursery at PhilRice Los Baños, UPLB Campus, College, Laguna.

- Accessions collected from Lucban, Quezon (PRRI-AZ-001-024), Majayjay, Laguna (PRRI-AZ-001-023), Bacacay, Albay (PRRI-AZ-001-084), Malilipot, Albay (PRRI-AZ-001-030), Los Baños, Laguna (PRRI-AZ-001-085) were evaluated every month for a period of one year. The growth rate of azolla ranged from 4 to 11 days and did not appear to be far different from growth rate exhibited by PRRI-001-005.

Table 8. Monthly doubling time (DT) of azolla accessions collected from farmers' field using pot experiments in PhilRice Los Baños Azolla Nursery.

PRRI code	DT (in days)											
	2014			2015								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
PRRI-AZ-001-005	6	7	6	6	7	7	6	6	6	6	6	7
PRRI-AZ-001-024	5	8	7	6	7	4	8	7	8	9	8	11
PRRI-AZ-001-023	5	4	5	6	6	10	9	5	8	5	9	9
PRRI-AZ-001-084	5	4	5	5	6	6	5	5	5	6	6	7
PRRI-AZ-001-030	7	4	6	7	7	6	7	5	7	7	6	8
PRRI-AZ-001-085	9	4	6	9	6	6	5	5	4	5	5	9

- Azolla strains namely PRRI-AZ-001-011 (ME 2002), PRRI-AZ-001-006 (ME 2028), PRRI-AZ-001-003 (CA 3005), PRRI-AZ-001-086 (MI 4098), PRRI-AZ-001-087 (MI 4099), PRRI-AZ-001-007 (PP 7001) and PRRI-AZ-001-008 (PP 7004) which performed well in the nursery were evaluated under irrigated rice field at Pili Drive, College, Laguna from March 11 to April 12, 2015. PRRI-AZ-001-011, PRRI-AZ-001-003, PRRI-AZ-001-007 and PRRI-AZ-001-008 are NAAP recommended strains distributed during its implementation. PRRI-AZ-001-006, PRRI-AZ-001-086 and PRRI-AZ-001-087 are azolla accessions observed to be spore producers.

Table 9. Doubling time (DT) of eight azolla accessions under irrigated rice field located at Pili Drive, College, Laguna from March 11 to April 12, 2015.

PRRI Code	DT* (in days)
PRRI-AZ-001-005	6
PRRI-AZ-001-011	6
PRRI-AZ-001-006	11
PRRI-AZ-001-003	10
PRRI-AZ-001-086	7
PRRI-AZ-001-087	8
PRRI-AZ-001-007	11
PRRI-AZ-001-008	7

- Biological Characteristics of Best Performing Azolla Strains under field condition in Los Baños, Laguna

PRRI-AZ-001-005 / UPLB-1	
Doubling Time (day):	4 to 7
Sporulation index:	100
MGS/MCS ratio:	440 / 872
Sporulation (month):	August, September, October, November, December, January, February, March, April
Peak of sporulation (month):	January
Observation during sporulation:	sturdy looking, prone to webworm, undergo senescence after sporulation

PRRI-AZ-001-011	
Doubling Time (day):	6 to 8
Sporulation index:	100
MGS/MCS ratio:	382 / 647
Sporulation (month):	February
Peak of sporulatio (month):	February
Observation during sporulation:	Fronds turn reddish before sporulation followed by new spore-bearing green fronds then plants become sturdy at the peak of sporulation.

PRRI-AZ-001-027	
Doubling Time (day):	5 to 7
Sporulation index:	92
MGS/MCS ratio:	285 / 599
Sporulation (month):	December
Peak of sporulatio (month):	December
Observation during sporulation:	Similar mechanism with PRRI-AZ-001-011

Improving the performance of flatbed drying operation through adoption of a continuous flow rice hull gasifier and an s-vane tube axial type air moving device

JA Ramos, MJC Regalado, AT Belonio, and EC Gagelonia

One of the drying facilities in the deck of farmers, seed growers, and cooperatives is the flatbed dryer wherein thousand units were dessiminated in recent years by DA through its mechanization support program. It is a more popular ones among farmers and seed growers because of its simplicity and cheaper cost. However, the inherent problem of grain exposure over flue gas and ash/char through the use of direct furnace remains an issue.

Recently, PhilRice has developed a continuous flow rice husk gasifier that was initially used as heat source in a batch recirculating dryer. The gasifier provided cleaner heated air unlike direct furnace, since the biomass material (rice husk) is being gasified to produce combustible gases before it is ignited in a burner. The ash/char is left remain in the gasifier.

That is exactly the same concept was adopted for application to flatbed drying operation but with changes on the size of gasifier and the simplicity of construction. Another area for improvement in the system is the use of more efficient fan since it is an important part of a drying system aside from the heat source that contributes to efficient drying operation.

Highlights:

- New model of a continuous flow gasfiier was built which was designed for a 6-ton flatbed dryer. The overall height of the gasifier was made proportional to the drying bed of the flatbed dryer. Currently, the prototype was completed in terms of fabricating each component parts (Figure 17). It was already installed beside the drying bed of the flatbed dryer wherein its burner section was placed at the upper inlet side of the blower. The burner assembly was made rotatable such that during ignition of the gasifier, the burner may be rotated so that the smoke emitted during ignition will not enter the drying bed.

Figure 17. Prototype of continuous flow rice hull gasifier.

- Another design of blower/fan was fabricated with an s-type vane design (Figure 18). The blower has the same size with that of the existing blower of a 6-ton faltbed dryer but with different blade configuration.

Figure 18. The s-vane tube axial type fan tested in a test duct system.

- Based on the results of blower test which was performed in a test duct, the airflow rate of the blower is increasing from about 10,000 to 18,000cfm under increasing speed of 900 to 1700 rpm. However, in terms of static pressure, the measurement was ranged from 12 to 38mm of H_2O under the same set of blower speed. The blower should be set at a minimum of 1300 rpm to produce about 25 mm of static pressure. Going beyond this speed shall increase the static pressure of the blower but operating at higher speed creates more vibration and intolerable noise of the blower apart from requiring more energy (Figure 19).

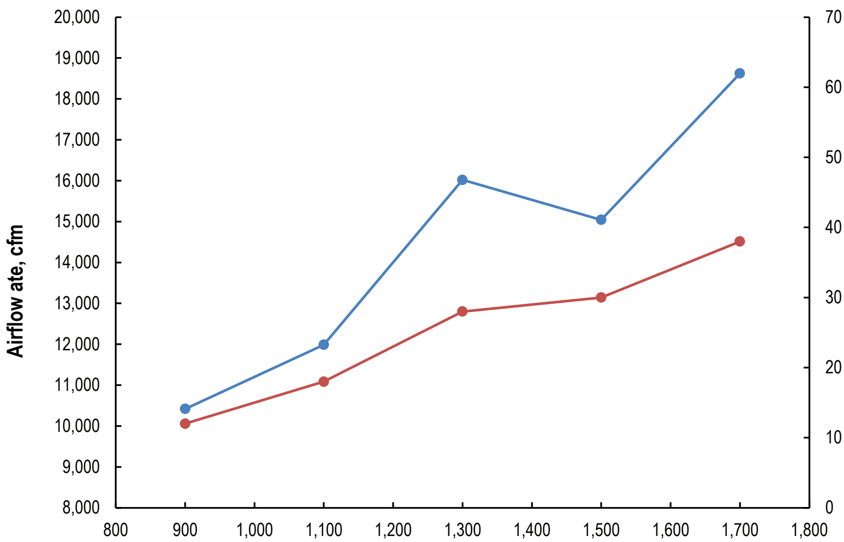

Figure 19. Airflow rate and static pressure at different speed.

- Results of blower test showed that the power input is increasing from 3.3 to 6.4kW under increasing speed of 900 to 1700rpm. The input power is increasing as higher airflow is being transmitted by the blower upon increasing its rotation. Though the blower can be operated even at higher speed, but it was not attempted since at speed beyond 1300rpm, the noise level of the blower becomes intolerable and it created excessive vibration (Figure 20).

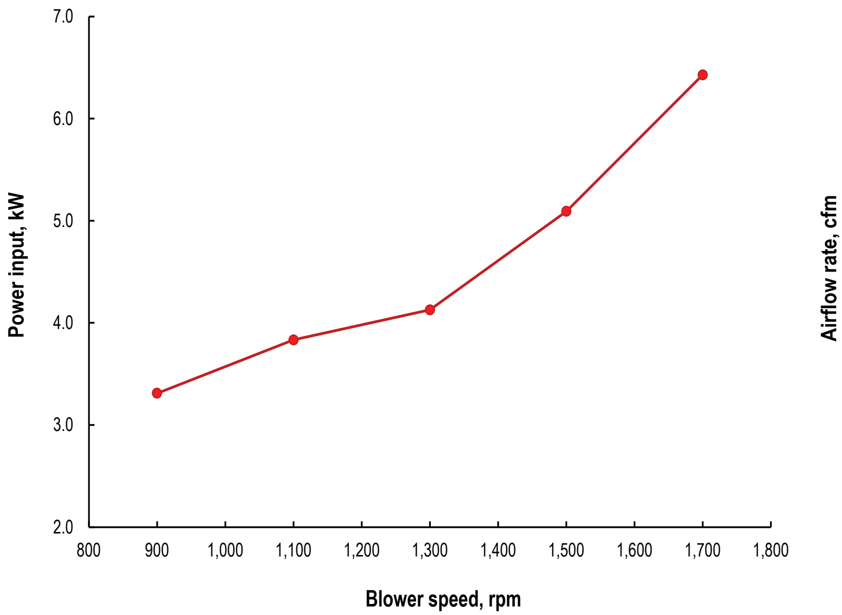

Figure 20. Input power at different speed.

III. Evaluation and utilization of alternative and potential non-fossil fuel based (nFFB) nutrition for rice farming

Project Leader: EF Javier

In the intent of packaging a pure organic based nutrient management for irrigated rice, two studies was conceptualized: (1) evaluate and determined the best farm wastes as substrate for a high quality basal nutrient supplement, and (2) to evaluate alternative fossil fuel free nitrogen sources as top dress for rice production.

Aside from the rising costs of input for the right nutrition of rice plants, the concern on soil health and productivity should also be addressed. The use of organic fertilizer is one of the best option for the maintenance and sustenance of the 3 factors for good soil health: physical, chemical and biological. However, voluminous quantity of organic fertilizer and its slow mineralization needed to boost the yield of rice should be farther studied and be optimized to balance high yield and soil productivity. Concern about the increases of GHG and nutrient imbalances is also imperative in organic-based nutrient management. Hence the recycling of farm wastes in a rice and rice-based farming system is worth looking into, both on grain productivity and sustenance of soil productivity.

Past results of organic fertilizer trial in flooded rice soils had indicated that farm wastes could be a good and direct basal applied nutrient supplement (Javier 2009), and the proper timing of organic fertilizer incorporation should be followed for best efficient nutrient use (Javier and Tabien, 2003). However, the nitrogen supply from these organic fertilizers was good only for 28 to 30 days after transplanting (Javier 2009/2014 Q&A series) . Hence this research project aims to optimize farm biomass recycling at the idea of closed nutrient supply system without importing from other farm site.

Evaluation and utilization of alternative and potential non-fossil fuel based (nFFB) nitrogen nutrition for rice farming

XXG Sto. Domingo, AJ Espiritu and EF Javier

To evaluate some green manures and other no-fossil fuel (NFF)-based nitrogen fertilizer sources of their efficiency as per required ecosystem and agro-ecological system, IRRI Germplasm by the virtue of a signed MTA (material transfer agreement) had provided us 12 varieties of Sesbania, 12 Aescynomene, and 40 Azolla sp. Screening them to the environment of Maligaya clay soils and PhilRice CES climatic condition, these green manure materials were now being reproduced and seed multiplied for experimental tests.

Highlights:
Experiment 1 (Green house condition); Screening of best basal organic supplement for Azolla

The main objective of this screen tests is to identify what kind of medium (basal organic input) can make a specific Azolla sp reproduce (sporulate) the highest number and produce highest biomass for N supply for rice plants. Likewise, the trial aims to identify the best condition that a potential alternative N sources can sustain its growth within the system without additional application of Azolla in the rice field.

- Only ten (10) Sesbania sp out of the 12 varieties had survived hence was reproduced and seed multiplied for experimental tests. However, in the WS, before the produced seeds were harvested, Typhoon Lando had devastated the area, and we can only banked on the available drop seeds, again as our mother seed for multiplication.

- Aeschynomene spp has low germination. The remaining original seeds are resown this season 2016 hoping that we may be able to improve their germination.

- On Azolla spp, the original material from IRRI was 40 varieties. They were grown under the Maligaya soil-agroclimatic condition which is generally be characterized as Maligaya clay soil series with high relative humidity and high soil water temperature. Under this condition, 30 out 40 Azolla sp had survived and were reproduced. Out of the 30 shortlisted, there were 12 Azolla sp have higher potential to survive the actual hot field condition

- In another trial where different Azolla varieties were seeded in different soils applied with different organic basal fertilizers at the common rate of 30kg N/ha: Rice straw (RS), Rice straw with EM1 (RSEM), chicken manure (CM), vermicompost (Vc), commercial organic fertilizer (COF), green manure (WSF). Azolla caroliniana (2.8%) have the highest % N content when grown in CM-applied soils, followed by Azolla pinnata (2.5%) in soils basally applied with RS, Azolla microphylla (2.0%) in Vc-applied soils. Considering their growth in each basal organic fertilizer application, Azolla caroliniana can add up to 20kg/ha biomass N in CM-applied soil, followed by Azolla pinnata (13kg/ha), and Azolla microphylla (9kg/ha) both in the Vc-applied soils.

Experiment 2. Adaptability assessment and optimization of the pre-screened bio fertilizers in the actual field conditions (2015WS-2018).

To assess and to package an organic-based nutrient management technology for rice using non-fossil fuel-based alternative basal and top dress fertilizers, responses of two different rice varieties: inbred (PSB Rc82) and hybrid (Bigante plus)) to different nFF alternative N source: Azolla microphylla, Indigofera tinctoria (tayum), Cochorus olitorius (saluyot), Vigna radiata (native mungbean), Sesbania and Aeschynomene) were observed. Control (unfertilized) and the key check no. 5 of Palay Check System will serve as check. All treatments were laid out in factorial split-plot design with four replications. Since the approval of this research project should start in the wet season 2015, only the A. microphylla was applied during the WS as inoculum for the next season. A. microphylla was applied at 10DAT, 30DAT and EPI using the 50kg/ha recommendation per application. Prior to laying out of the experimental field plots, homogenization was done to eliminate bias between treatments and to extract the residual nutrients applied from the last cropping season. It serves as a transition period from a blanket fertilizer recommendation to a non-fossil fuel based nutrient management. Other green manures were planted in a separate field for seed production as preparation for planting in the fallow period.

Initial results:

- The average yield obtained in PSB Rc82 was 5.0 tons ha -1 while 5.5 tons ha -1 was observed in Bigante Plus regardless of the green manure tested.

Optimization of efficient production and quality of vermicompost using different substrates

VIG Mapa and EF Javier

On farm, many wastes are generated by crop production. In rice particularly, rice straw is one of the major wastes that need proper disposal. Though recycling rice straw or incorporating it into the field again is the best, farmers still don't find it practical to do so. Still, many farmers burn their rice straw. Some make a pile and leave it to decompose. With vermicomposting, the rice straw can be composted faster, transforming it into useful and microorganism- and humus-rich fertilizer. However, nutrient content and overall quality of vermicompost varies with different materials and substrates, add to it the varying properties and procedures in treating these substrates. In order to standardize or at least establish a guide on the nutrient contents of vermicompost from a specific material, the sources, materials and the process need to be characterized. And if vermicomposting will be done on a commercial scale, a more standardized method for such scale must be optimized.

Partially composted rice straw (PRSC) was used as the main substrate, with the other three substrates (carabao manure, Azolla, and Sesbania) as additives giving seventeen treatments and their combinations of different ratios, and including two controls. The treatments were laid out in Randomized Complete Block Design (RCBD) in 4 replications during the 2015WS. Each bed initially contained 20kg of mixed substrates according to treatment and was introduced with one kilogram of earthworm per bed. After 35 days, the earthworms were separated from the already composted substrate, termed as vermicompost, and weighed. The vermicompost was left to dry for a few days, and was sieved to separate the compost (undigested material) from the vermicast (digested material). Both materials were weighed. The vermicast or the sieved materials were taken as samples and air dried for further analysis.

Highlights:

- The highest harvested vermicast was observed in the combination of PRSC+CM+Sesbania at the ratio of 50:25:25 (8.93kg), similarly high are those from PRSC + Sesbania (8.73kg), and PRSC+CM (8.17kg) both at the ratio of 70:30.

- Generally however, all the substrate mixes in the study gave higher vermicast yield than the check (MRF best substrate) that yielded only 3.47kg.

- However, in terms of its partial chemical properties, mixes have neutral to slight acidic which still an ideal pH for rice plants. The control (MRF best) gave an alkaline mixture (pH 8.06).

- The PRSC+Sesbania in all ratio gave the highest Nitrogen content (2.35 to 2.98%N),

- There was no statistically difference in the potassium (K) content of the vermicast from all the treatments. Numerically, PRSC + CM at 30:70 ratio has the highest K content with 1.15% K. The higher quantity of CM might have contributed to the high K value, but this has to be verified.

Table 10. Harvested vermicast and its chemical properties during the 2015WS set-up.

Treatment Code	Description		Harvested vermicast (kg)	pH	% N	%K
	Materials	Ratio				
T1	Partially decomposed rice		9.00 a	6.64 fg	1.80	0.54
T2	PRSC + Carabao Manure	70:30:00	8.73 ab	7.26 cde	1.88	0.97
T3	PRSC + Carabao Manure	50:50:00	5.27 cde	7.53 bc	1.59 efg	0.99
T4	PRSC + Carabao Manure	30:70	5.30 cde	7.79 ab	1.38 g	1.15 a
T5	PRSC + Sesbania	70:30:00	8.17 abc	6.35 gh	2.35 bc	0.68
T6	PRSC+ Sesbania	50:50:00	6.47	6.18 h	2.89 ab	0.73
T7	PRSC + Sesbania	30:70	5.70 bcde	6.21 h	2.98 a	0.75
T8	PRSC + *Azolla*	70:30:00	7.40 abcd	6.50 gh	1.75 defg	0.63
T9	PRSC + *A. microphylla*	50:50:00	6.53	6.40 gh	1.78	0.5 b
T10	PRSC + *A. microphylla*	30:70	5.27 cde	6.35 gh	2.14 cde	0.6 ab
T11	PRSC + Carabao	40:30:30	7.90 abcd	7.17 cde	2.21 cd	0.89
T12	PRSC + Carabao Manure	50:30:20	8.13 abc	7.07 de	2.02 cdef	0.79
T13	PRSC + Carabao Manure	50:25:25	8.93 a	6.94 ef	2.08 cde	0.52 b
T14	PRSC + Carabao Manure	40:30:30	4.80 de	7.15 cde	1.76 defg	0.62
T15	PRSC + Carabao Manure	50:30:20	6.00	7.36 cd	1.80	0.87
T16	PRSC + Carabao Manure	50:25:25	6.70 abcd	7.29 cde	1.62 efg	0.97
T17	MRF best substrate		3.47 e	8.06 a	1.48 fg	1.08
	CV		0.827	3.47 e	9.500	25.34
	SE Treatment		14.970	0.107	0.152	0.163
	F Value		7.570	55.030	16.380	2.970
	Pr(> F)		0.000	0.000	0.000	0.003

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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