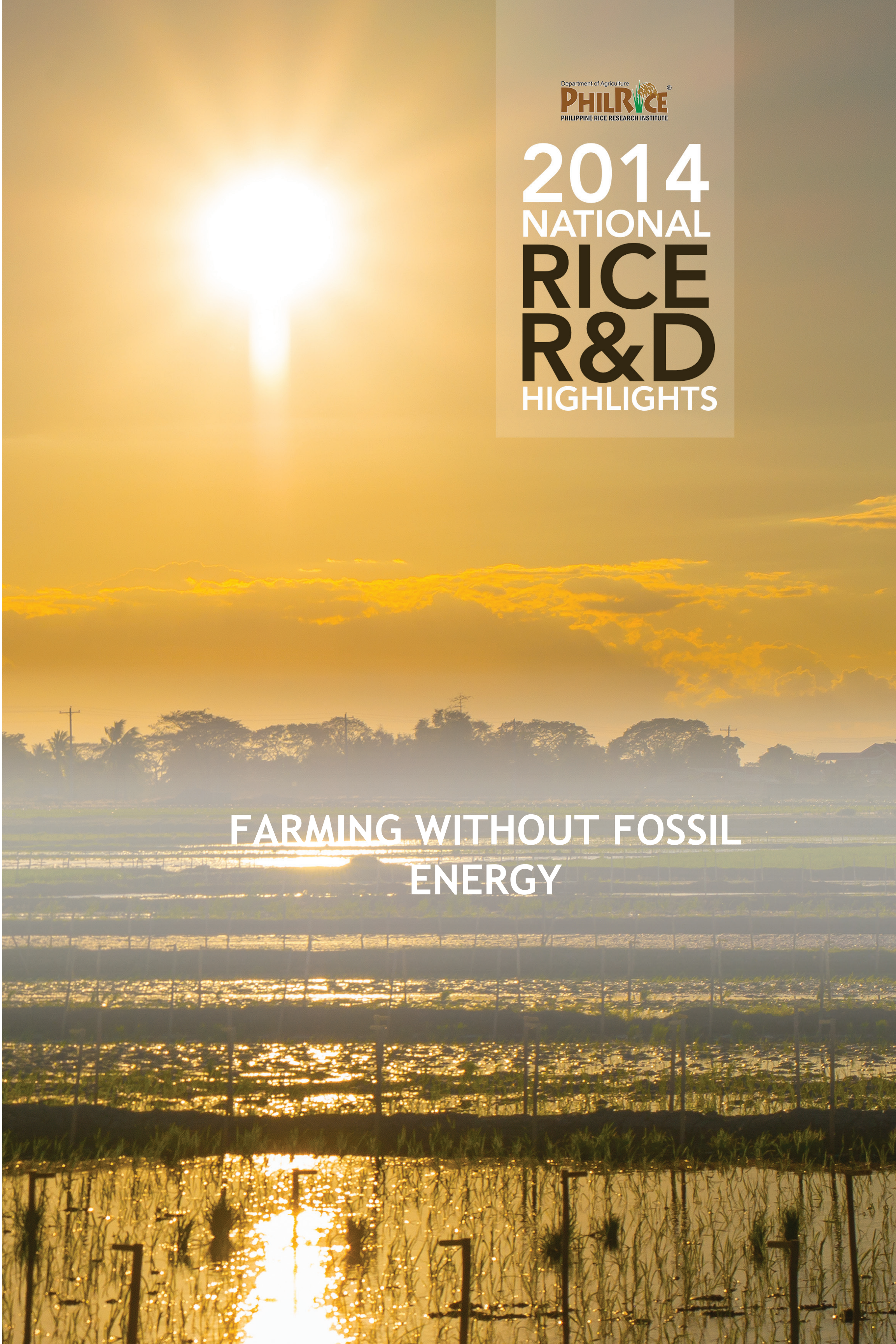

Department of Agriculture
PHILRICE
PHILIPPINE RICE RESEARCH INSTITUTE

2014 NATIONAL RICE R&D HIGHLIGHTS

FARMING WITHOUT FOSSIL ENERGY

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Farming without Fossil Energy

Program Leader - EC Gagelonia

Executive Summary

The Farming without Fossil Energy Program aims to substantially or entirely remove fossil fuels 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 various alternative and renewable energy resources such as biomass waste, wind, sun, water and plants in order to develop processes and technologies to help reduce dependence, if not totally remove, on fossil fuels in rice and rice-based farming operations. In addition, the program will study how energy resource use in rice production can be more efficient by identifying available technologies that are resource-use-efficient.

The program composed of three projects as follows:

1. Information, knowledge generation on energy profile in rice and rice-based farming system – this project is all about information of energy inputs in rice production, bioenergy sources in the rice environment and fuel properties of biomass and bioethanol that are necessary for the development of renewable and alternative technologies from rice and non-rice biomass.

2. 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.

3. 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 in the rice-based farming system.

The available biomass in the country such as rice husk and straw, coconut husk and shell, corn cob and stover, sugar cane bagasse are among the potential bioenergy resources for the development of renewable energy technologies. Maps showing spatial distribution of these bioenergy resources were generated in order to identify location for the promotion or transfer of the developed renewable technologies. Similarly, fuel properties of rice husk, straw, CRH and hydrous bioethanol were analyzed to assess its suitability as fuel.

The developed 100KWe rice husk gasifier for electric power generation was improved for efficient performance. Series of tests were done for evaluation of performance before bringing it to PhilRice – Negros.

Initial evaluation of instant steam generation concept (steam on demand) as replacement for boiler to drive reciprocating piston-type engines was done. During the initial tests, the ISG prototype in terms of pressure of the generated steam at different rates of flow of water introduced into the prototype is possible. Higher steam pressure was observed at lower pumping rates.

In the gasification of rice straw, results showed that the rice straw with different sizes can influence the heating value, gasification rate and the production of gases. In terms of heating value, there was no treatment interaction observed but the smaller size of rice straw of S3 (20 to 30mm) gave a heating value of 4.47 MJ/kg compared to the larger size of S1 (40 to 50mm) which had a 2.96 MJ/kg heating value. The difference in heating value was significantly higher in S3 (20 to 30mm) size of the rice straw. Two designs of bioethanol distilling facility for producing hydrous bioethanol from nipa sap were developed by PhilRice and the Mariano Marcos State University (MMSU). The one developed by PhilRice and the other one developed by MMSU were deployed in Infanta, Quezon and Pamplona, Cagayan, respectively for pilot testing and further evaluation. Both of the distilling facility have capacity of 200 li and can produce 95% hydrous bioethanol.

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, production and utilization of biodiesel from waste cooking oil, use of wind and solar energy sources for crop irrigation, azolla spore production as biofertilizer and the rice hull gasifier engine-pump system for optimum application in rainfed lowland farms.

I. Information, Knowledge Generation on Energy Profile in Rice and Rice-Based Farming System

Project Leader: EC Gagelonia

The primary goal of the Philippine rice industry is to become self-sufficient in rice as the staple food of the ever-increasing population of the country. For almost three decades, the Philippines has been a net importer of rice from neighboring Asian countries.

At present, we have very minimal references on energy usage and energy source in rice and rice-based farming. By having an inventory of these data, the energy input for each activity or operations can be assessed and the contribution or share to the total energy requirement can be determined. Also, the energy efficiency of the different farm machines can be assessed with the availability of these data.

The potential bioenergy sources in the rice environment need to be verified according to the location where it is produced and the volume of production. Mapping these resources is important in the promotion of the developed renewable technologies. Likewise determination of the fuel properties of these bioenergy sources is important in assessing its suitability as fuel.

Incidentally, the petroleum-based products which are necessary and required in the use and operation of machines and agricultural equipment are increasing in prices. Likewise, the alternative use of renewable energy resources are not yet fully developed and are not available in the market. Thus, it is important to look into the energy sources and efficient use of energy in agricultural farming operations and systems.

Mapping of Bioenergy Sources from the Rice Environment

KC Villota, PE Mabalot, EC Gagelonia

PhilRice with its struggle to pilot farming rice with minimal use of fossil fuel needs to understand the country's resource potential of bioenergy from rice environment. Husk and straw which have attractive potential energy are the residues from cultivation of rice. Other major biomass producing crops which concurrently or rotationally cultivated in or along rice fields are corn, sugarcane and coconut. Energy from these resources becomes available through various biomass conversion technologies. Straw and husk, when gasified in controlled environment, produces gas that is an excellent alternative fuel for electricity generation, water pumping and rice milling.

The adoptability of these technologies depends on many factors including the availability of sufficient biomass production in the area. A detailed biomass energy resource maps for the Philippines as output of the GIS mapping results was developed by the Biomass Energy Laboratory of the Philippines (PBEL) on 2000 before its closure. The method they used assumes that all the quantities of crop residues are available for bioenergy and did not consider competing uses such as residue cover for soil protection, the stover for animal grazing, among other things. Therefore, there is a need for updating the biomass energy resource maps particularly rice-based biomass which is the focus of this study. It will be a significant tool on decision-making for development and transfer of bioenergy technologies that can be used for rice farming operations.

Highlights:

- The provinces with the highest husk and straw production for bioenergy are shown in Figures 1a and 2b. The top five provinces such as Nueva Ecija, Isabela, Pangasinan, Cagayan and Iloilo account for about 30.59% of the country's rice biomass for bioenergy.

- The provinces with the highest coconut husk and shell production for bioenergy are shown in Figures 2a and 2b. The top five provinces such as Quezon, Davao Oriental and del Sur, Zamboanga del Norte and Leyte account for about 28.69% of the country's coconut by-products for bioenergy.

- The provinces with the highest corn cob and stover production for bioenergy are shown in Figures 3a and 3b. The top five provinces such as Isabela, Bukidnon, North and South Cotabato, Maguindano account for about 44.11% of the country's corn biomass for bioenergy.

- The provinces with the highest sugar cane bagasse production for bioenergy are shown in Figure 4. The top five provinces such as Negros Occidental and Oriental, Bukidnon, Batangas, and Iloilo account for about 81.91% of the country's sugarcane bagasse for bioenergy.

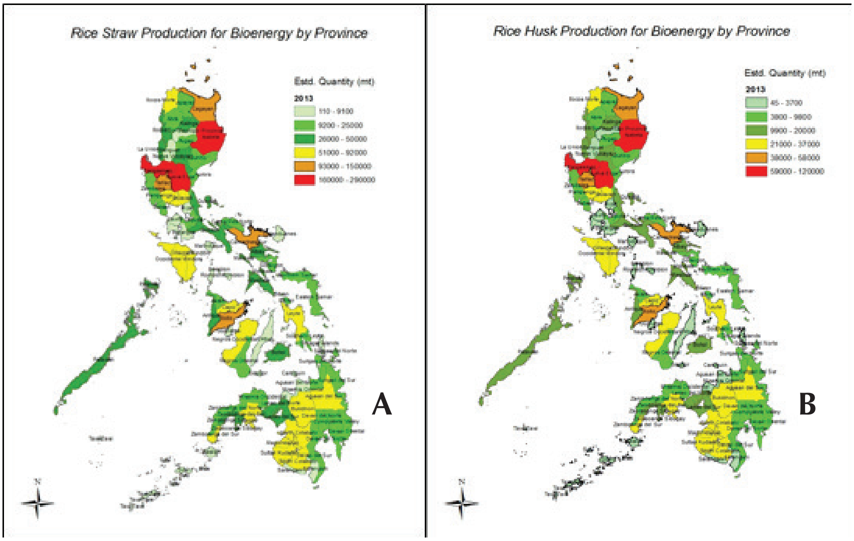


Figure 1. Spatial distribution of rice husk (a) and straw (b) production for bioenergy by province.

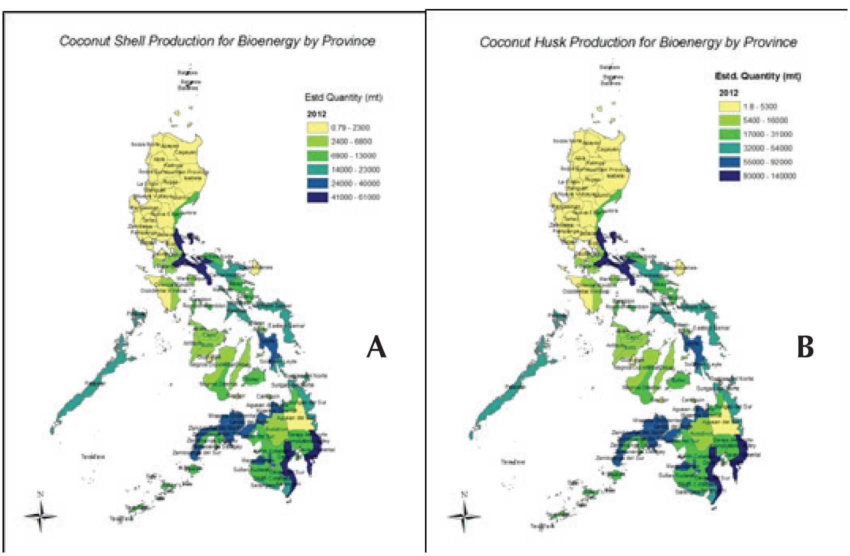


Figure 2. Spatial distribution of coconut shell (a) and husk (b) production for bioenergy by province.

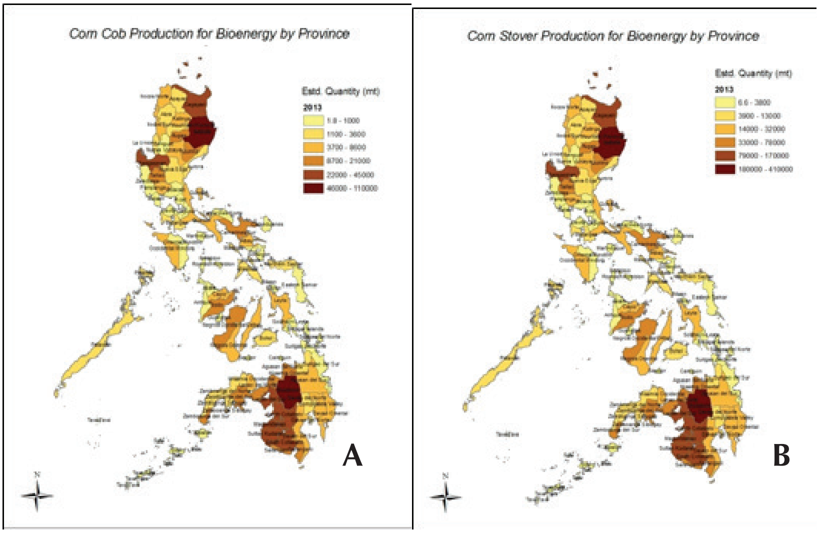


Figure 3. Spatial distribution of corn cob (a) and stover (b) production for bioenergy by province.

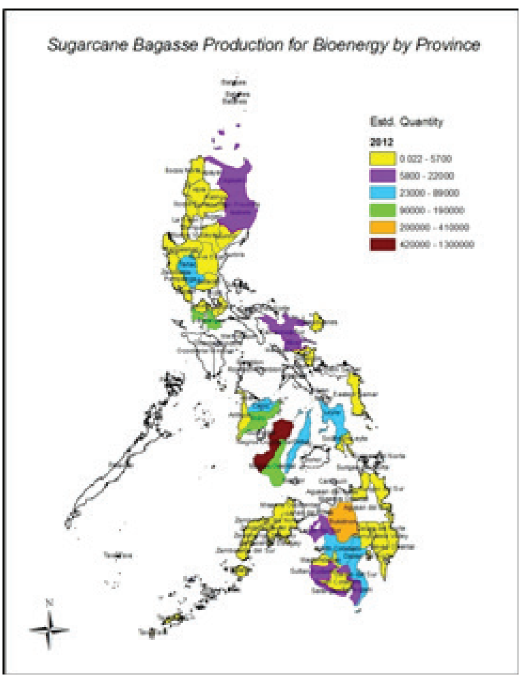


Figure 4. Spatial distribution of sugarcane production for bioenergy by province.

Determination of Fuel Properties of Rice Biomass from Inbred and Hybrid Rice Varieties and Hydrous Bioethanol from Fermented Nipa Sap
KC Villota , PRCastillo, EC Gagelonia, AT Belonio, MJC Regalado

Both producer gas and hydrous bioethanol are being explored by PhilRice as fuel for spark-ignition engines to power rice farming operations. Rice husk and rice straw which have attractive potential energy are the widely abundant agricultural waste. Rice biomass produces syngas also called producer gas when burnt in controlled environment such as gasifier. Similarly, nipa which commonly located in rice environment is a promising source of hydrous bioethanol.

Various biomass conversion technologies have been developed and locally adopted for exploitation of energy from these renewable sources. However, the manner that these technologies utilize bioenergy still needs improvement particularly the small scale applications. The design and performance of these technologies are heavily dependent on the fuel characteristics such as heating value, elemental composition, moisture content, fixed carbon content, and volatile matter content.

Each type of biomass has specific proportion of these characteristics that determine its performance as fuel in combustion or gasification device. Likewise, properties of hydrous bioethanol determine its suitability as fuel for spark ignition engines. Hence, there are needs for determination of these characteristics and properties for each type of bioenergy source to assess its suitability as fuel and as guide in developing efficient biomass conversion technologies.

A. Physical and Chemical Properties of Rice Biomass

Straw, husk/hull and CRH from rice varieties NSIC Rc222 (inbred) and NSIC Rc132H (hybrid) were the biomass considered in this study. Biomass of NSIC Rc222 and NSIC Rc132H were collected at Maligaya, Science City of Muñoz, Nueva Ecija (Figure 5) on dry season of 2013. Carbonization of husk was done using Philrice Gasifier Stove (Figure 6).

Analyses to determine the following properties: heating value (HV), moisture content (MC) and; weight percentages of volatile matter (VM), fixed carbon (FC), ash, carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and sulfur (S) were subcontracted to SGS Philippines. Table 1 shows the methods used for the analysis of rice biomass properties.

Figure 5. Collection of rice straw sample.

Figure 6. CRH from gasifier stove.

Table 1. Methods used for the analysis of rice biomass properties.

Property	Base	Method
Total Moisture, %	As received	ASTM D3302/D3302M-12
Volatile Matter, %	dry	ASTM D3175-11
Ash, %	dry	ASTM D3174-12
Fixed Carbon, %	dry	ASTM D3172-07a
Total Sulfur, %	dry	ASTM D4239-14
Carbon, %	dry	ASTM D5373-14
Hydrogen, %	dry	
Oxygen, %	dry	
Nitrogen, %	dry	
Gross Calorific Value, kcal/kg	dry	ASTM D5865-13
Net Calorific, kcal/kg	dry	

Highlights:

- MCs of husk, straw, and CRH were in the ranges of 12.7 to 13.3%, 13.1 to 14.7%, and 6.2 to 6.9%, respectively.
- VMs of husk, straw, and CRH were in the ranges of 57.7 to 58.5%, 62.2 to 65.5%, and 3.0 to 3.7%, respectively.
- FCs of husk and straw were in the ranges of 16.3 to 17.2% while 21.4 to 27.4% for CRH.
- Ash percentages of husk and straw were in the range of 17.38 to 25.13%.
- Net HVs of husk and straw were in the ranges of 2971 to 2966 kcal/kg and 3169 to 3330kcal/kg, respectively. For the two rice biomass (straw and husk) tested, net HVs of NSIC Rc132H were higher than these of NSIC Rc222.
- Net HV of CRH for NSIC Rc222 was 1677kcal/kg while 2183kcal/kg for NSIC Rc132H.
- Cs of husk and straw were in the range of 37.27 to 40.83% while 21.64 to 27.94% for CRH.
- Hs of husk and straw were in the range of 4.47 to 4.49% while 0.43 to 0.48% for CRH.

- Os of husk and straw were in the range of 32.7 to 36.3% while 2.0 to 2.3% for CRH.

- Ns of husk and straw were in the range of 0.23 to 0.68% while 0.27 to 0.33% for CRH.

- Ss of husk and straw were in the range of 0.02 to 0.1% while 0.05 to 0.06% for CRH.

B. Fuel Properties of Nipa Hydrous Bioethanol

Naturally fermented nipa sap was initially distilled using Crude Bioethanol Distiller (CBeD) with rice husk as fuel. The spirit produced has an alcohol content of 35 to 40% or being called crude bioethanol (CBe) for this study. Further concentration of alcohol up to 94% or the so called HBe was done using the Laboratory-scale Hydrous Bioethanol Distiller (HBeD) with 3kW electric heater as heat source.

Analyses of properties such as visual color, acid strength in pHe, copper concentration, densities at 15 and 20^{0}C, ethanol and methanol content, chloride content, acidity (as acetic acid), and water content were subcontracted to SGS Phils and CRL Environmental Corp. Table 2 shows the methods used for the analysis of properties.

Figure 7. Distillation of fermented nipa sap using crude bioethanol distiller.

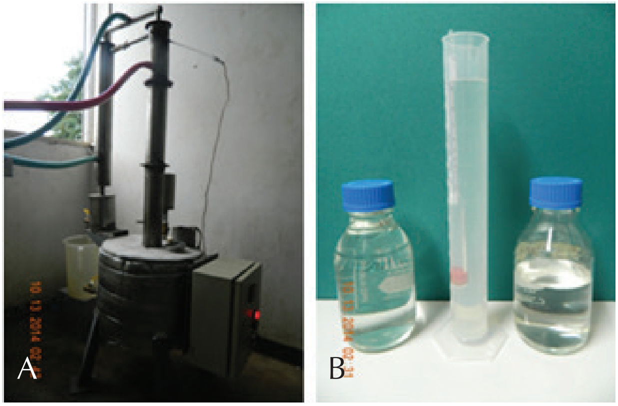


Figure 8. Distillation of hydrous bioethanol (b) using Hydrous BioethanolDistiller.

Table 2. Methods used for the analysis of HBe fuel properties.

Property	Method
Appearance	Visual
Visual Color	Visual color
Acid strength, in pHe	ASTM D6423-2008
S1-Copper concentration, mg/L	ASTM D1688_A-2012
Density at 15ºC, kg/L	ASTM D4052-11
Density at 20ºC, kg/L	ASTM D4052-11
Ethanol Content of denatured fuel ethanol by GC Ethanol purity, % (v/v) Methanol, % (v/v) Denaturant (estimated), % (v/v)	ASTM D5501-2012e1
Chloride content, mg/kg	ASTM D512 (Method C)-2010
Acidity (as acetic acid), % (m/m)	ASTM D1613 (modified)-06
Water Content, % (m/m)	ASTM D6304 (procedure A)

Highlights:

- Purity of HBe was 89.10% (v/v) resulting to density of 0.820kg/L. Both properties were out of specification since the required purity of bioethanol and fuel bioethanol is 99.6% (v/v) and 96.9% (v/v), respectively and bioethanol density of 0.7915kg/L.

- The methanol content of HBe was higher than 0.5% (v/v) required for both bioethanol and fuel bioethanol. However, it further shows that total alcohol content of sample was 91.48%

(v/v). Note that methanol is also a clean burning, high octane blending component for gasoline.

- Other properties such as organic chloride content and acetic acids which concentrations generally determine corrosiveness of bioethanol were at levels below the required fuel values.

- HBe appearance and visual color conformed to the required qualities such as colorless, clear, bright, and visibly free of suspended or precipitated contaminants.

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

Project Leader - AT Belonio

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.

Basically, the fuel that can be derived from biomass can be used as source of heat and power. Once power is available, it can be utilized to drive agricultural machines for mechanized operation and/or to produce electricity for powering farmstead equipment and for lighting purposes. At present, 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.

Rice Husk Gasification Systems for 100KWe Power Generation
AT Belonio, JA Ramos, LB Molinawe, JA. dela Cruz, MJC Regalado, EC. Gagelonia

The Rice Engineering and Mechanization Division started research and development of rice husk gasifier in the early 2000. In 2013, a 100kWe rated capacity moving-bed downdraft rice husk gasifier was designed and developed comprising of a gasifier reactor having a diameter of 1.20m, an impact-type wet scrubber, a packed-bed filter, and a holding tank for storing the gas. A high pressure blower located between the filter and the engine is used in pulling the gas from the reactor. With the urgency to power the existing deep-well pump at PhilRice Negros, the gasifier design was improved and tested. The following revisions were incorporated in the previous design: (a) The suction blower was relocated close to the engine intake manifold to increase the intake pressure of gas, (b) The existing radiator was replaced with a 1.5 cubic meter water tank to cool sufficiently the engine, (c) The belts that drives the alternator were realigned and replaced with automotive belts instead of commonly available agricultural A-type belts, (d) Char sweeper with water sealed bin is provided instead of vibratory hopper, and (e) Bucket elevator and screw conveyor were added to ease out the loading rice husks fuel and for discharging the char. Series of tests were conducted to determine whether the unit functions according to the design so that it can be brought to PhilRice Negros for series of field testing pilot study.

Highlights:

- By relocating the suction blower directly into the intake manifold of the engine, increased in the power output of the engine was observed. Engine speed was found to operate be more stable when the blower is directly coupled to the intake manifold of the engine as compared with the previous design.

- Engine temperature was highly reduced after a water cooling tank was provided. Tests showed that the engine continuously run for a minimum of 4 hours without experiencing overheating than in the previous design of having only the radiator for cooling the engine.

- Aligning and using the right type of belt did not easily-worn out the belts as previously experienced.

- The char discharging mechanism performs well compared with the previous vibratory device installed. Sweeping mechanism works well in discharging the char without smoke being emitted at the reactor.

- The generator works with the load at present using the 20 units of 1,500-watt bulbs fueled with gasoline. Test will be conducted soon with the engine fueled with producer gas.

- There is a need to have the bucket elevator and screw conveyors to facilitate loading of rice husk and to discharge the char.

- Generally, the gasifier unit is ready for shipment to PhilRice Negros for series of field and pilot testing.

Figure 9. The 100 KWe Rice Hull Gasifier.

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

PhilRice has recently developed the continuous rice hull (CTRH) carbonizer wherein heat is generated during its operation and recovered for various applications in the farm. One of these applications could be the conversion of water into steam for generating power, among other things, for household uses. The conventional steam boilers however are potentially dangerous when applied at the level of the farmers hence this study generally aims to come up with a safe alternative technology for generating steam for small scale biomass energy conversion systems. Specifically, it aims to (1) design and fabricate a prototype of an instant steam generator (ISG), (2) test and evaluate the performance of the prototype ISG at different operating conditions, making use of the heat generated from the CTRH carbonizer, and (3) make use of the prototype ISG to run a steam engine and evaluate the performance of the whole system

Highlights:

- A prototype of the ISG was designed and fabricated (Figure 10). It was made from 5mm diameter copper tubing formed into 21 coils with more or less uniform internal diameter of 358mm.

- Performance testing of the prototype ISG was conducted by putting the prototype ISG in the cooking attachment of the CtRH carbonizer. The carbonizer was then operated so as to supply heat into the ISG. A manually-operated piston pump to be used to force water into the ISG (Figure 11).

- Results of experiments showed that generating steam on demand is possible, making use of the continuous rice hull (CtRH) carbonizer as heat source.

- Even at the highest flow rate of pumped water (71L/ha), instant steam was generated at average pressure of 78psi. Higher steam pressures were observed at lower pumping rates (Figure 12).

Figure 10. Prototype of the instant steam generator (ISG).

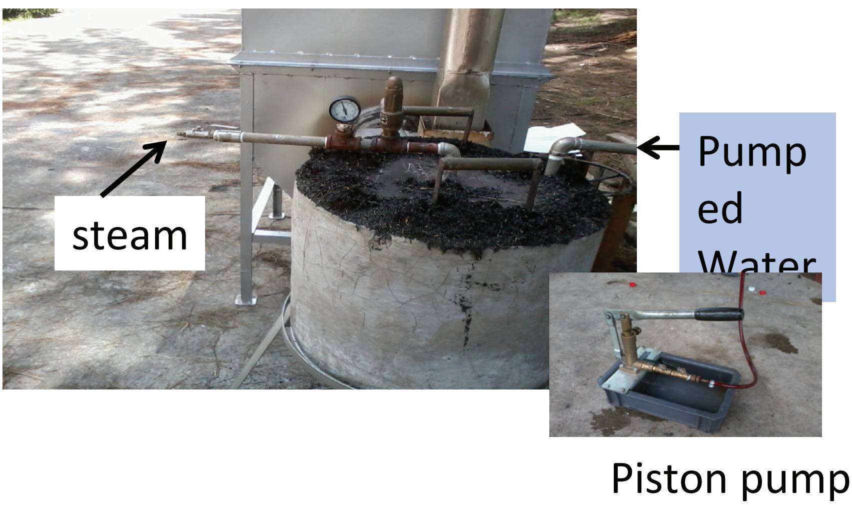


Figure 11. Setup during the conduct of test runs of the ISG prototype.

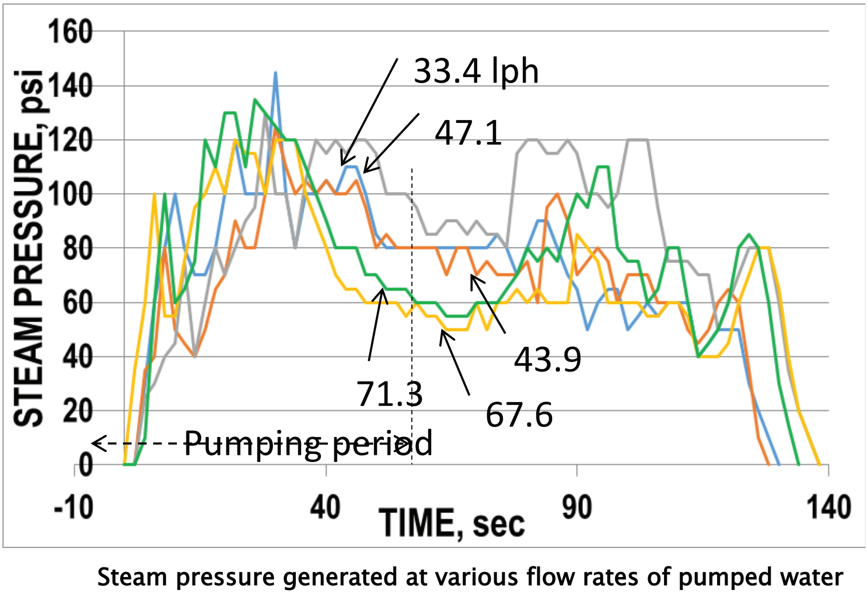


Figure 12. Performance of the ISG prototype in terms of pressure of the generated steam at different rates of flow of water introduced into the prototype.

Gasification of Rice Straw

PS Ramos, MJC Regalado

In the Philippines, the major battle cry in the energy sector is the ever-increasing cost and too much dependence from fossil fuel imports. Biomass energy resources are derived from animals and plants, which are converted into energy (Wise, 1983). Conversely, the call in the environmental side is the generation of huge amounts of biomass from rice such as rice hull and rice straw. Rice straw is one of the main non-edible biomass resources in Asia and in the Philippines. In 2013, rice production in the Philippines was 18.44 million metric ton (PSA, 2014) which means rice straw production of 23.05 million metric ton based on the average ratio of the rice grain: rice husk: rice straw of 1: 0.25: 1.25 (Haefele et. al., 2011). Rice straw is often times left on the fields and sometimes reincorporated in the soil, but a significant part is considered as waste and occupies large areas of the fields before its disposal through open-air burning or degradation. Rice straw left on the fields or burned in open fields creates pollution-related problems such as smoke and particle emissions due to incomplete combustion, and emissions of greenhouse gases including methane and nitrous oxide due to anaerobic degradation.

The purpose of using rice straw as fuel for energy production (direct heat or for electric production) is to reduce drastically the emissions of air pollutants from open combustion as particulate matter (less than 10 micron and less than 2.5 micron) and as polycyclic aromatic hydrocarbons (PAHs), as well as polychlorinated dibenzo-p-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs), referred to as dioxins and furans. These air pollutants have significant toxicological properties and are notably potential carcinogens. Air pollution not only affects human health and the environment, but also indirectly affects the economy of a country (Gadee, 2009).

Rice straw usually scattered in the field, the mode and time of collection, moisture content, and sizes are among the factors that affect the processing of rice straw.

There are so many sources of energy – solar, wind, water, geothermal and biomass but biomass is abundant and readily available in most places. Using the technologies for converting biomass into a usable form of energy will reduce or minimize the dependence of countries on petroleum products.

The purpose of the study was to determine the effect of size of rice straw on the production of combustible gases, determine the heating value, gasification rate, and gasification efficiency. Although the study used only one variety which is NSIC Rc222, the location, production management, harvest management and other production practices were not considered in this study.

Rice straw is very loose biomass after threshing. The JHT chopper/crusher powered by 6.5hp gasoline engine was used to reduce the size of the rice straw.

Highlights:

- According to the results, the rice straw with different sizes can influence the heating value, gasification rate and the production of gases.

- In terms of heating value, there was no treatment interaction observed but the smaller size of rice straw of S3 (20 to 30mm) gave a heating value of 4.47 MJ/kg compared to the larger size of S1 (40 to 50mm) which had a 2.96 MJ/kg heating value. The difference in heating value was significantly higher in S3 (20 to 30mm) size of the rice straw.

- In terms of gasification rate, the sizes of the rice straw used in this study did not significantly affect the gasification rate of the rice straw. The production of gases such as carbon monoxide, carbon dioxide, and hydrogen was affected by the size of the rice straw. The combustible gases like carbon monoxide and hydrogen (CO & H2) were significantly affected by the size of rice straw. The smaller size of the straw gave higher carbon monoxide and hydrogen. The Statistical Tool for Agricultural Research (STAR) developed by IRRI was used to analyze the results in this study.

Table 3. Heating Value and gasification rate as affected by sizes of rice straw.

Sizes of Rice Straw	Mean	
	Heating Value	Gasification rate
	MJ/kg	kg/hr.m2
S1 (40-50 mm)	2.96b	92.20
S2 (30-40 mm)	3.56b	100.42
S3 (20-30 mm)	4.47a	103.08

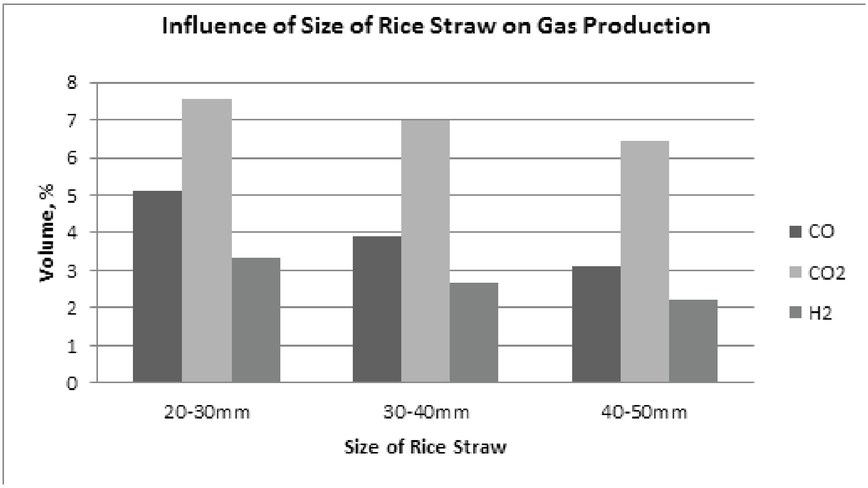


Figure 13. Influence of size of rice straw on gas composition.

The main composition of produced gases as demonstrated in Figure 13 shows that when the size of the rice straw increases, carbon monoxide, hydrogen, and carbon dioxide decrease. It means that the size of rice straw affects the production of gases in the gasification process. On the other hand, the content of carbon monoxide, hydrogen, and carbon monoxide increased as the particle size of the rice straw decreased. It means that when the particle size is decreased, the reactions are mainly pyrolysis and gasification. The results showed that the smaller the size of rice straw is more advantageous in the production of gases as reported by Xiao (2011).

Figure 14. Loose Rice Straw.

Figure 15. One passing to the chopper (S1).

Figure 16. Two passing to the chopper (S2).

Figure 17. Three passing to the chopper (S3).

Figure 18. Carbonized Rice Straw (product of gasification).

Pilot Testing of PhilRice Crude and Hydrous Bioethanol Distiller for Production and Utilization of Hydrous Bioethanol Fuel from Nipa
PM Reyes, KC Villota, M Rafael, AT Belonio, MJC Regalado

In 2014, REMD 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 and one proto-type of fuel injector to feed hydrous bioethanol to engines 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. The fuel injector, on the other hand, directly injects hydrous bioethanol into the engine by using a valve without passing the carburetor of the engine. The distillers were tested at PhilRice CES and in Infanta, Quezon. Brake dynamometer tests of the fuel injector retrofitted to a small spark-ignition engine were conducted. Field tests of the injector operating in an engine-pump system were also done.

Highlights:

- The crude bioethanol distiller can process alcohol feedstock sample or fermented nipa sap from 6.2 to 11.0% to 33 to 43% within 1 hour of heating the boiler/steamer. The computed alcohol recovery of the distiller ranges from 46 to 67%. On the average, for every 6 units of feedstock, 1 unit of crude bioethanol can be produced from the distiller.

- The hydrous bioethanol distiller on the other hand can process alcohol feedstock sample or fermented nipa sap from 6.5 to 10% to 92 to 97% alcohol within 2 hours. The computed distillation rate of the unit ranged from 1.8 to 2.2L/h with rice husk consumption rate of 18 to 20 kg per hour.

- Brake dynamometer tests of the retrofitted engine using hydrous bioethanol showed that the engine requires 1.5 to 2 times more fuel as compared with gasoline for the same output. Using the engine at constant load operation also showed that retrofitted engine can run solely on hydrous bioethanol fuel in pumping water.

- Based on the result of the study, pilot testing of the distillers and fuel injector need to be conducted during the 2015 to further see the merits of these technologies.

Figure 19. The hydrous bioethanol distilling facility installed in Infanta, Quezon.

Adaptation and Deployment of MMSU Fermentation and Distillation Technologies for Hydrous Ethanol Production Using Nipa Sap

SC Agrupis, N Mateo, A Cocson, R Ulep, MC Birginias, M Lucas, MT Blanco, F Abenes

The use of ethanol as gasoline oxygenate is mandated by the Philippine Biofuels Act of 2006. Currently, over 88% of the ethanol used by the petroleum industry is imported.

Since 2008, our group has been conducting integrated studies including: 1) fermentation experiments for sugar cane juice, sweet sorghum jaggery, molasses, and Nipa sap; 2) reflux distillation experiments using fermented hydrolysates from different feedstocks to produce hydrous bio-ethanol (MMSU 95-hBE); and 3) formulation, characterization, and testing of hydrous gasohol blends using MMSU 95-hBE and commercial E10 gasoline. We were able to develop proprietary fermentation and distillation techniques to produce high grade hydrous bio-ethanol from these multi-feedstock sources.

PhilRice on the other hand, is one of the many government research institutions that uphold the Biofuel Act of 2006. In its effort to participate in the full implementation of the law, it aggressively advocates a fossil-fuel free farming. All the above formed the foundation of this proposed collaborative project where MMSU fermentation and distillation propriety protocols will be evaluated using juice from nipa palm (Nypafruticans). If successful, it will be adapted in multi-location where these plants are locally grown to empower the farmers and become part of the biofuel revolution.

Highlights:

- Table 4 shows the ethanol concentration (% v/v) of nipa sap fermented under strictly aerobic and facultative anaerobic conditions. Results indicate that fermented sap stored under anaerobic conditions resulted in higher ethanol concentration than those subjected to aerobic conditions both at ex-situ and in-situ environment. After 8 days, fermented sap kept in open containers lost almost all its initial ethanol (0.75%) while those kept under anaerobic conditions remained at 4.74% in ex-situ conditions. Under in-situ environment, ethanol was not reduced as drastically as in ex-situ. We conclude that simply changing the storage conditions after harvesting the fermented sap can increase the yield of ethanol by as much as 33%. Further increase in ethanol yield may be achieved by controlling yeast activity during the collection process.

- In previous designs, concentration of the collected distillate ranges from 81 to 93% which made it necessary to subject the distillate to a 2nd distillation in order to produce the azeotropic 95.6% ethanol. This would be a considerable added input to the production cost that needed to be addressed. These were the prime considerations during the improvement of the distillation facilities. The distiller deployed in Pamplona Cagayan is the fifth iteration of the design (Figure 20) in order to achieve the optimum system efficiency and safety operation.

- The adaptability of the system to nipa sap was tried and evaluated against sweet sorghum. The results presented in Table 5 show that even at the low ethanol concentration of 5-6% v/v in the beer, the deployed system could recover the ethanol at 93% efficiency. For beer with higher ethanol concentration, the system could recover 98% azeotrope ethanol leaving only 2% of the total ethanol distillate for second distillation. The distillation process of 100L fermented nipa sap was completed in 3 hrs. Higher concentration of ethanol in the beer makes the distillation system more cost-effective.

- The developed village-scale bioethanol production facilities using nipa as feedstock were adapted and deployed successfully in Cabaggan, Pamplona, Cagayan. The facilities have been tried by the technology takers themselves under the close supervision of project personnel. As shown in Table 6, the three trials conducted by the farmer consistently show higher ethanol concentration in the beer (8% v/v) compared to the data obtained in Table 5 indicating the adaptability of the fermentation protocol (facultative anaerobic) in field and up-scale conditions. The efficiency of the distillation facilities to recover 95% Ethanol is lower than those obtained in Table 5. This is expected since technology adapters need more training in the operation of the facility especially in the firing and control of heat in the furnace.

Table 4. Ethanol concentration (% v/v) of Nipa Sap fermented under Strictly Aerobic and Facultative Anaerobic conditions.

<table>
<tr><th rowspan="3">Observation Time, day</th><th colspan="5">Ethanol concentration, % v/v on fermented sap</th></tr>
<tr><th colspan="2">Ex-situ condition</th><th rowspan="2">Observation Time, day</th><th colspan="2">In-situ condition</th></tr>
<tr><th>Strictly Aerobic</th><th>Facultative Anaerobic</th><th>Strictly Aerobic</th><th>Facultative Anaerobic</th></tr>
<tr><td>1</td><td>2.91</td><td>2.98</td><td>1</td><td>3.34</td><td>4.80</td></tr>
<tr><td>2</td><td>2.98</td><td>3.27</td><td>2</td><td>4.60</td><td>5.66</td></tr>
<tr><td>4</td><td>2.98</td><td>3.84</td><td>3</td><td>5.27</td><td>7.43</td></tr>
<tr><td>8</td><td>0.75</td><td>4.74</td><td>5</td><td>4.66</td><td>5.47</td></tr>
</table>

Table 5. Performance of Design 5 reflux distillation system using sweet sorghum and nipa sap beer.

Distillation Parameters	Feedstock		
	Nipa Trials		Sweet Sorghum Trials
Volume beer, L	100	100	100
Conc of ETOH in the beer, % v/v	19	5.5	12.7
Vol. 95% ETOH, L	17	5	13.5
Vol. lower grade ETOH, (87-89%)	3	0.4	1
Total Yield 100% ETOH, L	18.76	5.10	13.24
Processing time, hr	6	3	5.35
Distillation efficiency to collect 95% ETOH, %	98.74	92.72	98.07

Table 6. On-field validation on the adaptability of the fermentation and distillation protocols at village-scale.

Distillation Parameters	Farmer's Trial		
	12 Oct	16 Oct	20 Oct
Volume beer, L	160	160	160
Conc. of ETOH in the beer, % v/v	8.13	8.21	8.72
Vol. 95% ETOH, L	11	12	10
Vol. lower grade ETOH, (87-92%)	3	2	5
Total Yield 100% ETOH, L	13.01	13.14	13.91
Distillation efficiency to collect 95% ETOH,%	84.60	91.32	71.89

Figure 20. 200L capacity reflux distiller with improved furnace and cooling system.

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

Project Leader: JA Ramos

Adoption of modern technologies such as use of high yielding varieties and mechanization, among others, increases productivity but may lead to an equivalent increase in the energy input in production. This has been confirmed accurate by a study showing that the total energy input of mechanized system of rice production in irrigated and non-irrigated fields is 13,920 and 11,969MJ/kg, respectively. Hence, semi-mechanized system consumes lower at 11,501 and 10,160MJ/kg (Bautista 2010). Farming system such as this is the usual or the conventional farming system which is energy-intensive and consumes about 837Mcal of energy to produce a ton of paddy rice, three times higher than the energy input by organic farming system (Mendoza 2002). Nevertheless, most farmers are practicing this method of farming because they seek for high yields during harvesting period and sometimes they do not consider how much they spent to get that yield.

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, production and utilization of biodiesel from waste cooking oil, use of wind and solar energy sources for crop irrigation, azolla spore production as biofertilizer and the rice hull gasifier engine-pump system for optimum application in rainfed lowland farms.

Production and Utilization of Biodiesel from Waste Cooking Oil for Rice Farming Operations

DB Fenangad, JEO Abon, RF Orge

Providing the farmers alternative sources of fuel such as biodiesel produced from waste cooking oil is one possible way of helping them reduce their dependence on fossil fuels. Waste cooking oil can be a stable source of feedstock for biodiesel production since it can be easily accessed from restaurants and fast food establishments. If farmers would be able to use biodiesel, not only will they have a cheaper source of fuel for their farm equipment but they will also aid in the reduction of greenhouse gas emission. Moreover, they can have the chance of earning additional income from glycerin, a by-product of the biodiesel processing that could be used to manufacture soap, among other possible products.

The utilization of waste cooking oil for biodiesel production could also help solve the problem of its improper disposal. Studies have shown that recycling used cooking oil for frying food could form a toxin called 4-hydroxy-trans-2-nonenal (HNE). Consumption of foods containing HNE from recycled cooking oils has been associated with increased risks of cardiovascular disease, stroke, Parkinson's disease, Alzheimer's disease, Huntington's disease, various liver disorders and cancer.

However, before the technology of processing waste cooking oil to biodiesel can be promoted to the farmers, several issues have to be addressed and verified. Concerns on the sustainability and efficiency of biodiesel from waste cooking oil can be addressed by a more intensive testing of the biodiesel on different farm machineries. This study was therefore conducted to: (1) gather baseline data in the processing of waste cooking oil to biodiesel, (2) develop a system for a large scale processing of waste cooking oil to biodiesel, and (3) test the performance of biodiesel on different rice farming machinery.

Highlights:

- The cruzesterification method developed by Dr. Rico Cruz was verified to account for the varying quality of oil purchased. It was found out that the recommended 11 grams of potassium hydroxide (KOH) per liter of waste cooking oil is insufficient to convert waste cooking oil to biodiesel when the quality of oil is highly degraded. To account for this varying quality, purchased waste cooking oil was subjected to testing per tin can basis to determine the proper amount of KOH to be used per batch of mixing. It was observed that highly reused cooking oil will require up to 21 grams KOH per liter of waste cooking oil with a conversion rate of 72 to 75%. Waste cooking oil which was relatively less degraded on the other hand will require 11 to 15 grams KOH per liter of waste cooking oil and will be converted to biodiesel by as much as 92 to 95%.

- A micro-processing plant was fabricated for the large-volume processing of waste cooking oil to biodiesel. The set-up for the biodiesel processing plant has a 100L capacity (Figure 21). Large-scale mixing was conducted to initially test the micro-plant and at the same time to check if there would be possible revisions in the design. Twelve liters of newly purchased cooking oil was used in the preliminary testing of the micro-plant. The 110mL methanol and 6g KOH ratio was used for this test since this ratio produced the highest quantity of biodiesel basing from the previous test conducted. Separate container was used for the mixing of methanol and KOH to make sure that the KOH was totally dissolved in the methanol. Biodiesel produced from this test was 8L.

- Processed biodiesel were tested in PhilRice-CES farm machinery in different blends such as B20, B50 and B100.

B20 and B50 biodiesel blends were tested in the Kubota M7530 four-wheel tractor. Moreover, B20, B50 and B100 biodiesel blends were tested in a Kubota RK80 engine. No engine performance difference was observed in the engines run in biodiesel blends compared to 100% petroleum diesel. One notable difference however is that colorless smoke came out of the exhaust pipe in engines run on biodiesel blends instead of the usual black smoke emitted in 100% petroleum diesel fuelled engines.

- B20, B50 and B100 were tested on a RK-60 diesel engine and a load was not considered in this test. 2L of the biodiesel blend was filled in the engine and was run for 1 hour. After each run, the oil left was measured for the computation of fuel consumption. Before the next run, the engine was cooled down for 1 hour. The biodiesel used for the blends was batch B (processed from the previous testing). According to the results shown (Table 7), the three different blends performed well and colorless smoke came out of the exhaust pipe which proved that biodiesel is environment-friendly. In terms of fuel consumption, B20 and B50 showed no significant difference, however, B100 showed significant difference when the treatment means were compared statistically.

Figure 21. The prototype of a micro-processing plant for biodiesel production.

Table 7. Fuel consumption of Kubota RK60 diesel engine using different blends of biodiesel (average of three replications).

BLEND	FUEL CONSUMPTION (L/h)
B20	0.16b
B50	0.17b
B100	0.30a

Means followed by a common letter in the same column do not differ significantly at 5% level of significance using DMRT

Harnessing Wind and Solar Energy for Crop Irrigation in Ilocos Region

MG Galera, ND Ganotisi, MLO. Quigao, MAU Baradi, MJC Regalado, AT Belonio

Developed agricultural machineries and other irrigation equipment are very useful in crop production. In the case of Ilocos, water pumps are usually used for irrigation especially during the dry months. However, these pumps generally use fossil fuel to run. With the use of these fossil fuels, emission of greenhouse gasses particularly carbon dioxide increases which contribute to climate change, a global problem. Not only can contribute to this problem but also increases the cost of production, hence, will farmers get lesser income.

To date, the research for cheaper, environment-friendly and more efficient sources of renewable energies is actively being done. And with the increasing burden on natural oils and coal for production of energy, the promise of wind power and other sources of renewable energy offer an efficient alternative. These alternatives serve distinct advantages and hope to reduce if not replace the use of coal, oil and natural gas, and most importantly reduce the emission of harmful gasses. The wind power could be harnessed by using a wind pump to draw water for irrigation instead of using a fossil-fueled water pump. Another way to minimize the problem is to utilize the heat comes from the sun by using solar energy technologies.

Wind and solar energy is unlimited, natural, and renewable energy that can be converted into other forms of energy like mechanical, heat, and electrical energy and many other forms. The largest advantage of these renewable energy is that they are free and unlimited. They are also environment-friendly energy source, which cannot aggravate global warming.

Wind power can be converted into mechanical or electrical energy, for pumping or draining water, or sails to propel ships. Likewise, to convert solar into electricity is by photovoltaic (PV). PV systems use solar cell or panel to convert sunlight into direct current electricity.

Combining the two renewable energy sources will ensure additional alternative way of irrigating crops, if not continuous. It can more or less charge a common battery which in turn runs an electric pump. Whenever there is no enough sunshine but have enough wind to charge the battery, drawing water is still possible and vice versa.

Highlights:

- The materials and equipment needed for the conduct of the study were already purchased and initial testing of the system has been conducted.

- The wind turbine of the hybrid system has a starting wind speed of $2.5ms^{-1}$ but during the initial testing it was found that it can run even at $2.15ms^{-1}$ at 2m elevation head. Data on its capacity to charge the battery was not yet conducted since the wind turbine tower is still under construction.

- The testing of the pump system with solar energy as power source was initially conducted (Table 8). The initial water table during the testing was about 2m with 41m of discharge pipe. It produces an average pump discharge of 1.64lps. However, the water table dropped down from 2.12 to 2.82m in just 10min. The recharge of the well was not sufficient to sustain the discharge of the pump system. But with 86m length of discharge pipe, the pump discharge was reduced to 1.16lps. With this discharge, the water table was maintained even after an hour of testing.

- The battery charge dropped down by 0.48V per hour (Vhr^{-1}) of operation when the average discharge of the pump was 1.64lps. On the other hand, with 1.16lps discharge, the battery voltage drop was only $0.32Vhr^{-1}$.

- During the initial testing, the pump system using solar energy worked and allowed to operate for an hour. The 1.16lps (4.18m3h-1¬) of water drawn can irrigate 880m2 of eggplant or 860m2 of tomato or 300m2 of rice.

Table 8. Initial testing of the solar pump system, Nov. 25, 2014, 1:00-2:30 PM, 250 W solar panel.

Time (min)	Water table (m)	Charge of battery (V)	Pump Discharge (lps)
A. Length of Discharge Pipe = 41.0m			
0	2.12	12.02	1.64
10	2.82	11.94	
B. Length of Discharge Pipe = 86.0m			
20	2.71	11.88	1.16
30	2.70	11.86	
50	2.74	11.77	
70	2.73	11.66	
90	2.76	11.51	

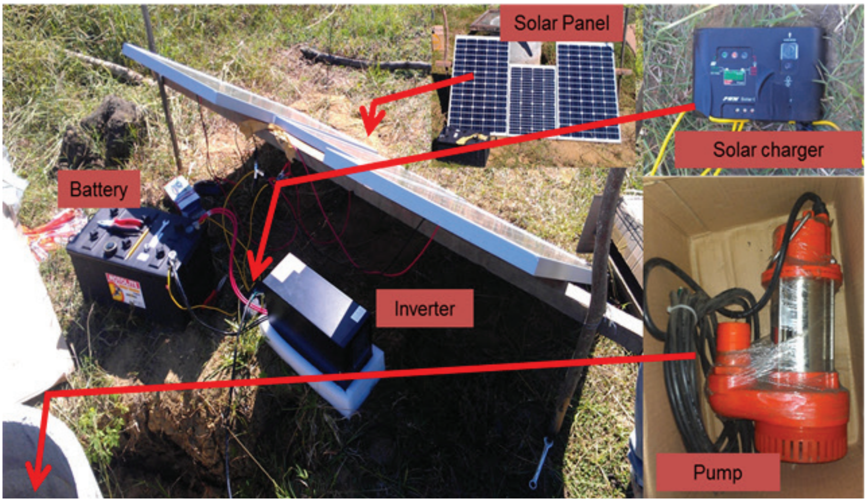


Figure 22. The pump system with solar energy as source of electricity.

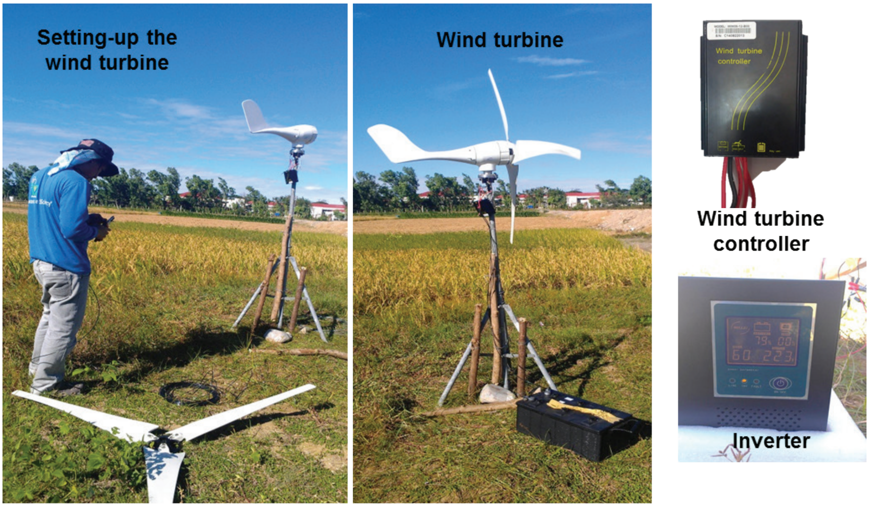


Figure 23. The installed wind turbine at 2 meter elevation for initial testing.

Development of Ricehull Gasifier Engine-Pump System for Optimum Application in Rainfed Lowland Farm
AS Juliano

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.

PhilRice designed a promising local gasifier engine-pump system with features that are compact, light-weight, mobile, and affordable for the small farmers. The capacity to irrigate crops of the existing ricehull gasifier engine-pump system designed by PhilRice is not enough and needs to be developed further for the rainfed lowland farm application specifically for small farmers with an average area of one hectare. Tapping the excess gas of the gasifier system and bringing it back to the reactor/scrubber is important to improve further the performance of the system specifically in increasing the time of operation without additional ricehull biomass.

The study will focus on the optimization of water utilization from the ricehull gasifier engine-pump system to be developed for the crops to be considered. The expected results of the study will be the basis for the selection of crops which can achieve its significant yield (growth and productivity) corresponding to the fluctuation of water supply from the gasifier system. Eventually, the system should be able to help farmers increase farm productivity.

Highlights:

- Finalized the design of the ricehull gasifier engine-pump system for rainfed farm application targeting an area of one (1) hectare. Improved the design of the existing mobile gasifier system by increasing the size of reactor, suction blower, settling bin, prime mover, and the dry filter in order to attain the 2 hours continuous operation of the system.
  - Blower diameter was increased from 30cm to 50cm and the height was increased also from 150cm to 200cm. It contains 4 bags of ricehull or 40 kilograms.
  - Suction blower was increased from 8″ diameter to 12″ diameter in order to provide enough pressure and gas velocity that supply in the 16 hp gasoline engine.
  - The two (2) settling bins were doubled the height in order to minimize the entry of liquid impurities and eliminate the entry of liquid impurities into the engine. Result of this improvement will help in running the engine continuously for 2 hours operation.
  - Doubled the height of the dry filter (using sawdust material). Further cleaning the produced was the effect of this improvement. Also, it minimized the presence of liquid impurities inside the filter chamber that helped in the continuous operation of the system.
  - Increased the prime mover from 6hp to 16hp gasoline engine. Greater power is required to operate the system for pumping water targeting 10li/sec discharge.
- Optimization tests of the prototype were conducted to determine the best settings of the system in the air valve opening (1,2,3 openings), gas valve opening (1/4, 1/3, 3/8 openings, and the suction blower pulley diameter (4″ and 3″). Some instruments (gas meter, tachometer) were used to determine the gas temperature, velocity, pressure, speed of engine, water pump, suction blower. Series of tests were done to determine the optimum performance of the engine in terms of shaft speed and ricehull utilization. Also determine

the necessary gas temperature, velocity, and pressure that the engine perform excellently.

- o As shown in table 9, the combination of 4″ diameter pulley in the suction blower, 1/3″ gas valve opening, and # 1 setting of the air valve gave the best average engine speed of 2106rpm, with a total operation time of 139 minutes (2.32 hours) using 38 kilograms of dry ricehull, with a gas temperature of 37oC entering into the engine at a pressure of 0.017psi and velocity of 13m/s. For one complete test operation, engine stability performance showed speed range of 1666 to 2705rpm (Figure 24). Other settings gave higher average engine speed but not stability in the whole operation (Figure 25).

- o Some settings gave lower engine output and other settings had no enough gas (low velocity and pressure) that maintain the requirement of the engine to continuously run and resulted to stoppage.

Table 9. Data gathered during the optimization tests.

At 4" diameter pulley for suction blower

Producer Gas valve opening	RC, kg			T.O. , min.			Shaft Speed, rpm			Temperature, ºC			Pressure, psi			Velocity, m/s		
	Air valve opening			AVO			AVO			AVO			AVO			AVO		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1/4 opening	38			106			1879			35			0.027			29		
1/3 opening	38	36	38.6	139	102	82	2106	2246	2228	37	35	33	0.017	0.010	0.041	13	9	18
3/8 opening	58	35		217	127		2747	2574		32	33		0.036	0.047		22	22	

At 3" diameter pulley for suction blower

Producer Gas valve opening	RC, kg			T.O. , min.			Shaft Speed, rpm			Temperature, ºC			Pressure, psi			Velocity, m/s		
	Air valve opening			Air valve opening			Air valve opening			Air valve opening			Air valve opening			Air valve opening		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1/4 opening	37			105			2090			34			0.012			9.87		
1/3 opening	41			104			1745			31			0.007			11		
3/8 opening	38	37		119	118		1893	2165		33	34		0.040	0.024		19	15	

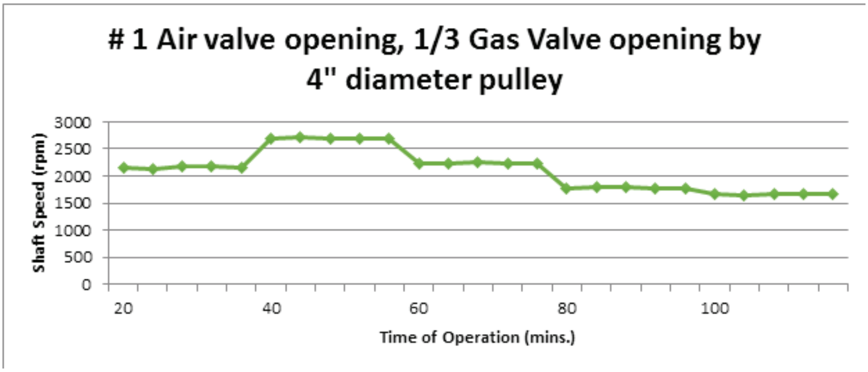


Figure 24. Best setting result on stability of engine speed performance.

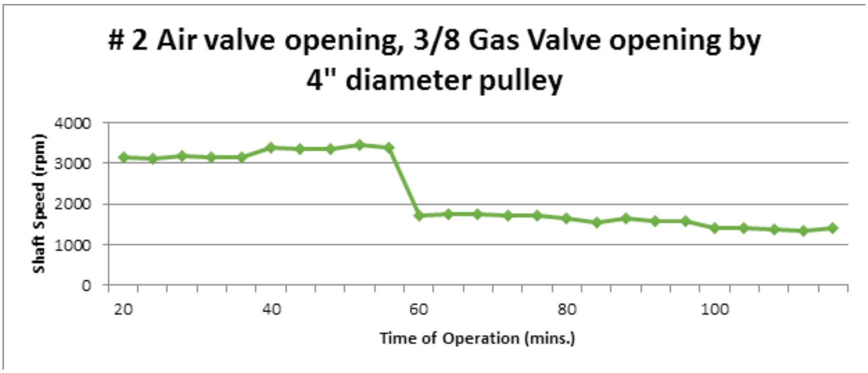


Figure 25. Setting with unstable engine performance resulted to stoppage.

- One trial test on the system developed returning the excess gas from the tank to the scrubber gave the result to an increase of engine operation time 10 minutes. It showed promising consideration for the system to run in longer operation for pumping water. Also, incorporating a pipe water source coming from the water pump and supplying the water scrubber continuously during pumping operation was tested and showed promising output without negative effect in the performance of the system. The incorporation of the pipe will lessen the work of the operator to replace water in the scrubber every completed operation. Also, cleaning of gas will further enhance using new and clean water replacing in the scrubber continuously.

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

Azolla as biofertilizer could supply nitrogen to the rice crop in amount proportional to the biomass produced and incorporated in the paddies during cropping. The nitrogen in Azolla is produced through symbiotic relationship with the blue-green algae, Anabaena azollae, thriving in the leaf cavities. The Philippine government established the National Azolla Action Program (NAAP) in 1982 to develop farm-based technology for the use of Azolla as an organic fertilizer for irrigated lowland rice fields recognizing the many potential uses of Azolla. The University of the Philippines Los Baños (UPLB) and the Department of Agriculture (DA) jointly implemented the program.

NAAP implemented activities to identify suitable Azolla strains for each for the various soil and climatic environment in the Philippines, establish the cultural requirements of the Azolla strains, multiply and distribute seeding materials of the suitable Azolla strains, produce enough materials for millions of rice fields, and train farmers how to use Azolla in rice-based farming system. NAAP established 12 regional nurseries, 98 provincial nurseries and 3,000 community propagation ponds to service the target area of 300,000ha of rice fields. 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 UPLB and collaborating institutions during the NAAP operation.

Several studies during NAAP operation have been focused on environmental factors affecting the Azolla growth in the rice paddies. The vegetative means of multiplying Azolla had been found possesses a problem to farmers when they need to re-inoculate. Azolla may loss in propagation ponds and farmer's field because of limited water supply, severe pest and disease outbreaks and natural calamities such as floods and droughts. The utilization of Azolla using vegetative means of propagation did not sustained the Azolla technology. The use of spores is believed to overcome the problems. The NAAP were already started to explore the sporulation component of Azolla. In 2004, because of budgetary constraints, UPLB decided to terminate NAAP. As a result, UPLB's collection of Azolla including the hybrids have not been maintained. Azolla in rice paddies in the Philippines is no longer noticeable unlike in 1980s. However, there are few places where Azolla still persist. These Azolla were found to be sporulating.

Production, processing and packaging of Azolla spores in large quantities for distribution are found possible during the implementation of NAAP. Studies on the techniques of collection, storage, sprouting of Azolla sporocarps and large-scale cultivation of sporelings were conducted

(Quing-Yuan et al. 1987). The Azolla in Brgy. Taytay, Majayjay, Laguna and several places in Bicol Region are explained by sporulating azolla adapted in that area. This study aims to make Azolla a stable component of rice-based farming system by (1) selecting prolific spore producing Azolla, (2) mass produced the spores of selected Azolla, (3) evaluate the performance of selected Azolla species or strains, (4) develop efficient azolla sporocarp production system, (5) identify range of rice farming environmental conditions favorable to sustainable biomass and spore production of Azolla, (6) develop an integrated management for rice-azolla system using sporocarps.

Highlights:

- The sporulation index, the megaspores and microspores of UPLB Hybrid 1 were monitored in Azolla nursery in Philippine Rice Research Institute (PhilRice) Los Baños. Figure 1 shows the sporulation of UPLB Hybrid 1 from September 1 to December 16, 2014. The highest number of microsporocarp and megasporocarp is observed to be at 95% sporulation index. Sporocarp formation is monitored by taking 100 plants from the trays every week. The best time for azolla spore production is when the intensity of the sporulation reaches 95%. Only mature azolla plants produce spores. The plants are almost fully grown in 15 to 20 days at such time they can already produce spore if environmental factors are favorable. Sporulating azolla are usually bigger, sturdy-looking, and slightly-yellowish or brownish at the centers of their fronds.

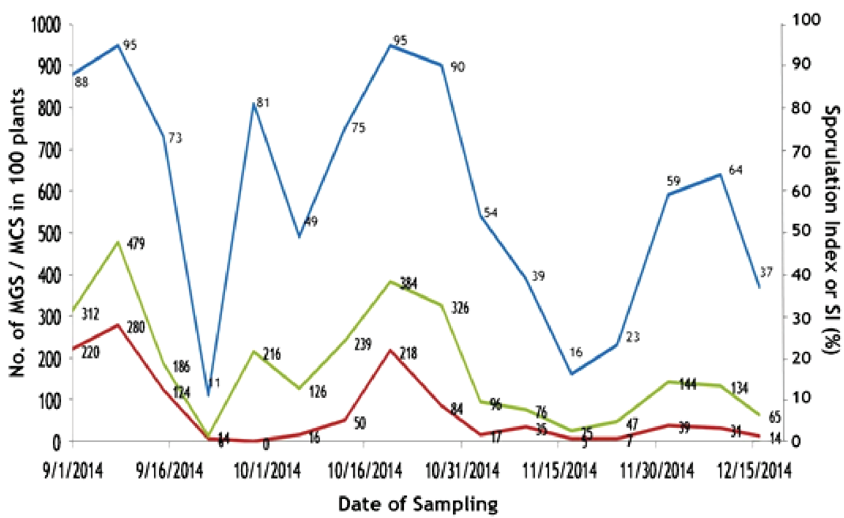


Figure 26. Sporulation of UPLB Hybrid 1 in PhilRice Azolla Nursery from September 1 to December 16, 2014.

- Figure 27 shows the summary of activities in azolla spore production. The activity should always begin with identifying the azolla strains sporulates in a given ecological condition. Another factor to be considered is the productivity of azolla in terms of vegetative growth. Doubling time is a good measure of vegetative growth and adaptability to a certain agroclimatic environment. Doubling time (DT) refers to the number of days an azolla species needs to double its mass through vegetative fragmentation. It can be computed using the formula $DT = 0.693\ t / \ln (A_t / A_o)$ where (t) is the number of days required to fill up a specified area, (At) is the final biomass, (A_o) is the initial biomass, and (ln) as natural logarithm.

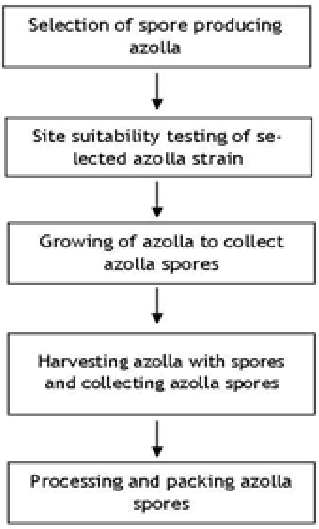


Figure 27. Summary of activities of azolla spore production.

- Sporulation pond (Figure 28) is needed to have a continuous supply of azolla spores. The requirements in establishing sporulation ponds and the care and maintenance needed to ensure continuous production of spores by the DA-UPLB-NAAP (1987) is adapted.

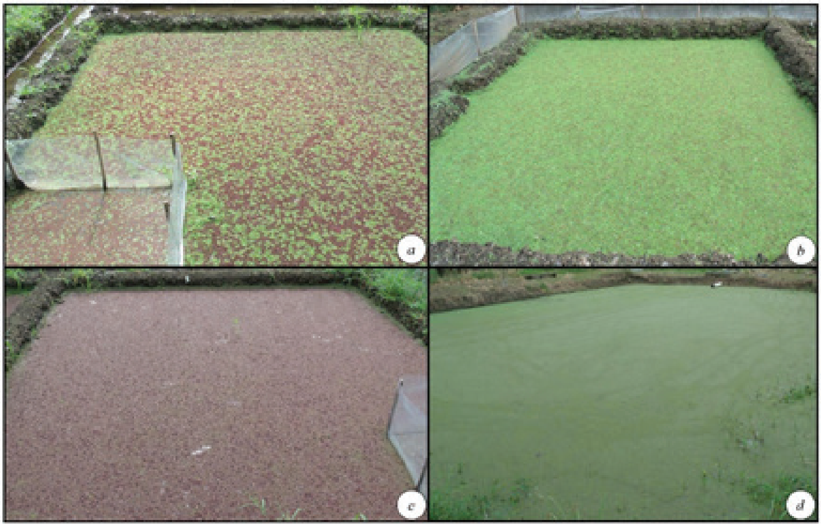


Figure 28. Production of spores of different azolla strains; (a, b & c) 36sq. m. sporulation ponds of different azolla strains; and (d) 400sq. m. sporulation ponds for testing big-scale spore production.

- Figure 29 shows the major consideration in incorporating azolla spores in lowland rice paddies. The methodology always begins with considering the amount of azolla spores available as inoculum. Otherwise, failing the first attempt of incorporating azolla in the rice farming system, making it a stable component in lowland rice farming is the next concern.

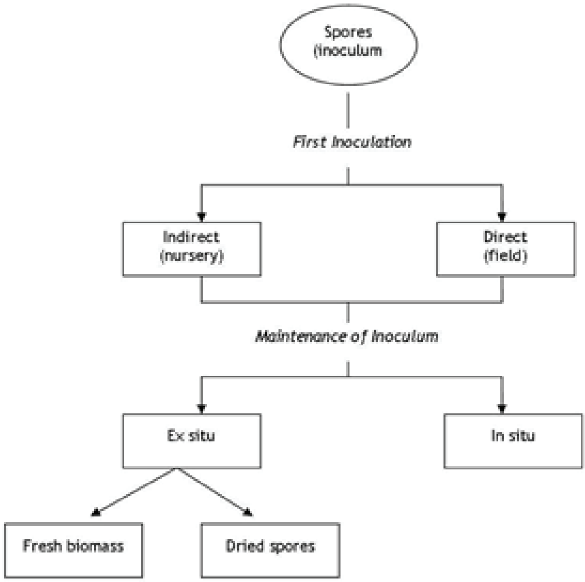


Figure 29. Summary of methodology of growing azolla from spores in lowland rice.

- Figure 30 shows the mature azolla plant in abaxial position with pairs of fruiting bodies of sporocarps along the branches but underneath the leaves. The sporocarps are of two sizes (Figure 6); the larger one is the microsporocarp (a) and the smaller is the megasporocarp (b). The higher the amount of microsporocarp is the higher the chance of megaspore to be fertilized. The microsporocarp contains 36 to 54 microspores while the megasporocarp has only one megaspore (NAAP-UPLB-DA, 1988).

- Flooded soil or medium enhances the rate of germination and increases the number of sporelings. Water increase the probability of contacts of microspore to megaspore, thus increase the number of 'fertile' or viable megaspore.

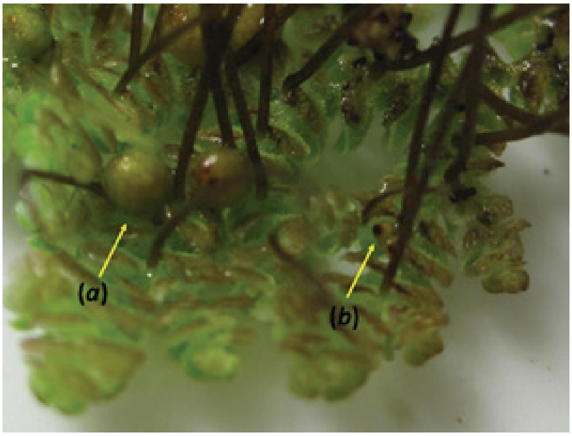


Figure 30. Azolla frond in abaxial position with sporocarps; (a) microsporocarp and (b) megasporocarp.

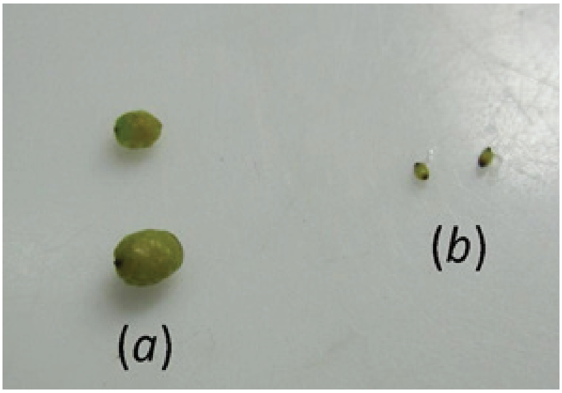
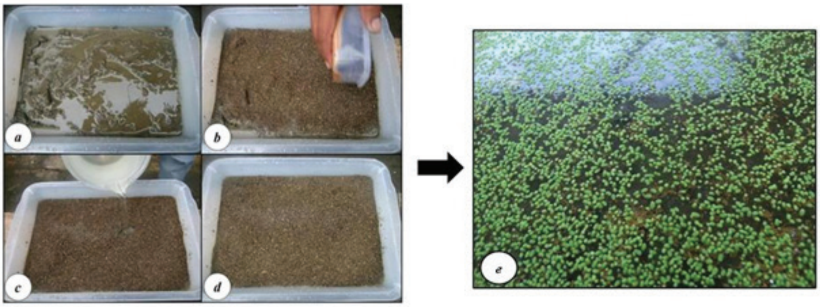


Figure 31. Azolla sporocarps; (a) microsporocarp and (b) megasporocarp.

- Steps in growing azolla spores (a to b), and sporelings with 5 to 10 leaves after 2 to 3 weeks ready for transfer on azolla plots prepared in the field (e).



- There are several factors affecting the stability of azolla in rice-based farming system. The suitability of azolla and the sporulation ability of azolla in the given location influences the thriving of azolla in that place. Reinoculation of azolla in the field may be done again and again if the environment is not favorable for azolla to sporulate. Also, extreme environmental conditions may cause the lost of azolla. In these circumstances, ex situ conservation is needed. In this system, spore production is a prerequisite. Azolla inoculum for spore production can be conserved by using fresh biomass and/or dried spores.

- There are areas where azolla can thrives in the environment and reinoculation is not needed anymore. In situ conservation may be possible in this condition, the life cycle of azolla is synchronized with the life cycle of rice and practices in the rice farming. In order to utilize azolla on lowland rice farm, it requires incorporation of azolla into the soil. A steady supply of water, good drainage, enough phosphorus and the farmer adapts the transplanted, straight row method are the prerequisites in this system. The azolla is grown with rice crop and can be incorporated into the soil three times; during the first and second weedings and during land preparation for the next crop with continues survival of azolla because of spores.

Improving the Efficiency 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, AT Belonio, MJC Regalado, EC Gagelonia

One of the drying facilities included in the Farm Mechanization and Postharvest Development of the Department of Agriculture is the flatbed dryer wherein thousand of units were provided to the beneficiaries of the program for the last 5 years. It becomes popular among farmers and seed growers because of its simplicity and cheaper cost. However, the common problems experienced by the adoptors were the darkening of grains and the smoke odor on dried grains which were caused by the direct exposure of the grains on flue gases and particulates coming off the furnace of the dryer.

Recently, PhilRice has developed a continuous flow rice husk gasifier that was initially used as heat source in a batch recirculating dryer. The gasifier provides cleaner heated air since the biomass material (rice husk) is being gasified to produce combustible gases that is to be fired then and provides heat for the dryer. The same concept is to be adopted for application to flatbed drying operation with changes on the size and simplicity of construction to make it compatible for the flatbed dryer. 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 a quality and efficient drying operation.

Highlights:

- The final prototype of the continuous flow rice hull gasifier as heat source for a 6-tonner recirculating dryer was completed (Figure 1). A number of test runs have been conducted to fine tune the gasifier which resulted to attaining the desired output of providing enough heat for a 6-tonner recirculating dryer. The gasifier consumed about 40 kilogram of rice husk in an hour of operation providing 70oC temperature at the plenum of the dryer with computed specific gasification rate of about 140kg/hr-m2. An invention patent for the technology was already filed at the Intellectual Property Office (IPOPHIL) in December 2014.

Figure 32. Final prototype of continuous flow rice hull gasifier as heating device for recirculating dryer.

- Another model of gasfiier was fabricated which is designed to fit to the requirements of a 6-ton flatbed dryer. The overall size of the unit was decreased to be proportionate to the dryer. The prototype is almost completed with only minor components left unfinished (Figure 33).

Figure 33. Prototype of continuous flow rice hull gasifier as heating device for flatbed dryer.

- A new fan was also fabricated with an s-type vane design (Figure 34). Initial test was conducted on the performance of the fan itself through a test duct where the airflow and static pressure capacity of the fan were determined. The initial data showed that the new fan achieved the minimum airflow and static pressure requirements for the 6-ton flatbed dyer.

Figure 34. The s-vane tube axial type fan being tested in a test duct system.

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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