2015 National Rice R&D Highlights

Coping with Climate Change Program

Department of Agriculture
PHILRICE
PHILIPPINE RICE RESEARCH INSTITUTE

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COPING WITH CLIMATE CHANGE PROGRAM

Program Leader: RF Orge

Being listed as one of the countries in the world that is most vulnerable to climate change effects, the Philippines needs to prepare for more extreme events in the future. With climate change, agriculture has become riskier than ever - the magnitude of the unknown that shall be dealt with have increased significantly transforming some risks into uncertainties. With the increasing population and rice areas reaching a plateau, R&D is one important tool for the country to cope with climate change, particularly ensuring food availability for every Filipino.

This Program started in 2013 with the goal of helping the country attain food self-sufficiency amidst the challenges brought about by climate change. It has three projects: the first one tackles on generating and managing local knowledge and information on climate change, second project deals with developing technologies that would help farmers adapt to or manage the impact of climate change, while the third focuses on enhancing rice farmers' resilience by providing them opportunities to produce additional sources of food and income.

In 2015, a total of eight studies were conducted, five of which are new to compensate with those that had been completed or terminated. Two of these new studies utilizes basic research to generate new information that would enhance understanding on the effect of various climate-related parameters on the rice crop, as well as insect pests and their natural enemies. The other three studies address urgent concerns related to climate change adaptation like: (a) coming with up with a super-efficient means of applying water in conditions where water is very limiting (as in the case El Nino), (b) providing farmers with low cost but typhoon resistant design of a multi-purpose farm structure, and (c) establishing optimal planting dates in areas that have already experienced changes in rainfall patterns such as the Ilocos region.

While the basic studies are still in their initial stage of experimentation, the applied studies have generated some proof of concepts. One study had yielded promising results that would lead to the development of a new irrigation system that has a very low water discharge (eliminating possible water losses due to run off, seepage, or percolation) and simple enough that it can be fabricated using recyclable materials at the farm level. Likewise, a prototype of a multi-purpose farm structure, designed to be typhoon-resistant yet also simple enough to allow local fabrication, had been constructed. Significant advancements had also been done in developing new planting calendar for the Ilocos region. With regards to further enhancing farmers' resilience to climate change, a diversified and integrated system of farming where azolla was integrated in the rice+duck system had been tested and found to generate additional income from the same piece of land planted to rice. Moreover, a multi-purpose dryer attachment to the continuous rice hull (CtRH) carbonizer had been developed which could provide farmers added income opportunities like production of dried tilapia ('tilanggit'), dried chips from root crops, and many other high value products.

I. Generation and management of local knowledge and information on climate change

Project Leader: AOV Capistrano

Inevitably, the general climatic patterns are bound to change as a result of unhampered accumulation of greenhouse gases in the atmosphere that were brought by incessant economic industrialization, and intensification of agriculture. Demand for food is also expected to exponentially increase as a consequence of a ballooning population further increasing the pressure to safeguard our food security.

Because of the miniscule total land area and population, the Philippines will not contribute significantly to the detriment of the climate. However, the country is in the forefront of bearing the brunt of the ill effects of climate change owing to its geographical location. Recent experiences of weather extremes such as intensified typhoons, increased frequency of flooding, and lenghtening episodes of El Niño are evidences that place the country in a very precarious position.

We may not be able to mitigate climate change but we can contribute to the understanding of its underpinning dynamics especially on how it will impact our currently vulnerable food security. Thus, the main goal of this project is to generate and manage local climate-related information and technologies in support to the climate change research. The output from this project will help provide knowledge on how climate change affects the local climate condition, crop production, pest and disease dynamics so as to, among other things, guide researchers and technical personnel on what further interventions to take in the future.

Analyzing climate effect on rice using long term data at PhilRice Central Experiment Station

AOV Capistrano

Historically, rice production in the country shows an increasing trend from 1970 up to the present, this span of time is also enough to assume that there has been a change in the climatic pattern following the globally accepted definition for climate change. An assessment of the rice production in the long-term against its corresponding climate was therefore being conducted to determine whether there really was climate change over this period and find out its contribution to rice production. At the PhilRice CES in Nueva Ecija, a long-term fertility experiment (LTFE) has been in place since 1968. Yield responses and trends to fertilization treatments has been recorded from this long-term experiment which can also be used to assess the climatic contribution to such yield responses using the weather data as early as 1974 from the Agromet station of PAGASA at the Central Luzon State University, approximately 10km from PhilRice-CES. This analysis may help us understand how the changing climate affects rice production that we may continue to adapt our practices and develop technologies that increase or sustain rice production amidst climate change.

Highlights:

- Simulated yield was compared with the actual yield of IR72 under NPK+ of LTFE and presented in Figure 1. Based on linear trend analysis, simulated yields were far from the actual yields obtained in the LTFE. Simulated yields were decreasing in trend whereas actual yields showed an increasing trend across years.

- Statistical analysis of the simulated yield and of actual yield in LTFE was conducted to determine the degree of probability of yield forecast by DSSAT. Using the LSD test at 5% level of significance, the probability of the simulated yield to occur in actual conditions is only 41% with a 4% deviation from the actual yield value. This low probability prohibits the study to move forward with the analysis because the yield performance of the varieties in LTFE cannot be fully verified that it was affected by weather parameters Rf, TO and SR, which were the input data in DSSAT. Had the modeling software (DSSAT) showed high consistency of simulated yield with the LTFE yield, differences in the weather patterns on a yearly basis can be analyzed.

- With the non-coherency of the actual LTFE yield and DSSAT simulated yield of IR72, simulations for IR8 and IR36 were no longer conducted. Further, the weather data supposed to be used for its simulation will come from PAGASA CLSU (i.e. due to unavailability of data from PhilRice from 1974-1984) which will potentially result in inconsistency because the weather data in the target simulation were different from the weather data in the LTFE site at PhilRice. As proof, periodic comparison of temperature data alone between PAGASA CLSU and PhilRice Agromet showed significant discrepancies from 1989-2006 when IR72 was included in the LTFE (Figure 2).

- In the absence of a modeling software that can be used to verify whether the actual LTFE yields were the result of variable weather parameters, analyzing climate effect on rice using this LTFE data may not be possible at the moment. Unless LTFE yields are verified to be consistent through crop modeling tools, only then can the weather patterns be analyzed of how it influenced the yield of rice.

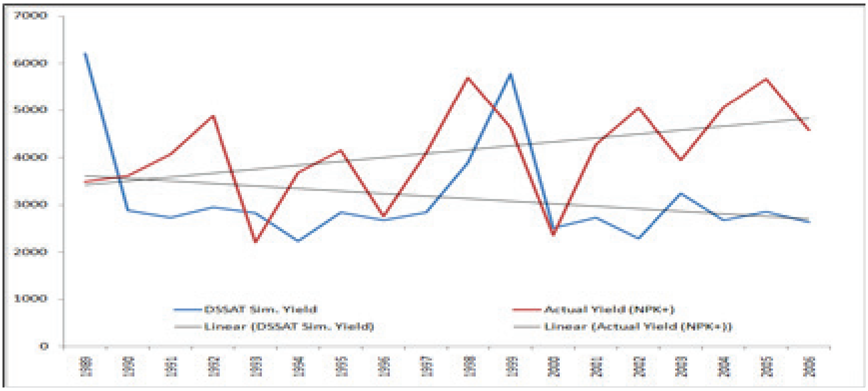

Figure 1. Comparison of the actual LTFE yield and simulated yield of DSSAT, 1989-2006.

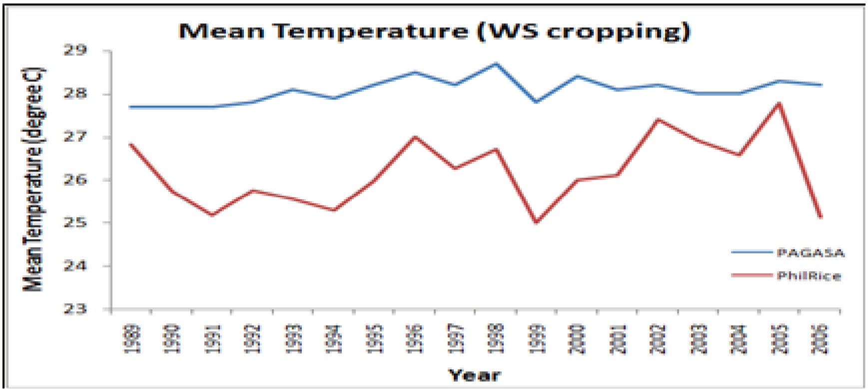

Figure 2. WS mean temperature as observed from PAGASA CLSU and PhilRice Agromet.

Identification of the growing degree-day (GDD) requirements at different phenological stages of public hybrid rice parentals and other inbreds
AOV Capistrano, JJE Aungon, and JEG Hernandez

The growing degree-days (GDD) of a crop is a more accurate/ specific basis of phenological stages than the number of departure days from the date of planting. Now that the earth is experiencing the climate change phenomenon, information of the GDD requirements and its optimization is particularly useful as surface temperatures become warmer and crop durations become shorter. Shorter physiological maturities also mean shorter phenological stages which could have serious implications in terms of farm management operations since execution of most farm operations are based on phenological stages of the crop. In rice, fertilizer management is one example of a farm operation dependent on the crop's phenology. Although, it can be argued that not-so-accurate schedules of fertilizer applications would only result in minimal yield losses however, the importance of knowing the accurate phenological duration cannot be undervalued in hybrid rice seed (F1) production. Synchronization of the flowering time is perhaps the best application of information regarding accurate phenological stages because unsynchronized flowering between hybrid rice parental would spell disaster in hybrid rice seed production hence, the need to accurately identify the phonological stages of the rice crop.

Highlights:

- Completed agronomic data gathering for four hybrid parental lines and nine inbred varieties.

- Monitoring of other phenological stages also completed.

- Sample data on tiller count for inbred and hybrid parental lines were partially processed and analyzed for trend patterns (Figure 3, 4 and 5).

- Temperature data from automatic weather station (AWS) were partially collected and processed for Heat Units.

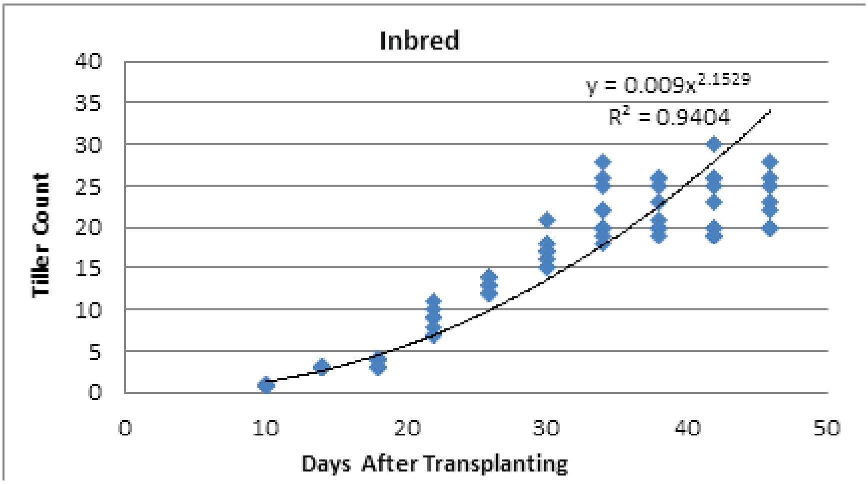

Figure 3. Days after transplanting (DAT) at reading and tiller count of NSIC Rc216.

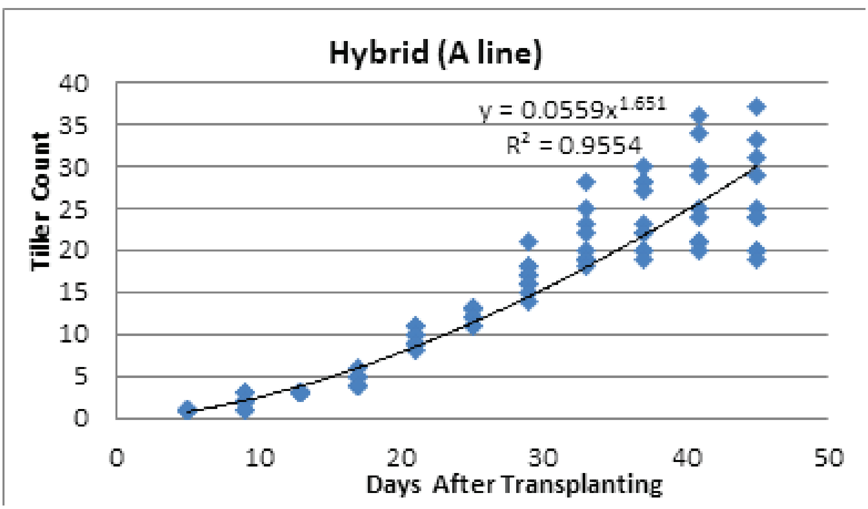

Figure 4. DAT at reading and tiller count of M55 (A line).

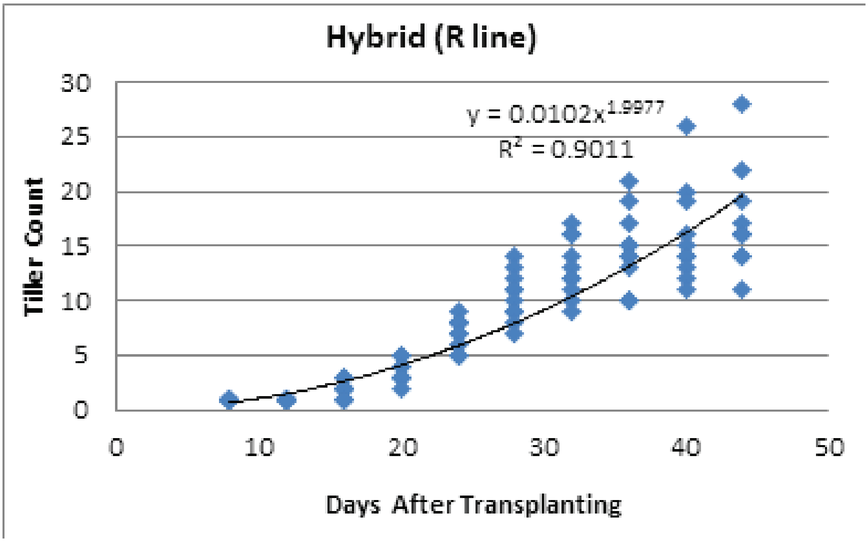

Figure 5. DAT at reading and tiller count of M55 (R line).

Impact of increasing temperature on rice insect pests and natural enemies

GS Rillon, AJ Gabriel, MJPS Ancheta, and JG Tallada

Temperature is probably the most important environment factor influencing insect behavior, distribution, development, survival and reproduction (Bale et. al. 2002). It has been estimated that, with a 2OC temperature increase, insects might experience one to five additional life cycles per season (Yamamura and Kiritani 1998). Moreover, climate change may affect the population dynamics of arthropods that will lead to change in the species composition of ecosystem, pests' migration and change in the geographic distribution of pests. On the other hand, naturally occurring biological control is expected to become a more important control tactic in the future because natural enemies may have faster potential growth rate. Warming might also have a negative effect on some natural enemies such as hymenopterans and small predators. Thus, understanding the impact of climate change to insects pests and their natural enemies is very important in preparing for and adapting management strategies against pests that may become established due to changes in their environments.

Highlights:

- The test prey insects such as brown planthopper (BPH) and green leafhopper (GLH) were collected and reared in the screen house.

- Completed the fabrication and testing of the insect growth chamber (IGC) for use in the conduct of future experiments (Figure 6). The IGC is equipped with a microcontroller (Arduino MEGA2560) which automatically controls the switching on and off of other electrical/electronic components of the IGC so as to maintain a certain range of the desired temperature of the air inside the IGC. It is also equipped with a DHT22 temperature sensor and a liquid crystal display that displays real time temperature of the air inside and outside of the IGC.

- For 2016, the IGC shall be used in the conduct of experiments that would determine the interaction of leaf hopper and its predator including the parasitism of yellow stem borer at three levels of temperatures (ambient temperature, 2°C and 4°C above ambient temperature).

Figure 6. The fabricated prototype of the IGC.

II. Development of crop management strategies, decision support systems and other technologies for climate change adaptation

Project Leader: ND Ganotisi

With the onset of climate change in the country, the importance of adaptation in rice production, among others, could not be emphasized more than ever. The onslaught of typhoons, subsequent droughts are just a preview of what the country could experience in the coming years. It is therefore imperative that a plan of action be put in place at the soonest possible time. Research and development initiatives must put all theories into practice to optimize technology potentials and equip the agriculture sector in order to minimize the effect of climate change impacts on food production. Thus, this project is being implemented in order to develop farming technologies, crop management strategies, and decision support tools for rice production that would help farmers cope up with the impacts of climate change.

Optimal planting dates based on recent agro climatic indices for rice and rice-based crops in Ilocos region

ND Ganotisi and MLO Quigao

This study was conducted to characterize the agro-climatic pattern of selected rice-based areas based on updated rainfall data (to serve as basis in developing more precise planting calendars) and to determine the agronomic and yield performances of rainfed rice as affected by different planting dates and by rice varieties. The 39 years daily rainfall data from the data bank of PAGASA MMSU were analyzed for the rainfall probability, dry weather harvest reliability (DWHR), sunshine reliability, weekly rainfall, number of rainy days, drought and excessive rainfall hazard. In addition, a field experiment was conducted in a typical rainfed site using the strip plot design with three replications to evaluate the eight planting schedules (first sowing - third week of June; second sowing - fourth week of June; third sowing - first week of July; fourth sowing - second week of July; fifth sowing - third week of July; sixth sowing - fourth week of July; seventh sowing - fifth week of July; and eight sowing - first week of August) and three rice varieties (PSB Rc82, NSIC Rc192 and Rc298) in Batac City, Ilocos Norte.

Highlights:

- Analyzed the daily rainfall data and prepared graphs of the agro-climatic indices based from 39 years (1978 to 2014) data from PAGASA-MMSU Agromet station which yielded the recommended planting schedules for rainfed in Ilocos Norte.

- Based from analysis, as shown in Figure 7, there was a 50%

rainfall probability starting from the third week of June, peaked during the first week until the third week of August at 65% probability and back to 50% during the third week of September. The rest of the months had lower than 50% rainfall probability. The DWHR was high from January to April then it decreased slightly from the first week of May until the last week of June. It was lowest from July and August and increased in September to October then it maintained high in November and December. Moreover, minimal rainfall occurred during January until the second week of May. Rainfall increased from the third and fourth week of May until an intense rainfall was persisting starting from the second week of July until the third week of September and peaks in the third and fifth weeks of August. Rainfall decreased until the fourth week of September and occurred slightly throughout November and December.

- There was a high probability of drought hazard during January to April and from November to December at 95 to 100%. On the other hand, excessive rainfall hazard occurred in July (58%), August (78%) and September (65%). There was a very low probability of excessive rainfall hazard during May and June ranging from 12 to 33% and the rest of the months have zero probability (Figure 8). The onset of rainy season occurred on the fourth week of May at 46% probability with 62 mm average weekly rainfall.

- Precise planting calendars were developed based from the analysis of the different agro-climatic indices wherein sowing of rice should start immediately after the onset of the rainy season and harvesting should fall during the period where the DWHR should not be lower than 70% as follows: (1) for early rice maturing varieties (≤110 DAS), sowing is recommended in the third to fourth week of June having an average weekly rainfall of 78 and 74 mm and it will be harvested in the fourth week of September to first week of October with DWHR of 76 and 81%, respectively; (2) the medium maturing varieties (111-126 DAS), is recommended to be sown from the first to the second week of June having an average weekly rainfall of 62 and 49 mm, respectively, and it will be harvested in the third to fourth week of October; and (3) the late maturing varieties (≥127 DAS), is recommended to be sown in the fourth to fifth week of May with an average weekly rainfall of 62 and 79 mm, respectively, and it will also be harvested in the fourth week of September to the first week of October.

- Results of field experiments showed that the plant height, productive tillers and yield were significantly affected by the different planting schedules and varieties measured at 110 DAS. Also, interaction of planting schedules at each level of variety significantly affected the plant height and yield but comparable on the number of productive tillers. Plants that were sowed in the first and second planting schedules were significantly taller than those in the other planting schedules. Plant height ranged from 61.9 to 85.7cm. On the other hand, yields of the varieties sown in the first planting schedule were significantly higher compared with the other planting schedules (Table 1).

- Highest yield was obtained from NSIC Rc298 sowed in the first planting schedule at 3.0t/ha and lowest was obtained from PSB Rc82 in the 8th planting schedule at 0.3t/ha.

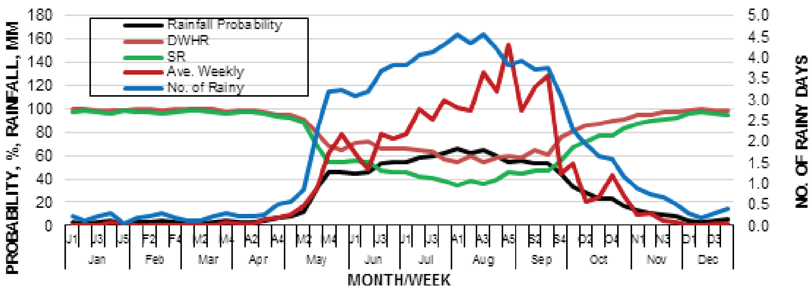

Figure 7. Agro-climatic indices derived from the daily rainfall data at PAGASA- MMSU Agromet station for the period 1979-2014.

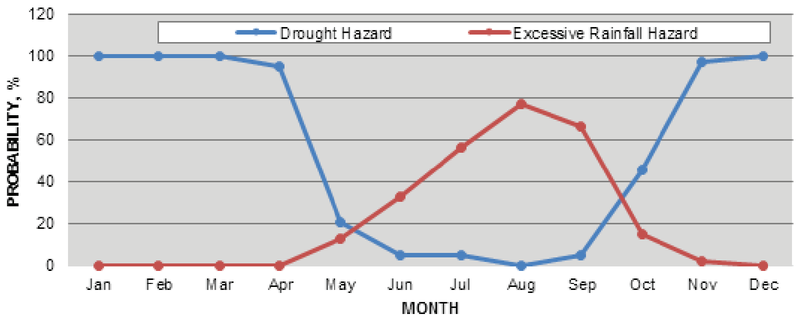

Figure 8. Drought and excessive rainfall hazards based from monthly rainfall data derived from PAGASA-MMSU for the period 1976-2014.

Table 1. Mean plant height, productive tillers at 110 DAS and yield as affected by planting schedules.

Planting Schedules	Plant Height (cm)		Productive Tillers per Hill		Yield (t/ha)	
1st	81.3	*a*	15	*a*	2.3	*a*
2nd	74.6	*ab*	13	*ab*	1.1	*b*
3rd	67.4	*bc*	12	*bc*	0.7	*bc*
4th	66.6	*c*	12	*bc*	0.7	*bc*
5th	65.9	*c*	12	*bc*	1.0	*b*
6th	62.5	*c*	11	*bcd*	0.8	*bc*
7th	64.9	*c*	9	*cd*	0.6	*bc*
8th	65.4	*c*	8	*d*	0.4	*c*

Design and development of prefabricated components for a low cost, easy to build and typhoon-resistant multi-purpose farm structure
RF Orge and DA Sawey

Farm structures play an important role in protecting farm investments. Obviously, during strong typhoons, these structures are not only the ones exposed to possible damage but also everything inside them. Thus, one way of protecting farm investments is to make the accompanying farm structures able to withstand strong typhoons.

Typhoon-resistant farm structures are perceived as costly because, among other things, farmers don't have access to inexpensive designs. In most cases, farmers are the ones making or designing their own structures in the farm and, in most cases, the science aspect of making these structures typhoon-resistant is often neglected. This study was conducted in order to come up with a design of a typhoon-resistant multi-purpose farm structure (MuFS) that would require low level of skill in its construction so that farmers can be trained to construct it by themselves. Through this, the cost of establishing a MuFS would be reduced and farmers would be empowered and capacitated thus enhancing their resilience to climate change.

Highlights:

- The first prototype of MuFS was designed following the same concept of a popular children's toy – the Lego bricks. It has a prefabricated basic construction unit (BCU) that has the shape of a pie but is curved along a plane that is perpendicular to its surface. The whole structure is dome shape, being considered as the nature's most efficient shape since, among other things, is covers the most floor area with the least total combined area of the wall and roof.

- Fabrication of the first prototype had been completed (Figure 9). With a floor area of 17.4m2, it is made of 32 BCUs with a total material cost of Php9,600 and consuming 147 labor-days.

- Each BCU was made of concrete (1:1 sand to cement ratio) reinforced with four layers of bamboo splits (approximately 1cm wide x 5cm thick) that had been weaved into 5cm x 5cm mesh.

- There were problems identified during the construction of the BCUs as well as during their assembly which resulted to more time spent in the construction of the individual BCUs as well as their assembly to form the whole structure. These had been considered in the second prototype to be constructed.

Figure 9. The multi-purpose farm structure during the start of assembling the BCUs (a) and when completed (b and c).

Irrigation by capillarity: development of an efficient method of irrigation for extreme drought

RF Orge and DA Sawey

Irrigation using the capillary principle, herein referred to as capillarigation, is a new concept of applying water and can be a practical and efficient way of irrigating crops. In this concept of irrigation, a stable supply of water is provided within the plants' root zone, making water (as well as nutrients mixed with it) always available to the plants. Unlike in drip irrigation system where there is still possibility of under-irrigation (resulting to water stressed plants) or over irrigation (too much water applied resulting to oversaturated root zone) as a result of miscalculation on the part of the farmer, in capillarigation, a stable supply of water is just placed within in the base of the root zone and is distributed throughout the vicinity by the capillary action thus always available and ready for pick up by plants. There is no danger of flooding since the movement of water is just governed by capillary action. This conserves a significant amount of water since, among other things, water lost through evaporation from the soil surface is minimized if not prevented. Moreover, the possibility of water loss due to seepage and percolation is eliminated.

In general, this study aims to develop an efficient system of applying water to plants specially during extreme drought conditions. Specifically, it aims to develop and evaluate the performance of an irrigation system for rice-based upland crops that operates by the principles of capillarity.

Highlights:

- Based on established criteria (low cost, maximizes use of locally available and recyclable materials, ease of fabrication, consistency of discharge, durability, ease of installation), a total of five materials, namely: bamboo strip (lapat), jute yarn, silk yarn (normally used in knitting, crocheting and weaving), cotton strip (from used t-shirts), and cotton yarn (from floor mop head) were identified and tested as to their suitability as to be used as wick using a laboratory setup shown in Figure 10.

- As shown in Table 2, among the wick materials tested, cotton yarn delivers the most uniform water discharge rate (WDR). Thus, it was selected as the most suitable wick material and was used in the follow-up experiments. By capillary action, a single cotton yarn (4 to 6mm dia) can deliver water at a rate of 35mL/h. As the size (diameter) of the cotton yarn increases, the WDR also increases.

- Among the parameters evaluated, the capillary height affects the WDR of the cotton yarn.

- The design of the whole irrigation system had been conceptualized using the results of the various laboratory trials and initial field trials had been established (Figure 11) showing the great potential of capillary-based irrigation system as a cost-efficient means of applying water especially during conditions when water supply is very limiting.

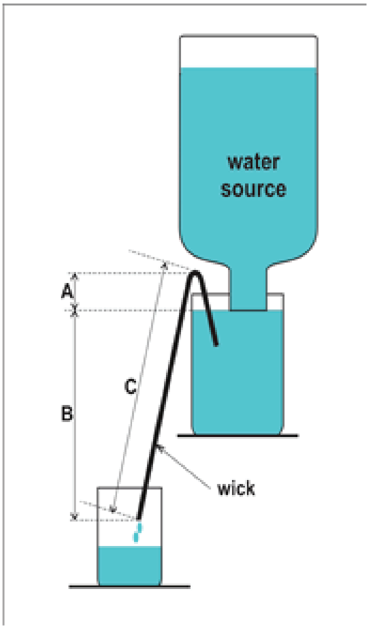

Figure 10. The experimental setup used in evaluating the water-carrying capacity of the selected wick materials.

Table 2. Water discharge rate of the different wick materials.

Wick material	Average discharge rate (mL/hr)	Standard deviation
Lapat	29.7	41.2
Jute yarn	31.5	15.4
Silk yarn	19.7	12.8
Cotton strip	45.3	7.3
Cotton yarn	30.6	3.8

Figure 11. Initial field setup of the capillarigation system using cotton yarn as wick and green pepper as test crop.

III. Enhancing the Adaptive Capacity of Rice Farmers through Diversification of Household Sources of Food and Income

Project Leader: RF Orge

It has been predicted that more people will be harmed than benefited by climate change. Those who will be harmed the most are those living in developing countries, particularly the poor. Studies show that without adaptation, climate change is generally problematic for agricultural production and for agricultural economies and communities; but with adaptation, vulnerability can be reduced and there are numerous opportunities to be realized. A lot of studies show that resilience to climate change can be best achieved through diversification of sources of income. Thus rice growing, being highly sensitive to extreme climate events, needs to be complemented with other income-generating activities that would maximize income generated given the limited land tilled by a farmer. This project is therefore being implemented to enhance the adaptive capacity of rice farmers through diversification of household sources of food and income.

Maximizing the use of the continuous rice hull (CtRH) carbonizer in generating additional sources of income for enhanced climate change resiliency of rice-based farming communities

RF Orge and DA Sawey

The production of rice hull into biochar using the PhilRice-developed CtRH carbonizer generates recoverable heat which could provide farmers additional income opportunities through processing of their produce into high value products. Under the Palayamanan system of farming, biochar from rice hull (carbonized rice hull) is popularly used as soil conditioner, animal bedding, and organic fertilizer ingredient, among other purposes. Thus while producing biochar which could be a regular activity in the farm, they can make use of this heat for various applications. This study generally aims to maximize the use of the CtRH carbonizer by utilizing the otherwise-wasted heat in creating additional income opportunities for the farmers, as a way of enhancing their resilience to climate change. Specifically, it aims to develop heat recovery attachments to the CtRH carbonizer and pilot test their use in the production of high value products.

Highlights:

- The performance of the CtRH carbonizer was monitored while being used in mushroom production at CES inorder to evaluate its performance under actual operating conditions. Operated at least once a week, the carbonizer was equipped with a heat reovery attachment wherein the heat generated during the carbonization process was used to generate steam that sterilized the mushroom fruiting bags. In every batch, the pasteurizer strilized 500 fruiting bags in 4 to 6 hours with zero, if not minimal, incidence of contamination (not exceeding 10%). The co-produced biochar from rice hull was then used extensively within the Palayamanan area.

- Among the major working parts, the chimney, steam generator, as well as the cover of the ignition chamber were the ones that need replacement, at most every six months for a weekly operation of the carbonizer. This was due to the fact that these parts are the ones exposed to extreme heat. In the design of the commercial prototype, these parts shall be made of stainless steel to lengthen their life span.

- A new heat recovery attachment to the CtRH carbonizer was also designed and fabricated as an answer to the request of the municipal government of Laoac, Pangasinan to develop a dryer for use in the production of dried tilapia (which they call 'tilanggit'). To maximize its application, the attachment was designed not only to dry fish but also other commodities (chips from root crops, charcoal briquettes, etc.) as well as other functions such as roasting fish and chicken as well as baking, by changing its trays and putting them in appropriate location relative to the source of heat. The first fabricated prototype was purchased by the municipality of Laoac and additional 4 units had been ordered for use in Tilanggit production as income generating project for their selected beneficiaries.

Figure 12. The multi-purpose dryer attached to the CtRH carbonizer.

Rice-duck-based farming system for enhanced climate change resiliency of farming households
RG Corales, JM Rivera, EM Valdez, and FS Grospe

Rice-duck production enables farmers to obtain higher yields while reducing the application of fertilizer, herbicides and insecticides. Ducks can be sold as pullets or can be kept for egg production.

Azolla is a floating fern and belongs to the family of Azollaceae, which is responsible for the fixation and assimilation of atmospheric nitrogen. Azolla is an important bio-fertilizer for wetland paddy and can be used as an ideal feed for fish, livestock, and poultry. It is popular and cultivated widely in countries like China, Vietnam, and the Philippines.

This study aims (1) to determine the effect of ducks and azolla on soil quality, methane emission, productivity and economics of rice production (2) to determine the effect of releasing two batches of ducks on weeds, snail and arthropod diversity, and disease incidence (3) to determine the effect of azolla on duck growth and development.

The study was conducted at PhilRice CES from January to December, 2015. The experiment was laid out in Randomized Complete Block Design with three replication. Plot size was 386m^2 . The treatments were: T1: 0-40-40 kg NPK/ha; T2: recommended fertilizer rate (RFR) (i.e.

120-40-40kg NPK/ha during dry season (DS) and 90-40-40kg NPK/ha during wet season (WS)), T3: RFR + 1 ton azolla/ha, T4: RFR with ducks, and T5: RFR + 1 t/ha azolla with ducks.

In 2015 DS, 500 heads 21-day old mallard ducklings were released in the rice paddies at 21 days after transplanting, and withdrawn at heading stage, followed by 1000 heads of 10-day old ducklings released at heading stage.

Highlights:

- There was an outbreak of stemborer during the DS causing significant yield losses in all treatments ranging from 25.57 to 36.52% white head counts. The outbreak could be the effect of the prolonged drought.

- Rice yields obtained during the DS ranged from 2.05 to 3.38t/ha (Table 3) with the highest yield obtained from 0-40-40kg NPK/ha treatment. The generally low yield was due to high stemborer infestation which reached to about 45% damage. The seemingly higher yield obtained from 0-40-40 kg NPK/ha treatment was due to lower stemborer infestation (18% damage).

- During the WS, treatments with azolla produced the highest yields (7.53t/ha) while the lowest yield was obtained from T1 (0-40-40 kg NPK/ha) with 5.97 t/ha (Table 3).

- Income obtained from rice production during the DS was also generally low ranging from -Php5,780.50 to Php19,828.00 because of low yield. Income from duck production was also generally low because of high mortality rate (around 30%) due to poor quality stock and transport stress of the ducklings (Table 4).

- Income derived from rice production during the WS ranged from Php62,000.00 to Php87,600.00 with the highest income obtained from RFR + azolla, while the lowest income was noted from 0-40-40 kg NPK/ha. Additional income of around Php19,500 was obtained from duck production in with and without azolla treatments (Table 5).

- The cumulative methane emission (718.7kg CH_4/ha) of rice plants integrated with duck and with azolla application was significantly higher compared to those with application of NPK alone (129.9kg CH_4/ha, NPK+ azolla (109.6kg CH_4/ha) and PK alone (90.2kg CH_4/ha), respectively.

Table 3. The effect of ducks and azolla integration on rice yield. PhilRice CES. 2015.

Treatment	Yield (t/ha)		
	Dry Season NSIC Rc202H	Wet Season (NSIC Rc160)	Mean
T1: 0-40-40 kg NPK/ha	3.38	5.97	4.68
T2: Recommended fertilizer rate (RFR)*	2.78	7.10	4.94
T3: RFR + Azolla (1t/ha)	2.05	7.63	4.84
T4: RFR with Duck	3.29	7.20	5.25
T5: RFR + Azolla + Duck	3.36	7.53	5.45
Mean	2.97	7.09	5.03

** DS: 120-40-40 kg NPK/ha; WS: 90-40-40 kg NPK/ha*

Table 4. Economic analysis of rice-duck based production system. PhilRice CES. 2015 DS.

Treatment	Rice			Ducks			Net Income/ Season
	Gross Income	Expenses	Net Income	Gross Income	Expenses	Net Income	
T1	67,600.00	47,772.00	19,828.00	–	–	–	19,828.00
T2	55,600.00	48,532.50	7,067.50	–	–	–	7,067.50
T3	41,000.00	46,780.50	(5,780.50)	–	–	–	(5,780.50)
T4	65,800.00	49,756.50	16,043.50	47,600.00	41,890.00	5,710.00	21,753.50
T5	67,200.00	49,924.50	17,275.50	49,700.00	42,100.00	7,600.00	24,875.50

Table 5. Economic analysis of rice-duck based production system. PhilRice CES. 2015 WS.

Treatment	Rice			Ducks			Net Income/ Season
	Gross Income	Expenses	Net Income	Gross Income	Expenses	Net Income	
T1	119,400.00	57,440.00	61,960.00	–	–	–	61,960.00
T2	142,000.00	62,843.60	79,156.40	–	–	–	79,156.40
T3	152,600.00	64,963.60	87,636.40	–	–	–	87,636.40
T4	144,000.00	61,743.60	82,256.40	63,000.00	43,430.00	19,570.00	101,826.40
T5	150,600.00	63,063.60	87,536.40	63,000.00	43,430.00	19,570.00	107,106.40

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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