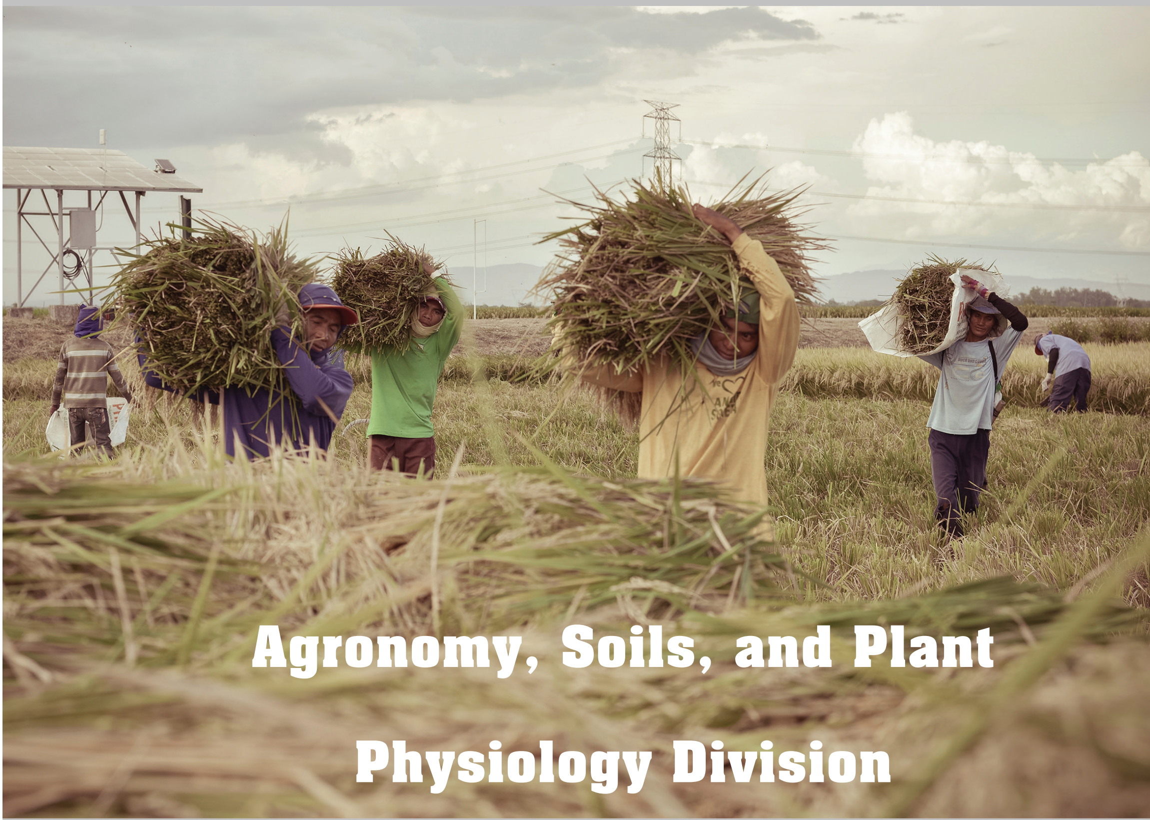
2015 National Rice R&D Highlights



Agronomy, Soils, and Plant Physiology Division

Department of Agriculture
PHILRICE
PHILIPPINE RICE RESEARCH INSTITUTE

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AGRONOMY, SOILS, AND PLANT PHYSIOLOGY DIVISION

Division Head: LM Juliano

Executive Summary

The ASPP Division leads national efforts in the conduct of quality research focused toward identifying, evaluating, refining, and facilitating delivery of improved soil, plant, nutrient, and water management practices that are resource-use efficient and environment-friendly for rice and rice-based ecosystems. This major final output should be able to contribute to the goal of PhilRice in helping attain and sustain rice self-sufficiency. The midterm goal is to package technologies to increase yield by 15% in less productive environments and sustain yield in high-yielding environments. The functional objectives are identified based on the specific tasks assigned to the division to wit: (1) identify and propagate approaches for nutrient and crop management with the integration of management of principal insect pests and disease; (2) develop technologies that will improve soil and water conservation practices; (3) develop practices to manage crop residues for healthy soils in rice ecosystems; (4) strengthen the scientific basis for rice-based cropping system technologies; and (5) assess the impact of developed technologies on environmental quality. Finally, the division is expected to develop crop management protocol, diagnostic tools, and processes toward sufficiency and sustainability.

In 2015, five (5) research projects and a project on laboratory management were implemented to partially approach the main objective of the Division. These projects were (1) Long-term Soil Fertility Evaluation and Rice Plant Responses, (2) Improved Rice Productivity and Resource-Use Efficiency using Diagnostic Support Systems, (3) Assessment and Evaluation of Crop Intensification and Resource Use Efficiency in Rice, (4) Assessment and Evaluation of Variety, Water, Nutrient and Pest Interactions, and to support these activities there is the ASPPD Research and Analytical Laboratory Systems and Maintenance.

I. Long-Term Soil Fertility Evaluation and Rice Plant Responses

Project Leader: WB Collado

In 2015, two studies have been conducted to assess the effectiveness of the different strategies in managing the nitrogen (N) requirement of lowland rice varieties under the Maligaya soil condition using inorganic and organic sources for the rice plant, and another study in determining the inherent productivity of different rice farms and assessing the durability of farmer's rice cropping based on their nutrient management approaches in Sta. Cruz, Laguna, Maligaya, Nueva Ecija, and San Manuel, Pangasinan.

The long-term fertility study aims to determine the sustainability of intensive double rice cropping, and provide an early warning indicator of nutrient imbalances and nutrient mining that can occur with crop intensification. The treatments with combinations of N, P, and K fertilizer assessed the long-term nutrient supplying capacity of the soil, while the control (without fertilizer application) assessed the long-term indigenous nutrient-supplying capacity of the soil of the experimental field.

In the long-term trial on the use of organic fertilizers, a trend of getting similar yield from the pure organically grown rice plants to that of the inorganically applied plants was consistently observed every after 2 years of continuous use of organic fertilizers in paddy soils as observed in the wet season only but not in the dry season with the exceptional case where after 6 years of organic fertilizer application, where such similar yield was observed after 4 years, and back to every 2 years thereafter.

Long-term soil fertility experiment

WB Collado (PhilRice), EV Laureles and RJ Buresh (IRRI)

The Long Term Fertility Experiment started in 1968, aims to study the sustainability of intensive double rice cropping and provide an early warning indicator of nutrient imbalances and nutrient mining that can occur with intensification in farmer's fields. The study aimed to achieve high and stable rice production on a sustainable basis in the treatment with full application of nitrogen (N), phosphorus (P) and potassium (K). The treatments with combinations of N, P, and K fertilizer enabled an assessment of the long-term nutrient supplying capacity of the soil. The control without N, P and K fertilizer application enabled an assessment of the long-term indigenous nutrient-supplying capacity of the soil of the experimental field.

Highlights:

Grain Yield

- The 2015 dry season cropping was severely affected by stemborer during the reproductive stage (Table 1). Highest incidence of stemborer damage (whitehead was recorded in the application of full NPK at 78.4 and 76.7% (average of 3 rice varieties) in the SSNM-N, +PK and +NPK treatments applied with 165 and 210kg N ha-1, respectively; lowest incidence of stemborer damage at 28.3% was observed in the –NPK treatment;

- Grain yields of the test rice varieties were very low due to the severe effect of stemborer infestation (Table 2);

- There was no trend on the effect of stemborer based on the fertilizer treatments, although, highest yield was obtained from the unfertilized plants (Table 2).

- The 2015 wet season cropping experienced some degree of yield loss from lodging due to the occurrence of two typhoons during the flowering and maturity stages. However, good yields were still obtained from plots that did not lodged totally (Table 103). Significantly lowest yield was obtained from the unfertilized plants with an average of 4.49t/ha-1. Highest yield was obtained from the plants that received nitrogen and phosphorus but without potassium (5.90t/ha-1), although this yield level was comparable to the plants applied with complete NPK (N applied at fixed time) and with PK but without N. The application of N based on the LCC gave an average yield of only 5.20t/ha-1 (average of NSIC Rc 158 and NSIC Rc160 only);

- Among the components of yield that contributed to the increase in grain yield was the number of spikelets per panicle. Higher number of spikelets were obtained from the plants applied with fertilizer regardless of the nutrient combinations. This was followed by the number of panicles per unit area. Again, higher number of panicles were obtained from the plants applied with fertilizer regardless of the nutrient combinations.

- No significant interaction between nutrient and pest was observed during the wet season cropping as no disease was observed and recorded.

- The agronomic nitrogen-use efficiencies (NUE) of the rice varieties tested varied with respect to the fertilizer treatments (Table 4). Highest average NUE of 17.68 kg grain kg N-1 was obtained in the treatment without K but with N and P. This was followed by the application of full NPK (N applied at fixed time across growth stages).

- The indigenous N, P and K supplies of the experimental area during the wet season cropping is shown in Table 12. Highest N supplies of 81.96 kg ha-1 was obtained in the –N, +PK treatment compared to the unfertilized plants or -NPK treatment (67.3kg/ha-1). Indigenous P supplies were similar in the –NPK and the –P, +NK treatments. Higher indigenous K supplies were obtained in the –K, +NK treatment (88.51kg/ha-1) compared to the –NPK treatment (67.3kg/ha-1)

Table 1. Incidence/severity damage of stemborer in the three test rice varieties. 2015 DS, PhilRice CES, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines.

FERTILIZER TREATMENT	PSB Rc52	NSIC Rc158	NSIC Rc160	MEAN
-NPK	25.0 bcd	46.7 abcd	13.3 cd	28.3
SSNM-N+PK	75.3 ab	76.3 ab	83.6 ab	78.4
+NK, -P	85.0 a	74.6 ab	28.6 abcd	62.7
+NP,-K	37.5 abcd	62.9 abc	2.1 d	34.2
+NPK	79.9 ab	71.1 abc	79.1 ab	76.7
-N, +PK	50.9 abcd	62.0 abc	45.7 abcd	52.9

In a column, means followed by a common letter are not significantly different at the 5% level by Scheffe's test.

Table 2. Grain yields of the test rice varieties as affected by stemborer infestation. 2015 DS, PhilRice CES, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines.

FERTILIZER TREATMENT	PSB Rc52	NSIC Rc158	NSIC Rc160	MEAN
-NPK	1.79	0.99	2.33	1.70
SSNM-N+PK	0.99	2.33	0.51	1.28
+NK, -P	2.33	0.51	0.77	1.20
+NP,-K	0.51	0.77	0.58	0.62
+NPK	0.77	0.58	0.72	0.69
-N, +PK	0.58	0.72	0.85	0.72

Table 3. Grain yields of the test rice varieties as affected by the fertilizer treatments. 2015 WS, PhilRice CES, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines.

FERTILIZER TREATMENT	VARIETY (V)			V MEAN
	PSB Rc52	NSIC Rc158	NSIC Rc160	
-NPK	4.61	4.41	4.45	4.49 c
SSNM-N+PK	4.50*	5.07	5.33	4.96 b (5.20) w/o PSB Rc52
+NK, -P	4.78*	5.24	5.77	5.27 b
+NP,-K	5.71	5.91	6.08	5.90 a
+NPK	5.42	5.50	5.47	5.46 ab
-N, +PK	5.21	5.51	5.60	5.44 ab

Means followed by a common letter are not significant at the 5% level by SNK test.
**Severe lodging due to typhoon*

Table 4. The components of yield (average of 3 rice varieties) as affected by the fertilizer treatments. 2015 WS, PhilRice CES, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines.

FERTILIZER TREATMENT	YIELD COMPONENTS			
	Spikelets/panicle	Panicle/m^2	Filled Grains, %	1000-Grain wt., g
-NPK	123.24 b	218.52 b	84.75 bc	22.68 b
SSNM-N+PK	147.56 a	236.81 ab	88.11 a	23.64 a
+NK, -P	146.47 a	243.06 a	87.64 ab	23.70 a
+NP,-K	137.8 a	258.56 a	84.10 c	22.90 b
+NPK	144.02 a	247.92 a	86.88 abc	23.69 a
-N, +PK	130.91 a	247.92 a	86.39 abc	23.63 a

Table 5. The agronomic nitrogen-use efficiencies of the test rice varieties (kg grain produced kg N-1 applied). 2015 WS, PhilRice CES, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines.

FERTILIZER TREATMENT	VARIETY (V)			V MEAN
	PSB Rc52	NSIC Rc158	NSIC Rc160	
SSNM-N+PK		7.41	9.78	8.60
+NK, -P	2.17	10.49	16.54	9.73
+NP,-K	13.75	18.79	20.49	17.68
+NPK	10.16	13.67	12.83	12.22

Table 6. The indigenous nutrient supplies of the experimental area (kg ha-1). 2015 WS, PhilRice CES, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines.

FERTILIZER TREATMENT	Indigenous Nutrient Supply (kg grain kg N^{-1})			V MEAN
	PSB Rc52	NSIC Rc158	NSIC Rc160	
INS (-NPK)	69.13	66.08	66.68	67.30
IPS (-NPK)	11.98	11.45	11.56	11.66
IKS (-NPK)	69.13	66.08	66.68	67.30
IPS (-P, +NK)	12.43	13.64	15.00	13.69
IKS (-K, +NP)	85.63	88.63	91.27	88.51
INS (-N, +PK)	81.33	82.48	82.07	81.96

'S: indigenous nitrogen supply; IPS: indigenous phosphorus supply; IKS: indigenous potassium supply

Long-term use of organic fertilizers in paddy soils

EF Javier and AE Espiritu

The experiment on the continuous use of organic fertilizers in paddy soils started in 2003 WS at the PhilRice CES with soil type characterized as Maligaya clay soil series, to (1) determine the long-term effects of different organic fertilizers or amendments on the physico-chemical characteristics and nutrient availability for rice in paddy soils; (2) assess sustainability of grain yield production and soil health by just the use of organic fertilizers in paddy soils as compared to the use of inorganic fertilizers; (3) assess grain quality, nutrient content and seed viability of organically nourished rice plants and (4) to produce database for the development of an organic-based rice production management protocol.

On the 11th year (2015) of the study, concern on the supply and availability of organic materials within the farming systems was considered and given attention. The Titonia diversifolia or wild sunflower as green manure treatment was replaced by Azolla microphylla. This Azolla variety, among other tested varieties can grow prolifically in the lowland irrigated rice ecosystem with high temperature and high relative humidity. It is now produced at PhilRice CES in large quantity, more so it can now be produced within the farming system. Likewise, with the availability of vermicompost at PhilRice Material Recovery Facility (MRF), replaced the commercial organic fertilizer. Vermicomposting is one of the internal process of recycling biomass and farm wastes within the farming system into fertilizers.

Highlights:

- In 2015 DS, there were no significant differences on the yield obtained from the different organic fertilizer tested. Lowest yield was obtained from control plot (4.12t/ha-1) and was comparable with yields obtained from OF. In 2015 WS, highest yield was obtained in plots with RS (6.38t/ha-1) but was not significantly different from other OF tested except for COF where grain yield was lowest (4.86t/ha-1) (Figure 31).

- At the average, highest yield (6.28t/ha-1) in the 2015 DS was obtained in plots applied with the full rate of inorganic NPK in combination with organic materials basally applied, regardless of the materials used. Likewise, using only 50% of inorganic NPK fertilizer rate combined with basal OF gave an average yield of 6.06t/ha-1. Lowest yields were obtained from the applied OF alone (ave 4.62t/ha-1).

- In WS, highest average yield was obtained in plots applied with 50% of inorganic NPK fertilizer combined with basal OF (6.30t/ha-1) and full rate of inorganic NPK in combination with organic materials basally applied (6.17t/ha-1).

- OF alone gave an average yield of 5.70t/ha-1. Lowest yields were obtained from control plot (4.77t/ha-1). This implied that in the WS, the OF can give an increased yield of 16% but not in the DS.

- In terms of agronomic use efficiency (Figure 42), the use of OF alone in WS showed higher agronomic use efficiency (average 15kg grain produced kg N-1 applied) than in DS (average 9kg grain per kg N applied).

- A trend of getting similar yield from the pure organically grown rice plants to that of the inorganically applied plants was consistently observed every after 2 years of continuous use of organic fertilizers in paddy soils is observed in the wet season only but not in the dry season (Figure 53) with the exceptional case where after 6 years of organic fertilizer application, where such similar yield was observed after 4 years, and back to every 2 years thereafter.

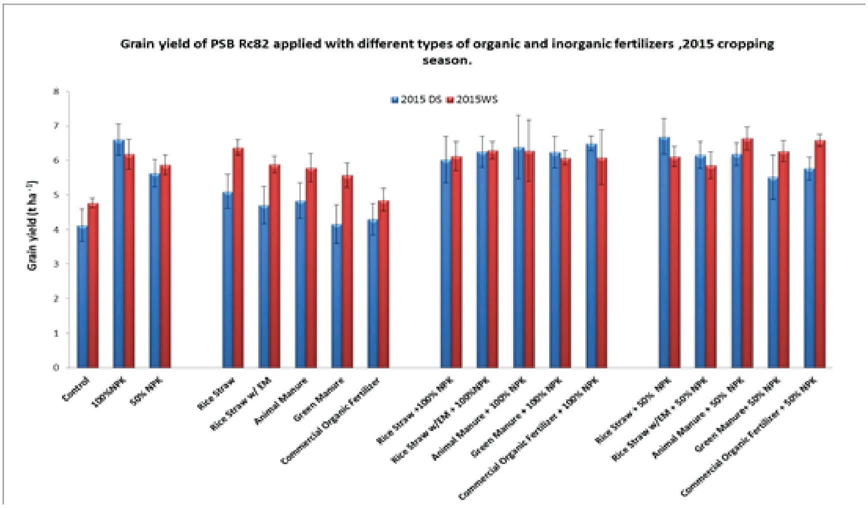

Figure 1. Grain yield (tons/ha) of PSB Rc82 applied with different types of organic and inorganic fertilizers in 2015 cropping season. 2015. PhilRice CES, Science City of Muñoz, Nueva Ecija.

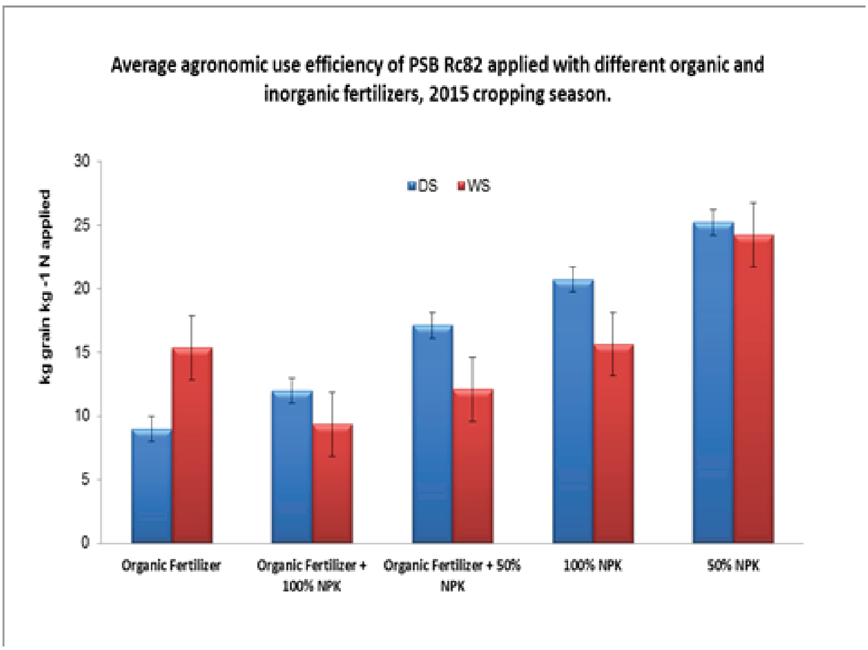

Figure 2. Agronomic use efficiency (kg grain kg-1 N applied) of PSB Rc82 applied with different types of organic and inorganic fertilizers in 2015 cropping season. PhilRice CES, Science City of Muñoz, Nueva Ecija.

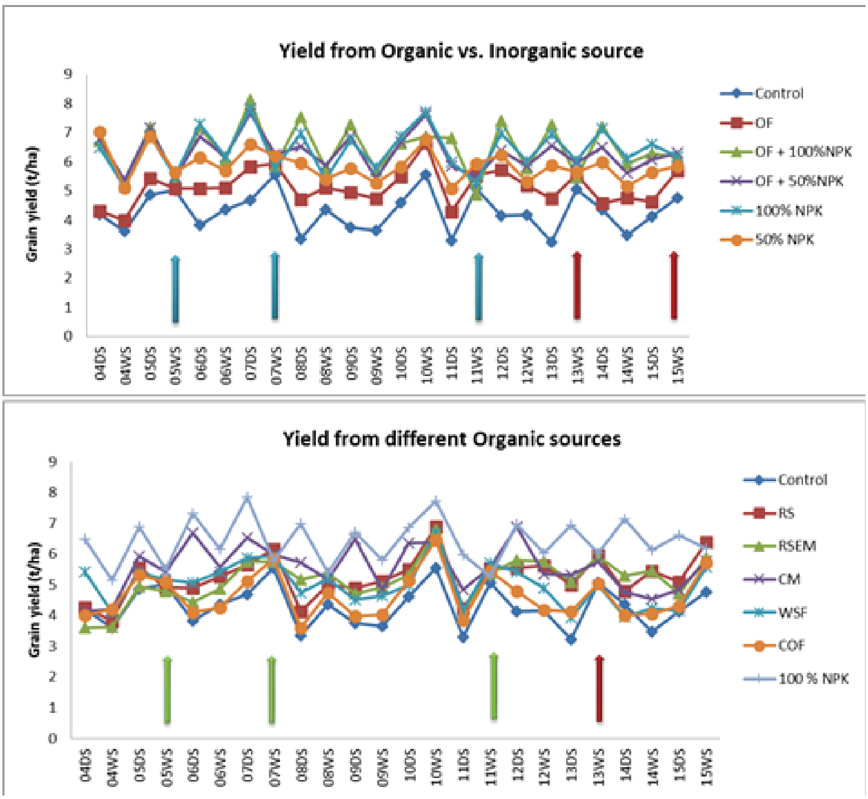

Figure 3. Yield of PSB Rc82 applied with different types of organic and inorganic fertilizers across seasons. 2004-2015. Maligaya clay soil series. Science City of Muñoz, Nueva Ecija.

Durability of rice-rice cropping in irrigated lowland ecosystem

JC Magahud, SLP Dalumpines, and WB Collado

Durability, in the level of cropping system, refers to the influence of time on the resources involved. A durable production system is one in which the quality or efficiency of the resources used does not diminish over time, so that for a given cropping system outputs do not decrease when inputs are not increased. Cropping system durability can be measured by assessing properties contributing to crop productivity that are inherent to soil, and those contributed by farm management practices. By assessing such, we can identify the weaknesses of cropping systems in terms of natural and farm management factors, so we can employ practices that can make our cropping systems durable. The objectives of the study is to determine the inherent productivity of paddy soils, assess the effect of farmers' nutrient management practices vis-à-vis Rice Crop Manager on soil productivity, and come up with management recommendations for improving productivity of paddy soils. To accomplish such objectives, suitability analyses based on the method of Sys et al. (1993), nutrient omission techniques, and partial NPK budget analysis of farmers' practice vs. Rice Crop Manager are being conducted.

Four sites each in three provinces were selected (Table 147). Sites in Sta. Cruz, Laguna has been managed by farmer-interviewees for at least 10 years. Sites in Muñoz City, Nueva Ecija (N.E.) has been managed for at least 7 years, and those in San Manuel, Pangasinan for at least 6 years.

Table 7. Identified soil series and water sources in the study sites. 2015.

Site	Soil Series	Irrigation Dam or Reservoir
Malinao, Sta. Cruz, Laguna a (Sta. Cruz A)	Lipa	Calumpang
Malinao, Sta. Cruz, Laguna b (Sta. Cruz B)	Lipa	Calumpang
Malinao, Sta. Cruz, Laguna c (Sta. Cruz C)	Lipa	Calumpang
Labuin, Sta. Cruz, Laguna (Sta. Cruz D)	Lipa	Calumpang
Maligaya, Muñoz City, N.E. A (Muñoz A)	Maligaya	Pantabangan
Maligaya, Muñoz City, N.E. A (Muñoz B)	San Manuel-Maligaya	Pantabangan
Maligaya, Muñoz City, N.E. A (Muñoz C)	Maligaya	Pantabangan
Catalanacan, Muñoz City, N.E. (Muñoz D)	Maligaya	Pantabangan
San Roque, San Manuel Pangasinan (San Manuel A)	San Manuel	San Roque
San Bonifacio, San Manuel Pangasinan (San Manuel B)	San Manuel	San Roque
Guiset Norte, San Manuel, Pangasinan a (San Manuel C)	San Manuel	San Roque
Guiset Norte, San Manuel, Pangasinan b (San Manuel D)	San Manuel	San Roque

Highlights:

Partial Nutrient Budget

- A positive nitrogen (N) balance is expected in Laguna sites due to combined inputs from chemical and organic fertilizers, and Azolla; and incorporation of rice straw. Nitrogen inputs from chemical fertilizers are relatively low in Nueva Ecija sites, but N is conserved in this area because farmers return rice straw into the field (Table 8a). Nitrogen inputs from chemical fertilizers are relatively higher in Pangasinan sites but farmers usually burn or remove rice straw from the fields.

- A positive phosphorus balance for Laguna ang Nueva Ecija sites can be expected due to combined inputs from chemical and organic fertilizers, and incorporation of rice straw (Table 8b).

- Potassium inputs from chemical fertilizers are relatively higher in Nueva Ecija sites (Table 8c).

Table 8a. Partial nitrogen budget of study sites based on fertilizers applied and rice straw management.

Site	Input from chemical fertilizers	Input from organic fertilizers and *Azolla*	Rice straw management [d]
Laguna			
Sta. Cruz A	74	120[b]	-3
Sta. Cruz B	66	235[ab]	+31
Sta. Cruz C	149	115[a]	+31
Sta. Cruz D	176	115[a]	+31
Average	**116**	**146**	**23**
Nueva Ecija			
Muñoz A	89	0	+31
Muñoz B	85	0	+31
Muñoz C	79	0	+31
Muñoz D	135	0	-3
Average	**97**	**0**	**23**
Pangasinan			
San Manuel A	156	0	-3
San Manuel B	163	0	-3
San Manuel C	115	0	-3
San Manuel D	103	0	+31
Average	**134**	**0**	**6**

[a]*manure fertilizer;* [b]*Azolla (Watanabe, 1982);* [d]*-3 kg/ha if straw is removed or burned, +31 if straw is returned or incorporated*

Table 8b. Partial phosphorus (P) budget of study sites based on fertilizers applied, P content of irrigation water and rice straw management.

Site	Input from chemical fertilizers	Input from organic fertilizers	Input from irrigation water [c]	Rice straw management [d]
Laguna				
Sta. Cruz A	3	0	2	-1
Sta. Cruz B	10	18[a]	1	+4
Sta. Cruz C	5	18[a]	1	+4
Sta. Cruz D	6	18[a]	2	+4
Average	**6**	**14**	**1**	**3**
Nueva Ecija				
Muñoz A	12	0	_	+4
Muñoz B	11	0	_	+4
Muñoz C	21	0	_	+4
Muñoz D	14	0	_	-1
Average	**15**	**0**		**3**
Pangasinan				
San Manuel A	13	0	_	-1
San Manuel B	12	0	_	-1
San Manuel C	5	0	_	-1
San Manuel D	11	0	_	+4
Average	**41**	**0**		**0**

[a]manure fertilizer; [c]10 kg/ha for 1 mg/kg of nutrient in irrigation water; [d]-1 kg/ha if straw is removed or burned, +4 if straw is returned or incorporated (Dobermann & Fairhurst, 2000)

Table 8c. Partial potassium (K) budget of study sites based on fertilizers applied, K content of irrigation water, and rice straw management.

Site	Input from chemical fertilizers	Input from organic fertilizers	Input from irrigation water[c]	Rice straw management[d]
Laguna				
Sta. Cruz A	6	0	64	-72
Sta. Cruz B	13	20[a]	59	-2
Sta. Cruz C	9	20[a]	59	-2
Sta. Cruz D	11	20[a]	62	-2
Average	**10**	**15**	**61**	**-26**
Nueva Ecija				
Muñoz A	48	0	_	-2
Muñoz B	32	0	_	-2
Muñoz C	40	0	_	-2
Muñoz D	27	0	_	-72
Average	**37**	**0**		**-26**
Pangasinan				
San Manuel A	26	0	_	-72
San Manuel B	23	0	_	-72
San Manuel C	9	0	_	-72
San Manuel D	21	0	_	-2
Average	**20**	**0**		**-55**

[a]manure fertilizer; [c]10 kg/ha for 1 mg/kg of nutrient in irrigation water; [d]-72 kg/ha if straw is removed or burned, -2 if straw is returned or incorporated

Suitability of Chemical Properties

- pH levels and organic matter, total N, available P and exchangeable K contents were generally below the optimum levels or contents (Table 169).

Table 9. Suitability of chemical soil properties to rice production of the different study sites.

Site	pH	organic matter %	total N %	available P mg/kg	exchangeable K me/100 g
Optimum level	5.6-6.7[a]	>2.67[b]	>0.20%[c]	>20.0[d]	>0.45[e]
Nueva Ecija					
Muñoz City A	5.5	3.02	0.13	3.1	0.25
Muñoz City B	4.9	2.23	0.11	3.5	0.32
Muñoz City C	4.8	2.54	0.15	6.5	0.38
Muñoz City D	5.1	2.35	0.10	10.0	0.18
Muñoz City E	4.8	2.42	0.12	7.6	0.14
Pangasinan					
San Manuel A	4.8	2.58	0.13	20.0	0.34
San Manuel B	5.5	3.46	0.13	23.0	0.38
San Manuel C	5.0	2.26	0.12	8.7	0.36
San Manuel D	5.4	3.59	0.15	14.0	0.49

[a]Costelo et al. (2008), [b]Sys et al. (1993), [c]Descalsota et al. (2005); [d,e]Dobermann & Fairhurst (2000)

Nutrient Status

- Out of the 13 sites, all are deficient in nitrogen, 92% are deficient in potassium and 69% are deficient in sulfur (Table 10).

- 77% of the sites are sufficient in copper and zinc.

Table 10. Nutrient deficiency (D) and sufficiency (S) in study sites using minus-one element technique (2015 WS)+.

Site	Omission Pots					
	-N	-P	-K	-S	-Cu	-Zn
Laguna						
Sta. Cruz A	D	D	D	D	D	D
Sta. Cruz B	D	S	D	D	S	S
Sta. Cruz C	D	D	D	D	S	S
Sta. Cruz D	D	S	D	D	S	D
Nueva Ecija						
Muñoz City A	D	D	D	D	S	S
Muñoz City B	D	S	D	D	S	S
Muñoz City C	D	S	D	D	S	S
Muñoz City D	D	S	D	S	S	S
Muñoz City E	D	S	D	D	S	S
Pangasinan						
San Manuel A	D	D	S	S	S	S
San Manuel B	D	D	D	S	D	D
San Manuel C	D	S	D	D	S	S
San Manuel D	D	D	D	S	D	S

+deficient if rice biomass is <80%, and sufficient if >80% of the biomass planted in the pot supplied with complete set of nutrients

Grain and Straw Yields of Farmer's Practice vs. Rice Crop Manager

- In general, grain and straw yields are not significantly different for farmer's practice and Rice Crop Manager in all sites (Table 11).

Table 11. Yield comparison for Farmer's Practice vs. Rice Crop Manager plots (2015 WS).

Site	Grain yield (t/ha)		Straw yield (t/ha)	
	Farmer's practice	Rice Crop Manager	Farmer's practice	Rice Crop Manager
Laguna				
Sta. Cruz A	4.9 a	4.4 a	9.1 a	11.5 a
Sta. Cruz B	5.1 a	5.2 a	8.2 a	6.2 a
Sta. Cruz C	6.4 a	5.7 a	10.7 a	11.0 a
Sta. Cruz D	5.1 a	4.1 a	8.7 a	8.7 a
Nueva Ecija				
Muñoz City A	4.5 a	4.7 a	6.2 a	8.2 a
Muñoz City B	4.3 a	4.2 a	6.5 a	6.6 a
Muñoz City C	4.7 a	4.0 a	6.9 a	6.6 a
Muñoz City D	4.3 a	4.0 a	7.3 a	6.6 a
Pangasinan				
San Manuel A	3.7 a	2.6 a	5.2 a	3.6 a
San Manuel B	3.3 a	2.7 a	4.1 a	4.7 a
San Manuel C	3.9 a	3.0 a	5.5 a	4.6 a
San Manuel D+	5.0	1.7	6.6 a	7.0 a

Means (Tukey's test) or median (Kruskal Wallis test) followed by the same letter for FP vs. RCM are not different at 5% level of significance +58% filled grains recorded in RCM, compared to 71% in FP plots, due to lodging at grain filling stage of rice.

II. Development of Soil, Water, Nutrient, and Crop Yield Diagnostic Techniques for Irrigated Lowland Rice

Project Leader: JG Tallada

Optimal nutrient management is one of the keystones to achieve maximum productivity of the irrigated rice. To support correct decisions on the required fertilization rate and timing, diagnostic techniques can be used. These decisions should not only account for the planted rice variety but also the edaphic and climatic factors, which persist throughout the growing season. Doing so will lead to a more holistic, intensified and systematic approach for crop management.

The use Decision Support System for Agrotechnology Transfer (DSSAT) crop model for a five (5) multi-location field trials provides insights on the robustness of this modelling approach. In 2015, appreciable model performance as indicated by lower normalized error rates (around 20% and less) was achieved in four of the sites. The PhilRice Bicol site component has yet to get additional soil data to be inputted into its model. While the generated sets of genetic coefficients for the models had seemed worked well within the context of the fields where they were developed, it would be interesting to know the steps that must be taken to minimize location specificity and achieve a more generalized form of the model. This in turn would allow a more audacious use of the general model to any location in the country.

From the two season experiments in 2015, the low-cost atLeaf+ chlorophyll meter was confirmed to performed well with respect to the more costly SPAD-502+. High correlations ($r>0.98$) at different crop stages, measurement time-of-day and between two users, as well as for the pooled data were noted. Using a simple linear model, the atLeaf values can be transformed into SPAD values to which many fertilizer field recommendations were based upon. Finally, the first attempt to use the concept of the nitrogen-rich plot to guide mid-season fertilizer application using an optical instrument (normalized difference vegetation index or NDVI) had shown the rudimentary requirement of this technology. At the core of the concept is the algorithm to guide the computation of the fertilizer rates based on the assumption that the relative yield index is highly correlated to the relative NDVI index taken during the early panicle stage. A working model equation between the yield variation and NDVI readings was essential to support the computations. A sequel wok must be undertaken to further refine and validate the technology at different climatic regimes.

The use of Decision Support System for Agrotechnology Transfer (DSSAT) CERES-Rice crop model to evaluate the potential yield of irrigated lowland rice under different nutrient management levels and climate types in the Philippines.

RT Cruz, SA Balidiong, GU Abordo-Nemeño, ZLE Espina, NS Sosa, GA Castañeda, and KN Salarda

The Decision Support System for Agrotechnology Transfer (DSSAT) is an application software developed to integrate the effects of crop genotype, soil, weather, and management options (Jones et al. 2003). In calibrating the model, a set of crop genetic coefficients of the rice varieties is obtained. Crop genetic coefficients are values that describe the phenology and growth stages of each rice variety grown under optimum crop management. In validating the model, the crop genetic coefficients obtained from calibration will be used to simulate the potential yield of the rice varieties and compare the simulated yield with the observed yield. The observed yield potential from the well-managed experimental field and simulated potential yield in another test site are compared to assess the acceptability of the model based on the normalized root mean square error or nRMSE (Chai and Draxler 2014 Geosci Mod Dev 7). After calibrating and validating the DSSAT CERES-Rice Crop Model, it can be used to simulate the potential yield of rice under optimum crop management in different locations with varying weather conditions. The DSSAT CERES-Rice Crop Model was utilized in this study to establish a new protocol to determine the yield potential of different inbred and hybrid rice varieties. Hence, nitrogen management levels were tested in relation to attainment of yield potential of rice varieties under different climate types in irrigated lowland rice areas in the Philippines. It was essential that calibration and validation data came from field trials with optimum crop management and had attained yield potential.

Field experiments were conducted at PhilRice Nueva Ecija, PhilRice Agusan, PhilRice Isabela, PhilRice Midsayap and PhilRice Bicol in 2015 dry season to assess the grain yield potential of the inbred PSB Rc82 (110 days to crop maturity) and hybrid Mestiso 20 (111 days). Fertilizer treatments were: (1) Control or no fertilizer, (2) -N, +P, +K or N omission plot where each P and K was applied at 40kg/ha, (3) LCC-based N application wherein 1 bag of Complete fertilizer (CF) 14-14-14-12S was applied at 14 days after transplanting (DAT) before LCC-based nitrogen (N) application. For LCC-based N application, 35kg N/ha were applied when LCC reading was below 4. LCC reading was done every week starting at 21 DAT until early flowering, (4) in another treatment, 6 bags of complete fertilizer 14-14-14-12S was applied. For LCC-based N application, 35kg N/ha were applied when LCC reading was below 4. (5) Growth stage-based N application wherein 50kg N/ha was applied at mid-tillering, 50kg N/ha at early panicle initiation, and 40kg N/ha at early flowering, and (6) Growth stage-based N application wherein 50kg N/ha was applied at mid-tillering, 100kg N/ha at early panicle initiation, and 40kg N/ha at early flowering. Grain yield sample from each treatment was obtained from a representative 5m^2 area, oven-dried and adjusted to standard 14% grain moisture content. As a standard methodology, the crop genetic coefficients generated in 2014 were used to simulate the potential yields and compared to actual yields in 2015. If the nRMSE was less than or equal to 10%, the DSSAT Rice Crop Model was considered to have excellent or highly acceptable predictive capability. If nRMSE was greater than 10% but less than 20%, the Model was considered to have good predictive capability. If nRMSE was greater than 20% but less than 30%, the Model was considered to have fair predictive capability. If nRMSE was greater than 30%, the Model was considered to have poor or unacceptable predictive capability.

Highlights:

- Using the Generalized Likelihood Uncertainty Estimation (GLUE) program of the DSSAT CERES-Rice Crop Model and after inputting the weather, soil, crop management, crop growth, development and yield data, the crop genetic coefficients of the inbred PSB Rc82 and the hybrid Mestiso 20 were generated in 2014 dry and wet seasons for eight crop developmental phases for Nueva Ecija (Table 12). The same procedure was followed for the same 2 varieties in generating the crop genetic coefficients for PhilRice Agusan, PhilRice Isabela and PhilRice Midsayap. Crop genetic coefficients were not generated for PhilRice Bicol due to incomplete soil profile data. Generally, the crop genetic coefficients generated in 2014 were similar to the values generated in previous years. After generating the crop genetic coefficients, the Model was validated using the 2015 dry season weather, soil, crop management, crop growth, development and yield data.

- Based on the comparison of simulated and actual crop yields for the different fertilizer treatments, the calculated nRMSEs for PhilRice Agusan were 17.8% for PSB Rc82 and 19.0% for Mestiso 20 (Table 13). The calculated nRMSEs for PhilRice Isabela were 6.1% for PSB Rc82 and 12.0% for Mestiso 20 (Table 14). The calculated nRMSEs for PhilRice Midsayap were 20.8% for PSB Rc82 and 16.1% for Mestiso 20 (Table 15). The calculated nRMSEs for PhilRice Nueva Ecija were 14.1% for PSB Rc82 and 21.8% for Mestiso 20 (Table 16). The fairly low nRMSEs for PSB Rc82 and Mestiso 20 indicate the acceptable predictive capability of the model using the crop genetic coefficients generated from PhilRice Agusan, PhilRice Isabela, PhilRice Midsayap and Nueva Ecija. However, to further decrease nRMSE, an updated soil profile, soil and plant nutrient analysis data will have to be inputted in the model.

Table 12. Genetic coefficients of the inbred PSB Rc82 and hybrid Mestiso 20 generated using the Generalized Likelihood Uncertainty Estimation (GLUE) program of DSSAT for Nueva Ecija data in 2014 DS and WS. These crop genetic coefficients were used to simulate the potential yields in 2015 in PhilRice Nueva Ecija. This procedure was followed for the other branch stations in generating their respective crop genetic coefficients.

Code	Crop Genetic Coeffficent	
	PSB Rc82	Mestiso 20
P1	380.3	503.2
P2R	31.90	32.70
P5	332.6	515.7
P2O	10.78	12.55
G1	58.06	52.47
G2	0.023	0.027
G3	0.474	0.719
G4	1.24	1.23

Note: P1- basic vegetative phase of the plant (GDD); P2R - extent to which phasic development leading to panicle initiation is delayed (GDD); P5 - beginning of grain filling to physiological maturity (GDD); P2O - critical photoperiod or longest daylength at which the development occurs at a maximum rate (hr); G1- potential spikelet number coefficient; G2- single grain weight (g); G3 - tillering coefficient relative to variety IR 64; G4 – temperature tolerance coefficient.

Table 13. Comparison of simulated and observed grain yields at different fertilizer treatments for PSB Rc82 and Mestiso 20 in DSSAT field experiment in 2015 DS in PhilRice Agusan with Type II Climate and their normalized root mean square errors (nRMSEs). Note: 1,000 kg/ha = 1 ton/ha.

Fertilizer treatment	Simulated and observed yields (kg/ha)			
	PSB Rc82		Mestiso 20	
	Observed	Simulated	Observed	Simulated
Control with no fertilizer	2859	4036	3051	4164
N-omission plot	2955	4630	3324	4513
LCC-based with 1 bag CF	5289	5248	5731	5080
LCC-based with 6 bag CF	5666	5265	6571	5214
Growth stage based with 140 N/ha	5582	5181	5501	5308
Growth stage based with 190 N/ha	5843	5432	5495	5037
RMSE	883.5		927.8	
nRMSE (%)	17.8		19.0	

Table 14. Comparison of simulated and observed grain yields at different fertilizer treatments for PSB Rc82 and Mestiso 20 in DSSAT field experiment in 2015 DS in PhilRice Isabela with Type II Climate and their nRMSEs.

Fertilizer treatment	Simulated and observed yields (kg/ha)			
	PSB Rc82		Mestiso 20	
	Observed	Simulated	Observed	Simulated
N-omission plot	3477	3185	4147	3878
LCC-based with 1 bag CF	5011	5173	5046	6278
LCC-based with 6 bag CF	5538	5665	6052	6908
Growth stage based with 140 N/ha	5858	5420	7843	7344
Growth stage based with 190 N/ha	5883	5498	7843	7289
RMSE	305.8		758.8	
nRMSE (%)	6.1		12.0	

Table 15. Comparison of simulated and observed grain yields at different fertilizer treatments for PSB Rc82 and Mestiso 20 in DSSAT field experiment in 2015 DS in PhilRice Midsayap with Type III Climate and their nRMSEs.

Fertilizer treatment	Simulated and observed yields (kg/ha)			
	PSB Rc82		Mestiso 20	
	Observed	Simulated	Observed	Simulated
Control with no fertilizer	3475	3945	4152	4483
N-omission plot	3474	4381	4152	4889
LCC-based with 1 bag CF	6462	5126	6512	5427
LCC-based with 6 bag CF	6721	5233	6558	5020
Growth stage based with 140 N/ha	5984	5393	5651	5636
Growth stage based with 190 N/ha	5984	5122	5651	5669
RMSE	1011.2		836.3	
nRMSE (%)	20.8		16.1	

Table 16. Comparison of simulated and observed grain yields at different fertilizer treatments for PSB Rc82 and Mestiso 20 in DSSAT field experiment in 2015 DS in PhilRice Nueva Ecija with Type I Climate and their nRMSEs.

Fertilizer treatment	Simulated and observed yields (kg/ha)			
	PSB Rc82		Mestiso 20	
	Observed	Simulated	Observed	Simulated
Control with no fertilizer	4721	4686	5790	4763
N-omission plot	4578	4280	5541	4324
LCC-based with 1 bag CF	7943	6435	7705	7418
LCC-based with 6 bag CF	8698	7424	8407	7229
Growth stage based with 140 N/ha	7969	7774	8380	6472
Growth stage based with 190 N/ha	7969	7123	8380	6610
RMSE	888.9		1340.4	
nRMSE (%)	14.1		21.8	

Evaluation of crop nutrient diagnostic tools techniques for increased nutrient-use efficiency for irrigated lowland rice

JG. Tallada and MA Ramos

Several chlorophyll meters are commercially available abroad that could have valuable potential use in the Philippine rice production system. The Minolta SPAD-502+ is being used in many research field experiments at PhilRice and IRRI which has been recommended for regular crop monitoring for many field experiments. It depends on measurement of normalized difference vegetation index or NDVI from the red and infrared light transmitted through the leaf. While this device is often found effective, it is quite too expensive with current prices ranging from Php90,000 to 105,000. A similar and cheaper electronic device called the atLEAF+ chlorophyll meter works on the same principle, which costs only about USD 300 (or about Php15,000) but it is not yet locally available. Both these meters are handheld device working on the principle of the transmitted light measurement to estimate the chlorophyll contents of single leaves, which indicates the level of plant nutritional health. A more promising device would be something that can measure simultaneously aggregated leaves for better and quicker nutrition estimates.

It was very appropriate to evaluate the local performance of these tools in Philippine rice agriculture, and to provide basis for a decision support system for better fertilizer management. They can also provide experience that could be translated to localizing the technologies so that they can be made affordable to support our production system.
The main goal of the research study was to evaluate the local performance of some electronic and non-electronic (leaf color charts) crop nutrient diagnostic tools for better fertilizer recommendation for increased grain yield

and nitrogen use efficiency. Specifically, the study aimed to simultaneously test these tools and assess their predictive ability for grain yield at different fertilization rates.

Highlights:

- In dry season 2015, a test on sensitivity to time of measurement showed high r=0.998 to SPAD-502+ and r=0.988 to atLEAF+ (Figure 64). The result showed that both tools can be used any time of the day as long as the proper measurement protocols are always observed.

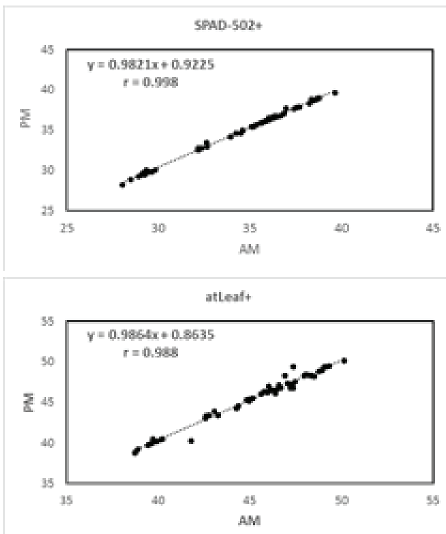

Figure 4. Comparison of morning and afternoon readings of SPAD-502+ (left) and atLEAF+(right) at panicle initiation stage.

- The correlation of the tools between two field users was also evaluated (Figure 75). The correlation coefficient is high in both SPAD-502+ (r=0.996) and atLEAF+ (r=0.993).

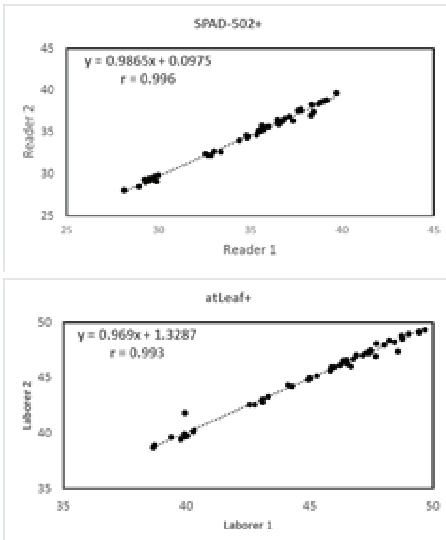

Figure 5. Inter-user comparison of SPAD 502+ and atLEAF+ measurements.

- In dry season 2015, there was high correlation of readings during panicle initiation between the atLEAF+ and SPAD-502+ meters (Figure 8). Because of this, atLEAF+ can be a good alternative chlorophyll meter to SPAD-502+ to estimate the chlorophyll contents of the crop.

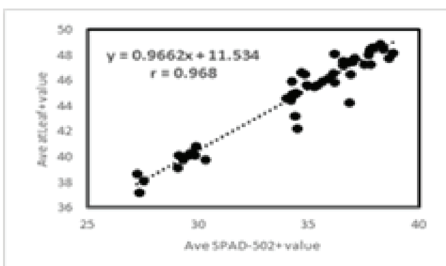

Figure 6. Comparison between atLEAF+ and SPAD-502+ readings during panicle initiation in 2015 DS.

- AtLeaf+ measures higher values than SPAD-502+ (Figure 7). The critical value for SPAD-502+ is 35, 45 for atLEAF+ and 4 for LCC. Below these numbers, additional nitrogen is needed by the plants.

- The light seal and method of measurement in SPAD-502+ is better than that of the atLEAF+. AtLEAF+ had fixed opening slit that would lead to different orientation of the leaf blade during measurement. Proper measurement must be done to have a good reading of the tool.

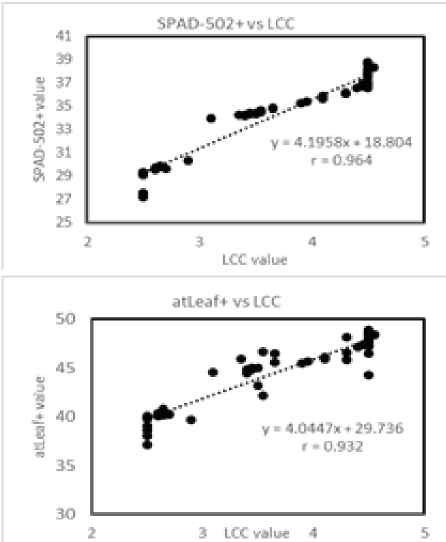

Figure 7. Comparison between SPAD-502+ and atLEAF+ values against LCC value during panicle initiation dry season 2015.

- The average grain yield tons per hectare is highest in 120 kg-N ha-1 (Figure 8). Excess nitrogen fertilizer has a negative effect that decreased the yield.

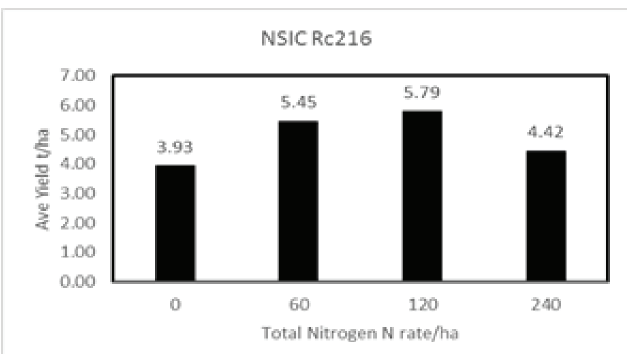

Figure 8. Average yield of NSIC Rc216 in 2015 DS.

- In wet season 2015, after simultaneous evaluation of chlorophyll meters we add another treatment which is the SPAD-502+-based, LCC-based and atLEAF+-based N fertilizer management using the check variety PSB Rc82.

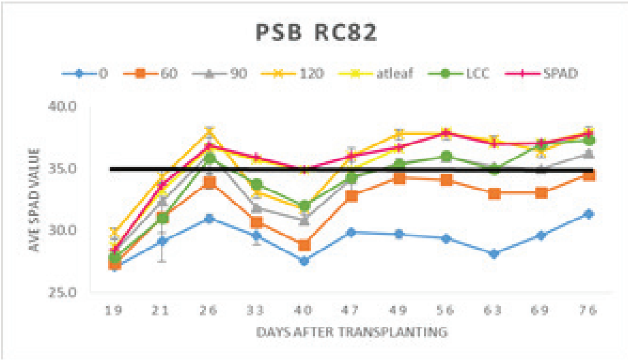

Figure 9. Average SPAD-502+ reading during the tillering to flowering stage.

- The treatment SPAD-502+-based was maintained above the critical value 35 (Figure 9). It tends to decline during the early panicle initiation, additional N fertilizer is added so that N will not be limited.

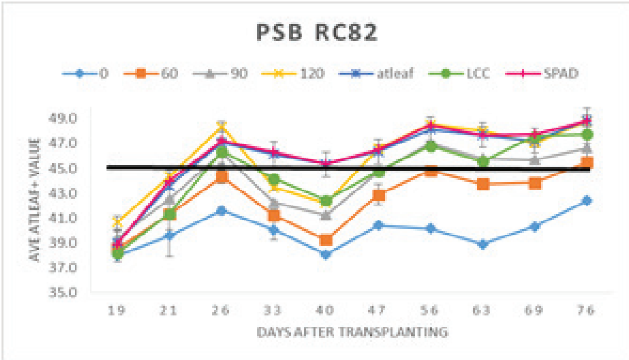

Figure 10. Average atLEAF+ reading during the tillering to flowering stage.

- The treatment atLEAF+-based was maintained above the critical value 45 (Figure 10). The value 35 in SPAD-502+ is equivalent to 45 in atLEAF+. Reading tends to decline during the early panicle initiation, additional N fertilizer is added so that N will not be limited.

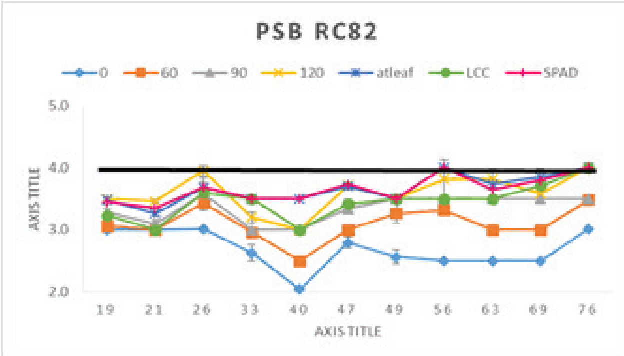

Figure 11. Average LCC reading during the tillering to flowering stage.

- The treatment LCC-based is always below the critical value of 4, additional N was always applied whenever the reading is below critical value (Figure 1311).

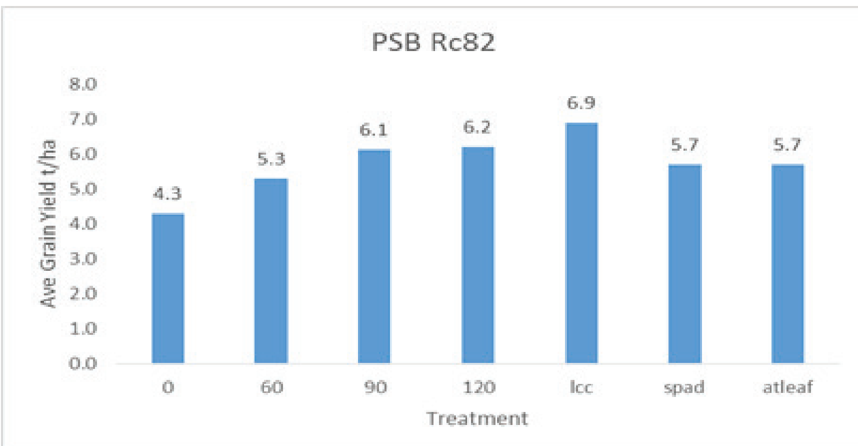

Figure 12. The figure shows average grain yield of PSB Rc82 in all treatment.

- The LCC-based has the highest yield of 6.9t/ha the total N-applied is 92kg N/ha distributed equally in four splits (Figure 12). The SPAD-502+-based and atLEAF+-based has the same average yield of 5.7t/ha the total N applied is 110kg N/ha distributed in tree splits.

- Based on the experiment LCC-based is the best treatment, four splitting of fertilizer N application can increase the grain yield considering the proper use of LCC but further study should be conducted to verify the result.

Estimating Mid-Season Nitrogen Requirements of Rice Based on Nitrogen-Rich Strip

JG Tallada and MA Ramos

The yield of most cereal crops vary from season to season even in plots receiving the same levels of fertilizer. Climatic elements particularly solar radiation and temperature may explain a significant portion of the variation, but there are edaphic and cultural factors such as nutrient mineralization rates and water availability during the fallow period that may further add explanation on yield variance over time. Nitrogen-rich plots are reference plot where the crop receives adequate balanced nutrition to maximize its yield.

Nitrogen is one of the most limiting nutrient in Philippine soil and the farmers practice apply high amounts of nitrogen in order to produce high yield but the yield is changing every year. N-rich plots will be a guide to the farmer for a proper time of applying nitrogen during midseason by visual assessment of the n-rich plot crop and crop in the other representative plots. By doing this it can help the farmers in decision making for a timing of nitrogen application and improve nutrient use efficiency.

In this study, SPAD-502+ and prototype Oklahoma State University (OSU) pocket sensor were used. The normalized difference vegetative index (NDVI) readings from the pocket sensor are practically the same as the NDVI from a more robust GreenSeeker handheld crop sensor.

The study aimed to develop algorithms for fertilizer recommendations based on the N-rich plots as a reference guide in applying nitrogen fertilizer at mid-season growth stage of rice plant. Further, it aimed to establish a nitrogen requirement and yield prediction model using NDVI measurements obtained from the prototype pocket sensor and SPAD-502+.

The study was conducted at PhilRice CES in Nueva Ecija in 2015 dry season. PSB Rc82 variety was used and eight (8) fertilizer treatments was laid out following a randomized complete block design (RCBD) with three (3) replications. Treatments included: 0-60-60 kg NPK ha-1; 120-60-60kg NPKha-1 and 150-60-60kg N ha-1 both applied in several splits as shown in Table 2417. The 150-60-60kg NPK ha-1 treatment will serve as the N-rich strip reference plot. The plot size was 5m x 4.9m (24.5m^2). A 14-day old seedling was transplanted in a 20 x 20cm planting distance 2 to 3 seedlings per hill. Cultural management for weeds and pest management was done when necessary.

Table 17. Treatment structure and description of the trials that was conducted at PhilRice, CES, 2015 DS.

Treatment	Pre-planting N kg ha-1	Early Tillering N kg ha-1	Mid-Tillering N kg ha-1	Panicle Initiation N kg ha-1
1	0	0	0	0
2	150	0	0	0
3	0	30	0	90
4	0	60	0	60
5	0	90	0	30
6	0	30	45	45
7	0	60	30	30
8	0	90	15	15

Highlights:

- Results showed that NDVI values for zero fertilizer treatment where lowest at 0.353 at 29 days after transplanting (DAT) and 0.390 at 63 DAT (Figure 1513). NDVI values increased (i.e. 0.404 to 0.504) with N fertilizer levels. Basal application is not advisable for the establishment of N-Rich plot. It is advisable to apply fertilizer N at early tillering stage of the crop.

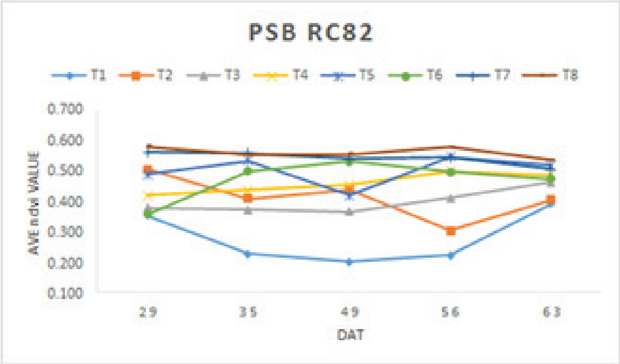

Figure 13. NDVI values of inbred PSB Rc82 at different growth stages (i.e., 29 to 63 days after transplanting) and N fertilizer levels in 2015 DS.

- SPAD-502+ chlorophyll meter is a good tool in measuring the chlorophyll content of the plant. Figure 1614 showed that at panicle initiation (49 DAT) SPAD values tend to decline meaning additional N is needed by the plant.

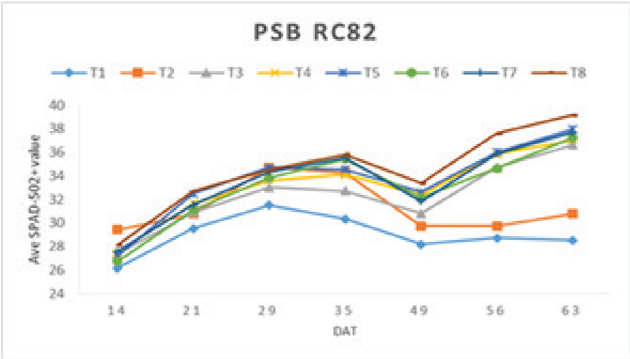

Figure 14. SPAD-502+ values of inbred PSB Rc82 at different growth stages (i.e., 29 to 63 days after transplanting) and N fertilizer levels in 2015 DS.

- Grain yield of PSB Rc82 where highest at 5.24 t/ha with 30 N kg/ha at early tillering and 90 N kg/ha at panicle initiation (Figure 15). Proper amount of fertilizer N should be given in the critical stage requirement of the plant to attain high yield. The plant needs more N at panicle initiation than early tillering stage.

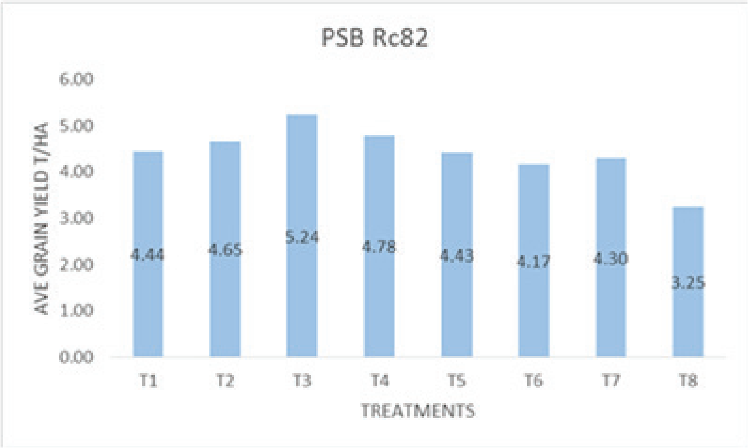

Figure 15. Grain yields of inbred PSB Rc82 at treatments.

III. Assessment and Evaluation of Crop Intensification and Resource Use Efficiency in Rice Production

Project Leader: MD Malabayabas

PhilRice continuously develop and improve rice production technologies that will help in addressing the country's goal for rice self sufficiency. Thus, the project assessed crop intensification strategies like ratooning and the adoption of resource use efficient technologies like controlled irrigation, Leaf Color Chart (LCC) and minimum tillage. Two studies under the project were conducted in 2015 DS and WS.

Ratooning abilities of 10 rice genotypes with different growth duration were evaluated under LCC-based N management and nitrogen (N) omission treatment for main crop, and N omission treatment and N application of 90kg ha-1 for the ratoon crop. The main crop yields of early maturing varieties like PSB Rc82 were generally higher than the medium and late-maturing varieties (NSIC Rc128, NSIC Rc160, and PSB Rc18, and Balatinaw) in N omission plot and LCC-based N application in DS and WS. The low yield in medium- and late-maturing varieties during DS was attributed to stem borer infestation. Traditional varieties like Balatinaw and Dinorado had lower yields than modern varieties due to lower harvest index. The ratooning ability of the genotypes during DS was masked by the high incidence of stem borer damage. Cutting height of stubble at 20 cm from the ground had higher ratoon yield than 5 cm cutting height in both N fertilizer treatments. This was due to rotting of crop stubble in 5 cm cutting height during irrigation. PSB Rc82 had the highest crop productivity among genotypes in both DS and WS.

The nutrient and water use efficiencies of 6 varieties were evaluated under minimum and conventional tillage in combination with controlled irrigation and use of Leaf Color Chart (LCC) as basis for nitrogen (N) fertilizer application. DS and WS results showed that grain yield, partial factor productivity (PFP) and water productivity (WP) did not significantly differ between conventional and minimum tillage. Grain yields, PFP and WP were relatively lower during DS due to high stem borer infestation in the area. Higher yield during WS was attributed to better growing condition resulting in higher percentage of filled spikelets and harvest index.

Ratooning ability of irrigated lowland rice: Response of selected rice genotypes with different growth condition under optimum nutrient and water management

RT Cruz, KN Salarda, and MJC Regalado

Ratooning is the ability of rice plant to regenerate new tillers from stubbles of the main crop and it can increase total crop productivity per unit area and time with lower cost for land preparation, labor and crop maintenance. To make ratooning more productive and economical, cultivars with good ratooning ability and a package of main and ratoon crop management system must be developed.

Field experiments were conducted at PhilRice Nueva Ecija in 2015 DS and WS to assess the ratooning abilities and yields of rice varieties namely, PSB Rc82 (110 days to crop maturity), Rc18 (123 d), Rc36 (127 d), NSIC Rc238 (112 d), Rc158 (113 d), Rc128 (118 d), Rc160 (122 d), Mestiso 20 (111 d), Balatinaw (125 d), and Dinorado (134 d). Fertilizer treatments for the main rice crop were (1) 0 N + 40kg ha-1 P2O5, + 40kg ha-1 K2O (N omission plot) and (2) PalayCheck System wherein 6 bags of complete fertilizer 14-14-14-12S were applied as basal in DS and 4 bags in WS + LCC-based N topdressing of 35kg N ha-1 in DS and 23kg ha-1 in WS when LCC reading was below 4. The total N rates applied in the main crop based on LCC were 105kg ha-1 in DS and 46kg ha-1 in WS. At harvest, the main crop was ratooned or cut at 20cm above the soil surface in DS. In WS, the main crop was ratooned at (1) 5cm and (2) 20cm above the soil surface. Immediately after ratooning, the field was flooded with 3 cm water and applied with 90kg N ha-1 in both DS and WS. N omission treatment was maintained in the ratoon crop.

Highlights:

- In the 2015 DS, in the N-omission plot with P and K fertilizers, the main crop of Balatinaw had the lowest yield of 0.4t/ha while the main crop of PSB Rc82 had the highest yield of 4.8t/ha-1 (Table 1). Generally, yields of early-maturing varieties (106 to 115 days from seeding to harvest) were higher than yields of the medium-maturing varieties (116 to 125 days) and late- maturing varieties (>126 days). With LCC-based N application, Balatinaw had the lowest yield of 0.5t/ha-1 while PSB Rc82 had the highest yield of 6.8t/ha-1. Generally, yields of early-maturing varieties were higher than the yields of the medium-maturing and late-maturing varieties. The low yields of medium-maturing varieties (i.e., NSIC Rc128, Rc160, and PSB Rc18, and Balatinaw) and late-maturing rice varieties (i.e. PSB Rc36 and Dinorado) in the N-omission plot and LCC-based N application treatments were possibly due to longer exposure to stem borer infestation. Compared to yields of PSB, NSIC and hybrid varieties, grain yields of the traditional varieties Balatinaw and Dinorado were lower due to lower harvest index.

- In the N-omission plot, the ratoon crops of PSB Rc82 and NSIC Rc238 each had the lowest yield of 0.2t/ha-1 while NSIC Rc158 had the highest ratoon yield of 0.4t/ha-1 (Table 18). With 90kg N ha-1, the ratoon crop of PSB Rc18 had the highest yield of 0.3t/ha-1 while PSB Rc82, NSIC Rc238, Rc158 and Rc218 each had a yield of 0.2t/ha-1. Compared to previous cropping seasons, ratoon crop yields were lower in 2015 DS due to stem borer damage or whiteheads. The ratoon crops of Mestiso 20, NSIC Rc160, Balatinaw, PSB Rc36, and Dinorado had no yields due to severe stem borer damage.

- In the N-omission plot with P and K fertilizers, the total crop productivity (i.e., main crop yield + ratoon crop yield) of Balatinaw was lowest at 0.4t/ha-1 (Table 18). The total crop productivity of PSB Rc82 was highest at 5.0t/ha-1. Total crop productivity of early-maturing varieties was higher than the total crop productivity medium-maturing and late-maturing varieties. In the LCC-based N application plus 90 kg N ha-1 for the ratoon crop, Balatinaw had the lowest total crop productivity of 0.5t/ha-1 while PSB Rc82 had the highest total crop productivity of 7.0t/ha-1. Likewise, the total crop productivity of early-maturing varieties was higher than the total crop productivity of medium-maturing and late-maturing varieties. The lower total crop productivity of medium-maturing varieties (i.e. NSIC Rc128, Rc160, PSB Rc18 and Balatinaw) and late-maturing rice varieties (i.e. PSB Rc36 and Dinorado) in the N-omission plot and LCC-based N application treatments could be attributed longer exposure to stem borer infestation and hence, greater yield reduction.

- In the 2015 WS, in the N-omission plot with P and K fertilizers, the main crop of PSB Rc36 had the lowest yield of 2.4t/ha-1 while the main crop of PSB Rc82 had the highest yield of 5.8t/ha-1. (Table 19). Generally, yields of early-maturing varieties (106 to 115 days from seeding to harvest) were higher than yields of the medium-maturing varieties (116 to 125 days) and late-maturing varieties (>126 days). In the LCC-based N application, PSB Rc36 had the lowest yield of 2.3t/ha-1 while PSB Rc82 had the highest yield of 5.6t/ha-1.

- In the N-omission plot with 5cm cutting height, ratoon crops of Balatinaw had the lowest yield of 0.1t/ha-1 while PSB Rc82 and NSIC Rc160 had the highest ratoon yield of 0.3t/ha-1 (Table 19). With 20cm cutting height, ratoon crops of Balatinaw had the lowest yield of 0.1t/ha-1 while NSIC Rc160 had the highest ratoon yield of 0.6t/ha-1.

- In the LCC-based N application treatment with 5cm cutting height, ratoon crops of PSB Rc82 and Rc36 had the lowest yield of 0.1t/ha while NSIC Rc238 and Rc128 had the highest ratoon yield of 0.2t/ha-1 (Table 19). With 20cm cutting height, ratoon crops of Balatinaw had the lowest yield of 0.1t/ha-1 while PSB Rc82, NSIC Rc158, and Rc128 had the highest ratoon yield of 0.4t/ha-1. Generally, yields of the ratoon crops cut 5 cm above the ground were lower due to rotting of the crop stubbles during irrigation.

- In the N-omission plot with P and K fertilizers, the total crop productivity (i.e., main crop yield + ratoon crop yield) using 5cm cutting height was lowest at 2.4t/ha-1 for PSB Rc36 (Table 19). The total crop productivity of PSB Rc82 was highest at 6.1t/ha-1. The total crop productivity using 20 cm cutting height was lowest at 2.4t/ha-1 for PSB Rc36. The total crop productivity of PSB Rc82 was highest at 6.3t/ha-1. Total crop productivity using 20cm cutting height was higher than using the 5cm cutting height.

- In the LCC-based N application treatment plus 90 kg N ha-1, total crop productivity (i.e., main crop yield + ratoon crop yield) using 5cm cutting height was lowest at 2.4t/ha-1 for PSB Rc36 (Table 19). The total crop productivity of PSB Rc82 was highest at 5.7t/ha-1. The total crop productivity using 20cm cutting height was lowest at 2.3t/ha-1 for PSB Rc36. The total crop productivity of PSB Rc82 was highest at 6.0t/ha-1. Total crop productivity using 20 cm cutting height was higher than using the 5cm cutting height. The lower total crop productivity using the 5cm cutting height in the N-omission plot and LCC-based N application treatments could be attributed to the rotting of crop stubble during irrigation.

Table 18. Grain yields (t/ha-1) of the main crop and ratoon crop cut 20 cm from the ground, and total crop productivity in N-omission and N-fertilized plots for 9 inbred varieties and 1 hybrid variety in 2015 DS. Rice varieties that did not have ratoon yields were heavily damaged by stem borer. In a column, means followed by a common letter are not significantly different at 5% level by Fisher's Least Significant Difference (LSD) test.

Variety and Crop Maturity (day)	Main Crop Yield (t ha^{-1})		Ratoon Crop Yield (t ha^{-1})		Total Crop Productivity = main crop yield + ratoon crop yield (t ha^{-1})	
	N-omission plot	LCC-based N application	N-omission plot	90 kg N ha^{-1}	N-omission plot	LCC-based N + 90 kg N ha^{-1}
PSB Rc82 (110 days)	4.8 a	6.8 a	0.2	0.2	5	7.0
NSIC Rc238 (112 days)	3.9 ab	5.5 ab	0.2	0.2	4.1	5.7
NSIC Rc158 (113 days)	3.8 abc	5.1 bc	0.4	0.2	4.2	5.3
Mestiso 20 (111 days)	3.8 abc	5.7 ab	0.0	0.0	3.8	5.7
NSIC Rc128 (118 days)	0.8 e	1.2 fg	0.3	0.2	1.1	1.4
NSIC Rc160 (122 days)	2.5 cd	2.4 ef	0.0	0.0	2.5	2.4
PSB Rc18 (123 days)	2.9 bcd	3.9 cd	0.3	0.3	3.2	4.9
Balatinaw (125 days)	0.4 e	0.5 g	0.0	0.0	0.4	0.5
PSB Rc36 (127 days)	2.3 d	3.6 de	0.0	0.0	2.3	3.6
Dinorado (134 days)	2.6 cd	3.4 de	0.0	0.0	2.6	3.4

Table 19. Grain yields (t/ha-1) of the main crop and ratoon crops cut (a) 5 cm and (b) 20 cm from the ground, and total crop productivity in N-omission and N-fertilized plots for 9 inbred varieties and 1 hybrid variety in 2015 wet season. Rice varieties that did not have ratoon yields were affected by the rotting of the crop stubble especially with ratoon cut 5 cm from the ground. In a column, means followed by a common letter are not significantly different at 5% level by Fisher's Least Significant Difference.

Variety	Main crop yield ($t\ ha^{-1}$)		Ratoon crop yield ($t\ ha^{-1}$)				Total Crop Productivity = main crop yield + ratoon crop yield ($t\ ha^{-1}$)			
	N-omission plot	LCC-based N application	N-omission plot		90 kg N ha^{-1}		N-omission plot		LCC-based N + 90 kg N ha^{-1}	
			5 cm	20 cm	5 cm	20 cm	5 cm	20 cm	5 cm	20 cm
PSB Rc82	5.8 a	5.6 a	0.3	0.5 abc	0.1	0.4 a	6.1	6.3	5.7	6.0
NSIC Rc238	5.2 ab	5.2 a	0.2	0.3 bcd	0.2	0.3 ab	5.4	5.5	5.4	5.5
NSIC Rc158	4.8 abc	4.0 ab	0.2	0.4 abc	0.1	0.4 ab	5.0	5.2	4.1	4.4
Mestiso 20	5.4 ab	5.4 a	0.0	0.05 de	0.0	0.1 ab	5.4	5.5	5.4	5.5
NSIC Rc128	3.7 bcd	4.0 a	0.2	0.5 ab	0.2	0.4 ab	3.9	4.2	4.2	4.4
NSIC Rc160	4.4 abc	5.2 a	0.3	0.6 a	0.0	0.2 ab	4.7	5.0	5.2	5.4
PSB Rc18	4.0 abc	3.2 b	0.0	0.2 cde	0.0	0.3 ab	4.0	4.2	3.2	3.5
Balatinaw	3.3 cd	3.2 b	0.1	0.1 de	0.0	0.1 ab	3.4	3.4	3.2	3.3
PSB Rc36	2.4 d	2.3 b	0.0	0.0 e	0.1	0.0 b	2.4	2.4	2.4	2.3
Dinorado	3.3 cd	2.5 b	0.0	0.0 e	0.0	0.0 b	3.3	3.3	2.5	2.5

Evaluation of water and nutrient use efficiencies of varieties with high yield potential

MD Malabayabas, AJ Espiritu, and NR Dadufalza II

Nutrients and water are vital factors in the attainment of higher rice productivity. However, the cost of fertilizer is continuously increasing while water is becoming scarce. Thus, water and nutrients must be efficiently utilized by rice to compensate for the high production cost. The adoption of energy resource use efficient technologies like controlled irrigation, Leaf Color Chart (LCC) and minimum tillage in combination with high yielding varieties should be considered to reduce production cost while maintaining productivity.

The study was conducted at PhilRice experimental area where the only source of irrigation is water pump. Conventional and minimum tillage and were employed in preparing the field. Minimum tillage involved dryland rotavation after which the field was kept flooded for 10 days before seeding followed by 1 harrowing and final land leveling. Conventional tillage involved wetland plowing, 3 harrowing and final land leveling. Pre-germinated seeds of PSB Rc18, NSIC Rc160, Rc222, Rc238, Rc240 and Rc298 were broadcast-seeded at the rate of 20kg ha-1. Three bags of complete fertilizer (14-14-14-12S) in DS and 2 bags in WS and 40kg ha-1 each of P2O5 and K2O were applied 10 days after sowing (DAS). N fertilizer rate of 35kg ha-1 in DS and 23kg ha-1 in WS were topdressed when LCC reading was below 3. The field was irrigated at 10 DAS with standing water maintained at 2 to 5cm depth until 21 DAS. Thereafter, irrigation schedule was based on the perched water table in the observation well (15cm below the soil surface). Water productivity (WP) was used as measure of water use efficiency and partial factor productivity (PFP) for nitrogen use efficiency.

Highlights:

- Grain yield ranged from 2.40 to 3.96t/ha-1 (Table 20). The yields of NSIC Rc238 and Rc298 were significantly higher than the yield of Rc160 but comparable with Rc222, Rc240 and PSB Rc18. The same trend was observed in terms of partial factor productivity ranging from 14.90 to 24.62kg grain kg-1 N. A total of 161kg N ha-1 was applied in all varieties based on LCC. WP in NSIC R298 was significantly higher than Rc160 but comparable with other varieties. Grain yield, PFP and WP between reduced tillage and conventional land preparation did not differ significantly. The yield and PFP during DS were relatively low due to high stem borer infestation in the area ranging from 19 to 30%. This also resulted in lower percentage of filled spikelets ranging from 56 to 74.6%, 1000-grain weight of 20.69 to 22.35g and harvest index of 0.25 to 0.42.

- In WS, grain yield ranged from 4.96 to 5.75 t/ha-1 (Table 21). NSIC Rc298 and Rc240 showed significantly higher yield than Rc238 and PSB Rc18 but comparable with Rc160 and Rc222. PFP ranged from 59.69 to 69.30kg gain kg-1 N fertilizer. The trend in PFP was the same as the grain yield. The total N fertilizer rate applied in all varieties based on LCC was 83 kg N ha-1. The yield, PFP did not differ significantly in both tillage operations. However, there was significant interaction in WP between variety and tillage. Under conventional tillage, Rc298 had significantly higher WP Rc18 and Rc238 but comparable with Rc160, Rc222 and Rc240. Under minimum tillage, Rc240 had significantly higher WP than Rc238 and Rc160 but comparable with the rest of the varieties. High grain yields in Rc298, Rc240 and Rc160 can be attributed to higher percentage of filled spikelets and harvest index. Higher grain yield, PFP and WP were obtained in WS than DS due to high stem borer infestation in DS.

Table 20. Grain yield, partial factor productivity (PFP) and water productivity (WP) of 6 high yielding inbred varieties in 2015 DS. In a column, means with the same letter are not significantly different at 5% level by Tukey's or Honest Significant Difference (HSD) test.

Variety	Grain yield ($t\ ha^{-1}$)	PFP (kg grain kg^{-1} N)	WP (kg grain m^{-3} water)
PSB Rc18	3.16 ab	19.60 ab	0.33 ab
NSIC Rc160	2.40 b	14.90 b	0.40 b
NSIC Rc222	3.16 ab	19.67 ab	0.49 ab
NSIC Rc238	3.96 a	24.62 a	0.42 ab
NSIC Rc240	3.03 ab	18.84 ab	0.64 ab
NSIC Rc298	3.94 a	24.52 a	0.43 a

Table 21. Grain yield and partial factor productivity (PFP), water productivity (WP) of 6 high yielding inbred varieties in 2015 WS. In a column, means with the same letter are not significantly different at 5% level by Tukey's or Honest Significant Difference (HSD) test.

Variety	Grain yield ($t\ ha^{-1}$)	PFP (kg grain kg^{-1} N)	WP (kg grain m^{-3} water)	
			Conventional tillage	Minimum tillage
PSB Rc18	4.96 c	59.69 c	0.69 b	0.68 ab
NSIC Rc160	5.27 abc	63.48 abc	0.84 ab	0.58 b
NSIC Rc222	5.66 ab	68.13 ab	0.87 ab	0.75 ab
NSIC Rc238	5.03 bc	60.56 bc	0.65 b	0.63 b
NSIC Rc240	5.72 a	68.95 a	0.71 ab	0.89 a
NSIC Rc298	5.75 a	69.30 a	0.94 a	0.68 ab

IV. Research and Analytical Laboratory Systems and Maintenance

Project Leader: EF Javier

This project was established to (1) provide assistance in the improvement/upgrading of laboratory facilities for better quality research outputs; (2) constantly optimize laboratory/chemical procedures for soils and plant analyses; and (3) manage a database and inventory of information on the chemical and laboratory supplies and usages. Activities in this project include (1) chemical and laboratory supplies inventory and purchase; (2) annual equipment preventive maintenance service and calibration; (3) database management system; and (4) consultation, technical networking and inter-laboratory collaboration.

Analytical laboratory system and management

AE Espiritu

To support the ASPPD R&D activities, there is a need to capacitate the laboratory system for quality data and analyses. ASPPD research commonly presents yield responses of rice varieties due to application of some cultural inputs like seed, fertilizers, water and other sources of production input. But to back up this research output with basic and scientific data such as nitrogen use efficiency, efficient utilization and uptake of nutrients be it from inorganic or organic source. Likewise, the current ASPPD laboratories and greenhouse facilities needs some improvement and equipment upgrade as well as preventive maintenance services and calibration.

Highlights:

- Acquisition and maintenance of laboratory facilities according to ISO policies on EMS, QMS and OSHAS (in collaboration with the PPD).
  a. Acquisition and installation of 1 unit of canopy
  b. Acquisition of 2 units of nitrogen analyzer funded by DOST- PCAARRD project

- Annual preventive maintenance service (PMS) and calibration of laboratory equipment.
  a. 28 laboratory equipment due for annual preventive maintenance service and calibration had undergone PMS
  b. 11 laboratory equipment were repaired

- Database on the inventory of chemicals and procurement.

a. Maintained and updated the inventory of chemicals preventing incidence of oversupply

- Submitted 2015 semi-annual report on the requirement of "Permit to Purchase" and "Controlled Precursors and Essential Chemicals" to Supply Property Office on the procurement and usage of chemical supplies in our research activities controlled by the Philippine Drug Enforcement Agency (PDEA).

- Prepared and submitted lists of equipment for upgrading, and replacement of unserviceable equipment.

- Networking and consultation services
  a. Provided technical assistance to (1) thesis student of CLSU; (5) thesis students of Nueva Ecija University of Science and Technology, Cabanatuan City; (2) thesis students of Honorato C. Perez Senior Memorial Science High School-Mabini Extension and (1) thesis student from Talavera Science High School.
  b. Accommodated 9 On-the-Job training of students from Pangasinan State University and 1student from CLSU.
  c. Accommodated walk-in and arranged visits of several guests: (37) Biochemistry students from UST (laboratory orientation and facility tour), (30) foreign students from IRRI (laboratory orientation and facility tour) , Owner of Duran Farm Training and Agribusiness Center including engineers and professors from Bulacan State University (laboratory benchmarking), staff from the Department of Tourism, (5) students from Technological University of the Philippines Manila (technical assistance on the use of STK) and (3) Indonesian nationals (Dr. Muhamad Sabran and party).
  d. Use of ASPPD laboratory facility by other divisions (CCC, ISD, RCFS, REMD,IRBAS, KOPIA, ABCRE, PBBD) and MS students from CLSU.

Short term and long-term assessment of heavy metals in the paddy soils of Region 1 and 3
EF Javier, JC Magahud, PS Ramos, Jr., and AE Espiritu

The recent issue on the rupture of the mine's tailing pond in Benguet had created so much concern and publicity that needs to be studied and resolved. Downstream communities include irrigated agricultural lands. To date, no data or written report reflecting the effect of the incident particularly in the rice growing areas.The main concern now is the build-up of sediments in San Roque Dam which in turn is used as supplier of water to the main irrigation system. Likewise, concerns on the risks of contamination nd bioaccumulation of heavy metals in the areas being served by the San Roque Dam. Heavy metals when taken up by the paddy rice through root absorption could be toxic for human consumption when it enter, deposit and bioaccumualte into the fatty tissues.

Aside from immediate effects of the incident on contamination in the rice areas, attention should also be taken into consideration on the long-term effects it has on the rice environment and the produced grain itself. Heavy metal contamination might possibly cause rice yield reduction due to inhibition of root growth. Hence this project was conceptualized to determine the extent, levels, build- up and long-term effects of heavy metal contamination in the paddy rice soils and rice grain particularly in areas being served by the Agno River.

Several rice areas near or along the different irrigation laterals in reference to the main canals of San Roque Dam (SRD) and Agno River. Seven laterals were pegged in the upstream of SRD main canal; five in the middle of the SRD main canal; five in the dowstream of the SRD main canal; four in the laterals of river including the Agno river; and 2 sites along irrigation canal not serviced by irrigation system connected to the SRD main stream. These areas were also characterized per their cropping sequence, fertilizer application level, pesticide application level, and the extent of mechanization.

Several farmers along these pegged areas were interviewed for the baseline information and their perceptions on the extent of the effect of the leak of mine tailings. Likewise, soils, rice straw, water and grains were gathered for chemical analyses of possible uptake of heavy and light metals. A biennial interview of the residents in the affected area will be done to know the status and further changes years after the leak.

Highlights:

- As observed by the farmers in the affected areas, there was deposition of sandy-like white to gray materials, the soil become difficult to plow, the irrigation water is milky-like, plant rice have stunted growth, fewer tillers, hence reduced yield. As mitigation, the farmers made some excavation to serve as the impounding pond of siltation between the irrigation canal gates to their farms; apply more fertilizers or more frequent irrigation.

- Soil copper, chromium, arsenic, mercury, zinc, and iron levels from the sampling sites are higher than soil quality guideline but they do not exceed intervention values (Table 2922).

- While heavy metals have decreasing concentration from the irrigation canal entrance relative to the origin of the mine tailing leaks, the concentration found in the grains from the different location were all similar (data not shown here). Hence the bioaccumulation of the heavy metals in the grain may not indicative of the distance of the rice areas to the origin of mine tailing leakage.

- Comparing the possible effects of other farm practices, the soil metal levels analyzed in the study are controlled by irrigation system, soil texture, available P, amount of granular fertilizers and pesticide applied.

- On the other hand, metals in grain are affected by soil pH and amount of granular fertilizer and pesticide applied (Table 3023).

- The observed index of bioaccumulation is highest for cadmium hence the most element to be accumulated in the rice grains.

Table 22. Heavy metal levels in soils of study sites as compared to background values and guidelines of countries (in lieu of the establishment of critical levels of heavy metals in the Philippines, as set by the Department of Health (DOH) and Department of Environment and Natural Resources (DENR 2014-2015. Science City of Munoz, Nueva Ecija.

Metal Guidelines and Values/Site	Cr	As	Cd	Hg	Pb	Cu	Zn	Fe	Mn
	mg kg^{-1}							%	
Natural abundance in Japanese paddy soils (N=97-408)[a]	64.0	9.0	0.45	0.32	29.0	32.0	99.0	-	-
Philippine paddy soils (N=54)[b]	130.0	-	-	-	-	37.0	81.0	2.70	0.15
Canadian soil quality guidelines for agricultural soils[c]	64.0	12.0	1.40	6.60	70.0	63.0	200.0	-	-
Netherlands target values for soils (2000)[d]	100.0	29.0	0.80	0.30	85.0	36.0	140.0	-	-
Netherlands intervention values for soils (2009)[d]	180 (VI)	76.0	13.0	36.0	530	190.0	720.0	-	-
Sediment samples adjacent to ARIIP's reservoir	52.9	5.2	0.34	0.14	18.3	243.7	125.0	4.41	0.14
Upstream ARIS sites									
Santiago ditch	30.4	17.0	0.29	0.32	46.1	446.9	175.0	4.78	0.09
Lateral A extra	39.1	16.3	0.20	0.31	39.3	364.7	169.0	4.60	0.09
Turn-out Service Area	31.7	15.0	0.29	0.20	40.7	612.6	177.7	4.76	0.09
Lateral B-adjacent	64.8	16.8	0.34	0.30	42.9	366.4	174.7	4.88	0.08
Namangonan canal	60.2	17.4	0.33	0.37	50.0	589.2	205.3	4.84	0.10
Lateral C	42.9	12.0	0.32	0.13	24.2	452.6	157.3	5.02	0.09
Midstream ARIS sites									
Lateral D	52.5	12.9	0.38	0.18	42.8	225.8	160.0	4.09	0.08
Lateral E	35.7	10.7	0.20	0.15	28.9	633.7	145.3	4.56	0.09
Lateral F	53.5	5.0	0.24	<0.1	12.3	89.7	77.3	3.26	0.07
Lateral F2	59.1	7.1	0.32	<0.1	15.7	124.8	95.3	3.74	0.13
Lateral G	27.2	18.8	0.40	0.19	45.5	512.5	192.3	4.86	0.11

Table 22. Heavy metal levels in soils of study sites as compared to background values and guidelines of countries (in lieu of the establishment of critical levels of heavy metals in the Philippines, as set by the Department of Health (DOH) and Department of Environment and Natural Resources (DENR 2014-2015. Science City of Munoz, Nueva Ecija. Con't.

Tanggal Perez canal	31.6	7.1	0.29	0.12	18.3	226.3	123.7	4.85	0.13
Downstream ARIS sites									
Lateral H	37.3	11.3	0.33	0.10	30.9	371.0	140.0	4.83	0.11
Lateral K	34.4	8.7	0.28	0.16	18.9	218.1	121.0	4.33	0.13
Lateral M	167.2	11.6	0.37	0.13	22.7	343.6	158.7	5.17	0.12
LARIS sites									
Site 1	82.4	3.1	0.30	<0.1	6.9	66.0	92.3	5.17	0.07
Site 2	66.4	3.9	0.25	<0.1	6.4	46.8	77.0	4.76	0.11
Site 3	68.6	3.5	0.18	<0.1	7.3	45.9	75.7	4.51	0.13
Site 4	73.7	3.4	0.35	<0.1	8.3	68.9	104.0	5.68	0.10
Site 5	65.1	6.4	0.23	<0.1	11.5	80.4	112.0	5.37	0.12

itagishi and Yamane (1981), [b]Domingo and Kyuma (1983), [c]Canadian Council of Ministers of the Environment d.),
inisterie van Volkshuisvesting, Ruimtelijke Ordening en Milieu (n.d.)

Table 23. Heavy metal levels in rice grains of study sites as compared to standards based in other countries (in lieu of the establishment of critical levels of heavy metals in the Philippines, as set by the Department of Health (DOH) and Department of Environment and Natural Resources (DENR) 2014-2015. Science City of Munoz, Nueva Ecija.

Metal Guidelines and Values/Site	Cr	As	Cd	Hg	Pb	Cu	Zn	Fe	Mn
					mg kg^{-1}				
Natural abundance in Japanese brown rice, N=30-8163[a]	-	0.16	0.09	0.01	0.19	2.90	19	-	-
Unhulled rice harvested from:									
Korea, contaminated soils, N=8[b]	-	-	0.03-0.65	-	0.20-0.70	1.60-4.60	11.8-21.8	-	-
Korea, uncontaminated soils, N=6[b]	-	-	0.24	-	0.50	3.00	18.4	-	-
India, irrigation contaminated by Hg only[c]	0.09	0.08	0.01	0.03-1.19	-	-	-	-	-
Tanzania, uncontaminated soils, N=18[d]	1.01	-	0.12	0.00152	0.31	5.90	48.7	-	-
Malaysia, uncontaminated soils, N=25-29[e]	2.98	-	0.07	-	2.01	0.08	11.1	96.7	23.9
Upstream ARIS sites									
Santiago ditch	0.50	<1	0.05	0.03	0.80	4.77	18.0	80.0	48.0
Lateral A extra	0.67	<1	0.06	0.02	<0.5	3.97	16.7	40.0	37.3
Turn-out Service Area	0.40	<1	0.09	0.02	0.47	4.17	16.0	43.3	51.7
Lateral B-adjacent	0.40	<1	0.03	0.01	0.43	4.07	16.3	33.3	40.7
Namangonan canal	0.43	<1	0.10	0.02	<0.5	4.40	15.7	36.7	58.7
Lateral C	1.47	<1	0.11	0.01	1.13	5.90	18.0	120.0	44.0
Midstream ARIS sites									
Lateral D	1.33	<1	0.05	0.03	1.37	3.93	17.7	73.3	53.3
Lateral E	4.03	<1	0.02	0.01	<0.5	3.83	14.0	73.3	42.7
Lateral F	1.77	<1	0.06	0.03	<0.5	3.07	16.7	100.0	46.0
Lateral F2	5.20	<1	0.10	0.02	<0.5	2.25	18.5	115.0	72.5
Lateral G	1.53	<1	0.03	0.01	0.83	3.77	15.7	80.0	74.3
Tanggal Perez canal	2.63	<1	0.08	0.02	0.53	4.13	17.7	110.0	84.3
Downstream ARIS sites									
Lateral H	<0.5	<1	0.11	0.01	0.43	5.43	20.0	103.3	77.3
Lateral K	1.73	<1	0.15	0.01	<0.5	3.67	16.3	73.3	76.7

Table 23. Heavy metal levels in rice grains of study sites as compared to standards based in other countries (in lieu of the establishment of critical levels of heavy metals in the Philippines, as set by the Department of Health (DOH) and Department of Environment and Natural Resources (DENR) 2014-2015. Science City of Munoz, Nueva Ecija. Con't.

Lateral M	0.70	<1	0.01	0.01	<0.5	3.50	16.7	73.3	68.3
LARIS sites									
Site 1	<0.50	<1	0.06	0.02	<0.5	3.00	16.0	103.3	64.0
Site 2	0.83	<1	0.10	0.02	<0.5	4.27	16.3	176.7	65.0
Site 3	4.60	<1	0.02	0.01	<0.5	4.70	18.3	343.3	64.0
Site 4	1.00	<1	0.03	0.01	0.53	3.37	15.3	140.0	48.3
Site 5	1.03	<1	0.04	0.01	<0.5	3.07	15.0	150.0	71.3

[a]Iimura 1981, [b]Lee et al. 2001, [c]Sing et al. 2011, [d]Machiwa 2010, [e]Alrawiq et al. 2014, Khairiah et al. 2013

V. Assessment and Evaluation of Variety, Water, Nutrient, and Pest Interactions

Project Leader: LM Juliano

The project was established to develop a holistic approach in crop and pest management. The interaction of nutrient and water with the prevalence of pests and diseases should be evaluated to come up with a strategy to better manage these complexities in crop management. Variety evaluation along with its response to the application of nutrients, the interaction of water and the prevalence of pests and diseases pose a complex interaction among growth resources of the rice plant. Studies under this project are implemented in the different stations.

The use of rice varieties with high yield potential is one of the key factors in achieving higher productivity. Along with genotype, crop management like nitrogen application and location has large contribution to the attainment of yield potential. Therefore, the maximum yield potential of new varieties and even promising lines and the associated N management at specific location must be determined before recommendation to farmers and other stakeholders. Varieties with high yield potential should reach farmers to contribute to the goal of rice sufficiency. Hence, nutrient management especially on the use of nitrogen (N) is fundamental in achieving the yield potential of any variety.

Yield potential of irrigated lowland rice varieties in response to nitrogen management

MD Malabayabas, NR Dadufalza II and RT Cruz

One way to increase rice productivity is through the use of varieties with high yield potential coupled with appropriate nutrient management particularly nitrogen (N). Thus, a study was conducted at PhilRice CES in 2015 Dry Season (DS) and Wet Season (WS) to determine the yield potential of early to medium maturing varieties and their response to N management. The experiment was laid out in split plot design with N management as main plot and variety as sub-plot with three replications. N management treatments were (1) 0 N or N omission plot (NOP) + 40kg ha-1 P2O5, + 40kg ha-1 K2O+ 10kg ha-1 ZnSO4 applied at 1 day before transplanting (DBT); (2) 6 bags 14-14-14-12S in DS and 4 bags in WS + 10kg ha-1 Zn SO4 applied at 14 days after transplanting (DAT) + N topdressing of 35kg N ha-1 in DS and 23kg N ha-1 in WS when Leaf Color Chart (LCC) LCC reading fell below 4; (3) fixed N rate of 190kg N ha-1 in DS and 95kg ha-1 in WS (applied in 3 splits) + 40kg ha-1 each of P2O5 and K2O + 10kg ha-1 ZnSO4, applied at 1 DBT. The test varieties (and growth duration) were NSIC Rc122 (121 days), Rc238 (110 days), Rc240 (115 days), Rc302

(115 days), Rc308 (110 days) and Rc360 (122 days) with PSB Rc18 (123 days) and Rc82 (110 days) as checks. Pest incidence/damage was assessed by the Crop Protection group at hard dough stage.

Highlights:

- In 2015 DS, grain yield in the NOP ranged from 2.96 to 4.93t/ha (Table 24). In the LCC-based N application, yield ranged from 6.60 to 7.65t/ha and 6.41 to 9.48t/ha with fixed N rate of 190kg ha-1. N management and varieties showed significant interaction in yield. NSIC Rc238, Rc240, Rc302 and Rc308 produced significantly higher yield at 190kg N ha-1 comparable with Rc82 in the NOP and LCC-based N management. But these varieties did not out yield Rc82 at 190kg N ha-1.

- On the other hand, Rc360 had significantly higher yield with LCC-based N application. Rc18 and Rc122 showed significantly lower yield due to high whitehead (WH) damage of 22 and 32.83%, respectively. WH damage at 190kg N ha-1 was significantly higher (17.22 %) than the LCC-based (9.97%) and NOP (8.69%). Other pest damage was minimal.

- N management and variety also showed significant interaction in Agronomic Efficiency for N (AEN) during DS. Most varieties had significantly higher AEN with LCC-based N application than fixed N rate of 190kg ha-1 except in Rc82 and Rc238 where AEN were comparable in both N management treatments (Table 25). In LCC-based, Rc240 and Rc360 had comparable AEN with PSB Rc18 and Rc82 while the rest were comparable only with Rc82. At 190kg N ha-1, AEN of new varieties were mostly comparable with the checks. The total N fertilizer rates with LCC-based N management ranged from 77 to 112kg ha-1.

- In WS, grain yield ranged from 4.9 to 5.73t/ha (Table 26). All new varieties gave comparable yield with Rc82. Grain yield between LCC-based and fixed N rate of 95 kg ha-1 did not differ significantly but AEN was significantly higher with LCC-based application (Table 34). AEN among varieties were comparable except that AEN of Rc122 was significantly higher than Rc238 (Table 27). PSB Rc18 had significantly lower yield due to WH damage of 4.4% in the NOP, 13.8% in LCC-based and 17% in the fixed N rate application of 95kg ha-1.

- Results showed that most varieties showed high yield potential in both LCC-based and fixed N rate application. However, higher AEN was achieved with LCC-based N management giving N fertilizer cost savings of 22% to 59%.

Table 24. Grain yield (t/ha) of varieties at each N management treatment, 2015 DS.

Variety	0-40-40 kg NPK	LCC-based-40-40	190-40-40 kg N ha^{-1}
PSB Rc18 (check)	2.96 b	6.60 b	6.41 c
PSB Rc82 (check)	4.65 a	7.65 a	9.48 a
NSIC Rc122	3.09 b	5.40 c	5.23 d
NSIC Rc238	4.55 a	7.16 ab	7.88 b
NSIC Rc240	4.64 a	7.29 ab	8.21 b
NISC Rc302	4.93 a	7.36 ab	8.43 b
NSIC Rc308	4.60 a	7.11 ab	7.70 b
NSIC Rc360	4.40 a	7.20 ab	6.61 c

Means with the same letter are not significantly different at 5% level of significance by HSD.

Table 25. Agronomic Efficiency for Nitrogen (AEN) of varieties with LCC-based N application and fixed N rate of 190kg ha-1, 2015 DS.

Variety	N management	
	LCC-based	Fixed N rate -190 kg ha^{-1}
PSB Rc18	47.35 a (77)	18.18 ab
PSB Rc82	26.81 bc (112)	25.42 a
NSIC Rc122	20.68 c (112)	11.29 b
NSIC Rc238	23.37 bc (112)	17.55 ab
NSIC Rc240	34.39 ab (77)	18.79 ab
NISC Rc302	31.51 bc (77)	18.38 ab
NSIC Rc308	32.63 bc (77)	16.30 ab
NSIC Rc360	36.28 ab (77)	11.65 b

Means with the same letter are not significantly different at 5% level of significance by HSD. Figures in parentheses were the total N fertilizer rate with LCC-based N management.

Table 26. Grain yield and Agronomic Efficiency for Nitrogen (AEN) of varieties, 2015 WS.

Variety	Grain yield (t ha^{-1})	AEN (kg grain kg N^{-1})	Total N fertilizer rate with LCC-based application (kg ha^{-1})
PSB Rc18	4.90 b	30.67 ab	51
PSB Rc82	5.73 a	24.22 ab	74
NSIC Rc122	5.47 ab	35.64 a	51
NSIC Rc238	5.53 ab	16.90 b	74
NSIC Rc240	5.73 a	28.04 ab	51
NSIC Rc302	5.69 a	29.80 ab	51
NSIC Rc308	5.63 a	31.15 ab	51
NSIC Rc360	5.58 a	25.10 ab	51

Means with the same letter are not significantly different at 5% level of significance by HSD.

Table 27. Grain yield and Agronomic Efficiency for Nitrogen (AEN) at different N management, 2015 WS.

N management	Grain yield (kg ha^{-1})	AEN (kg grain kg N^{-1})
NOP	4.25 b	-
LCC-based	6.15 a	34.75 a
Fixed N rate – 95 kg ha^{-1}	6.21 a	20.63 b

Means with the same letter are not significantly different at 5% level of significance by LSD.

Validating the mechanism of tolerance of rice genotypes to stagnant flooding and submergence stresses

RT Cruz, NV Desamero, SA Balidiong and JH Ajos

Rice yield is reduced by abiotic stresses, nutrient deficiencies (Lafitte et al. 2004 International Crop Science Congress Australia) and biotic stresses due to pest and disease (Peterson and Higley 2010 CRS Press 261). Types of abiotic stresses in the rainfed lowland ecosystem are flooding, submergence, drought and salinity. The said abiotic stresses and high temperature are anticipated to worsen as the consequences of climate change (Mackill et al. 2010 Crop Environment & Bioinformatics 7). Yields range from 1.5 to 2.5t/ha in flood-prone and submergence-prone rainfed areas. Short-term flooding or short-term partial flooding (STPF) occurs when 30 to 50 cm floodwater depths partly submerge the rice plants in the field for 2 weeks. Flooding results in hypoxia, a condition with 2 to 3 % O2 that can affect crop growth, development and yield. Rice response to submergence stress may vary depending on the degree and duration of stress, genotypic tolerance, crop management and other environmental conditions. The quiescence strategy (slow shoot elongation) is advantageous in flash-flood prone areas where the whole shoot is submerged at a depth difficult for the leaves to have contact with air, or the flooding duration is short or less than 2 weeks. The escape strategy, characterized by fast underwater shoot elongation, is crucial for survival in deepwater rice areas where floodwater deepens rapidly in the field (Colmer and Voesenek 2009 Functional Plant Biol 2009; Colmer et al. 2014 Progress in Bot 75). The degree of elongation during submergence stress is gene-regulated, resulting to ethylene biosynthesis, regulation of abscisic acid, gibberelic acid, amylase activities, and hence shoot and root growth (Ismail et al. 2009 Ann Bot 103; Ismail et al. 2012 AoB PLANTS 2012; Miro and Ismail 2013 Frontiers in Plant Science 4). However, neither quiescence nor escape strategy on its own leads to successful tolerance of longer-term partial flooding or stagnant flooding (SF) and achieving high yields (Vergara et al. 2014 AoB PLANTS 6). For SF treatment wherein floodwater was gradually increased at a rate of 2cm day-1 to reach a final depth of 50 cm and then maintained until maturity, grain yield was reduced by 47% (6.1t/ha in Control vs. 3.1t/ha in Stress) across rice genotypes (Kato et al. 2014 AoB PLANTS 6). The reduction in yield was mainly attributed to reduction in biomass caused by reduced light interception and leaf growth above water. SF also reduced panicle number due to reduced tillering.

Shoot elongation rate kept pace with rising floodwater and correlated positively with leaf growth and biomass production. However, stem non-structural carbohydrate (NSC) concentration correlated negatively with shoot elongation rate, indicating that fast-elongating genotypes actively consume NSCs to avoid complete submergence. Moderate shoot elongation rate strongly and positively correlated with grain yield. But elongation rates greater than 2.0 cm day-1 was associated with reduced harvest index due to smaller panicle size and increased lodging. Tolerant varieties were found to be inherently tall or elongate moderately with rising floodwater.

The present study assessed the tolerance of rice genotypes to short-term partial flooding, i.e., 2 weeks duration of flooding with 30 cm floodwater depth in the screenhouse at PhilRice Nueva Ecija and 50 cm floodwater depth in the field at PhilRice Midsayap during the vegetative growth stage. The performance of the genotypes was assessed in terms of growth and biomass or dry matter yield. The genotypes tested in the screenhouse were PSB Rc82, PSB Rc222, PSB Rc68, NSIC Rc194, PSB Rc18, Ciherang Ag+ Sub1, PR41561-B-2-Sal 1-1-1, PR41561-B-2-Sal 2-1-1-1 and PR41543-B-14-2-1-2. The susceptible check was IR42 and the tolerant check was FR13A. The genotypes tested in the field were PSB Rc82, PSB Rc68, Ciherang Ag+ Sub1 and PR41543-B-14-2-1-2. FR13A is a submergence tolerant traditional variety from India. Ciherang Ag+ Sub1 was derived from the introgression of the anaerobic germination tolerance gene (Ag+) from Kha Hlan On, a Myanmar landrace, and a submergence tolerance gene (Sub1) from FR13A to Ciherang, a popular variety in Indonesia. PR41561-B-2-Sal 2-1-1-1, PR41561-B-2-Sal 2-1-1-1 and PR41543-B-14-2-1-2 are lines developed by PhilRice for flood-prone and submergence-prone areas. PSB Rc82, PSB Rc222, PSB Rc68, PSB Rc18 and NSIC Rc194 are popular inbred varieties with good grain yield and quality.

Highlights:

Screenhouse Experiment

- Before the start of short-term partial flooding (STPF) at 21 days after transplanting (DAT), plant heights were 67.4cm for the susceptible check IR42 and 91.3 cm for the tolerant check FR13A (Table 35). Plant heights of PSB Rc82, Ciherang Ag+ Sub1 and the other genotypes ranged 64.4 to 84.3cm. Results indicate that FR13A is a relatively tall rice genotype. Seven days after flooding or 28 DAT, plant heights were 82.5cm for IR42 and 109.4 for FR13A. Fourteen days after flooding or 35 DAT, plant heights were 95.1cm for IR42 and 114.9cm for FR13A. Plant heights of PSB Rc82, Ciherang Ag+ Sub1 and the other genotypes ranged from 91.0 to 117.3cm. Twenty one days after de-flooding or 56 DAT, plant heights were 95.1 cm for IR42 and 117.5 cm for FR13A. Plant heights of PSB

Rc82, Ciherang Ag+ Sub1 and the other genotypes ranged from 94.8 to 119.3cm. Average tiller count per plant was close to 3 and did not differ significantly among the genotypes (Table 28).

- Seven days after STPF with 30 cm floodwater depth at 28 DAT, shoot elongation rates were 0.43 cm/day for IR42 and 0.52cm/day for FR13A (Table **29**). Shoot elongation rates of PSB Rc82, Ciherang Ag+ Sub1 and the other genotypes ranged from 0.36 to 0.83cm/day. Fourteen days after STPF with 30 cm floodwater depth at 35 DAT, shoot elongation rates were 0.79cm/day for IR42 and 0.68 cm/day for FR13A. Shoot elongation rates of PSB Rc82, Ciherang Ag+ Sub1 and the other genotypes ranged from 0.68 to 0.94cm/day. Twenty one days after de-flooding at 56 DAT, shoot elongation rate was 0.75cm/day for IR42 and FR23A. Shoot elongation rates of PSB Rc82, Ciherang Ag+ Sub1 and the other genotypes ranged from 0.76 to 1.14cm/day. Across flooding and de-flooding treatments and compared to the other genotypes, the susceptible check IR42 and the tolerant check FR13A tend to exhibit the quiescence strategy or slow shoot elongation.

- Before flooding at 21 DAT, shoot and root biomasses of the IR42 were 0.55g/plant and 0.12g/plant, respectively (Table 37). Shoot and root biomasses of FR13A were 0.91 and 0.15g/plant, respectively. Shoot biomasses of PSB Rc82, Ciherang Ag+ Sub1 and the other genotypes ranged from 0.49 to 1.1g/plant. Root biomasses ranged 0.06 to 0.16g/plant. After 2 weeks of STPF and 21 days after de-flooding at 56 DAT, shoot and root biomasses of IR42 were 1.73 and 0.10 g/plant, respectively. Shoot and root biomasses of FR13A were 11.85 and 1.36g/plant, respectively (Table 30). Shoot biomasses of PSB Rc82, Ciherang Ag+ Sub1 and the other genotypes ranged from 4.81 to 8.24g/plant. Root biomasses ranged 0.11 to 0.86g/plant.

- Although both the susceptible check IR42 and the tolerant check FR13A tend to exhibit the quiescence or slow shoot elongation strategy, FR13A could have had a better adaptive mechanism that resulted to the highest shoot and root biomasses after flooding and de-flooding (Table 30). PSB Rc82, Ciherang Ag+ Sub 1, PR1561-B-2-Sal 2-1-1-1 and other genotypes that generally had higher shoot elongation rates than IR42 and FR13A, had intermediate shoot and root biomasses. Compared to the other genotypes, IR42 had the lowest shoot and root biomass accumulation after STPF and de-flooding (Table 30). Biomass allocation is a major factor in the response of plants to limiting resource supply (Poorter and Nagel 2000 Australian J Plant Physiol 27) which in our study is the low oxygen level under short-term partial submergence or flooding. Genotypes with higher shoot and root biomass accumulation can be associated to good recovery after de-flooding. Better recovery after de-flooding can be attributed to leaf chlorophyll retention during submergence or flooding (Singh et al. 2014 AoB Plants) and other internal plant mechanisms (Miro and Ismail 2013 Frontiers in Plant Sci 4).

Field Experiment

- Before the start of STPF at 21 days after transplanting (DAT), plant heights of PSB Rc82, PSB Rc68, PR41543-B-14-2-1-2 and Ciherang Ag+ Sub 1 in the control and STPF-designated treatments ranged from 40.0 to 51.0cm/plant and did not differ significantly (Table 31). Tiller number ranged from 7 to 13 tillers/pant and likewise did not differ significantly among the genotypes.

- One week after STPF with 50cm floodwater depth at 28 DAT, plant height ranged 60.4 to 64.9cm/plant in the control and 54.7 to 59.4cm/plant with STPF and did not differ significantly among the genotypes (Table 31). Tiller number ranged from 11 to13 tillers/plant in the control and 9 to 11 tillers/plant with STPF and did not differ significantly among the genotypes. Based on the control, plant height was reduced by 1.7 to 18.6% with STPF for the 4 test genotypes. Tiller number/plant was reduced by as much as 30%.

- Similar trends for plant height and tiller number were observed for the 4 test genotypes 2 weeks after STPF. However, based on the control, reductions in plant height and tiller number were reduced by as much as 21.2 and 66.7%, respectively. One week after de-flooding, plant height was reduced by as much as 32.5% and tiller number was reduced by as much as 220%. Two weeks after de-flooding, plant height was reduced by as much as 31.6% and tiller number was reduced by as much as 400%.

- Before STPF at 21 DAT, shoot biomass of PSB Rc82, PSB Rc68, PR1543-B-14-2-1-2 and Ciherang Ag+ Sub1 in the control and STPF-designated treatments ranged from 6.2 to 8.1g/plant and did not differ significantly for most of the genotypes (Table 32). Root biomass in the control and STPF-designated treatments ranged from 5.3 to 6.8 g/plant and did not differ significantly among the genotypes.

- Two weeks after STPF and 28 days after de-flooding at 63 DAT, shoot biomass of PSB Rc82, PSB Rc68, PR41543-B-14-2-1-2 and Ciherang Ag+ Sub 1 ranged from 8.1 to 10.8 g/plant and did not differ among the genotypes. In the control, shoot biomass ranged 23.3 to 33.9g/plant and did not differ significantly among the genotypes (Table 3932). Root biomass ranged 5.9 to 6.9g/plant with STPF and did not differ significantly among the genotypes. In the control, root biomass ranged 12.6 to 31.8g/plant and did not differ significantly among the genotypes. Based on the control, shoot biomass decreased by as much as 214% while root biomass decreased by as much as 301%. In the screenhouse experiment, PSB Rc82, PSB Rc68, PR41543-B-14-2-1-2 and Ciherang Ag+ Sub 1 had higher shoot elongation rates than the susceptible check IR42 and tolerant check FR13A (Table 36) but their shoot and root biomasses were lower than FR13A (Table 37). Due to inadequate amount of seeds, IR42 and FR13A were not tested in the field. Hence, contrasting putative mechanisms of adaptation to short-term partial flooding were not validated in the field. For example, the quiescence strategy or slow shoot elongation in the case of FR13A and IR42 but differing in their biomass yields vs. the escape strategy or fast shoot elongation in the case of Ciherang Ag+ Sub1, PSB Rc82 and the other genotypes but their biomass yields lower than FR13A, should have been studied in the field.

Table 28. Screenhouse experiment. Performance of 9 rice genotypes including 1 susceptible check (IR42) and 1 tolerant check (FR13A) before, during and after exposure to short-term partial flooding (STPF), i.e., 2 weeks with 30cm floodwater depth. Means followed by the same letter in a column are not significantly different at 5 % level of significance using Tukey's Honest Significant Difference (HSD) Test. BF= before flooding. AF= after flooding. ADeF= after de-flooding.

Days After Transplanting (DAT)	Genotypes	Shoot Elongation or Plant height (cm/plant)	Tiller Number/Plant
21 DAT **(4 hours BF)**	**IR42 (susceptible check)**	67.4 de	3 ab
	PSB Rc82	66.5 de	2 b
	PSB Rc222	64.8 e	3 ab
	PSB Rc68	72.5 cde	2 ab
	PSB Rc18	64.4 e	3 ab
	NSIC Rc194	69.3 cde	4 a
	PR41543-B-14-2-1-2	75.8 bcd	3 ab
	PR41561-B-2-Sal 1-1-1	79.5 bc	2 ab
	PR41561-B-2-Sal 2-1-1-1	84.3 ab	3 ab
	Ciherang Ag+ Sub1	69.0 cde	3 ab
	FR13A (tolerant check)	91.3 a	2 b
28 DAT **(AF)**	**IR42 (susceptible check)**	82.5 c	4 a
	PSB Rc82	79.2 c	2 b
	PSB Rc222	80.6 c	3 ab
	PSB Rc68	92.9 bc	2 ab
	PSB Rc18	85.3 bc	3 ab
	NSIC Rc194	89.4 bc	3 ab
	PR41543-B-14-2-1-2	97.5 ab	3 ab
	PR41561-B-2-Sal 1-1-1	108.6 a	3 ab
	PR41561-B-2-Sal 2-1-1-1	106.8 a	3 ab
	Ciherang Ag+ Sub1	85.5 bc	3 ab
	FR13A (tolerant check)	109.4 a	3 ab
35 DAT **(AF)**	**IR42 (susceptible check)**	95.1 b	3 a
	PSB Rc82	90.6 b	3 a
	PSB Rc222	91.0 b	3 a
	PSB Rc68	96.4 b	2 a
	PSB Rc18	93.0 b	3 a
	NSIC Rc194	95.5 b	3 a
	PR41543-B-14-2-1-2	108.4 a	3 a
	PR41561-B-2-Sal 1-1-1	113.8 a	3 a
	PR41561-B-2-Sal 2-1-1-1	117.3a	3 a
	Ciherang Ag+ Sub1	94.4 b	3 a
	FR13A (tolerant check)	114.9 a	4 a
56 DAT **(ADeF)**	**IR42 (susceptible check)**	95.1 bc	3 a
	PSB Rc82	97.9 bc	6 a
	PSB Rc222	97.4 bc	5 a
	PSB Rc68	104.0 abc	5 a
	PSB Rc18	94.8 c	6 a
	NSIC Rc194	95.8 bc	3 a
	PR41543-B-14-2-1-2	113.3 ab	4 a
	PR41561-B-2-Sal 1-1-1	119.3 a	3 a
	PR41561-B-2-Sal 2-1-1-1	119.3 a	3 a
	Ciherang Ag+ Sub1	101.6 abc	3 a
	FR13A (tolerant check)	117.5 a	7 a

Table 29. Screenhouse experiment. Shoot elongation rate of 9 rice genotypes including 1 susceptible check (IR42) and 1 tolerant check (FR13A) after short-term partial flooding (STPF) with 30 cm floodwater depth at 21 days after transplanting (DAT) and 35 DAT and after de-flooding at 56 DAT.

Genotype	Growth rate (cm/day)		
	28 DAT or 7 days after flooding	35 DAT or 14 days after flooding	56 DAT or 21 days after de-flooding
IR42 (susceptible check)	0.43	0.79	0.75
PSB Rc82	0.36	0.69	0.90
PSB Rc222	0.45	0.75	0.93
PSB Rc68	0.58	0.68	0.90
PSB Rc18	0.60	0.82	0.87
NSIC Rc194	0.58	0.75	0.76
PR41543-B-14-2-1-2	0.62	0.93	1.07
PR41561-B-2-Sal 1-1-1	0.83	0.98	1.14
PR41561-B-2-Sal 2-1-1-1	0.64	0.94	1.00
Ciherang Ag+ Sub1	0.47	0.73	0.93
FR13A (tolerant check)	0.52	0.68	0.75

Table 30. Screenhouse experiment. Biomass accumulation of 9 rice genotypes including 1 susceptible check (IR42) and 1 tolerant check (FR13A) before short-term partial flooding (STPF) with 30cm floodwater depth at 21 days after transplanting (DAT) to 35 DAT and 21 days after de-flooding at 56 DAT. The experiment was conducted in 2015 WS (September to November, 2015). Means followed by the same letter in a column were significantly different at 5% level of significance using Tukey's Honest Significant Difference (HSD) Test. BF= before flooding. ADeF= after de-flooding.

Days After Transplanting (DAT)	Genotype	Shoot Biomass ($g/plant^-$)	Root Biomass ($g/plant^-$)
21 DAT (4 hours BF)	**IR42 (susceptible check)**	0.55 bc	0.12 a
	PSB Rc82	0.49 c	0.10 a
	PSB Rc222	0.67 abc	0.08 a
	PSB Rc68	0.58 bc	0.14 a
	PSB Rc18	0.50 c	0.06 a
	NSIC Rc194	0.79 abc	0.16 a
	PR41543-B-14-2-1-2	0.93 ab	0.10 a
	PR41561-B-2-Sal 1-1-1	0.68 abc	0.11 a
	PR41561-B-2-Sal 2-1-1-1	1.08 a	0.16 a
	Ciherang Ag+ Sub1	0.63 bc	0.13 a
	FR13A (tolerant check)	0.91 abc	0.15 a
56 DAT (ADeF)	**IR42 (susceptible check)**	1.73 c	0.10 c
	PSB Rc82	8.24 ab	0.86 ab
	PSB Rc222	7.31 abc	0.39 bc
	PSB Rc68	5.07 bc	0.43 bc
	PSB Rc18	3.69 bc	0.14 c
	NSIC Rc194	3.90 bc	0.17 c
	PR41543-B-14-2-1-2	5.57 bc	0.11 c
	PR41561-B-2-Sal 1-1-1	4.81 bc	0.15 c
	PR41561-B-2-Sal 2-1-1-1	5.66 abc	0.34 bc
	Ciherang Ag+ Sub1	5.66 abc	0.24 c
	FR13A (tolerant check)	11.85 a	1.36 a

Table 31. Field experiment. Performance of rice genotypes in the control (2 to 3cm flood water) and short-term partial flooding or STPF (50cm floodwater depth from 21 days after transplanting or DAT to 35 DAT) and after de-flooding at 42 and 56 DAT. The field experiment was conducted in 2015 WS (September to November, 2015). In a column, means followed by a common letter are not significantly different at 5 % level with Tukey's Honest Significant Difference (HSD) Test. BF= before flooding. AF= after flooding. ADeF= after de-flooding. IR42 and FR13A were not included due to inadequate seeds. Note: control of depth of water (i.e., maintaining 50 cm water depth) was more difficult in the field than maintaining 30 cm water depth in the steel tank in the screenhouse.

Genotype	Shoot Elongation or Plant Height (cm/plant⁻)		Tiller Number/Plant	
	Control	Short-Term Partial Flooding	Control	Short-Term Partial Flooding
21 DAT (4 hours BF)				
PSB Rc82	40.0 a	50.7 a	7 a	13 a
PSB Rc68	50.0 a	50.7 a	9 a	7 a
PR41543-B-14-2-1-2	41.0 a	50.7 a	8 a	13 a
Ciherang Ag+ Sub1	46.0 a	51.0 a	9 a	10 a
28 DAT (AF)				
PSB Rc82	60.4 a	59.4 a	11 b	9 a
PSB Rc68	64.5 a	59.1 a	13 a	10 a
PR41543-B-14-2-1-2	64.9 a	54.7 a	13 a	9 a
Ciherang Ag+ Sub1	62.0 a	55.3 a	11 b	11 a
35 DAT (AF)				
PSB Rc82	71.5 a	70.4 a	12 b	8 a
PSB Rc68	80.1 a	71.1 a	15 a	9 a
PR41543-B-14-2-1-2	77.5 a	71.1 a	15 a	9 a
Ciherang Ag+ Sub1	75.0 a	61.9 a	12 b	9 a
42 DAT (ADeF)				
PSB Rc82	84.0 a	71.0 a	16 a	5 a
PSB Rc68	87.5 a	66.5 a	13 a	6 a
PR41543-B-14-2-1-2	79.2 a	72.8 a	14 a	7 a
Ciherang Ag+ Sub1	86.1 a	65.0 a	13 a	6 a
56 DAT (ADeF)				
PSB Rc82	83.9 a	78.4 a	20 a	4 a
PSB Rc68	88.2 a	67.0 a	17 ab	5 a
PR41543-B-14-2-1-2	77.3 a	64.6 a	15 b	6 a
Ciherang Ag+ Sub1	87.4 a	67.9 a	16 b	4 a

Table 32. Field experiment. Biomass accumulation of rice genotypes in the control (2 to 3cm floodwater) and short-term partial flooding or STPF (50cm floodwater depth from 21 days after transplanting (DAT) to 35 DAT) and 28 days after de-flooding at 63 DAT. The field experiment was conducted in 2015 WS (September to November, 2015). In a column, means followed by a common letter are not significantly different at 5 % level with Tukey's Honest Significant Difference (HSD) Test. BF= before flooding. ADeF= after de-flooding. IR42 and FR13A were not included due to inadequate seeds.

Days After Transplanting (DAT)	Genotype	Shoot Biomass (g/plant⁻)		Root Biomass (g/plant⁻)	
		Control	Short-Term Partial Flooding	Control	Short-Term Partial Flooding
21 DAT (4 hours BF)	PSB Rc82	8.1 a	6.7 a	5.7 a	5.7 a
	PSB Rc68	6.2 b	7.8 a	5.3 a	6.8 a
	PR41543-B-14-2-1-2	7.8 a	6.4 a	6.5 a	5.6 a
	Ciherang Ag+ Sub1	7.8 a	7.3 a	6.3 a	6.2 a
63 DAT (ADeF)	PSB Rc82	23.3 a	8.1 a	12.6 a	5.9 a
	PSB Rc68	32.2 a	10.7 a	15.8 a	6.3 a
	PSB Rc82	23.3 a	8.1 a	12.6 a	5.9 a
	PR41543-B-14-2-1-2	29.1 a	9.7 a	12.7 a	6.0 a
	Ciherang Ag+ Sub1	33.9 a	10.8 a	31.8 a	6.9 a

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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