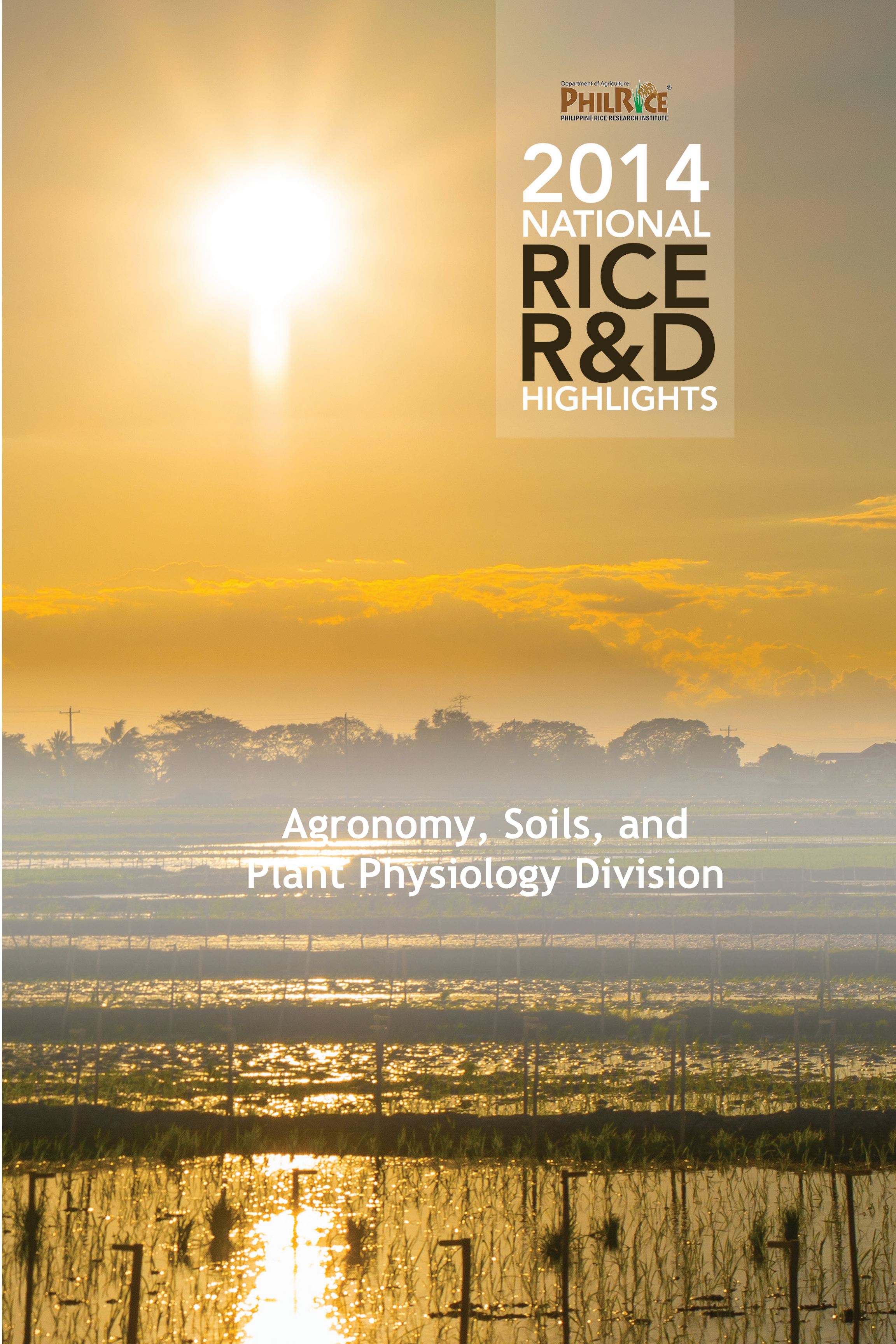

Department of Agriculture
PHILRICE
PHILIPPINE RICE RESEARCH INSTITUTE

2014 NATIONAL RICE R&D HIGHLIGHTS

Agronomy, Soils, and Plant Physiology Division

TABLE OF CONTENTS

Executive Summary	Page
Agronomy, Soils, and Plant Physiology Division	1
I. Long-Term Soil Fertility Evaluation and Rice Plant Responses	2
II. Development of Soil, Water, Nutrient, and Crop Yield Diagnostic Techniques for Irrigated Lowland Rice	20
III. Assessment and Evaluation of Crop Intensification and Resource Use Efficiency in Rice Production	30
IV. ASPPD Research and Analytical Laboratory Systems and Maintenance	61
V. Assessment and Evaluation of Variety, Water, Nutrient and Pest Interactions	67
Abbreviations and acronymns	76
List of Tables	78
List of Figures	82

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 2014, an additional project (Assessment and Evaluation of Variety, Water, Nutrient and Pest Interactions) was established to address concerns on nutrient and water by pest interactions. These four (4) R&D projects and another 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 2014, studies were conducted to assess the effectiveness of the different strategies in managing the nitrogen (N) requirement of lowland rice varieties under Maligaya soil condition using inorganic and organic sources of nutrients for the rice plant. Generally, mean grain yields of the rice varieties tested from the dry and wet seasons showed an increasing trend with nitrogen (N) application regardless of the methods of N application (Table 1). However, it was observed that the application of 60kg N ha^{-1} gave higher mean grain yield of 5.79t/ha^{-1} than the applications of 80kg N ha^{-1} (5.21t/ha) and 90kg N ha^{-1} (5.56t/ha). Highest mean grain yield of 7.15t/ha was obtained in the dry season with the application of 120kg N ha^{-1} (fixed-time N application). At higher N rates (180 and 210kg N ha-1), mean grain yields did not further increase and was much lower than the application of 120kg N ha^{-1}, but higher than the applications of 45to 90kg N ha^{-1}. In the LCC-based N application, mean grain yields of the rice varieties tested was only 6.02 t/ha with the applications of 65 to 185kg N ha^{-1} in the dry season and 90 to 150kg N ha^{-1}.

The mean agronomic efficiency of the applied N (AEN) varied across N rates and the methods of N application (Table 2). The highest production of grains per unit of N applied was obtained by the application of 120 and 45kg N ha^{-1} (fixed-time N application) at 23.29 and 37.61kg grain kg N^{-1} applied in the dry and wet seasons, respectively. It was also observed that the application of 60kg N ha^{-1} (fixed-time application) produced higher grains per unit of applied N than the applications of 80 and 90kg N ha^{-1}. The LCC-based N application gave lower mean AEN of 14.88 kg grain kg N^{-1} compared to the applications of 45-120kg N ha^{-1}.

In the organic-based fertilization study, the application of pure organic fertilizer sources gave significantly lower mean grain yield (4.65t/ha) than the application of pure inorganic and the combination of organic and inorganic fertilizers regardless of rates (Figure 1). Highest mean grain yield of 6.61 and 6.56t/ha was achieved by the applications of 100% rates of inorganic and the combination of organic and 100% inorganic fertilizers, respectively. However, the results showed that the combination of organic and inorganic fertilizers regardless of rates did not further increased the mean grain yields of the rice varieties tested. Highest AEN was obtained by the application of 50% inorganic fertilizer at 32.33kg grain kg N^{-1}, although the mean grain yield was lower than the applications of 100% inorganic and the combination of organic and 100% inorganic fertilizers.

In the long-term soil fertility experiment, the mean indigenous nutrient supplying (INS) capacity of the experimental site (Block III, Lot 1a) during the 2014 croppings per season were 61.5kg N ha-1, 10.5kg P2O5 ha-1, and 64.5kg K2O ha^{-1}. Further, the INS capacity of the experimental field was 58.65 kg/ha. In the yield potential study, the INS of the experimental field was 61 kg/ha. Overall, the mean INS of the experimental fields used in the three studies was 60.31kg N ha^{-1}.

The grain quality characteristics of the inbred, hybrid and traditional rice varieties harvested from the 2013 DS cropping ranged from 0.98 to 2.1% for grain N content, 5.8 to 12.5% for crude protein content, 3.2 to 27.3% for amylose content, 72.7 to 79.6% for brown rice recovery, 61.4 to 74.9% for milled rice recovery and 28.3 to 60.8% for head rice recovery across fertilizer treatments (Table 3). Correlation analysis showed positive linear relationship between grain yield and grain quality characteristics except for grain N and crude protein content. Applied N fertilizer was positively correlated with grain N content, crude protein content and grain yield but negatively correlated with the AEN.

Table 1. Mean grain yields of the rice varieties tested at different nitrogen rates for the three studies. 2014, PhilRice CES, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines. (Note: MEAN indicates the average grain yield from the dry and wet seasons).

STUDY	0 N	45 N	60 N	80 N	90 N	120 N	180 N	210 N	LCC-N
	MEAN	WS	MEAN	WS	MEAN	DS	MEAN	DS	MEAN
ASD-002-001	3.75			5.21				6.50	6.03
ASD-002-002	3.91	5.16	5.97		6.12	7.15			
ASD-002-005	4.70		5.60		5.00		6.40		6.00
MEAN	**4.12**	**5.16**	**5.79**	**5.21**	**5.56**	**7.15**	**6.40**	**6.50**	**6.02**

Table 2. Mean agronomic efficiency of the applied nitrogen as affected by the different rice varieties and methods of N application from the three studies. 2014, PhilRice CES, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines. (Note: MEAN indicates the average AEN from the dry and wet seasons).

STUDY	45 N	60 N	80 N	90 N	120 N	180 N	210 N	LCC-N
	WS	MEAN	WS	MEAN	DS	MEAN	DS	MEAN
ASD-002-001			18.38				13.10	17.32
ASD-002-002	37.61	27.04		29.50	23.29			
ASD-002-005		15.47		12.68		9.87		12.44
MEAN	**37.61**	**21.26**	**18.38**	**21.09**	**23.29**	**9.87**	**13.10**	**14.88**

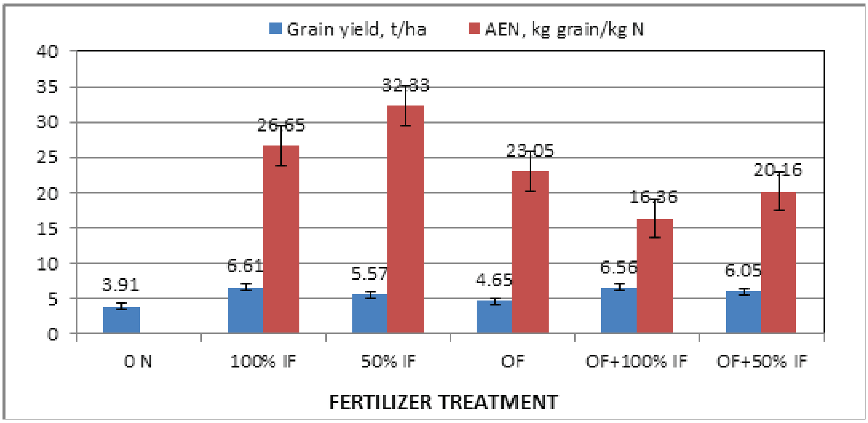

Figure 1. Mean grain yield and AEN of the rice varieties tested as affected by the different fertilizer treatments in the long-term organic fertilizer study (ASD-002-002). 2014, PhilRice CES, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines.

Table 3. Correlation coefficients (r) among grain yield, total N fertilizer applied, agronomic nitrogen use efficiency (AEN) and grain quality characteristics across rice varieties of the 2013 dry season grain yield. ns = not significant, * = 1% significance, ** = 5% significance

Grain Quality Characteristics	**Grain Yield** n = 135	**Total N Fertilizer Applied** n = 135	**AE_N** n = 108
Grain N (%)	0.06 ns	0.73 **	-0.39 **
Crude Protein (%)	0.06 ns	0.73 **	-0.39 **
Amylose Content (%)	0.45 **	-0.07 ns	0.19 *
Brown Rice Recovery (%)	0.37 **	0.08 ns	-0.10 ns
Milled Rice Recovery (%)	0.24 **	0	-0.09 ns
Head Rice Recovery (%)	0.18 *	0.03 ns	0.28 **
Grain Yield (t/ha)	1	0.46 **	0.59 **
N Fertilizer (kg N/ha)	0.46 **	1	-0.36 **
AE_N (kg grain/kg N applied)	0.59 **	-0.36 **	1

Long-Term Fertility Experiment

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

The Long Term Fertility Experiment has been on-going at the Philippine Rice Research Institute, Maligaya, Science City of Muñoz, Nueva Ecija since 1968. The study served the purpose of examining the sustainability of intensive double rice cropping and providing 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 2014 dry and wet season croppings showed significant mean grain yield differences among the fertilizer treatments (Table 4);
- Highest mean grain yields of the rice varieties tested were obtained in the treatment with complete N, P and K applications;
- During the dry season, mean grain yields in the +NPK and +NP (without K) treatments were comparable to each other; lowest grain yields were obtained by the non-fertilized plots (zero NPK treatment) and the +NK, - P treatment;
- During the wet season, mean grain yields in the treatments with N, with or without P or K were comparable to each other; lowest grain yields were obtained by the non-fertilized plots (zero NPK treatment) and the +NK, - P treatment;
- Highest total annual grain yields of 12.05 and 11.71t/ha were obtained in the SSNM-N, +PK and +NPK treatments, respectively;
- The control treatment (0-0-0kg NPK ha-1) was able to produce a total annual grain yield of 7.50t/ha;

- In the minus-one treatments, total annual grain yield in the –K treatment (9.70t/ha) was higher than the –P (8.67t/ha) and –N (8.89t/ha) treatments; total annual grain yields of the –P and –N treatments were comparable;

Table 4. Grain yields (average of 3 rice varieties) in the dry (DS) and wet (WS) seasons as affected by the fertilizer treatments. PhilRice-CES, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines.

TREATMENT	2014 Grain Yields, t/ha		
	DS	WS	Annual
Zero NPK	3.76 c	3.74 c	7.50
SSNM-N, +PK	6.55 a	5.50 a	12.05
+NK, -P	3.74 c	4.93 ab	8.67
+NP, -K	4.98 ab	4.72 ab	9.70
+NPK	6.5 a	5.21 ab	11.71
-N, +PK	4.37 b	4.52 bc	8.89

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

Components of Yield

- The components of yield differed significantly among the fertilizer treatments (Table 5);

- Significantly higher number of panicles per unit area were obtained by the treatments with N application regardless of season;

- Spikelet number per panicle varied across season; no difference in the dry season , but significantly higher number of spikelets per panicle were produced in the SSNM-N treatment;

- Percent filled grains varied across season; significant differences were observed during the dry season, but not in the wet season;

- Weight of 1,000 grains varied significantly and the treatment without P application in the minus-one treatments gave the lightest grains in both season;

Table 5. The components of yield (average of 3 varieties) as affected by the different fertilizer treatments. 2014 Dry Season, PhilRice-CES, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines.

FERTILIZER TREATMENT	COMPONENTS OF YIELD							
	Panicle m^{-2}		Spikelet $panicle^{-1}$		Filled Grains, %		1,000-Grain weight, g	
	DS	WS	DS	WS	DS	WS	DS	WS
Zero NPK	321.c	300.3 b	66.3 a	82.5 c	89.1 a	87.6 a	21.3 ab	21.8 b
SSNM-N, +PK	479.5 ab	376. 4 a	84.5 a	100.0 a	82.3 ab	88.0 a	22.3 a	23.1 a
+NK, -P	507.6 a	410.4 a	72.4 a	86.1 bc	69.8 c	86.9 a	19.8 b	21.6 b
+NP, -K	439.6 b	404.2 a	73.2 a	84.1 bc	79.1 bc	87.5 a	22.0 a	22.6 ab
+NPK	459.4 ab	388.2 a	80.6 a	91.7 b	80.2 ab	86.4 a	22.3 a	22.5 ab
-N, +PK	328.8 c	323.3 b	74.3 a	90.1 bc	88.2 ab	89.5 a	22.4 a	22.1 ab

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

Agronomic Nitrogen-Use Efficiency

- Agronomic nitrogen-use efficiency (AEN) of the rice varieties tested varied significantly between the treatments (Figure 2);

- AEN in the complete NPK treatments was relatively higher in both seasons than the minus-one and the non-NPK fertilized treatments;

- Higher AEN was generally obtained in the wet season than the dry season;

- Mean AEN per season was highest at 17.3kg grain kg N^{-1} for the SSNM-N and 15.7kg grain kg N^{-1};

- Lower mean AEN was obtained by the minus-one treatments (7.4 and 9kg grain kg N^{-1});

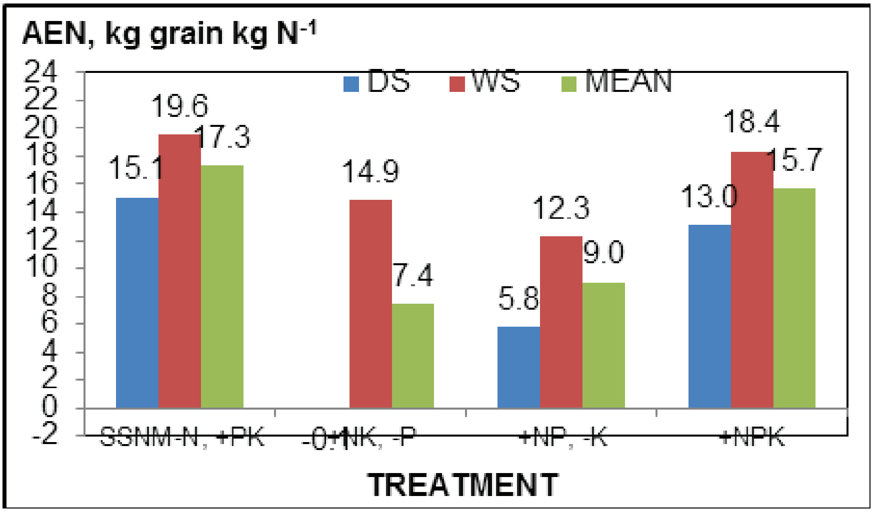

Figure 2. The agronomic nitrogen-use efficiency expressed in kg grain produced per kg N applied of the rice varieties tested (average of 3 varieties) in the treatments with N application during the 2014 dry and wet seasons cropping. PhilRice-CES, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines.

Indigenous Nutrient Supplies

- The indigenous nutrient supplies of the experimental site during the 2014 dry and wet seasons croppings are shown in Table 6; the values used in the determination of the indigenous nutrient supplies during the trial period was based on the calculations done by IRRI from trials conducted in the Philippines during the dry and wet seasons under the Mega Project; N, P and K were estimated to be 15, 2.8 and 15kg t^{-1} of grain yield; P and K are expressed in oxide forms;

- Indigenous N, P and K supplies were higher in the minus-one treatments than the control treatment;

- Overall, the trial site was able to provide an average of 61.5kg N ha^{-1} $season^{-1}$, 10.5kg P2O5 ha^{-1} season-1, and 64.5kg K2O ha^{-1} $season^{-1}$;

Table 6. The indigenous nutrient supplies of the experimental site based on the minus-one and control treatments during the 2013 Dry Season cropping. PhilRice-CES, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines.

TREATMENT	Indigenous Nutrient Supply								
	INS			IPS			IKS		
	kg N ha^{-1}			kg P ha^{-1}			kg K ha^{-1}		
	DS	WS	MEAN	DS	WS	MEAN	DS	WS	MEAN
0-0-0	56.4	56.1	56.3	9.8	9.7	9.8	56.4	56.1	56.3
+NP, -K							74.7	70.8	72.8
+NK, -P				9.7	12.8	11.2			
+PK, -N	65.6	67.8	66.7						
MEAN	**61.0**	**55.9**	**61.5**	**9.8**	**11.2**	**10.5**	**65.6**	**63.5**	**64.5**

INS: indigenous nitrogen supply
IPS: indigenous phosphorus supply
IKS: indigenous potassium supply

Long-term use of organic fertilizers in paddy soils

EF Javier, AE Espiritu

The experiment on the continuous use of organic fertilizers in paddy soils started in 2003 wet season at the PhilRice Central Experiment Station with soil type characterized as Maligaya clay soil series, to (1) determine the long-term effects of different organic fertilizers or amendments on the soil physico-chemical characteristics, and nutrient availability for paddy rice; (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.

The field experiment was laid out in Randomized Complete Block Design (RCBD) with four replications. Treatments include (1) organic fertilizers alone (OF); (2) combination of organic and recommended full rate of inorganic fertilizers (OFFR) and; (3) combination of organic and half the recommended rate of inorganic fertilizers (OFHR). Control plot (without any amendment) and plots applied with only inorganic fertilizer were also included as check. Organic fertilizers include fresh rice straw (RS) incorporated 30 days before transplanting, rice straw with Effective Microorganism Base Inoculants (RSEM) incorporated 14 days before transplanting, chicken manure (CM) applied 7 days before transplanting; wild sunflower (WSF) incorporated 2 days before transplanting; and commercial organic fertilizers (COF) applied 7 days before transplanting. Recommended full rate for inorganic fertilizer was 120-40-60kg NPK/ha for DS and 90-40-40kg NPK/ ha for WS.

Highlights:

- In 2014DS, among the OF tested, highest yield was obtained in plot treated with RSEM (5.3ts/ha) but was not significantly different from RS and CM (4.8t/ha). Lowest yield was obtained from COF plot (4.0t/ha) and WSF plot (3.9t/ha). In 2014WS, the same trend of highest yield was obtained in plots with RSEM and RS (5.5t/ha). Lowest yield was obtained from COF plot (4.1t/ha) (Figure 3).

- At the average, highest yield (ave 7.2t/ha) in the 2014 DS was obtained in plots applied with the full rate of inorganic NPK in combination with basally applied organic materials, regardless of the materials used. Likewise, using only 50% of inorganic NPK fertilizer rate combined with basal OF gave an average yield of 6.5t/ha. Lowest yields were obtained from plots applied with OF alone (ave 4.6t/ha), and from the control plot (4.4t/ha).

- In the WS, highest average yield was obtained in plots applied with the full rate of inorganic NPK in combination with organic materials (5.9t/ha) and with the application of 50% inorganic NPK fertilizer rate combined with basal OF (5.6t/ha).

- OF alone gave an average yield of 4.75t/ha. Lowest yields were obtained from control plot (3.47t/ha). This implied that in the WS, the OF can give an increased yield of 27% but not in the DS

- Likewise, the use of OF alone in WS showed higher agronomic use efficiency (ave 23kg grain produced kg N^{-1} applied) than in DS (ave 3kg grain per kg N applied) (Figure 4).

- The grain yield due to applied OF getting even or similar with the yield due to applied IF every after 3 years of continuous use of organic fertilizers in paddy soils is observed in the wet season only but not in the dry season (Figure 5).

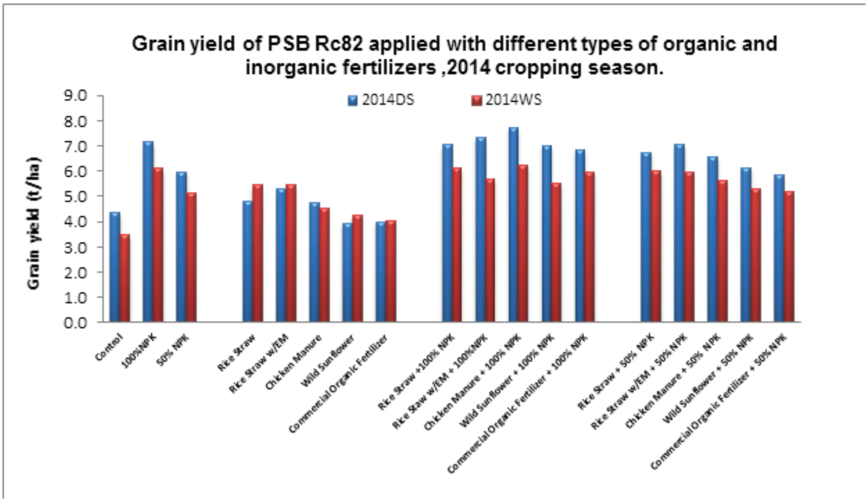

Figure 3. Agronomic efficiency of applied nitrogen (AEN) of PSB Rc82 applied with different types of organic and inorganic fertilizers in 2014 cropping season. 2014. PhilRice Central Experimental Station. Science City of Muñoz, Nueva Ecija.

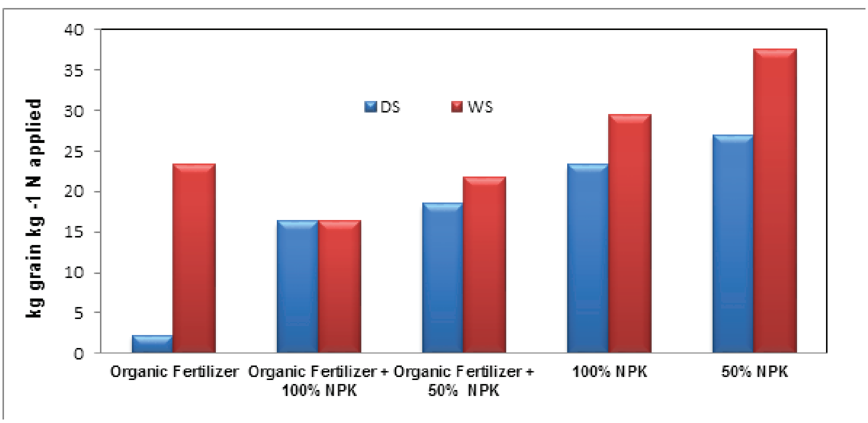

Figure 4. Agronomic nitrogen-use efficiency (kg grain kg-1 N applied) of PSB Rc82 applied with different types of organic and inorganic fertilizers in 2014 cropping season. 2014. PhilRice Central Experimental Station. Science City of Muñoz, Nueva Ecija.

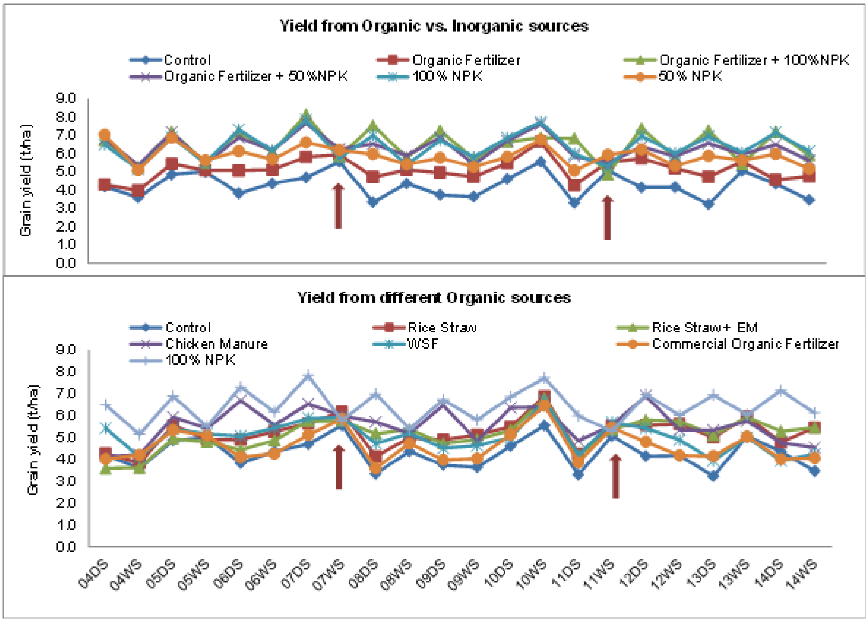

Figure 5. Yield of PSB Rc82 applied with different types of organic and inorganic fertilizers across seasons. Maligaya clay soil series. Science City of Muñoz, Nueva Ecija. (EFJavier, et al, 2014, PhilRice).

Yield Potential, Nitrogen-Use Efficiency and Grain Quality of Irrigated Lowland Rice Varieties

HAF Makahiya, HM Corpuz, MV Romero, EC Arocena, RT Cruz

Yield potential is the maximum yield of a variety in an environment where nutrient and water are non-limiting and with minimum pests under favourable weather condition. Reports for cereals showed that yield potential and grain quality such as protein content are negatively correlated (Blanco et al. 2011 Mol. Breeding; Bogard et al. 2010 J Exp. Botany). The negative correlation between yield potential and protein content may be attributed to differential energy requirements (Penning de Vries et al. 1974 J Theoretical Biology; Garcia del Moral et al. 1995 Agron. J).

This study aimed to assess the yield potential, nitrogen use efficiency and grain quality of different varieties in response to varying nitrogen (N) management. Field experiment was conducted at PhilRice Nueva Ecija in 2014 dry season (DS). Varieties tested were the inbreds NSIC Rc148 (111 days crop maturity), NSIC Rc160 (122 days), NSIC Rc222 (114 days), NSIC Rc240 (115 days), NSIC Rc13 (glutinous rice, 120 days), PSB Rc82 (110 days), hybrid Mestiso 20 (111 days), and traditional varieties Balatinaw (pigmented rice, 115 days) and Dinorado (107 days). Fertilizer treatments were (1) Control or no N fertilizer with adequate phosphorus (P) and potassium (K), (2) fixed-time N fertilizer application treatments each for a total of (a) 60kg N/ha, (b) 90kg N/ha and (c) 180kg N/ha, wherein N fertilizer was applied in three splits, i.e., 14 days after transplanting (DAT), early panicle initiation (EPI) and heading, and (3) "real-time" LCC-based N fertilizer application wherein 35kg N/ha in DS was applied when LCC reading was below the critical value of 4. LCC readings were done weekly from 21 DAT until early flowering. Adequate P and K fertilizers were applied at 14 DAT. Grain yield (t/ha) was obtained from a 5 m2 sample area and adjusted to 14% grain moisture content. Agronomic nitrogen use efficiency [AEN = (kg grain yield/ha in N fertilized plot – kg grain yield/ha in unfertilized plot) / total N fertilizer applied] was estimated from the difference between grain yields in N fertilized plot and plot that did not receive N fertilizer divided by total amount of N fertilizer applied. Grain quality characteristics of polished rice grains in terms of grain N content, crude protein content, amylose content and milling recoveries (i.e., brown rice, milled rice and head rice) were determined in 2013 DS following the guidelines in National Cooperative Testing Manual (1995). The correlation analysis was done for grain yield, N fertilizer treatment and grain quality characteristics.

Highlights:

- In the Control treatment with no N fertilizer, grain yields ranged from 3.1 t/ha for the traditional variety Dinorado to 6.1 t/ha for the hybrid Mestiso 20 (Figure 6A) in 2014 dry season (DS). The fixed-time N fertilizer application treatments with totals of (a) 60kg N/ha, (b) 90kg N/ha and (c) 180kg N/ha, each had an initial application of complete fertilizer of 14-14-14-12S at 14 DAT in DS. Grain yields ranged from 4.5t/ha for NSIC Rc148 to 8.7t/ha for NSIC Rc240 at 60kg N/ha, 4.7t/ha for NSIC Rc148 to 8.9t/ha for NSIC Rc222 at 90kg N/ha and from 5.4t/ha for Balatinaw to 10.0t/ha for NSIC Rc13 at 180kg N/ha. Grain yield of NSIC Rc148 was low at 4.5t/ha due to stem borer damage. Across fixed-time N fertilizer treatments, yields of the traditional varieties Balatinaw and Dinorado were lower than yields of inbreds and hybrids due to lower harvest index. The inbreds NSIC Rc13, NSIC Rc160, NSIC Rc222 and NSIC Rc240 and the hybrid Mestiso 20 had the highest yields close to 10t/ha at 180kg N/ha. The inbred PSB Rc82 had a yield of 6.7t/ha at 180kg N/ha.

- The "real-time" LCC-based N fertilizer application treatment had an initial application of complete fertilizer 14-14-14-12S at 14 DAT in 2014 DS. With LCC-based total N application of 100kg N/ha, yields ranged from 5.7t/ha for Balatinaw to an average of 8.8t/ha for NSIC Rc222, NSIC Rc240 and Mestiso

20 (Figure 6B). With LCC-based total N application of 65kg/ha, average yield was 5.2t/ha for PSB Rc82 and Dinorado. Likewise, NSIC Rc148 had the lowest yield of 4.4t/ha due to stem borer damage.

- The fixed-time N fertilizer application treatment with a total of 60kg N/ha had agronomic N use efficiencies (AENs) ranging from 16.1 to 51.0kg grain/kg N applied (Figure 7) and did not differ significantly among rice varieties (Figure 7). With total N fertilizer application of 90kg N/ha, AENs ranged from 4.1 to 30.3kg grain/kg N applied and did not differ significantly among rice varieties. With total N application of 180kg N/ha, AENs ranged from 6.5 to 24.3kg grain/kg N applied and did not differ significantly among rice varieties. Overall, with fixed-time N fertilizer application, AEN decreased as total N fertilizer application increased. But yields increased with N fertilizer application for varieties NSIC Rc160, NSIC Rc222, NSIC Rc240, NSIC Rc13 and Mestiso 20.
- The LCC-based N fertilizer application treatment with a total of 65kg N/ha had AENs ranging from 3.1 to 30.4kg grain/kg N applied and did not differ significantly among rice varieties. With total N fertilizer of 100kg N/ha, AENs ranged from 12.7 to 32.4kg grain/kg N applied and did not differ significantly among rice varieties.

- With the highest average yield potential of 9.5t/ha, AENs ranged from 11 to 24.3kg grain/kg N applied for NSIC Rc160, NSIC Rc222, NSIC Rc240, NSIC Rc13 and Mestiso for a total N application of 180kg N/ha with fixed-time N application method. With LCC-based total N application of 100kg N/ha, the highest yield potential close 9.2t/ha had AENs ranging from 18.5 to 32.9kg grain/kg N applied for NSIC Rc222, NSIC Rc240 and Mestiso 20. Results indicate that attainment of a high yield potential of 9t/ha can be achieved with an average AEN of 25.7kg and 44% savings in N fertilizer use for LCC-based N application method compared to fixed-time N application method.

- In 2013 DS, grain quality characteristics of the inbred, hybrid and traditional rice varieties ranged from 0.98 to 2.1% for grain N content, 5.8 to 12.5% for crude protein content, 3.2 to 27.3% for amylose content, 72.7 to 79.6% for brown rice recovery, 61.4 to 74.9% for milled rice recovery and 28.3 to 60.8% for head rice recovery across fertilizer treatments. Grain yield had significant positive linear correlation with grain quality characteristics except for grain N content and crude protein content (Table 7). This indicates that dry matter accumulation in the grain may have a high degree of independence from protein synthesis and grain N uptake. This needs further studies in relation to energy requirements. N fertilizer applied was positively correlated with grain N content, crude protein content and grain yield but negatively correlated with AEN.

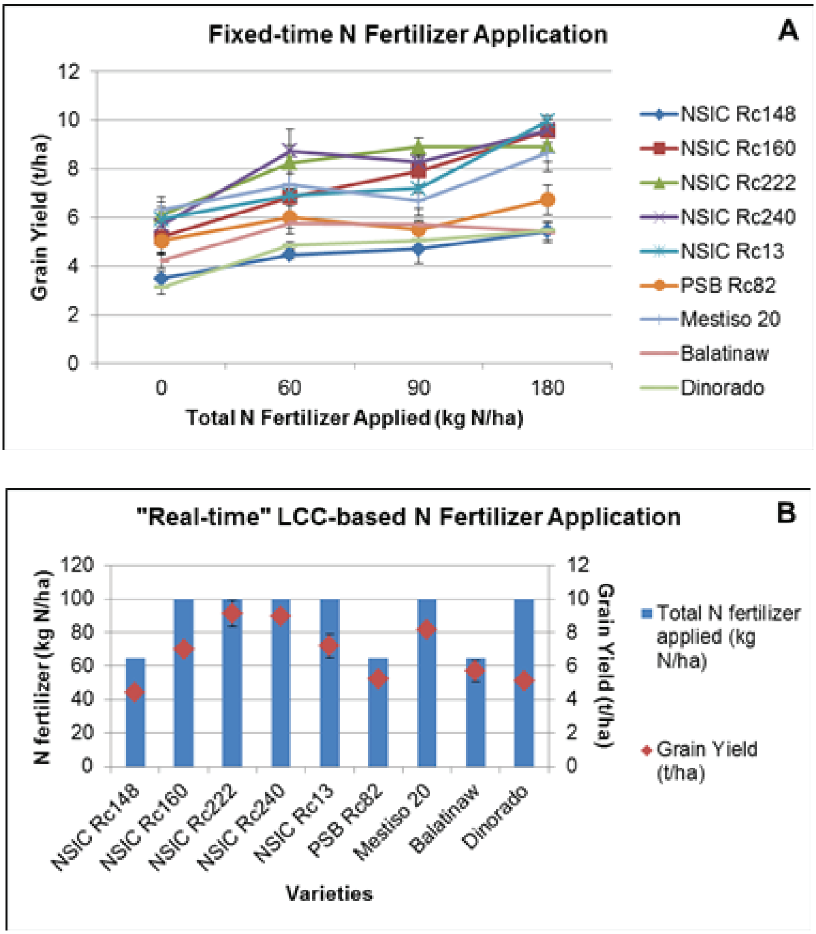

Figure 6A and 6B. Grain yield (t/ha) of irrigated lowland rice varieties in response to fixed-time N fertilizer application (1A) and LCC-based N application. 2014 DS, PhilRice CES, Maligaya, Science City of Muñoz, Nueva Ecija (vertical bars indicate standard error of the mean).

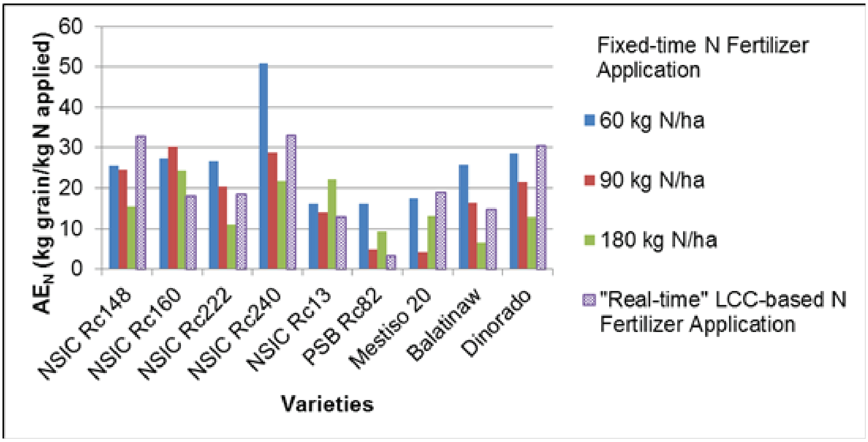

Figure 7. Agronomic nitrogen use efficiency (AEN) (expressed in kg grain kg N-1 applied) of irrigated lowland rice varieties in response to the fixed-time and LCC-based N fertilizer applications. 2014 DS, PhilRice CES, Maligaya, Science City of Muñoz, Nueva Ecija.

Table 7. Correlation coefficients (r) among grain yield, total N fertilizer applied, agronomic nitrogen use efficiency (AEN) and grain quality characteristics across rice varieties of the 2013 dry season grain yield.

Grain Quality Characteristics	Grain Yield n = 135	Total N Fertilizer Applied n = 135	AE_N n = 108
Grain N (%)	0.06 ns	0.73 **	-0.39 **
Crude Protein (%)	0.06 ns	0.73 **	-0.39 **
Amylose Content (%)	0.45 **	-0.07 ns	0.19 *
Brown Rice Recovery (%)	0.37 **	0.08 ns	-0.10 ns
Milled Rice Recovery (%)	0.24 **	0	-0.09 ns
Head Rice Recovery (%)	0.18 *	0.03 ns	0.28 **
Grain Yield (t/ha)	1	0.46 **	0.59 **
N Fertilizer (kg N/ha)	0.46 **	1	-0.36 **
AE_N (kg grain/kg N applied)	0.59 **	-0.36 **	1

ns = not significant, * = 1% significance, ** = 5% significance

Characterization of organic rice production system of PhilRice Negros

JEADBibar, BTSalazar, DKMDonayre, CETayson, EMLibetario

PhilRice Negros has already devoted and established areas for organic system. Yet, production components are needed to be refined based on scientific data for a more practical and sustainable system. Hence, this study was proposed to characterize, improve and standardize the organic production of the station through investigations on the response of rice to different organic inputs and the changes in soil and irrigation water properties within an established organic lowland rice system. Component sub-studies of this study include evaluation of different organic solutions as nutrient source; monitoring of rice yields, soil and water qualities under organic rice system, and evaluation of rice yield performance using different rates of organic fertilizers. At the end of this-two-year study, the information to be generated could be used by researchers, practitioners, and certifying bodies for fine-tuning and standardization of the organic production and certification system.

Highlights:

- In April 2014, an organic rice production system protocol was developed by the researchers of PhilRice Negros. This protocol describes key production components and best recommended practices that were identified to be suitable for the conditions of the station. At present, researchers follow the protocol in their respective field studies with necessary modifications based on the study objectives and treatments.

- From June to July 2014, 7 natural fermented solutions (NFS) were produced and analyzed for nutrient contents (Table 8). When used as seed treatments for germination test, comparable germination rates were observed among different NFS. However, radicle and plumule development were observed to be enhanced by indigenous microorganisms (IMO) and egg calcium phosphate (caphos).

- Starting WS 2014, a first field study was established to monitor rice, soil and irrigation water dynamics in a lowland rice ecosystem under organic production system. Soil and water samples were collected before establishment and analyzed to determine initial site characteristics (Table 9). These soil and water parameters will be monitored every season to assess possible changes in quality over time. Pest assessments are also conducted every season to monitor dynamics of pests and diseases. At the end of the first season of implementation, NSIC Rc282 produced an average grain yield of 4,137 kg/ha under organic system.

- A second field study was also established starting WS 2014 to monitor yield performance of lowland rice within under organic system with different rates of organic fertilizers (vermicast) and water regimes (continuously flooded and controlled irrigation). This study aims to determine the appropriate fertilizer rate for PhilRice Negros' conditions (Figure 8).

Table 8. Nutrient content of different natural fermented solutions produced from locally-available farm resources.

NFS solution	main substrate	Nutrient content (1:200 solution v/v), ppm								
		P	K	Ca	Mg	Fe	Zn	S	Cu	Na
Indigenous Microorganisms (IMO)	fermented rice	2.317	51.089	19.770	5.349	0.235	0.051	4.397	0.151	1.232
Fermented Plant Juice (FPJ)	Banana, kangkong	1.388	48.844	15.373	3.945	0.256	0.050	2.560	0.116	1.340
Fermented Fruit Juice (FFJ)	Banana, papaya	1.288	49.551	14.395	3.830	0.227	0.041	2.884	0.102	0.895
Kuhol Amino Acid (KAA)	Golden apple snails (GAS)	1.189	51.075	62.829	8.015	3.173	0.085	6.396	0.101	2.139
Oriental Herbal Nutrient (OHN)	Garlic, onion, ginger	1.587	48.085	17.150	7.905	0.256	0.046	4.073	0.107	1.010
Egg Calcium phosphate (Caphos)	Egg, GAS shells	0.060	1.931	75.134	4.013	0.046	0.029	0.669	0.094	1.401
Vermitea	Rice straw, cow manure	0.325	4.877	2.890	<LOD	0.075	0.020	1.425	0.095	0.587

Table 9. Initial soil and water physical and chemical properties for field study on rice, soil and irrigation water dynamics in a lowland rice ecosystem under organic production system.

Soil		Irrigation water*	
%Moisture content	3.41	Salinity	0.00
pH	5.55	Total dissolved solids mg/L	40.42
Organic matter, %	1.20	pH	7.60
Nitrogen, %	0.09	Total Hardness mg/L	56.00
Phosphorus, ppm	6.32	Magnesium mg/L	4.80
Potassium, ppm	12.04	Calcium mg/L	14.00
Calcium, ppm	863.04	Chloride mg/L	7.30
Magnesium, ppm	132.90	Sulfate	nil
Zinc, ppm	0.20	Bicarbonate ppm	61.20
Iron, ppm	47.34	NO_2-Nitrogen ppm	0.01
Sulfur, ppm	10.97	NO_3-Nitrogen, ppm	2.01
Sodium, ppm	28.52	NH_3-Nitrogen, ppm	0.06
Copper, ppm	3.32	Phosphate, ppm	0.05
Aluminum, meq	5.20	Sodium, %	0.51
Hydrogen, meq	4.66	Boron, ppm	0.69
Exch Acidity	9.86	Iron, ppm	0.65
		Total coliform	70960.00
Heavy metals		Heavy metals	
Cadmium, mg/kg	<10	Cadmium, mg/kg	<0.003
Chromium, mg/kg	<0.83	Chromium, mg/kg	<0.0075
Lead, mg/kg	<0.25	Lead, mg/kg	<0.00025

*Average of 5 samples collected strategically from irrigation canals including entry and exit points relative to study field.

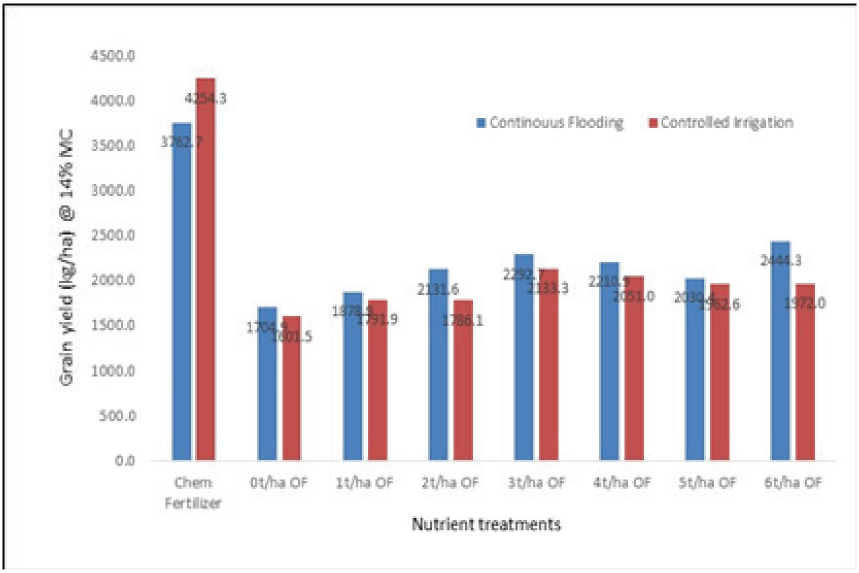

Figure 8. Grain yield (kg/ha) of NSIC Rc284 applied in 2 water regimes and different nutrient treatments during WS 2014.

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

Project Leader: JG Tallada

The productivity of irrigated lowland rice production heavily depends on how well the nutrient levels are managed. We need diagnostic techniques to provide technical guidance on how much fertilizers must be applied and the timing of their application. This must be done economically to maximize farmers' income while maximizing nutrient use efficiencies. Several tools and techniques had been made available from software decision support system to hardware chlorophyll meters and the inexpensive leaf color charts. These tools must be technically evaluated in terms of their merits of use and their contribution to overall productivity of the rice lands. The main goal of this project is improved rice productivity and resource-use efficiency using diagnostic support systems. Three studies were funded and operationalize in 2014, and their accomplishment for the year are reported herein.

The Use of Decision Support System for Agrotechnology Transfer (DSSAT) CERES-Rice Crop Model to Evaluate the Potential Yield of Irrigated Lowland Rice

KN Salarda, HAF Makahiya, FH Bordey, GA Castañeda, SA Balidiong, RT Cruz

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. In the calibration of the model, a set of genetic coefficients of the rice varieties is obtained. Genetic coefficients are values that describe the phenology and growth stages of each rice variety grown under optimum crop management. After calibrating 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 observed yield potential from the well-managed experimental field and simulated potential yield are compared to assess the acceptability of the model based on normalized root mean square error (nRMSE). 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 data came from field trials with optimum crop management and had attained yield potential.

Field experiments were conducted at PhilRice Nueva Ecija in 2014 dry season (DS) and wet season (WS) to assess the grain yield potential of three varieties namely, PSB Rc82 (110 days to crop maturity), NSIC Rc160 (122 days) and Mestiso 20 (111 days). Fertilizer treatments were: (1) -N, +P, +K or N omission plot where each P and K was applied at 40kg/ha, (2) 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 in DS and 23 kg N/ha in WS were applied when LCC reading was below 4. LCC reading was done every week starting at 21 DAT until early flowering, (3) in another treatment, complete fertilizer 14-14-14-12S was not applied. For LCC-based N application, 35kg N/ha in DS and 23kg N/ha in WS were applied when LCC reading was below 4. (4) Growth stage-based N application wherein 35kg N/ha in DS and 23kg N/ha in WS were each applied at 14 DAT, early panicle initiation and early flowering and (5) In DS, Farmer's Practice used 4 bags of 14-14-14-12S at 14 DAT, 3 bags of 14-14-14-12S and 1 bag of urea 46-0-0 at 45 DAT and at first flowering. In WS, farmer's practice applied 4 bags/ha of 14-14-14-12S at 14 DAT, 3 bags of 14-14-14-12S and 1 bag of urea were applied at 45 DAT.

Grain yield sample from each treatment was obtained from a representative 5 m2 area, oven-dried and adjusted to standard 14% grain moisture content. Soil, weather, crop management data and experimental data on growth and phenology were collected and inputted into the CERES-Rice model of the DSSAT program. Different sets of genetic coefficients for each variety were generated using the Genetic Likelihood (GLUE) program in DSSAT. Genetic coefficients governed the growth stages of rice and its interaction with inputs, management practices, soil and weather.

Highlights:

- In 2014 DS in the N-omission plot (Control), PSB Rc82 obtained the lowest yield of 3.8t/ha while Mestiso 20 had the highest yield of 4.9t/ha (Table 10). Application of N fertilizer significantly increased the grain yields PSB Rc82, NSIC Rc160 and Mestiso 20. Among the three N fertilizer treatments, Growth stage-based N application had the lowest yield of 5.2t/ha for PSB Rc82 while the LCC-based N application with with earlier application of "complete fertilizer" (CF with 14-14-14-12S) had the highest yield of 8.3t/ha for Mestiso 20. These three N fertilizer application treatments had higher yields than the Farmer's Practice for the three varieties.

- In 2014 WS in the N-omission plot (Control), PSB Rc82 obtained the lowest yield of 3.8t/ha while Mestiso 20 had the highest yield of 4.9t/ha (Table 10). Application of fertilizer significantly increased the grain yields of PSB Rc82 but not NSIC Rc160 and Mestiso 20. Among the three N fertilizer treatments, LCC-based N application with CF had the lowest yield of 4.4 t/ha for PSB Rc82 but it also had the highest yield of 5.7t/ha for Mestiso 20. The yields of these three N fertilizer application treatments were not significantly different than yields with Farmer's Practice for the three varieties. The yields across the N fertilizer treatments were higher in DS than in WS. This could be attributed to lower irradiance in WS (18.6 MJ/m^2) than in DS (20.5 MJ/m^2) and hence lower growth and lower demand for N in WS.

- Using the GLUE program of the CERES-Rice Model, the genetic coefficients of PSB Rc82, NSIC Rc160 and Mestiso 20 were generated in 2014 DS and WS for eight crop developmental phases (Table 11). For PSB Rc82, the genetic coefficients were 0.023 at G2 for single grain weight to 380.3 at P1 for the basic vegetative phase. For NSIC Rc160, the genetic coefficients were 0.026 at G2 to 524.4 at P5 or the beginning of grain filling to physiological maturity. For Mestiso 20, the genetic coefficients were 0.027 at G2 to 515.7 at P5. Earlier calibration of the Rice Model for 2012 dry and wet seasons showed different genetic coefficients for PSB Rc82 and NSIC Rc160 (Cruz et al. 2015 Rice-Based Biosystems Journal

Issue 1) . For PSB Rc82 the genetic coefficients were 0.026 at G2 to 566.1 for P1. For NSIC Rc160, the genetic coefficients were 0.025 at G2 to 691.2 at P1. For Mestiso 20, the genetic coefficients were 0.027 at G2 to 469.5 at P1 (unpublished data). Some of the factors causing differences in crop genetic coefficients for similar varieties across experiments and years were the fertilizer treatments and the response of the crop to these treatments (He et al. 2010 Decision Support System for Agrotechnology Transfer Version 4.5 Volume 3 DSSAT v4.5: ICASA Tools). In 2014, N fertilizer rates ranged from zero to 147kg N/ha. In 2012, N fertilizer rates ranged zero to 131kg N/ha. Also, published reports showed tremendous variation in soil nitrogen supply among lowland rice fields with similar soil types or in the same field over time (Cassman et al. 1998 Field Crops Research Vol. 56). Hence, when calibrating (i.e., generating the crop genetic coefficients) and validating (i.e., using the crop genetic coefficients to simulate potential yield) the CERES-Rice Model, the dynamic nature of soil N supply should be carefully considered.

Table 10. Average grain yield of PSB Rc82, NSIC Rc160, and Mestiso 20 under N-omission plot, LCC-based N application with complete fertilizer (CF) application (i.e., 14-14-14-12S), LCC-based N application without CF application, Growth stage-based N application, and Farmer's practice in 2014 dry and wet seasons.

Treatment	Average Yield (t/ha)					
	PSB Rc82		NSIC Rc160		Mestiso 20	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
N-omission plot	3.8[d]	3.7[c]	4.0[b]	4.8[a]	4.9[c]	4.6[a]
LCC-based N application with CF application	6.3[a]	4.4[b]	7.0[a]	5.0[a]	8.3[a]	5.7[a]
LCC-based N application without CF application	5.8[ab]	4.8[ab]	6.7[a]	5.2[a]	7.3[ab]	5.6[a]
Growth stage-based N application	5.2[bc]	4.8[ab]	6.7[a]	5.3[a]	79[ab]	5.4[a]
Farmer's practice	4.7[cd]	5.0[a]	6.5[a]	4.7[a]	6.9[b]	5.5[a]

Means followed by similar letter in a column were not significantly different at 5% level.

Table 11. Initial genetic coefficients of PSB Rc82, NSIC Rc160 and Mestiso 20 generated using the Genetic Likelihood (GLUE) program in DSSAT model using data from Nueva Ecija in 2014 dry and wet seasons.

Codes	Genetic Coefficients		
	PSB Rc82	NSIC Rc160	Mestiso 20
P1	380.3	457.2	503.2
P2R	31.90	71.20	32.70
P5	332.6	524.4	515.7
P2O	10.78	12.98	12.55
G1	58.06	59.60	52.47
G2	0.023	0.026	0.027
G3	0.474	0.631	0.719
G4	1.24	1.232	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 (scaler value); G4- temperature tolerance coefficient.

Evaluation of Field Techniques for Fertilizer Recommendation in Irrigated Lowland Rice

MM Sarong, MVR Bascon, RT Cruz

Field nutrient diagnostic techniques (NDTs) have been developed to manage nutrients in irrigated lowland rice system because NDTs are practical to use and less expensive than laboratory techniques. However, the various NDTs developed can be confusing to farmers and technicians. Some of the NDTs developed were (1) the PalayCheck System of integrated crop management that used the Leaf Color Chart (PalayCheck-LCC) for 'real-time' assessment of leaf nitrogen (N) status, (2) Minus-One Element Technique (MOET) that determined N, P, K, Zn and S deficiencies based on visual assessment of plant nutrient deficiency symptoms for the particular fertilizer element not applied (while applying the rest of the required elements) in the pot of soil under irrigated lowland condition at the vegetative stage, (3) Soil Test Kit (STK) that used a prepared solution for a fairly dry soil sample to determine soil pH and NPK levels by colorimetric method and referred to a table for fertilizer recommendation and (4) Nutrient Manager (NM), a software program that provided fertilizer recommendation based on standard soil and crop input data. Thus, we evaluated the four NDTs and the Farmer's Fertilizer Practice or FFP based on grain yield and nutrient-use efficiency to guide farmers and technicians on which NDT to use.

The field experiment was conducted at PhilRice Nueva Ecija in 2014 dry (DS) and wet season (WS). The popular rice variety PSB Rc82 was used. Nitrogen omission plot was established to assess the indigenous N supply (i.e., -N+P+K) and a zero fertilizer plot to assess if soil N was more limiting than soil P and K by comparing grain yields in those two plots. In N-omission plot, application of NPK is 0-40-40kg/ha in DS, and 0-30-30kg/ha in WS 14 days after transplanting (DAT). The four NDTs evaluated were (a) PalayCheck-LCC wherein 42 kg/ha each of N, P and K were applied in 14 DAT and 35kg N/ha was applied when LCC reading was below 4 from 21 DAT to early flowering in DS and application of 28 kg/ha each of N, P and K were applied in 14 DAT and 23kg N/ha was applied when LCC reading was below 4 from 21 DAT to early flowering in the WS, (b) MOET with LCC-based N application and P and K application based on deficiency symptoms, (c) STK with total NPK application of 120-60-60kg/ha in DS and 60-30-0kg/ha in WS wherein 50% N and all P and K were applied 14 DAT and the remaining 50% N was applied at panicle initiation, (d) Nutrient Manager or NM with total NPK application of 150-35-65kg/ha in DS and 126-32-32kg NPK/ha in WS wherein 20% N and all P and K were applied 14 DAT and the remaining 40% N was each applied at active tillering and panicle initiation (PI), and PhilRice General Fertilizer Recommendation with NPK application of 90-40-40kg/ha in WS only wherein 50% N and all P and K were applied at 14 DAT, 25% N at active tillering (AT), and 25% N at panicle initiation (PI). The Farmer's Fertilizer Practice (FFP) had a total NPK application of 106-14-14kg/ha in DS and 60-30-20 kg/ha in WS wherein 56% N and all P and K were applied 14 DAT and the remaining 22% N was each applied at PI and flowering.

Highlights:

- Grain yields of PSB Rc82 in the zero fertilizer plot and N-omission plot with P and K fertilizers did not differ significantly and had an average yield of 4.6t/ha in DS and 4.9t/ha in WS (Table 12). This indicates that soil N was more limiting than soil P and K. Likewise, based on our 2012 DS report, yields in the N-fertilized plots with or without P and K fertilizers were significantly higher than the zero fertilizer and N omission plots, indicating that indigenous soil N supply was more limiting than soil P and K supplies. This condition allowed a more direct assessment of agronomic N use efficiency represented by ANUE or AEN.

- The Nutrient Manager (NM) had a grain yield of 8.3t/ha and did not differ significantly from yields of PalayCheck-LCC, Soil Test Kit (STK) and Minus-One Element Technique or MOET in DS. The Farmer's Fertilizer Practice (FFP) had the lowest grain yield of 6.9t/ha in DS. In WS, NM had grain yield of 5.2t/ha and had the lowest grain yield among the nutrient diagnostic techniques but the yields of the NDTs were not significantly different.

- The total N fertilizer applied were 150kg N/ha for NM, 147kg N/ha for PalayCheck-LCC, 120kg N/ha for STK, 128kg N/ha for MOET and 106kg N/ha for FFP in DS. Trends indicated that grain yield of PSB Rc82 increased with total N fertilizer application.

- Although yields were similar among NM, PalayCheck-LCC, STK and MOET, the highest ANUE of 27.1kg grain/kg N applied was obtained for STK. Trends indicated that the yield potential of PSB Rc82 close to 8t/ha was obtained with ANUEs of 23.1 to 27.1kg grain/kg N applied. However, the relatively higher ANUE obtained with STK with similar grain yield indicated more savings in N fertilizer.

- Compared to other NDTs, STK did not recommend application of K fertilizer and MOET did not recommend application of P and K fertilizers. In the long run, it is not known how non-application of P and K fertilizers for plant maintenance can lead to soil P and K depletion.

Table 12. Grain yield of PSB Rc82 in zero fertilizer plot, nitrogen omission plot or indigenous soil N supply, PhilRice general recommended rate, the four NDTs (i.e., Nutrient Manager or NM, PalayCheck-LCC, Soil Test Kit or STK and Minus-One Element Technique or MOET) and the Farmer's Fertilizer Practice or FFP in 2014 cropping season.

Treatment	Average grain yield (t/ha)	
	Dry season	Wet season
No fertilizer	4.3[a]	4.7[b]
N-omission plot	4.8[a]	5.0[ab]
Gen. Rec. Rate	--	5.2[ab]
MOET	7.8[ab]	5.3[ab]
PalayCheck-LCC	8.2[a]	5.6[a]
STK	8.1[a]	5.3[ab]
NM	8.3[a]	5.2[ab]
FFP	6.9[b]	5.4[a]

Means with the same letter are not significantly different at 5% level of significance using Tukeys's Honest Significant Difference (HSD) Test. --means no data.

Evaluation of Crop Nutrient Diagnostic Tools Techniques for Increased Nutrient-Use Efficiency for Irrigated Lowland Rice

JG Tallada, MA Ramos

Crop nutrient diagnostic tools can provide guidance for more economical use of fertilizers. We need to evaluate the different electronic and non-electronic meters in terms of usability, performance and cost. The SPAD 502+, a simple and portable chlorophyll meter, has been shown as an effective reference meter to measure the chlorophyll or greenness of rice leaves. A critical SPAD value of 35 and 32 for Dry and Wet seasons (DS, WS), respectively, have been recommended for transplanted irrigated rice. There are other available monitoring tools such as the atLeaf+, PPW3000 available at hand, and the PhilRice recommended Leaf Color Chart (LCC) that can be compared with the standard SPAD. The initial goal of this study is to evaluate the performance of several diagnostic tools in terms of usability and ability to monitor crop nutrient status. During the DS and WS, four varieties (PSB Rc82, NSIC Rc216, NSIC Rc204H and NSIC Rc206H) and four levels (0, 60, 120, 240kg-N ha^{-1}) of nitrogen were established. Readings for chlorophyll meter started at 21DAT until early flowering at weekly intervals.

Highlights:

- A test on sensitivity to time of measurement showed no significant difference between measurements done in the morning and afternoon for all the diagnostic tools except for LCC. The result showed that both SPAD-502+ and atLeaf+ can be used any time of the day as long as the proper measurement protocols are always observed. LCC readings can vary remarkably with time of day measurements, hence, it is quite important to observe proper time consistency (Figure 9).

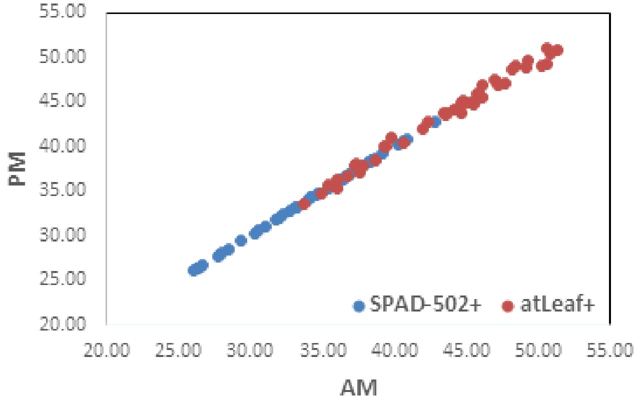

Figure 9. Comparison of morning and afternoon readings of SPAD 502+ and atLeaf+.

- The performance of the tools between users was also evaluated (Figure 10). The correlation coefficient is higher in SPAD-502+ than atLeaf+ mainly because 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.

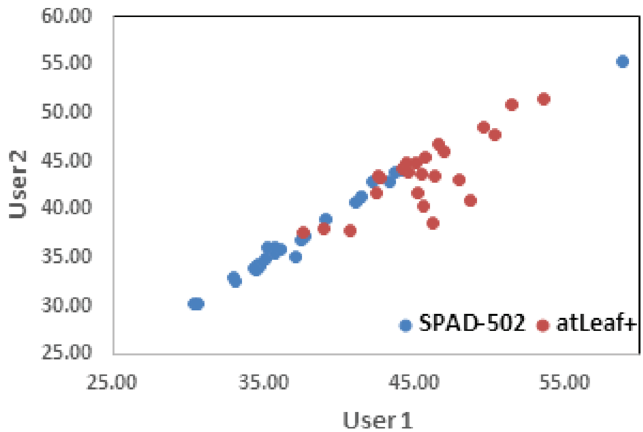

Figure 10. Inter-user comparison of SPAD 502+ and atLeaf+ measurements.

- There was high correlation of readings between the atLeaf+ and SPAD-502+ meters (Figure 11). Because of this, atLeaf+ can be a good alternative chlorophyll meter to SPAD to estimate the chlorophyll contents of the crop. AtLeaf+ had lower investment cost (about Php 11,250 for atLeaf+ against Php 98,000 for SPAD-502+).

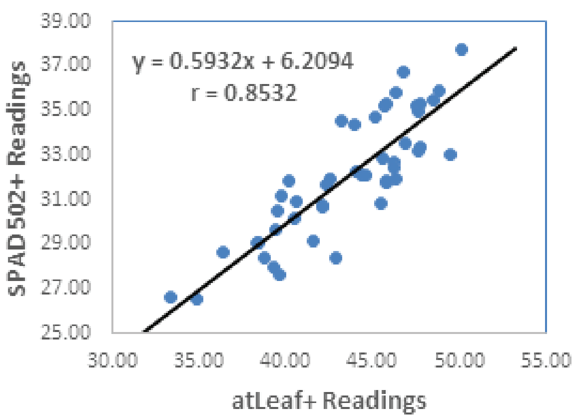

Figure 11. Comparison between atLeaf+ and SPAF 502+ readings during early panicle initiation (41 DAT) in DS 2014.

- There was no interaction effect for grain yield observed between varieties and nitrogen fertilizer application rates (Figure 12). Generally, higher levels of application of nitrogen led to higher yields except for the 240kg-N ha-1 wherein the yield started to decline. Highest grain yield was obtained from 120kg-N ha-1 during the DS 2014, and almost similar yields between the 60 and 120kg-N ha-1(Figure 13). We will try to relate this with the interval measurements of chlorophyll values using the different diagnostic tools.

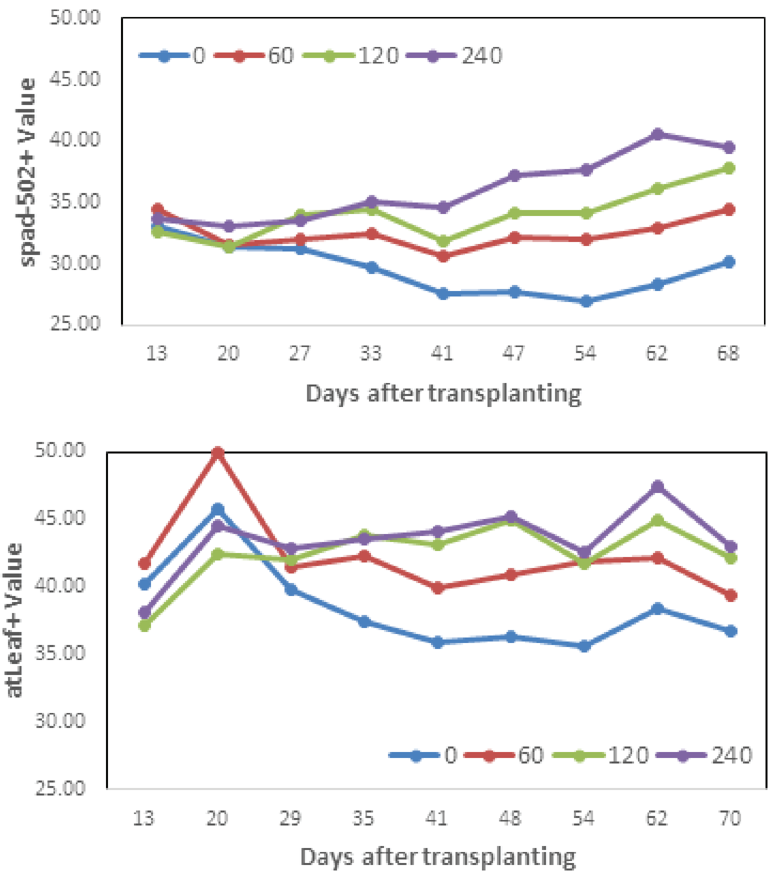

Figure 12. Variation of SPAD 502+ and atLeaf+ readings over time for PSBRc 82 during DS 2014.

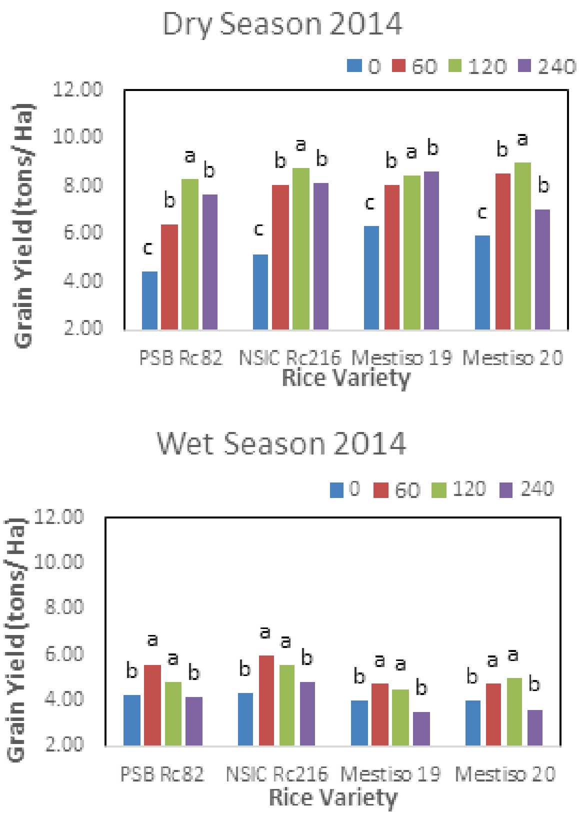

Figure 13. Grain yield data during the Dry and Wet Seasons 2014.

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

Project Leader: MD Malabayabas

With the country's current goal to achieve rice self sufficiency, rice productivity must be continuously improved. Crop intensification through ratooning and the adoption of resource use efficient technologies are vital in attaining the demand for rice of the growing population. To address these issues, the project consisting of six studies was implemented in 2014. The two studies dealing on root responses were completed in 2014 Dry Season (DS).

The effect of nitrogen (N) application on root responses of 7 genotypes to progressive water deficit was assessed. Root system based on the total root length of DSR14, IR64 and NSIC Rc11 increased with application of N fertilizer before the onset of drought. DRS14 showed the highest plastic root system development among genotypes.

A raised bed method with 20cm layer of top soil and 5cm gravel layer was found effective in screening the rooting ability of drought resistant lines for upland rice breeding. Among the 20 genotypes tested, CT9993, DHL50, DHL138, DHL40, DHL141 and PLB2242 showed potential deep rooting ability in response to drought stress condition.

Ratooning ability of PSB Rc18, Rc82, NSIC Rc298, Rc160, Rc216, Rc240, Mestiso 19, and Mestiso 20 was evaluated under transplanting and direct wet- seeding systems and two N management methods. In DS, ratoon yield of transplanted rice ranged from 5.2 to 31.3% of the main crop for LCC-based N and 11.7 to 29.9% for fixed-time N application. There were no significant differences in the ratoon crop yields between LCC-based and fixed-time N application under transplanting method. In direct wet seeding method, ratoon yields ranged from 7 to 25.6% of the main crop for the LCC-based and 2.3 to 23.2% for fixed-time N application. Ratoon yield was significantly higher with LCC-based N application than with fixed-time N application. Rc298 showed the highest ratoon yield in both transplanting and direct wet-seeding methods. In Wet Season (WS), ratoon crop yields in transplanted rice were higher than direct wet seeded rice since all 8 genotypes produced ratoons in the transplanting method.

Resource use efficient technologies for maximizing rice productivity like reduced tillage, drum seeding method of crop establishment, controlled irrigation, LCC-based N application and harvesting with combine harvester were used in evaluating the response of SL8H and Mestiso 19 under two LCC-based N management methods. Grain yields between the two varieties and between fixed- time and rate N application (FTR) and the fixed-time adjustable rate N application did not significantly differ in DS and WS. However, higher partial factor productivity (PFP) of 47.1kg grain per kg N applied was obtained in the FTAR-N than in the FTR in DS. In WS, PFP was higher in the FTR-N than the FTAR-N. The energy inputs utilized from other resource use efficient technologies were recorded.

System of Rice Intensification (SRI) retained crop management practices like planting density of 1 seedling per hill, alternate wetting and drying (AWD) and weed management using a rotary weeder were evaluated and compared with conventional methods using Rc82 and Rc222. Grain yield, straw yield, harvest index, 1000-grain weight and partial factor productivity for N did not differ significantly across water management, planting density and weed management treatments in both cropping seasons. The yields of Rc82 and Rc222 in the PalayCheck System that used inorganic fertilizer were higher than the SRI that used organic fertilizer.

Water and nutrient use efficiencies and input energy of 6 varieties with high yield potential were evaluated using controlled irrigation (CI) and Leaf Color Chart (LCC)-based N application. CI significantly reduced irrigation and fuel input energy and higher water productivity than continuous flooding. Rc298, Mestiso 19 and Mestiso 20 showed lower irrigation and fuel input energy than Rc82 while Rc222 and Rc300 were comparable with Rc82. Rc300 had significantly higher water productivity than Mestiso 20 but these 2 varieties were comparable with other varieties. Grain yield between CI and CF did not differ significantly in both cropping seasons. In nutrient management experiment, grain yield, agronomic N use efficiency (AEN) and rice yield energy output did not vary significantly between the LCC based N application and fixed rate N application of 150kg N ha^{-1} during DS and 120kg N ha-1 in WS. Likewise, there were no significant differences in AEN and nitrogen input energy among varieties.

Studies on the assessment of root plasticity of different genotypes to progressive drought with N application and seedbed calibration for screening rooting ability of drought resistant upland genotypes are useful in hastening the selection process for breeding drought resistant or tolerant genotypes. Ratooning of responsive varieties like Rc298 can increase yield up to 30% of the main crop yield. Evaluation of the SRI retained crop management practices did not show yield advantage over the PalayCheck System. The use of controlled irrigation increased water productivity and reduced fuel and irrigation input energy of high yielding varieties. Likewise, LCC-based N application increased partial factor productivity or nitrogen use efficiency of rice thereby reducing fertilizer input.

Effect of Nitrogen Application before the Onset of Drought on the Plastic Root System Development Responses to Progressive Water Deficit in Rice
JM Niones, NB Lucob, RR Suralta

Crop productivity under drought is determined by maintained water uptake during progressive soil drying. However, the ability to maximize soil water capture depends on the degree of plastic root system development during progressive drought. This study examined if the application of Nitrogen (N) can enhance plastic root system development during the onset of drought in rice.

Seven genotypes namely: DrS14, DrS111, DrS66, IR64, NSIC Rc9, NSIC Rc11 and DHL98 were grown under continuously waterlogged (CWL) and drought (DR, simulated rainfed) conditions with two N fertilizer treatments (1) without N (-N) as control and (2) with 30kg N ha^{-1} (+N) applied at 60 days after transplanting (DAT) before the onset of drought at panicle initiation under field conditions.

Highlights:

- Shoot dry weight, leaf area, water use, SPAD value, whole plant transpiration and photosynthesis were significantly increased with N application in IR64 under CWL (Table 14).

- DRS111 shoot dry weight, leaf area, water use, SPAD value, whole plant transpiration and photosynthesis showed a significantly increased with N application under DR. The trends of root traits response with N application under CWL differed between IR64 and DRS111 (Table 15).

- The mean length of nodal roots in IR64 was significantly shorter with N application, whereas it was not affected in DRS111. Under DR, however, L-type LR was the only root trait that significantly responded with N application in IR64, while root dry weight and total length of nodal roots in DRS111. The L-type LR was generally promoted by DR regardless of N treatments but the extent of promotion was significantly greater in DRS111 than in IR64.

- DRS111 showed higher plastic RSD than IR64 under DR regardless of N treatment through greater promotion of L-type LR (Table 15). This genotype showed high RSD plasticity

- When fertilizer N was made available during progressive soil drying, this observed plastic RSD in DRS111 under drought significantly contributed to the maintenance of accumulated water use, estimated daily whole plant transpiration and higher N uptake as indicated by higher relative chlorophyll content

- Shoot dry weight (SDW) on all the genotypes significantly increased with N application under waterlogged. SDW was higher in the waterlogged than in the droughted treatment.

- Progressive drought significantly reduced dry matter production on all genotypes. While three genotypes: DRS 111, DRS 66 and NSIC 11, showed an increase in dry matter production with N application before the onset of drought (Figure 14).

- Among the root traits examined, the total nodal root length (TNRL) of DRS 66 was significantly improved with N application under drought (Figure 15).

- The result showed that application of N prior to the onset of drought apparently improved root system development through maintained nodal root elongation resulting in higher photosynthesis in DRS66, consequently increase shoot dry matter reduction under drought stress.

- There was an interaction between the genotype and N source applied before the onset of drought on the shoot dry matter production (Table 16). Shoot dry weights (SDW) in DRS111 and DRS66 were significantly increased with application of N regardless of sources.

- Root system development response based on total root length (TRL) tended to increase with the availability of N fertilizer before the onset of drought. Among genotypes, DRS111 and DRS66 had longer total root length with N application especially ammonium sulfate.

- All genotypes in CWL showed increase in total biomass production with N fertilizer application while only NSIC Rc9, DrS111, DrS14 and IR64 showed increase in grain yield (Table 17). Relative to CWL, all genotypes showed a significant reduction in total biomass production and grain yield in DR condition regardless of N treatment.

- DrS14, DrS66, IR64 and NSIC Rc11 genotypes showed increase in biomass and grain yield with N application but only DRS14 showed significant increase under DR.

- Rainfed rice production system, farmers are unwilling to follow the recommended timing of N application similar to that of irrigated lowland rice production system because the timing of N application may sometimes coincide with the expected immediate occurrence of progressive drought, which may bring about loss of fertilizer applied rather than being taken up by the rice plant.

- The present study showed that the use of genotypes with drought resistance through drought (dehydration) avoidance mechanism attributed by plastic root response to N availability during drought is important in maintaining biomass production.

Table 14. Some shoot growth and physiological parameters of the rice genotypes IR64 and DRS111 under N treatments and grown under continuously waterlogged (CWL) and draughted (DR) soil conditions.

Genotypes	Water Treatments	Nitrogen Treatments	Shoot Dry Weight (g)	Leaf Area (cm^2)	Water Use (g)	SPAD Value	Transpiration (mmol s^{-1} $plant^{-1}$)	Photosynthesis (µmol s^{-1} $plant^{-1}$)
IR64	CWL	-N	0.93 b	191.92 c	495.2 bc	29.50 d	0.215 b	0.463 c
		+N	1.26 a	254.26 ab	660.2 a	34.63 bc	0.310 a	0.599 b
	DR	-N	0.77 b	153.79 c	410.1 de	35.50 ab	0.166 bc	0.348 cd
		+N	0.78 b	134.78 c	446.5 cd	38.17 a	0.104 c	0.293 d
DRS111	CWL	-N	0.86 b	145.74 c	412.2 cde	33.30 bc	0.177 bc	0.374 cd
		+N	1.50 a	277.84 a	554.7 b	34.23 bc	0.337 a	0.744 a
	DR	-N	0.54 c	105.77 d	375.0 e	32.30 cd	0.110 c	0.265 d
		+N	1.30 a	228.38 b	439.2 cd	38.07 a	0.209 b	0.563 bc

In a column, means followed by a common letter are not significantly different at 5% level LSD.
SPAD - soil and plant analysis development
-N, without fertilizer N; +N, with fertilizer N

Table 15. Root dry weight, number and length of nodal roots and linear frequency of lateral roots of the rice genotypes IR64 and DRS111 under N treatments and grown under continuously waterlogged (CWL) and droughted (DR) soil conditions.

Genotypes	Water Treatments	Nitrogen Treatments	Root Dry Weight (g)	Nodal Roots			Lateral Roots (no. cm^{-1} nodal roots)	
				(no.)	total length (cm)	mean length (cm)	L-type	S-type
IR64	CWL	-N	0.25 de	49.0 b	894.8 c	18.9 bc	0.47 d	11.4 b
		+N	0.28 cd	86.0 a	1073.8 b	12.9 d	0.40 d	11.6 b
	DR	-N	0.31 bc	34.6 bc	743.8 cd	21.2 ab	1.40 c	14.9 ab
		+N	0.28 cd	34.7 bc	730.0 de	21.1 ab	2.13 b	15.9 a
DRS111	CWL	-N	0.27 cd	79.0 a	1331.8 a	16.9 c	0.53 d	9.2 b
		+N	0.33 b	81.7 a	1318.8 a	16.2 c	0.40 d	12.0 b
	DR	-N	0.22 e	32.0 c	625.4 e	19.7 ab	3.60 a	16.8 a
		+N	0.46 a	39.0 bc	844.6 cd	22.5 a	3.97 a	13.5 ab

In a column, means followed by a common letter are not significantly different at 5% level LSD.
-N, without fertilizer N; +N, with fertilizer N

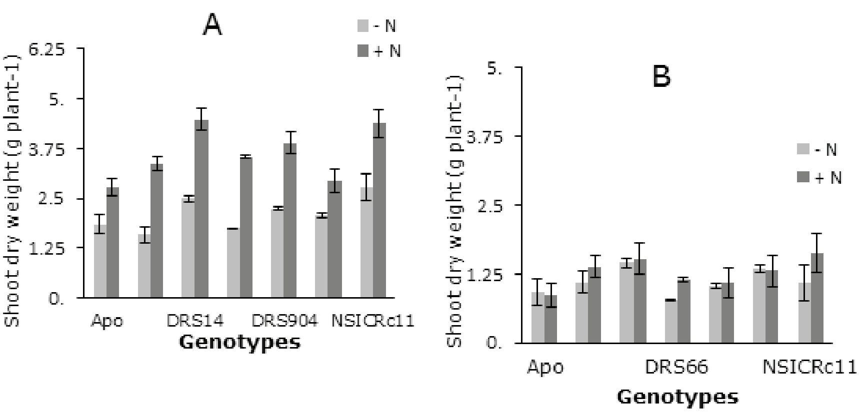

Figure 14. Shoot dry weight of the different genotypes under N treatments and grown under waterlogged (A) and draughted (B) soil condition.

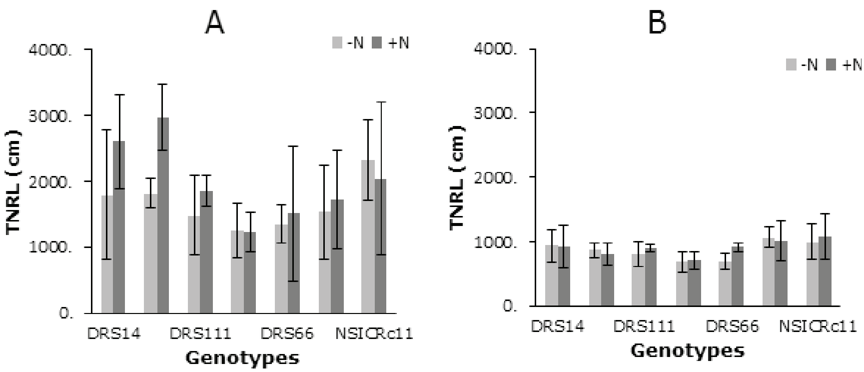

Figure 15. Shoot dry weight of the different genotypes under N treatments and grown under waterlogged (A) and draughted (B) soil condition. TNRL was moderately correlated with shoot dry weight (0.55) with N application under DR condition (data not shown).

Table 16. Shoot dry weight, transpiration and total root length of the different genotypes grown under transient waterlogged for 14 days followed by progressive drying maintained at 10% SMC at various N sources applied at 80 kg/ha before the onset of drought.

Genotypes	N Sources	Shoot dry weight (g)	Transpiration	Total root length (cm plant^{-1})
DRS111	Control	1.09 d	0.14 cd	7651.02 b
	Ammonium sulfate	**3.04 a**	**0.30 a**	**14430.40 a**
	Urea	1.68 b	0.24 ab	8835.85 ab
DRS66	Control	0.68 e	0.10 d	5926.40 b
	Ammonium sulfate	1.57 bc	0.20 bc	8041.30 ab
	Urea	0.98 de	0.15 bcd	5600.13 b
IR64	Control	1.64 b	0.19 bcd	10818.70 ab
	Ammonium sulfate	1.52 bc	0.20 bc	10350.80 ab
	Urea	1.71 b	0.23 abc	10031.71 ab
NSIC Rc11	Control	1.27 cd	0.20 bc	9135.29 ab
	Ammonium sulfate	1.56 bc	0.22 abc	10156.90 ab
	Urea	0.98 de	0.13 abc	6469.94 b

Values followed by the same letter in a column within each treatment are not significantly different at 5% by Fisher's LSD test.

Table 17. Grain yield and total biomass of seven genotypes with different N fertilizer treatment grown under CWL and DR conditions in 2013DS.

	Grain yield (tons/ha)		Biomass (tons/ha)	
	−N	+N	−N	+N
CWL				
NSIC Rc9	10.25 abc	10.40 abc	15.06 a	15.97 a
DRS111	9.52 abc	8.60 abc	12.87 a	15.18 a
DRS14	9.39 ab	11.61 a	13.71 a	15.65 a
DRS66	7.02 abc	9.73 abc	15.06 a	16.06 a
DHL98	8.03 bc	6.96 abc	11.27 a	12.68 a
IR64	6.77 abc	9.18 abc	11.99 a	14.86 a
NSIC Rc11	9.11 abc	9.49 abc	13.79 a	13.95 a
DR				
NSIC Rc9	4.31 ab	4.32 ab	10.25 ab	10.40 ab
DRS111	3.83 ab	3.30 ab	9.52 ab	8.60 abc
DRS14	4.20 ab	5.58 a	9.39ab	11.61 a
DRS66	3.99 ab	4.13 ab	7.02 ab	9.73 abc
DHL98	2.92 b	2.51 ab	8.03 b	6.96 abc
IR64	2.31 b	4.10 ab	6.77 b	9.18 abc
NSIC Rc11	4.08 ab	4.39 ab	9.11 ab	9.49 abc

Means followed by a common letter across N treatments and water treatments are not significantly different at 5% level of HSD

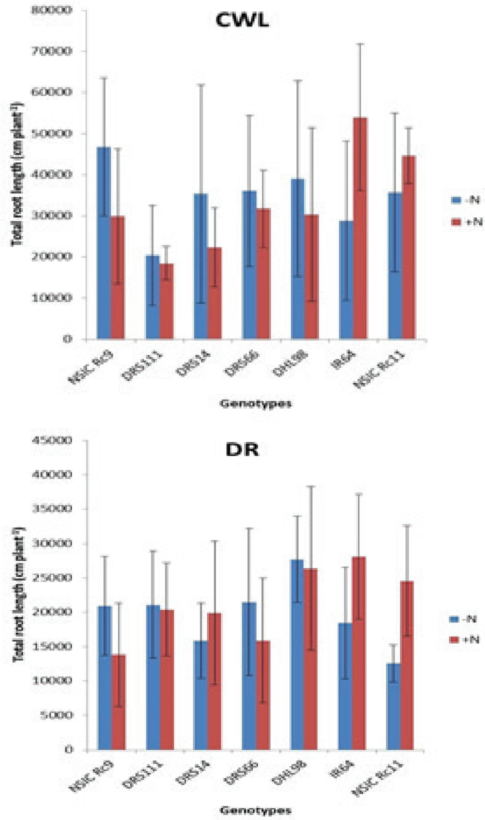

Figure 16. Total root length of seven genotypes with different N fertilizer treatments grown under CWL and DR conditions.

Calibration of Raised bed as a Facility for Screening Drought Resistant Lines for Upland Rice Breeding

JM Niones, NB Lucob, RR Suralta

Upland rice are vulnerable to fluctuating soil moisture and mild soil water deficit stresses and this can cause significant reduction to shoot biomass and yield (Kato et al. 2006c; Kamoshita 2007; Yang et al. 2005). Genotypic variation in the growth response to water availability in upland fields has been widely recognized (Atlin et al. 2006; Kato et al. 2006b, c). Some researchers suggest that this variation may arise primarily from genotypic variation in the rooting depth of the plants (Azhiri-Sigari et al. 2000; Kato et al. 2006a), a factor that determines the amount of water available to rice plants under drought conditions (Kato et al. 2007a; Siopongco et al. 2005, 2006, 2007, 2009). Crops with deep root system allow extraction of more water available at deeper soil layer during drought. Rice cultivars adapted exclusively to upland conditions are typically characterized by deep and coarse root system. Thus, there is a need to develop or improve a system that effectively screen and select genotypes with effective rooting depth to capture water available at deeper soil layer for maximum productivity under upland conditions.

The study aimed at calibrating the raised bed system as a screening facility for identifying genotypes with deep rooting traits and utilize this in breeding to improve drought resistance in rainfed and upland systems.

Highlights:

- A raised bed was constructed 25cm above the ground level. In the bed 20-cm-thick layer of topsoil was added above 5-cm-thick gravel layer. On the other hand, normal bed (without gravel layer), which received well-watering, served as control (Figure 17). Twenty genotypes composed of advance breeding lines with potential stay-green characteristics and double haploid lines (CT9993/ IR62266 crosses and parents) were grown in each bed until maturity.

- Five genotypes, namely DRS 42, DRS 66, Azucena, NSIC Rc11, and NSIC 192, showed higher plant dry weight under raised bed than normal bed (Table 18). NSIC Rc11 an increase of spikelet fertility under raised bed

- Correlation result showed that the variations in plant dry weight were contributed by the 19.36% variations in TRL below the gravel layer (Table 19).

- Plant dry weight and spikelet fertility were more associated with the genotypic differences in TLRL than TNRL below the gravel layer (Table 19).

- The results implied that potential deep rooting as reflected by their ability to penetrate the 5cm gravel layer at 25cm from the soil surface contribute to dry matter production during intermittent drought stress.

- Thermal image analysis during one of the drought periods showed that genotypes in raised bed had higher leaf temperatures than in the well-watered bed (Figure 18).

- Soil moisture dynamics in the raised bed showed that the soils above the sand gravel layer (embedded at 30 cm below the soil layer) was constantly higher those below the sand gravel layer, this indicates blocking the capillary rise of water underneath (Figure 19). Thus creating two distinct moisture contents between soil layers above and below the sand gravel (Figure 19 and Figure 20).

- The soil moisture dynamics showed that capillary rise of water across the gravel at D30 and D60 was prevented in the mylar tube experiment. The soil above the gravel was drier relatively drier in these treatments than in either drought or well watered conditions (D0 and WW, respectively).

- Deep rooting beyond 30cm soil depth had positive and significant contribute to the maintenance of water uptake (transpiration) and dry matter production during progressive soil drying (Tables 20, 21 and 22).

- In conclusion, soil moisture dynamics in the raised bed showed a two distinct soil moisture conditions, which the soil moisture above the gravel layer was constantly higher than the soil below the gravel layer. This result indicates that the 5cm gravel layer effectively blocked capillary rise of water. This calibrated raised bed system is an effective screening facility for identifying genotypes with deep rooting traits and its contribution in maintaining water uptake and productivity under drought.

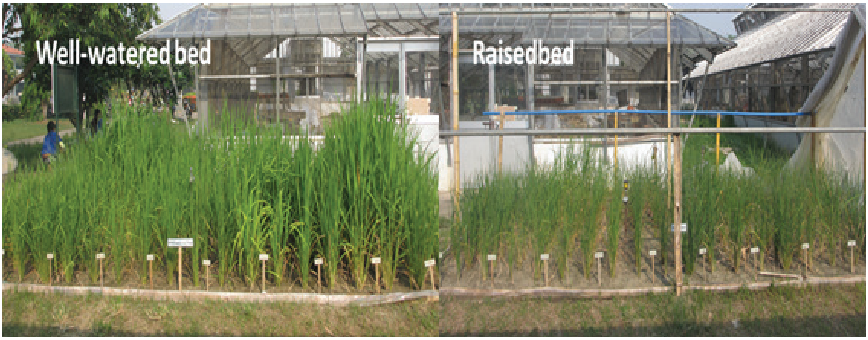

Figure 17. The well-watered bed and raised bed at 74 days after sowing. Images were taken during one of the drought periods in raisedbed.

Table 18. Plant dry weight and shoot dry weight of the different genotypes under the raised bed and normal treatment.

Genotype	Plant dry weight (g plant⁻¹)		Spikelet fertility (%)	
	Normal bed	Raised bed	Normal bed	Raised bed
DRS 904	20.16 4beder	26.81 4 13.81	42.87 4 13.8	23.66 4 13.81
PSB Rc 82	62.52 823.81	31.79 823.8	29.81 823.81	24.84 823.8
IR 64	33.11 823.81	26.36 823.8	49.12 823.81	34.77 823.8
NSIC Rc9	67.12 c923.8	62.22 c923.8	44.35 c923.81	37.06 c923.8
NSIC 192	46.07 9223.81	51.99 924.98	34.59 924.981	22.58 924.98
NSIC Rc11	38.78 c11.98	42.74 c11.98	28.21 c11.98	30.24 c11.981
Azucena	36.86 a11.98	47.63 a11.98	49.10 a11.98	28.72 a11.981
DRS 111	47.22 111.981	37.01 111.981	34.21 111.981	36.61 111.981
DRS 66	55.75 111.981	56.61 1112.72	44.84 1112.72	21.76 1112.72
DRS 42	33.63 1112.72	53.15 1112.72	44.15 1112.72	39.27 1112.7

Table 19. Relationship of plant dry weight, spikelet fertility and root parameters above and below the gravel layer under raised bed.

	TRL			TNRL			TLRL		
	Above gravel	Below gravel	Total	Above gravel	Below gravel	Total	Above gravel	Below gravel	Total
Spikelet fertility	−0.15	0.12	−0.13	−0.01	0.49	0.00	−0.13	0.19	−0.11
Plant dry weight	0.13	**0.44**	0.15	0.76	0.61	0.76	0.10	0.41	0.12

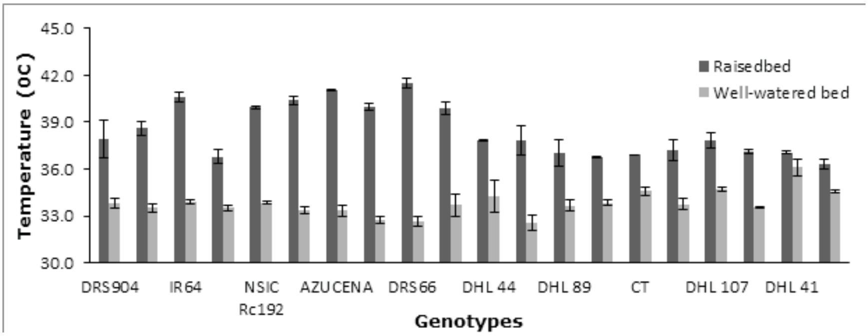

Figure 18. Thermal image analysis of raisedbed and well-watered bed.

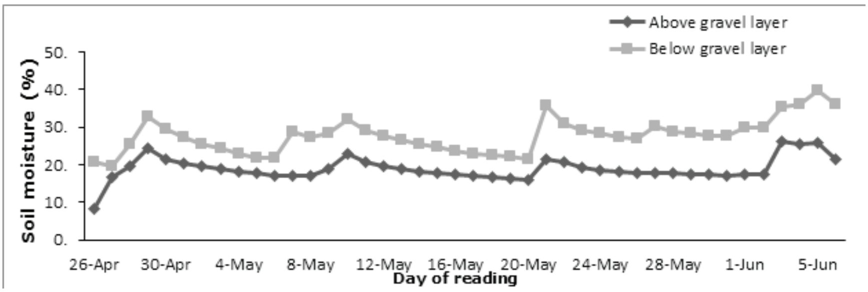

Figure 19. Soil moisture dynamics of layers above and below the gravel layer in raised bed.

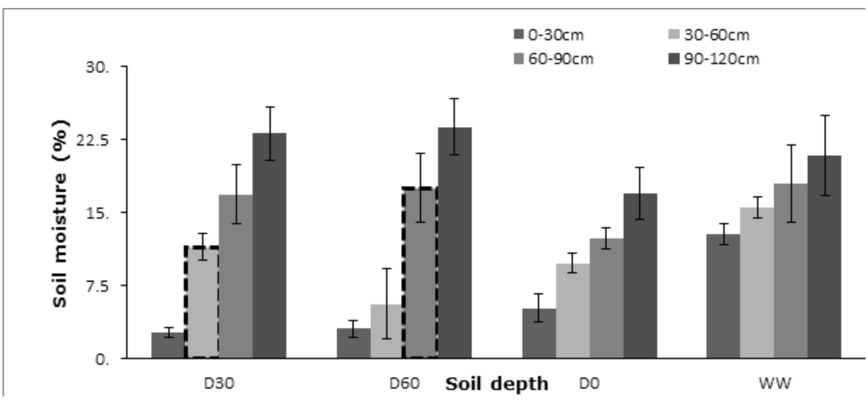

Figure 20. Effect of gravel layer on soil moisture contents at different soil depths. D30-gravel layer imposed at depth 30cm, D60-gravel layer imposed at depth 60cm, D0-drought, WW-well-watered. Broken lines in the graph the location of gravel layer.

Table 20. Correlation matrices of parameters measured in different genotypes grown under drought (DR) conditions without sand layer embedded at any soil depths (D0).

PARAMETER	SHOOT DRY WEIGHT	TRANSPIRATION
Shoot dry weight		0.39
Total root length (whole root system)	0.80***	0.53*
Total root length (30–90 cm soil depth)	0.90***	0.67**
Total root length (60–90 cm soil depth)	0.74***	0.49*
Total lateral root length (whole root system)	0.78***	0.50*
Total lateral root length (30–90 cm soil depth)	0.86***	0.67**
Total lateral root length (60–90 cm soil depth)	0.86***	0.49*
Number of nodal roots	0.76***	0.39
Total nodal root length (whole root system)	0.89***	0.60**
Total nodal root length (30–90 cm soil depth)	0.79***	0.53*
Total nodal root length (60–90 cm soil depth)	0.77***	0.36
Root length density (whole root system)	0.80***	0.53*
Root length density (30–90 cm soil depth)	0.90***	0.67**
Root length density (60–90 cm soil depth)	0.74***	0.49*
Root dry weight (whole root system)	0.58**	0.90***
Root dry weight (30–90 cm soil depth)	0.61**	0.83***
Root dry weight (60–90 cm soil depth)	0.55**	0.90***
Deepest nodal root length	0.80***	0.49*

Values are indicated by asterisks: *$p < 0.05$, **$p < 0.01$, and ***$p < 0.001$.

Table 21. Correlation matrices of parameters measured in different genotypes grown under drought (DR) conditions with sand layer embedded at 60cm below the soil surface (D60).

PARAMETER	SHOOT DRY WEIGHT	TRANSPIRATION
Shoot dry weight		-0.65
Total root length (whole root system)	0.73***	-0.33
Total root length (60-90 cm soil depth)	0.09	0.27
Total lateral root length (whole root system)	0.73***	-0.31
Total lateral root length (60-90 cm soil depth)	0.11	0.24
Number of nodal roots	0.12	-0.32
Total nodal root length (whole root system)	0.14	-0.28
Total nodal root length (60-90 cm soil depth)	-0.03	0.32
Root length density (whole root system)	0.73***	-0.33
Root length density (60-90 cm soil depth)	0.09	0.27
Root dry weight (whole root system)	0.50*	-0.39
Root dry weight (60-90 cm soil depth)	0.03	0.34
Deepest nodal root length	0.40*	-0.05

Values are indicated by asterisks: *$p < 0.05$, **$p < 0.01$, and ***$p < 0.001$.

Table 22. Correlation matrices of parameters measured in different genotypes grown under drought (DR) conditions with sand layer embedded at 30cm below the soil surface (D30).

PARAMETER	SHOOT DRY WEIGHT	TRANSPIRATION
Shoot dry weight		-0.13
Total root length (whole root system)	0.44*	0.38
Total root length (30-90 cm soil depth)	0.47*	0.36
Total lateral root length (whole root system)	0.39*	0.36
Total lateral root length (30-90 cm soil depth)	0.39*	0.35
Number of nodal roots	-0.16	0.04
Total nodal root length (whole root system)	0.23	0.20
Total nodal root length (30-90 cm soil depth)	0.44*	0.23
Root length density (whole root system)	0.44*	0.38
Root length density (30-90 cm soil depth)	0.47*	0.36
Root dry weight (whole root system)	0.51*	0.21
Root dry weight (30-90 cm soil depth)	0.51*	0.40
Deepest nodal root length	0.06	0.55**

Values are indicated by asterisks: *$p < 0.05$, **$p < 0.01$, and ***$p < 0.001$

Ratooning Ability of Irrigated Lowland Rice: Response of Selected Rice Genotypes Under Transplanting and Direct Wet Seeding Systems

RT Cruz, MVR Bascon, MM Sarong, MJC Regalado

Rice ratooning is one practical way of intensifying crop production per unit area and per unit time. Ratooning is the ability of the plant to regenerate new tillers from the main crop stubbles. Thus, the study aimed to assess the ratooning ability and productivity of rice genotypes popular among rice farmers under transplanting and direct wet seeding systems.

Field experiment was conducted at PhilRice Nueva Ecija in 2014 DS and WS. The crop establishment treatments were (1) transplanting method with a seed rate of 40kg/ha and (2) direct wet seeding method with a seed rate of 40kg/ha. Rice varieties tested were (1) PSB Rc18, (2) PSB Rc82, (3) NSIC Rc160, (4) NSIC Rc216, (5) NSIC Rc240, (6) NSIC Rc298, (7) Mestiso 19 and (8) Mestiso 20. The main rice crop was managed following the PalayCheck System for Irrigated Lowland Rice. Nitrogen fertilizer was applied following the LCC-based N fertilizer management. At harvest, the main crop stubble was cut at 20 cm above the soil surface. The field was flooded at 3cm water depth immediately after harvesting the main crop. Fertilizer treatments in the ratoon crop were (1) LCC-based N fertilizer application wherein 35kg N/ha was applied when LCC reading was below 4 for transplanted rice and below 3 for direct wet-seeded rice in DS and (2) Fixed-time N application wherein 90 kg N/ha was applied immediately after harvesting the main crop in DS and WS.

Highlights:

- With transplanting method for the 8 rice genotypes tested, the main crop grain yields ranged from 6.0t/ha for PSB Rc82 to 8.1t/ha for NSIC Rc240 in DS (Table 23). With LCC-based N application for a total rate of 105kg N/ha, ratoon yields of the main crops ranged from 0.8t/ha for PSB Rc82 to 2.1t/ha for NSIC Rc298. These transplanted rice LCC-based ratoon yields were 13.3 to 31.3% of the main crop yields. With Fixed-time N application for a total rate of 90kg N/ha, ratoon yields of the main crops ranged from 0.7t/ha for PSB Rc82 to 2.0t/ha for NSIC Rc298. These transplanted rice Fixed-time N application-based ratoon yields were 11.7 to 29.9% of the main crop yields. The rice genotypes PSB Rc18, NSIC Rc240, Mestiso 19 and Mestiso 20 had no ratoon tillers or ratoon panicles or with relatively low ratoon yields. There was no significant difference in ratoon yields (LSD 5% = 0.1) for LCC-based N application and Fixed-time N application treatments. Hence, for 44 to 55 ratoon crop maturity days, it will be more practical and economical to use the Fixed-time or one-time application of 90kg N/ha right after harvesting the main crop in dry season.

The ratoon crop was less responsive to LCC-based N fertilizer application as LCC reading did not increase to 4 even with three N fertilizer applications.

- With direct wet seeding method for the 8 rice genotypes tested, the main crop grain yields ranged from 6.6t/ha for PSB Rc18 to 8.6t/ha for Mestiso 20 in DS (Table 2). With LCC-based N application for a total rate of 105kg N/ha, ratoon yields of the main crops ranged from 1.3t/ha for PSB Rc82 to 2.1t/ha for NSIC Rc298. These direct wet-seeded rice LCC-based ratoon yields were 16.2 to 25.6% of the main crop yields. With Fixed-time N application for a total rate of 90kg N/ha, ratoon yields of the main crops ranged from 1.0t/ha for PSB Rc82 to 1.9t/ha for NSIC Rc298. These direct wet-seeded rice Fixed-time-based ratoon yields were 12.5 to 23.2% of the main crop yields. Likewise, PSB Rc18, NSIC Rc240, Mestiso 19 and Mestiso 20 had no ratoon tillers or ratoon panicles or with relatively low ratoon yields. However, in contrast to transplanted rice, there was a significant difference (LSD 5% = 0.1) in ratoon yields that were higher for LCC-based N application than the Fixed-time N application treatments for direct wet-seeded rice. Hence, for 44 to 55 ratoon crop maturity days for direct wet-seeded rice, LCC-based N application (i.e., three N applications) for a total of 105kg N/ha gave higher ratoon yields than the Fixed-time or one-time application of 90kg N/ha right after harvesting the main crop in dry season (Table 24).

- Across the 8 rice genotypes tested in DS, the main crop grain yields of transplanted rice (Table 23) were lower than the main crop yields of direct wet-seeded rice (Table 24). Results were in contrast to our previous findings that under similar optimum crop and pest management, yields of transplanted rice were similar to yields of direct wet-seeded rice.

- For PSB Rc82, NSIC Rc298, NSIC Rc160 and NSIC Rc216, the ratoon yields with LCC-based N fertilizer application and Fixed-time N fertilizer application were similar for transplanted system (Table 23). However, for direct wet-seeded system, the ratoon yields with LCC-based N fertilizer application were significantly higher than ratoon yields with Fixed-time N fertilizer application (Table 24). There is a need to investigate the phenological response of ratoon crops to N fertilizer application under transplanting and direct wet seeding systems.

- In transplanted system, the total crop productivity (i.e., main and ratoon crop yields) of PSB Rc82, NSIC Rc298, NSIC Rc160 and NSIC Rc216 were similar for LCC-based and Fixed-time N application methods (Table 20). But the total crop productivity was higher with LCC-based N application than with Fixed-time N application for direct wet-seeded system (Table 24). Overall, the total crop productivity (i.e, main crop yield + ratoon crop yield) was higher and total crop maturity (main crop maturity + ratoon crop maturity) lower for direct wet-seeded rice than transplanted rice in DS.

- With transplanting method for the 8 rice genotypes tested, the main crop grain yields ranged from 5.2t/ha for PSB Rc82 to 6.4 t/ha for NSIC Rc216 in WS (Table 25). With Fixed-time N application for a total rate of 90kg N/ha, ratoon yields of the main crops ranged from 0.2t/ha for Mestiso 20 and 1.6t/ha for NSIC Rc240. These transplanted rice Fixed-time N application-based ratoon yields were 4.2 to 28.7 % of the main crop yields. All of the rice genotypes produced ratoon yields.

- With direct wet seeding method for the 8 rice genotypes tested, the main crop grain yields ranged from 5.5 t/ha for Mestiso 19 to 6.1t/ha for Mestiso 20 in WS (Table 26). With Fixed-time N application for a total rate of 90kg N/ha, ratoon yields of the main crops ranged from 0.2t/ha for PSB Rc18 and 0.9t/ha for NSIC Rc240. These direct wet-seeded rice Fixed-time-based ratoon yields were 2.7 to 15.7% of the main crop yields. The rice genotypes NSIC Rc160 and Mestiso 20 had no ratoon tillers or ratoon panicles or with relatively low ratoon yields.

- Across the 8 rice genotypes tested in WS, the main crop grain yields of transplanted rice (Table 25) were not significantly different to the main crop yields of direct wet-seeded rice (Table 26). Results the same to our previous findings that under similar optimum crop and pest management, yields of transplanted rice were similar to yields of direct wet-seeded rice. However, ratoon crop yields in transplanted rice were higher than the direct wet-seeded rice since all 8 rice genotypes produced ratoon crops in the transplanting method.

- The total crop productivity (i.e., main and ratoon crop yields) of transplanted rice and direct wet-seeded rice were lower in WS than in DS. This is due to lower irradiance during the WS (18.6MJ/m2) than in DS (20.5MJ/m2). There is no significant difference between the overall productivity of transplanted rice and direct wet-seeded rice in WS.

Table 23. Grain yields (t/ha) of the main and ratoon crops of transplanted rice (with 40kg seeds/ha) for 8 genotypes in 2014 dry season (DS).

Varieties	Main Crop Yield (t/ha)	Ratoon Crop Yield (t/ha)		Total Crop Productivity (t/ha) (Main Crop + Ratoon Crop)		Crop Maturity (days)		
		LCC-based N (105kg N/ha total application)	Fixed-time N (90kg N/ha total application)	LCC-based N	Fixed-time N	Main Crop	Ratoon Crop	Total
PSB Rc18	6.3 b	NRT	NRT	6.3	6.3	116	NRT	116
PSB Rc82	6.0 b	0.8 (13.3)	0.7 (11.7)	6.8	6.7	110	44	154
NSIC Rc298	6.7 ab	2.1 (31.3)	2.0 (29.9)	8.8	8.7	116	45	161
NSIC Rc160	7.1 ab	1.8 (25.4)	1.8 (25.4)	8.9	8.9	118	55	173
NSIC Rc216	7.1 ab	1.5 (21.1)	1.5 (21.1)	8.6	8.6	116	45	161
NSIC Rc240	8.1 a	NRT	NRT	8.1	8.1	112	NRT	112
Mestiso 19	7.7 a	NRT	NRT	7.7	7.7	112	NRT	112
Mestiso 20	7.6 a	0.4 (5.2)	NRP	8.0	7.6	116	46	162

The main crop plot was split into two to accommodate the LCC-based N application and Fixed-time N application treatments. NRT = no ratoon tillers. NRP = no ratoon panicles but with tillers. Figures in parentheses were ratoon yields as percentages of main crop yields. Means followed by the similar letters in a column were not significantly different at 5% level of confidence using Fisher's Least Significant Difference (LSD) test. Note: For the ratoon crop of transplanted rice, LCC-based N fertilizer was applied at a rate of 35kg N/ha when LCC reading was below 4. But after N application, LCC reading did not increase to 4 even when 3 applications were made for a total N application of 105kg N/ha. For the fixed-time method, a one-time application of 90kg N/ha was made after harvesting the main crop.

Table 24. Grain yields (t/ha) of the main and ratoon crops of direct wet-seeded rice (with 40kg seeds/ha) for 8 genotypes in 2014 dry season (DS).

Varieties	Main Crop Yield (t/ha)	Ratoon Crop Yield (t/ha)		Total Crop Productivity (t/ha) (Main Crop + Ratoon Crop)		Crop Maturity (days)		
		LCC-based N (105 kg N/ha total application)	Fixed-time N (90 kg N/ha total application)	LCC-based N	Fixed-time N	Main Crop	Ratoon Crop	Total
PSB Rc18	6.6 b	NRT	NRT	6.6	6.6	109	NRT	109
PSB Rc82	8.0 ab	1.3 (16.2)	1.0 (12.5)	9.3	8.0	108	44	153
NSIC Rc298	8.2 a	2.1 (25.6)	1.9 (23.2)	10.3	10.1	103	45	148
NSIC Rc160	8.3 a	1.8 (21.7)	1.5 (18.1)	10.1	9.8	114	55	169
NSIC Rc216	8.5 a	1.6 (18.8)	1.4 (16.5)	10.1	9.9	103	44	147
NSIC Rc240	8.3 a	NRT	NRT	8.3	8.3	103	NRT	103
Mestiso 19	8.2 a	NRT	NRT	8.2	8.2	116	NRT	116
Mestiso 20	8.6 a	0.6 (7.0)	0.2 (2.3)	9.2	8.8	109	46	115

The main crop plot was split into two to accommodate the LCC-based N application and Fixed-time N application treatments. NRT = no ratoon tillers. NRP = no ratoon panicles but with tillers. Figures in parentheses were ratoon yields as percentages of main crop yields. Means followed by the similar letters in a column were not significantly different at 5% level of confidence using Fisher's Least Significant Difference (LSD) test. Note: For the ratoon crop of direct wet-seeded rice, LCC-based N fertilizer was applied at a rate of 35kg N/ha when LCC reading was below 3. But after N application, LCC reading did not increase to 3 even when 3 N applications were made for a total N application of 105kg N/ha. For the fixed-time method, a one-time application of 90kg N/ha was made after harvesting the main crop.

Table 25. Grain yields (t/ha) of the main and ratoon crops of transplanted rice (with 40kg seeds/ha) for 8 genotypes in 2014 wet season (WS).

Varieties	Main Crop Yield (t/ha)	Ratoon Crop Yield (t/ha)	Total Crop Productivity (t/ha) (Main Crop + Ratoon Crop)	Crop Maturity (days)		
				Main Crop	Ratoon Crop	Total
PSB Rc18	6.0 ab	0.2 (3.53)	6.2	123	37	160
PSB Rc82	5.2 b	0.7 (14.34)	5.9	112	49	161
NSIC Rc298	5.6 b	1.1 (19.89)	6.7	112	54	166
NSIC Rc160	5.6 b	0.8 (14.54)	6.5	117	43	160
NSIC Rc216	6.4 a	0.3 (4.19)	6.7	112	49	161
NSIC Rc240	5.6 b	1.6 (28.72)	7.2	117	48	165
Mestiso 19	5.7 ab	0.7 (12.15)	6.4	112	37	149
Mestiso 20	5.7 ab	0.2 (4.19)	5.9	123	46	169

The main crop plot was subjected with Fixed-time N application treatment only. NRT = no ratoon tillers. Figures in parentheses were ratoon yields as percentages of main crop yields. Means followed by similar letters in a column were not significantly different at 5% levelof confidence using Tukey's Honest Significant Difference (HSD) test. Note. For the fixed-time method, a one-time application of 90kg N/ha was made after harvesting the main crop.

Table 26. Grain yields (t/ha) of the main and ratoon crops of direct wet-seeded rice (with 40kg seeds/ha) for 8 genotypes in 2014 wet season (WS).

Varieties	Main Crop Yield (t/ha)	Ratoon Crop Yield (t/ha)	Total Crop Productivity (t/ha) (Main Crop + Ratoon Crop)	Crop Maturity (days)		
				Main Crop	Ratoon Crop	Total
PSB Rc18	6.0 a	0.2 (2.69)	6.1	117	18	135
PSB Rc82	5.9 ab	0.5 (8.78)	6.4	111	36	147
NSIC Rc298	5.9 ab	0.7 (12.3)	6.6	111	41	152
NSIC Rc160	5.8 ab	NRT	5.8	117	0	117
NSIC Rc216	6.0 a	0.2 (2.5)	6.2	111	36	147
NSIC Rc240	6.0 a	0.9 (15.72)	6.9	111	35	146
Mestiso 19	5.5 b	0.6 (11.52)	6.1	111	36	147
Mestiso 20	6.1 a	NRT	6.1	117	0	117

The main crop plot was subjected with Fixed-time N application treatment only. NRT = no ratoon tillers. Figures in parentheses were ratoon yields as percentages of main crop yields Means followed by similar letters in a column were not significantly different at 5% levelof confidence using Tukey's Honest Significant Difference (HSD) test. Note. For the fixed-time method, a one-time application of 90kg N/ha was made after harvesting the main crop.

Resource Efficient Technologies for Maximizing Rice Productivity
WB Collado, MD Malabayabas, AJ Espriritu, MJC Regalado

With the enduring effort to attain rice self-sufficiency and increased productivity, PhilRice continuously develops rice production technologies that can readily be used by farmers and other rice stakeholders. Recently, technological progress has enabled multi-cropping per unit area. The adoption of high-yielding rice varieties, appropriate machinery and fertilizers has generally enhanced soil productivity. However, these schemes have increased the energy input per unit area. The utilization of technologies should be appropriately evaluated to ensure high energy efficient production. Thus, the study was conducted to evaluate the performance of selected newly-released high-yielding rice varieties using resource-efficient rice technologies like the drum-seeding method of crop establishment in the dry season (DS), the researchers' fixed time and rate (FTR) and the LCC-based, fixed time-adjustable rate (FTAR) of N fertilizer application methods, and the controlled irrigation scheme.

Highlights:

- The 2014 DS and WS cropping did not show significant differences in mean grain yields of the rice varieties tested as affected by the method of N applications (Figure 21). The total amounts of N applied in the two N fertilizer treatments were 180 kg N ha^{-1} in the fixed time and rate of N application (FTR-N) and 150 kg N ha-1 in the LCC-based or fixed time-adjustable rate (FTAR-N) during DS. A saving of 16.7% on N application was obtained by the FTAR-N. In WS, the two methods of N application showed similar rate of N application of 90 kg N ha^{-1}.

- The partial factor productivities (PFPN) of the two N treatments showed that more grains were produced per unit of N applied in the FTAR-N treatment during DS but not in WS (Figure 22). The FTAR-N strategy of N management produced more grains per unit of N applied than the FTR-N in the dry season. However, higher PFPN was obtained by the FTR treatment in the WS than DS. In the FTAR treatment, mean PFPN obtained in both seasons were similar. The PFPN obtained by the test rice varieties were below the optimum value of 50 kg grain kg N^{-1} applied measured in the irrigated lowland rice fields of Asia;

- The total time used in the drum-seeding activity by 2 persons in DSwas 0.783 hours for an area of 0.385776 ha or a total of 2.4 hours ha^{-1} and an energy input of 1.13 M MJ ha^{-1};

- The total time spent in the irrigation of the experimental plot with an area of 0.02697 ha was 26.2 minutes or a total of 16.2 hours ha^{-1}. The total amount of irrigation water used from 22 days after transplanting to the last irrigation was 5,301.3m^3 ha^{-1} in DS and 9,947m3 ha^{-1} in WS; and irrigation input energy of 3,261MJ ha^{-1} in DS and 6,118MJ ha-1 in WS.

- The two fertilization techniques showed a difference on the total amountsof N but showed comparable grain yield levels in DS but not in WS. Thus, the FTAR-N treatment showed lower cost of N and therefore will obtain a higher return on investment during DS.

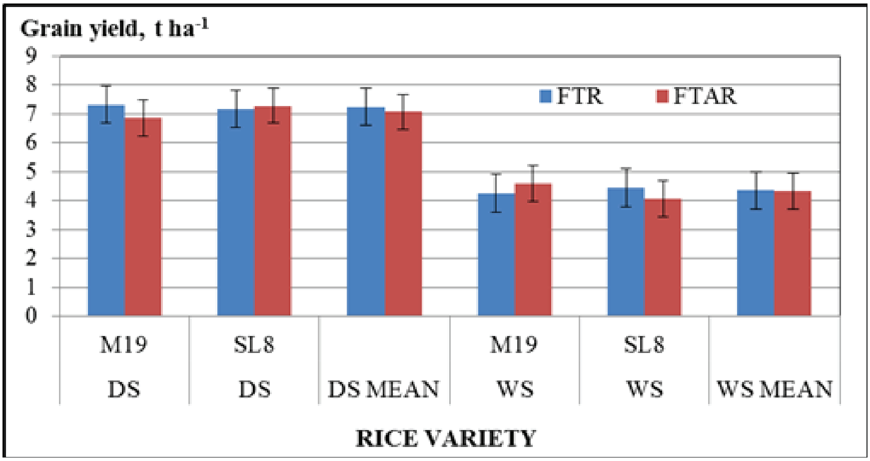

Figure 21. Grain yields of the test rice varieties as affected by the fertilizer treatments (FTR-N: fixed time and rate N application; FTAR-N: fixed time-adjustable rate LCC-based N application). 2014 Dry and Wet Seasons, PhilRice-CES, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines.

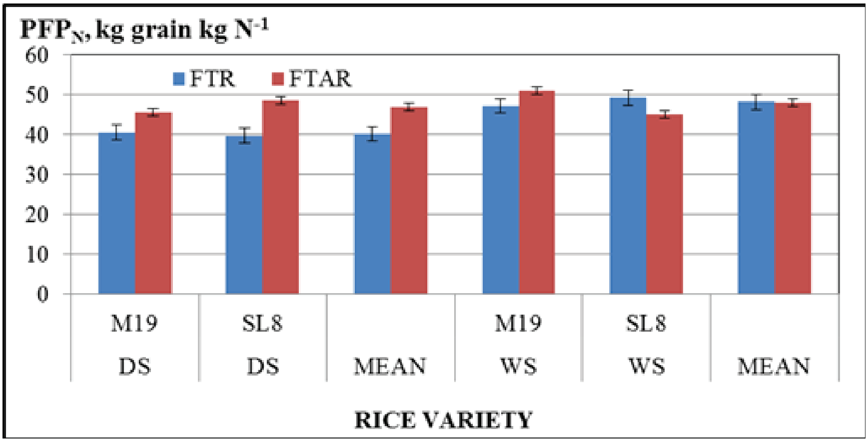

Figure 22. The partial factor productivity (PFP) from the applied N of the test rice varieties. 2014 Dry and Wet Seasons, PhilRice-CES, Maligaya, Science City of Muñoz, Nueva Ecija, Philippines.

Evaluation of the Common System of Rice Intensification (SRI) Practices in Irrigated Lowland

RT Cruz, MV Bascon, MM Sarong, ET Rasco, Jr.

In cultivating lowland rice, the most common management practices are flooded paddies, transplanting of 21-day old seedlings, 20cm x 20cm spacing between plants, use of pesticides and inorganic or chemical fertilizers (Lales et al. 2010 Phil. J. Crop. Sci. 35). However, Uphoff (2002 http//cifad.cornell.edu.) believes these practices inhibit the inherent genetic potential of rice. By using the System of Rice Intensification (SRI), a set of principles developed by Fr. Henri de Laulanié in the highlands of Madagascar, the productivity of land, labor and water is increased. SRI is characterized by use of young seedlings transplanted at wider spacing, alternate wetting and drying, organic fertilizers and no pesticides. However, SRI was critically evaluated with regards to its potential to raise rice yield (Dobermann 2004 Agric. Systems 17; Sheehy et al. Field Crops Res. 88). Average rice yields were 3.2t/ha with SRI-organic fertilizer and 6.9t/ha with PalayCheck System that used inorganic fertilizer (Lales et al. 2010 Phil. J. Crop. Sci. 35). Results of other researches showed that the influence of SRI on rice yield was variable. This could be due to the changes in SRI crop management practices over time. Based on our recent comprehensive review from 1993-2011, there were three SRI practices that were retained across the years. These were (a) crop establishment that utilized a planting density of 1 seedling per hill, (b) water management that utilized alternate wetting and drying or intermittent irrigation or controlled irrigation, and (c) weed management that utilized rotary weeding equipment. Therefore, the current field study aimed to evaluate the effect of the retained SRI practices on rice crop growth, yield and return on investment.

Field treatments were: (1) planting densities of 1, 2, and 3 seedlings/hill; (2) genotypes PSB Rc82 and NSIC Rc222; (3) water management treatments with (a) continous flooding (CF) and (b) alternate wetting and drying (AWD) and (4) weed management treatments with (a) hand weeding up to 40 days after transplanting (DAT) and (b) mechanical weeding using rotary weeder with 7-day interval from 10 to 40 days after transplanting (DAT). Commercial organic fertilizer was applied at a rate of 45kg N/ha, 60 kg P/ha and 45kg K/ha in dry and wet season. The adjacent experimental setup for PalayCheck System of integrated crop management served as the Control. In the PalayCheck System, inorganic fertilizers were applied at rates of 112kg N/ha, 42kg P/ha and 42kg K/ha in dry season (DS) and 74kg N/ha, 28kg P/ha, and 28kg K/ha in the wet season (WS).

Highlights:

- In 2014 DS, plant height at mid-tillering and panicle initiation stages did not differ among planting densities, water and weed management treatments for PSB Rc82 and NSIC Rc222.

- Field was weeded 4 times in both hand-weeding and rotary weeding treatments across plant densities and water management treatments for PSB Rc82 and NSIC Rc222.

- Grain yield (t/ha) for PSB Rc82 (Table 27) and NSIC Rc222 (Table 28), straw yield, harvest index, weight of 1,000 grains and partial factor productivity for N (kg grain/kg N applied) did not differ significantly across water management, planting density and weed management treatments in DS. Grain yield for PSB Rc82 and NSIC Rc222 did not differ significantly across water management, planting density, and weed management treatments in the WS.

- For PSB Rc82 and NSIC Rc222, no significant difference in yield components was observed in the water and weed management treatments. Alternate wetting and drying and continuous flooding had yields close to 6 t/ha but did not differ significantly for PSB Rc82 and NSIC Rc222 (Tables 24 and 25).

- For PSB Rc82 and NSIC Rc222, the Control treatment or PalayCheck System that used inorganic fertilizer had an average yield of 8.0t/ha in the DS and 5.4t/ha in the WS while SRI treatments that used organic fertilizer had an average yield of 6.0t/ha in the DS and 4.3t/ha in the WS. Results agreed with our previous findings (Lales et al. 2010 Phil. J. Crop. Sci. 35) that even when the rates of organic fertilizer were tripled, yields were significantly lower than yields with PalayCheck System that used inorganic fertilizer.

Table 27. Grain and straw yield and harvest index for the 3 retained SRI practices* (i.e., alternate wetting and drying, 1 seedling/hill and rotary weeding) vs. continuous flooding, 2 and 3 seedlings per hill and hand-weeding in 2014 cropping season for PSB Rc82.

SRI Treatment	Grain yield t/ha	
	Dry Season	Wet season
Water management		
Continuous flooding	5.9 a	4.4 a
Alternate wetting and drying*	5.8 a	4.1 a
Planting density		
1 seedling/hill*	6.1 a	4.2 a
2 seedlings/hill	6.0 a	4.4 a
3 seedlings/hill	6.0 a	4.2 a
Weed management		
Rotary weeding*	5.9 a	4.4 a
Hand Weeding	5.9 a	4.1 a

Means with the same letter are not significantly different at 5% level of significance using Tukeys's Honest Significant Difference (HSD) Test.

Table 28. Grain and straw yield and harvest index for the 3 retained SRI practices* (i.e., alternate wetting and drying, 1 seedling/hill and rotary weeding) vs. continuous flooding, 2 & 3 seedlings per hill and hand-weeding in 2014 cropping season for NSIC Rc222.

SRI Treatment	Grain yield	
	Dry season	Wet season
Water management		
Continuous flooding	5.9 a	4.5 a
Alternate wetting and drying*	6.0 a	4.3 a
Planting density		
1 seedling/hill*	5.9 b	4.2 a
2 seedlings/hill	6.3 a	4.7 a
3 seedlings/hill	5.9 b	4.3 a
Weed management		
Rotary weeding*	6.0 a	4.3 a
Hand Weeding	6.1 a	4.5 a

Means with the same letter are not significantly different at 5% level of significance using Tukeys's Honest Significant Difference (HSD) Test.

Evaluation of Water, Nutrient Use and Energy Efficiencies of Varieties with High Yield Potential

MD Malabayabas, AJ Espiritu, CR Esaga-Ventura

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. Water and nutrients must be efficiently utilized by rice to compensate for the high production cost. The adoption of energy resource use efficient varieties with high yield potential should be considered to reduce production cost while maintaining productivity.

Water and energy efficiencies of new high yielding varieties namely: NSIC Rc222, Rc298, Rc300, Mestiso 19, Mestiso 20 and PSB Rc82 (control variety) were evaluated under continuous flooding (CF) and controlled irrigation (CI) in 2014 Dry Season (DS) and Wet Season (WS). Plastic sheets were installed in each treatment plot to prevent seepage. In another experiment, agronomic nitrogen use efficiency (AEN) and N input energy (NIE) were determined with Leaf Color Chart (LCC)-based N application and fixed time and rate N application of 150 kg/ha in DS and 90 kg/ha in WS. Pre-germinated seeds were drum-seeded at the rate of 20 kg/ha. Reduced tillage (1 dry plowing, two harrowing and final leveling) was adopted in the land preparation.

Highlights:

- Higher water productivity was achieved with CI in DS (Table 29). NSIC Rc300 had higher productivity than Mestiso 20 but these two varieties were comparable with the rest of the varieties (Table 30). The irrigation input energy (IIE) and fuel input energy (FIE) were lower with CI than CF (Table 31). NSIC Rc298, Mestiso 19 and Mestiso 20 had lower irrigation and fuel input energy than the control variety Rc82 while Rc222 and Rc300 were comparable with Rc82.

- In WS, there was no significant difference in water productivity, IIE and FIE between the two water management methods and among varieties.

- Grain yield in the water management experiment ranged from 5.90 to 7.12t/ha in DS and 4.92 to 6.27 t/ha in WS. Grain yield between CF and CI and among rice varieties did not differ significantly in both cropping seasons. Similarly, Rice yield energy outputs (RYEO) were not significantly different among varieties and between water management in both seasons.

- In the nutrient management study, AEN ranged from 23.4 to 34.9kg grain kg N-1 fertilizer in DS and 22 to 36.3kg grain kg N^{-1} in WS (Figure 23). AEN in the fixed rate N application of 150kg/ha and LCC-based N application did not differ significantly in DS. Higher rate of N fertilizer was applied in Rc82, Rc222 and Rc300 with LCC-based N management than the fixed N rate of 150kg/ha during DS (Figure 24). In WS, the rates of N fertilizer applied with LCC-based were lower than the fixed rate of 90kg/ha and this accounts for the higher AEN obtained in WS than DS. NIE, grain yield and RYEO did not differ significantly among the test varieties in both DS and WS.

Table 29. Water productivity (WP) at two water management methods, 2014 DS, PhilRice-CES.

Water management	WP (kg m^{-3})
Continuous flooding (CF)	0.57 b
Controlled irrigation (CI)	1.25 a

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

Table 30. Water productivity (WP) of selected varieties with high yield potential, 2014 DS, Philrice-CES.

Variety	WP (kg m^{-3})
PSB Rc82	0.85 ab
NSIC Rc222	0.98 ab
NSIC Rc298	0.90 ab
NSIC Rc300	1.08 a
Mestiso 19	0.88 ab
Mestiso 20	0.75 b

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

Table 31. Irrigation Input Energy (IIE) and Fuel Input Energy (FIE) of selected varieties with high yield potential, 2014 DS, PhilRice-CES.

Variety	IIE (MJ ha^{-1})		FIE (MJ ha^{-1})	
	CF	CI	CF	CI
PSB Rc82	11920 a	5164 a	15119 a	6694 a
NSIC Rc222	11897 a	4870 ab	15061 a	6290 ab
NSIC Rc298	11919 a	4429 b	15119 a	5713 b
NSIC Rc300	11930 a	4518 ab	15119 a	5829 ab
Mestiso 19	11897 a	4165 b	15061 a	5367 b
Mestiso 20	11897 a	4165 b	15061 a	5367 b

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

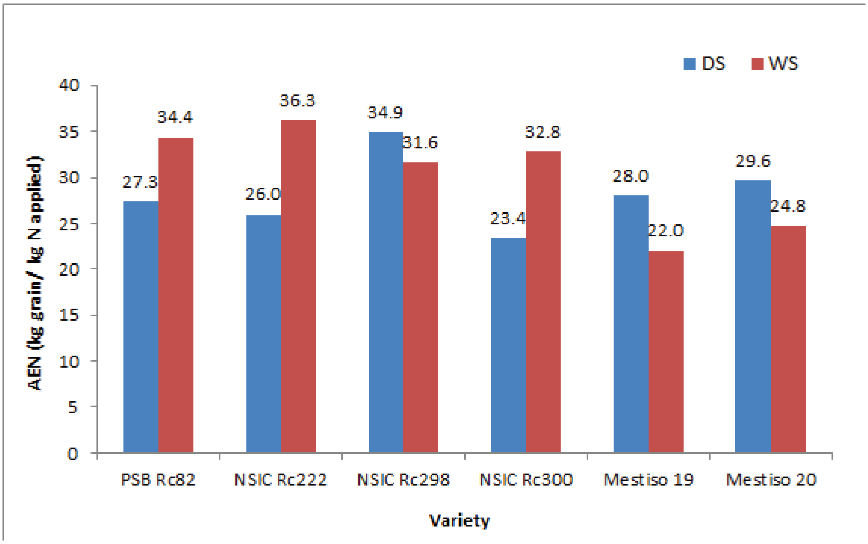

Figure 23. Agronomic nitrogen use efficiency (AEN) of varieties across N management in 2014 DS and WS, PhilRice-CES.

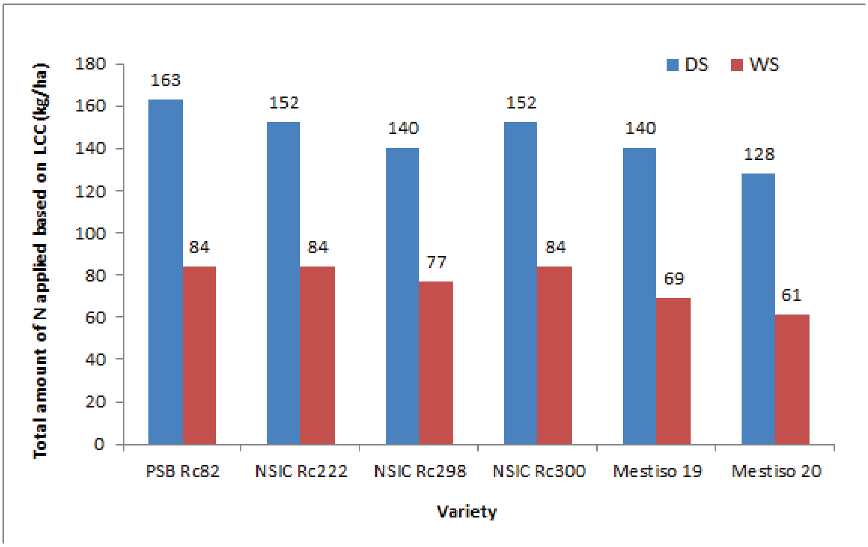

Figure 24. Total amount of applied N fertilizer based on Leaf Color Chart (LCC), 2014 DS and WS, PhilRice-CES.

IV. ASPPD Research and Analytical Laboratory Systems and Maintenance

Project Leader: EF Javier

The project on ASPPD Research and Analytical Laboratory Systems and Maintenance was proposed and funded in 2012DS. Its main goal is to capacitate the ASPPD laboratory system for its R&D functional objectives. The existence of the laboratory was then supported from little contributions of some research projects housed in the division according to their approved minimal budget. Usually, laboratory management and maintenance to complement and implement the IMS policy of the Institute had been sourcing out funds from external sources. The external sources though of higher fund support are not stable, hence this project was established to (1) provide assistance in the improvement/upgrade of the laboratory facilities for better quality research output; (2) constantly optimize laboratory/ chemical procedures for soils and plant samples; and (3) build-up 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) data-based 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 through more basic and scientific data like nitrogen use efficiency, efficient utilization and uptake of nutrients be it from inorganic or organic source, so on and so forth is still insufficient due to lack of physiological or chemical data. Likewise, the current ASPPD laboratories and greenhouse facilities needs some improvements and equipment updating as well as preventive maintenance services and calibration (in conformance to the ISSO certification of PhilRice, ISO 9001:2008 and ISO18001:2007). Hence this research activity/concern was proposed to have a little funds that could assist the maintenance of the laboratory in support to the ASPPD R&D activities.

Highlights:

- Attendance of all laboratory staff to the Chemical Spill Drill spearheaded by ISSO.
- Attendance of some staff to seminar regarding the new analytical techniques on Spectroscopy and Demo seminar of automatic titrator and pH meter.
- Acquisition and maintenance of laboratory facilities according to ISO policies on EMS, QMS and OSHAS (in collaboration with the PPD).
- Processed repair of several laboratory facilities (sinks and electrical outlets).
- Processed repair of equipment (MRK Nitrogen analyzer, Gallenkamp oven, Barnstead water distilling unit.
- Processed repainting of old and corroded chemical racks, chemical cabinets and soil shaker.
- Acquired additional canopy and exhaust fan in the laboratory.
- Annual preventive maintenance service (PMS) and calibration of laboratory equipment.
- Equipment due for annual preventive maintenance service and calibration had undergone PMS.
- Database on the inventory of chemicals and procurement.
- Maintained and updated the inventory of incoming and outgoing of chemicals which prevented the over-supply of chemicals.
- Submitted 2014 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 lists of equipment for upgrading, and replacement of unserviceable instruments and equipment.
- Researched specifications and prices of equipment needed in

the laboratories, in accordance also to availability of funds.

- Consulted and collaborated with several chemical and laboratory equipment suppliers regarding equipment to be upgraded.

- Networking and consultation services.
  - Provided technical assistance to 5 thesis students from NEUST Laboratory High School.

- Recognition
  - Received Certificate of Recognition (ASPPD Laboratory) for demonstrating Outstanding Housekeeping and Health and Safety Practice in the laboratories during the 1st inspection period 2014 conducted by ISSO.

Short term and long-term assessment of heavy metals in the paddy soils of Regions 1

EF Javier, JC Magahud, 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. Such analyses are still going on.

Highlights:

- In the 17 sites selected (Table 32), 14 sites observed deposition of materials that are sandy-like (11 sites), gray when dry (11 sites). Tremendous effort was spent for manual excavation of mine tailings from the irrigation entrance (3 sites), as the deposition had restricted the flow of irrigation water (5 sites). Soils became difficult to plow (6 sites). Milky irrigation water was also observed after the leakage (13 sites).

- Rice plants had stunted growth (10 sites), with fewer tillers than before the incident (11 sites), hence reduced yield (12 sites). The leaves were observed to be yellowish, brownish or reddish (10 sites).

- Mitigation done by interviewed farmers is to apply more fertilizers, more frequent irrigation was done, and just manually remove the mine tailings from the heavily silted portion of their field. Yield was observed to have slightly increased (3 sites) but some observed no increase of yield (3 sites) (Table 33)

- In so far, no health problem had been observed and perceived by the interviewed farmers as they consumed their harvested rice.

- Initial chemical analysis of the sediment sample adjacent to the San Roque dam reservoir however revealed copper level (243.7ppm) higher than intervention value (190mg kg^{-1}) (Table 34).

Table 32. Selected sites for the monitoring of the extent of heavy and light metals accumulation.

Site	Source of irrigation water	Site validation & Farmers' interview	Soil & grain sample collections	Sample preparation	Sample submi-ssion to laboratory	Availability of lab results		Statistical analysis & Reporting of results	Identification/ Validation of Soil Series
						Heavy metal levels	Soil properties		
Sites in the upstream of SRD main canal									
Santiago ditch	SRD	✓	✓	✓	✓	✕	✓	✕	✕
Lateral A extra	SRD	✓✕	✓	✓	✓	✕	✓	✕	✕
Don Moteo	SRD	✓	✓	✓	✕	✕	✓	✕	✕
Turn-out Service Area	SRD	✓	✓	✓	✓	✕	✓	✕	✕
Namangonan canal	SRD	✓	✓	✓	✕	✕	✓	✕	✕
Casantiagoan canal	SRD	✓	✓	✕	✕	✕	✓	✕	✕
near Lateral C	SRD	✓	✓	✓	✕	✕	✓	✕	✕
Sites in the middle of SRD main canal									
Lateral E	SRD	✓	✓	✓	✓	✕	✓	✕	✕
Lateral D	SRD	✓	✓	✓	✓	✕	✓	✕	✕
Lateral G	SRD	✓	✓	✓	✓	✕	✕	✕	✕
Lateral F1	SRD	✓	✓	✓	✓	✕	✓	✕	✕
Lateral F2	SRD	✓	✓	✓	✓	✕	✕	✕	✕
Sites in the downstream of SRD main canal									
Lateral H	SRD	✓	✕	✕	✓	✕	✕	✕	✕
Lateral H2	SRD	✓	✓	✓	✓	✕	✕	✕	✕
Lateral J	SRD	✓	✕	✕	✕	✕	✕	✕	✕
Lateral K	SRD	✓	✓	✓	✓	✕	✓	✕	✕
near Lateral M	SRD	✓	✓	✓	✓	✕	✓	✕	✕
Sites in the laterals of rivers									
Tanggal Perez canal	river	✓✕	✓	✓	✓	✕	✓	✕	✕
Sta. Barbara/Mangaldan lateral	river	✕	✕	✕	✕	✕	✕	✕	✕
LARIS lateral 1	Agno river	✓✕	✓	✓	✓	✕	✕	✕	✓
LARIS lateral 2	Agno river	✕	✓	✓	✓	✕	✕	✕	✕
Control sites									
San Manuel/near lateral B	aquifer	✓	✓	✓	✓	✕	✕	✕	✕
Villasis	deep well	✓✕	✕	✕	✕	✕	✕	✕	✓

SRD-San Roque dam /= done

LARIS-Lower Agno River Irrigation System x= yet to be done

Table 33. Initial characterization of the different selected sites as per their land use or cropping sequences, and farm input levels.

Site	Annual crop sequence	Fertilizer level[a]	Pesticide level[b]	Mechanization level[c]	Source of irrigation
Sites in the upstream of SRD main canal					
Santiago ditch	rice-rice	medium	low	high	SRD
Lateral A extra	rice-rice	medium	-	high	SRD
Don Moteo	rice-rice	medium	low	high	SRD
Turn-out Service Area	rice-rice	medium	low	high	SRD
Namangonan canal	rice-rice	medium	medium	high	SRD
Casantiagoan canal	rice-rice	medium	low	-	SRD
near Lateral C	rice-rice	medium	low	high	SRD
Sites in the middle of SRD main canal					
Lateral E	rice-rice	medium	high	high	SRD
Lateral D	rice-rice	medium	high	high	SRD
Lateral G	rice-rice	medium	medium	high	SRD
Lateral F1	rice-rice	medium	medium	high	SRD
Lateral F2	rice-rice	medium	medium	high	SRD
Sites in the downstream of SRD main canal					
Lateral H	rice-rice	high	high	high	SRD
Lateral H2	rice-rice	high	high	high	SRD
Lateral J	rice-rice-mungbean	high	high	high	SRD
Lateral K	rice-rice	medium	high	high	SRD
near Lateral M	rice-rice	medium	high	high	SRD
Sites in the laterals of rivers					
Tanggal Perez canal	rice-rice	medium	high	-	river
Sta. Barbara/Mangaldan lateral	-	-	-	-	river
LARIS lateral 1	rice-rice	low	high	medium	Agno river
LARIS lateral 2	-	-	-	-	Agno river
Control sites					
San Manuel/near Lateral B	rice-rice	medium	low	high	aquifer
Villasis	corn-rice-corn	high	high	high	deep well

[a]21 and above bags of granular fertilizers/ha/year—high, 11-20—medium, 10 and below—low
[b]61 and above sprayers of foliar pesticides/ha/year—high, 31-60—medium, 30 and below—low
[c]11 and above mechanized operations—high, 6 to 10—medium, 5 and below—low

Table 34. Concentrations of metals in sediment sample as compared to intervention values.

	Cr	As	Cd	Hg	Pb	Cu	Zn	Fe	Mn
	mg kg^{-1}								
intervention value	180 (III) 78 (VI)	76	13	36 (inorganic) 4 (organic)	530	190	720	–	–
sediment sample	52.9	5.2	0.34	0.14	18.3	243.7	125.0	44100	1403

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

Project Leader: LM Juliano

The project was established in 2014 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.

The influence of timing and level of nitrogen and potassium application on physiological traits responsible for yield heterosis on hybrid rice

ML Pini

Rice is an important agricultural commodity with more than 155 million hectares grown worldwide. It can be grown using variety of cultural management practices. Tillage systems, seeding rates, and nitrogen (N) rates are management factors that are critically important in achieving optimum rice grain yields. N is one of the essential macro-elements for rice and the most yield-limiting nutrient in rice production because of its vital morpho-physiological functions. N is the main nutrient associated with yield. Its availability promotes crop growth, tillering and number of panicles and spikelet during the early panicle formation stage. Although most soils were N deficient, sources like rainfall, crop residues, manures and commercial inorganic fertilizer could replenish it. The amount of N fertilizer needed to optimize crop yield often differs significantly from one field to another. In other hand, potassium absorbed during the reproductive and ripening phases increases the plants' resistance to diseases affecting the panicle, grains, and increases the protein content of the grains; thus improving the quality of the crop. At present, different levels of nitrogen and potassium were formulated to address the needs of rice. However, the best level and timing of N and

K application must be determined to prevent the early and late flowering of parental lines and hybrid leading to poor synchronization. This study, therefore, aimed to evaluate the influence of timing and level of nitrogen and potassium application on the physiological traits of rice especially on hybrid rice and parental lines. More specifically, this study aimed at determining the improvement of the yield heterosis of rice as affected by different timing and level of nitrogen and potassium application; recommending the right time application of nitrogen and potassium in hybrid rice; and determining how much N and K fertilizer needed to optimize seed yield and yield.

Highlights:

- The soil were pre-analyzed in the analytical services laboratory (ASL) to determine each chemical properties;

- The field experiment was conducted outside the PhilRice Isabela Experiment Station located at San Manuel,San Mateo,Isabela. The set-up was laid out in a split-plot design with three replications with 20m2 plot size. Mestizo 48 was the variety used, a new hybrid variety release from the Central Experiment Station. The treatments were applied in different level and timing. Chemical control for weeds, snails and prevalent insects were applied to minimize the damages caused by these pests;

- Treatments were as follows for nitrogen fertilizer application: (1) No N application,(2) 100kg N/ha, (3) 150kg N/haand (4) 200kg N/ha and for potassium application: (1) No K application, (2) 60kg K/ha, (3) 150kg K/ha, (4) 200 kg K/ha;
- Below are the soil chemical properties indicating the soil pH, organic carbon, available P and available K.

Table 35. Chemical properties of the soil where the set-up was conducted (2014 WS).

	pH	OM content (%)	Available P (ppm)	Available K (ppm)
Soil chemical properties (level)	5.3	2.29	15.8	144

- For yield and yield components of rice, 100kg N/ha: 5.75t/ha and 150kg N/ha: 6.01t/ha obtained the highest yield compare to the three treatments. Heading of the plants were first observed in Treatment IV (200kg N/ha) (see Table 36).

Table 36. Yield and yield components of M48 as affected by different nitrogen fertilizer level treatments irrigated lowland ecosystems (2014 WS).

Treatment	Plant Height(cms)	Tiller Number(cms)	Grain Yield(t/ha)
I	96.46	14	4.79b
II	100.2	11	5.75a
III	101.43	14	6.01ab
IV	92.97	15	5.68a
*Means with the same letter are not significantly different at 5%level of significance			

- In potassium plots treatments, treatment 3(150kg K/ha) attained the highest yield with two splits of potassium at basal and early panicle application compared to the three treatments. Heading stage was first observed on treatment 3.

Table 37. Yield and yield components of M48 as affected by different potassium fertilizer level treatments irrigated lowland ecosystems (2014 WS).

Treatment	Plant Height(cms)	Tiller Number(cms)	Grain Yield(t/ha)
I	97	13	4.64b
II	104	11	5.82a
III	102	14	6.1ab
IV	97	12	5.8a
*Means with the same letter are not significantly different at 5%level of significance.			

Yield Potential of PhilRice- bred Promising Lines and New Rice Varieties in Response to Nitrogen Management
MD Malabayabas, CR Esaga-Ventura

With the current goal of the country to achieve rice self-sufficiency, rice farmers should use varieties with high yield potential. Besides variety, nutrient management particularly nitrogen (N) is crucial in the attainment of yield potential. Thus, the study was conducted at PhilRice-CES in 2014 Dry Season (DS) and Wet Season (WS) to determine the yield potential of new varieties and promising lines and their response to N management. Treatments were arranged in split plot design with N as main plot and variety as sub-plot. The N treatments were (N1) basal application of 6 bags of 14-14-14-12S in DS and 4 bags in WS with N topdressing based on Leaf Color Chart (LCC) reading (applied 35kg N/ha in DS and 23kg in WS when LCC was below 4 (LCC-real time or LCC-RT); (N2) the same basal fertilizer application as N1 but N topdressing was based on LCC-fixed time adjustable rate (LCC-FTAR) i.e. 45kg of N ha^{-1} in DS and 35 kg/ha in WS was applied when LCC was below 4 and 30kg in DS and 23kg in WS when LCC was greater than or equal to 4; and (N3) fixed rate application of 200kg N ha^{-1} in

DS (N splitting: 60 basal, 40 at mid-tillering, 80 at panicle initiation and 20kg N ha^{-1} at first flowering) and 150kg N ha^{-1} in WS (N splitting: 45 basal, 30 at MT, 60 at EPI and 15kg N ha-1 at FF). The rate of P2O5 and K2O were 60kg each per hectare. The test varieties were CPR-01(two-line hybrid promising line), Mestiso1 Mutant (inbred promising line), NSIC Rc202H (Mestiso 19), NSIC Rc204H (Mestiso 20), NSIC Rc298, NSIC Rc308, NSIC Rc342SR. Popular varieties PSB Rc18, PSB Rc82 and NSIC Rc222 were used as checks. Pest incidence/damage was also assessed by Mr. Rillon of Crop Protection Division in WS.

Highlights:

- In 2014 DS, grain yield ranged from 7.50 to 8.53t/ha (Table 38). Mestiso 19, 20, NSIC Rc298, Rc308 and Rc342SR gave comparable yield with the check PSB Rc82 and Rc222. NSIC Rc308 and Rc342SR significantly out yielded Rc18. Mestiso 19 and Rc342SR had significantly higher spikelet number m-2 and panicle-1 than Rc18. Other test varieties were comparable with the checks. Rc308 showed comparable percentage of filled spikelets with Rc18, Mestiso 19 and Rc298 but significantly higher than the other checks and test varieties. N management did not significantly affect the yield, spikelet number per m2, spikelet number per panicle and percentage of filled spikelets. On the other hand, harvest index was significantly highest in the LCC-RT. Higher N rate of 200kg N ha^{-1} gave significantly the lowest harvest index indicating that the high biomass produced was not able to translate into high yield. M19 had significantly higher harvest index than Rc18 and Rc222 but comparable with Rc82 (Table 40).

- The weight of 1000 grains was significantly higher in the LCC-FTAR than LCC-RT (Table 39). Higher amount of N fertilizer at 200kg N ha^{-1} significantly reduced the weight of 1000 grains. All new varieties/promising lines had significantly heavier grain weights than Rc222 (Table 40). NSIC Rc342SR and M19 had significantly heavier grains than Rc18 and Rc82 while the rest had comparable weight with the two checks.

- There was significant interaction between variety and N management with respect to the number of panicle m^{-2}. Mestiso1 mutant and Rc82 gave significantly higher number of panicles with LCC-FTAR and fixed rate application of 200kg N ha^{-1}. On the other hand, Rc222 with 200kg N had significantly lower panicle number m-2 than with FTAR. In the LCC-RT, panicle number m-2 did not significantly differ among varieties.

- In 2014 WS, the yield ranged from 5.81 to 7.62t/ha. LCC-RT approach gave significantly higher yield than the LCC-FTAR and fixed rate N application of 150 kg N ha-1 (Table 40). Grain yield did not differ significantly among varieties despite the significant differences in panicle and spikelet numbers, percent filled spikelets, 1000-grain weight and harvest index (Table 41).

- There were more N fertilizers applied in the LCC-FTAR (N2) and fixed rate N application (N3) than the LCC-RT (N1) (Figures 25 and 26) during DS and WS but the yield was not significantly increased. This implies that yield potential of test varieties can be achieved with LCC-based real time N application, which in general had the lowest amount of applied N fertilizer. Moreover, grain yield of more than 8 t/ha can be achieved in DS with N rates of 77 to 89kg N ha^{-1} and more than 6 t/ha in WS with N rates of 51 to 82kg, provided all other crop management practices and weather conditions are optimum.

- Pest assessment in WS generally indicated very low pest damage (< 10%) except for the 5 to 22% bacterial leaf streak (BLS) damage in varieties applied with fixed rate application of 150kg/ha (N3). NSIC Rc222 had zero BLS damage in all N levels.

Table 38. Grain yield, spikelet number m2, spikelet number $panicle^{-1}$ and filled spikelets, 1000-grain weight and harvest index of rice varieties/lines, PhilRice-CES, 2014 DS.

Variety	Grain yield (t/ha)	Spikelet number m^{-2}	Spikelet number $panicle^{-1}$	% filled spikelets	1000-grain weight (g)	Harvest index
PSB Rc18	7.59 cd	41389 d	118 c	83.99 ab	22.77 cd	0.53 d
PSB Rc82	8.08 abcd	48055 abcd	131 bc	79.35 bcd	23.03 bcd	0.58 ab
NSIC Rc222	7.98 abcd	48701 abc	141 abc	77.15 cd	21.93 d	0.55 bcd
CPR-01	7.50 d	44895 bcd	137 abc	75.54 d	23.76 abc	0.57 abc
M1 mutant	7.78 bcd	48082 abcd	118 c	79.02 bcd	23.60 abc	0.57 abc
Mestiso 19	8.27 abc	52404 a	157 ab	81.31 abcd	24.77 a	0 .61 a
Mestiso 20	8.36 ab	47830 abcd	141 abc	78.19 bcd	24.32 ab	0.54 cd
NSIC Rc298	8.01 abcd	42766 cd	128 c	82.62 abc	24.33 ab	0.54 cd
NSIC Rc308	8.53 a	45099 bcd	125 c	87.40 a	23.81 abc	0.57 abc
NSIC Rc342SR	8.50 a	51474 ab	159 a	77.82 bcd	24.63 a	0.57 abc

In a column, means with the same letter are not significantly different at 5% by HSD.

Table 39. 1000-grain weight and harvest index at different N management, PhilRice-CES 2014 DS.

N Management	1000- grain weight (g)	Harvest index
LCC-RT	23.74 b	0.58 a
LCC-FTAR	23.97 a	0.56 b
Fixed N rate (200 kg/ha)	23.37 c	0.55 c

In a column, means with the same letter are not significantly different at 5% by LSD.

Table 40. Panicle number m^{-2}, spikelet number m^{-2}, and spikelet number panicle $^{-1}$, PhilRice-CES, 2014 WS.

Variety	Panicle number m^{-2}	Spikelet number m^{-2}	Spikelet number panicle $^{-1}$	% Filled Spikelets	1000-Grain weight	HI
PSB Rc18	277 abc	31971 ab	116 ab	82.47 abc	23.4 e	0.45 b
PSBRc82	308 ab	33815 ab	110 b	85.73 ab	23.2 f	0.53 a
NSICRc222	304 ab	39183 a	129 ab	75.91 c	23.8 d	0.49 ab
CPR01	267 bc	37243 ab	141 a	79.85 bc	24.4 c	0.54 a
M1mutant	326 a	35766 ab	110 b	83.20 abc	25.2 b	0.53 a
Mestiso 19	260 bc	33591 ab	130 ab	78.48 bc	25.4 a	0.54 a
Mestiso 20	247 c	29341 b	120 ab	84.34 ab	24.4 c	0.50 ab
NSICRc298	264 bc	34861 ab	135 ab	83.28 abc	25.1 b	0.53 a
NSICRc308	299 ab	32740 ab	109 b	89.14 a	23.2 ef	0.52 a
NSICRc342SR	259 bc	34895 ab	139 a	85.64 ab	25.4 a	0.54 a

In a column, means with the same letter are not significantly different at 5% by HSD.

Table 41. Grain yield and spikelet number panicle $^{-1}$, PhilRice-CES, 2014 WS.

Nirogen	Grain yield	Spikelet number panicle $^{-1}$
LCC-RT	7.26 a	125.30 b
LCC-FTAR	6.75 b	133.87 a
Fixed N rate (150 kg N ha^{-1})	6.69 b	112.30 c

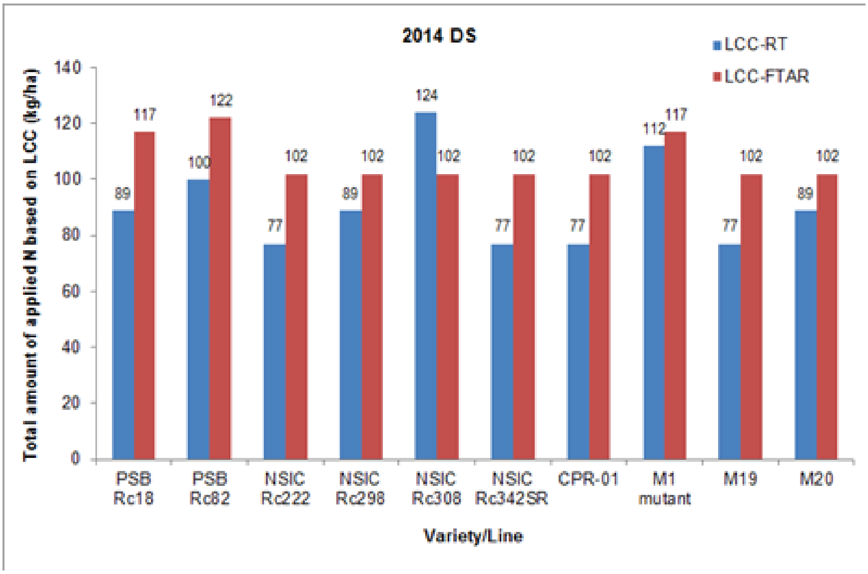

Figure 25. Total amount of applied N fertilizer based on LCC-real time (LCC-RT) and LCC-fixed time adjustable rate (LCC-FTAR), PhilRice-CES, 2014 DS.

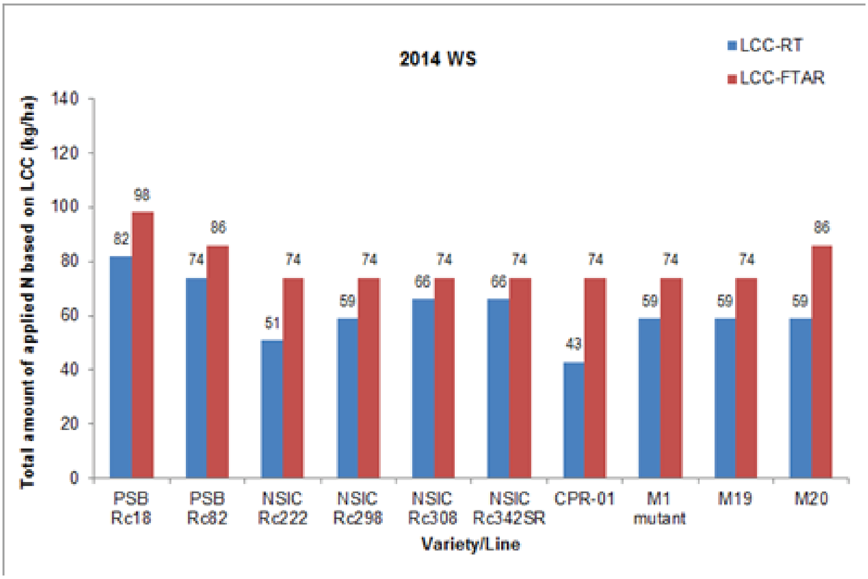

Figure 26. Total amount of applied N fertilizer based on LCC-real time (LCC-RT) and LCC-fixed time adjustable rate (LCC-FTAR), PhilRice-CES, 2014 WS.

Optimizing crop establishment and water management technologies for organic rice production systems of PhilRice Negros

BTSalazar

In 2011, PhilRice Negros was designated as the institute's organic rice center. Since then, the station's research activities were refocused on explaining the science behind organic farming, as well as on the improvement of practices. In 2012, average yield of organic rice in the station is 2.3t/ha, 1 ton lower compared with conventional rice. Increasing the yield will increase the production, and the income of the station since organic rice are commercially sold at Php60/kl. One way to increase the production is to optimize the practices under organic rice seed production system.

The study aims to optimize crop management technologies, specifically seedling age and water management, for organic rice seed production system of PhilRice Negros. A 3x2x3 factorial experiment was laid out in split-split plot design, with fertilizer management (conventional, organic, zero) as the main plot, water regime as the sub-plot (controlled irrigation and flooded), and seedling age (10, 15, 20) as the sub-sub-plot.

Highlights:

- Initial result of the study shows that there is no signicant interaction between fertilizer treatments, water management and seedling age (Table 42 and 43). However, the different fertilizer treatments caused significant differences in plant height, tiller number, productive tillers, spikelet fertility, harvest index and yield (Table 42and43). Initial result showed that plants in conventional fertilizer plots are generally taller, produced more tillers, and recorded the highest yield. Surprisingly, plants fertilized with organic fertilizers recorded the most number of filled grains, 3% and 6% higher than zero and conventional plots, respectively. Also, seedling age caused notable differences in plant height, productive tillers, spikelet fertility, and harvest index (Table 42and43). Though younger seedlings produced more productive tillers, its spikelet fertility is 3% lower than older seedlings resulting in poorer yield. Water management treatments were not properly imposed during wet season due to frequent rainfall. Still waiting laboratory results of plant tissue and soil samples for nutrient use efficiencies. Dry season set-up of the study started ealy January 2015.

Table 42. Summary of ANOVA for height and tiller number, WS 2014.

Treatment	Height (cm)			Tiller Number		
	Days after transplanting			Days after transplanting		
	30	60	120	30	60	120
Fertilizer (F)	**	**	**	**	**	**
Water (W)	ns	ns	ns	ns	ns	ns
Seedling Age (SA)	*	*	ns	ns	ns	ns
FxW	ns	ns	ns	ns	ns	ns
FxSA		ns	ns	ns	ns	ns
WxSA	ns	ns	ns	ns	ns	ns
FxWxSA	ns	ns	ns	ns	ns	*
c.v. (%)	5.42	6.33	3.38	19.49	23.12	13.9

ns-not significant; *significant at 5% level; **significant at 1%.

Table 43. Summary of ANOVA for yield and yield components, WS 2014.

Treatment	Productive Tillers	Unproductive Tillers	Spikelet Fertility (%)	Harvest Index	Yield (t)
Fertilizer (F)	**	ns	*	**	**
Water (W)	ns	ns	ns	ns	ns
Seedling Age (SA)	*	*	**	**	ns
FxW	ns	ns	ns	ns	ns
FxSA	ns	ns	ns	ns	ns
WxSA	ns	*	ns	ns	ns
FxWxSA	ns	ns	ns	ns	ns
c.v. (%)	14.99	36.42	7.88	7.05	10.52

ns-not significant; *significant at 5% level; **significant at 1%.

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

List of Tables

	Page
Table 1. Mean grain yields of the rice varieties tested at different nitrogen rates for the three studies.	3
Table 2. Mean agronomic efficiency of the applied nitrogen as affected by the different rice varieties and methods of N application from the three studies.	3
Table 3. Correlation coefficients (r) among grain yield, total N fertilizer applied, agronomic nitrogen use efficiency (AEN) and grain quality characteristics across rice varieties of the 2013 dry season grain yield.	4
Table 4. Grain yields (average of 3 rice varieties) in the dry (DS) and wet (WS) seasons as affected by the fertilizer treatments.	6
Table 5. The components of yield (average of 3 varieties) as affected by the different fertilizer treatments.	7
Table 6. The indigenous nutrient supplies of the experimental site based on the minus-one and control treatments during the 2013 Dry Season cropping.	9
Table 7. Correlation coefficients (r) among grain yield, total N fertilizer applied, agronomic nitrogen use efficiency (AEN) and grain quality characteristics across rice varieties of the 2013 dry season grain yield.	16
Table 8. Nutrient content of different natural fermented solutions produced from locally-available farm resources.	18
Table 9. Initial soil and water physical and chemical properties for field study on rice, soil and irrigation water dynamics in a lowland rice ecosystem under organic production system.	19
Table 10. Average grain yield of PSB Rc82, NSIC Rc160, and Mestiso 20 under N-omission plot, LCC-based N application with complete fertilizer (CF) application (i.e., 14-14-14-12S), LCC-based N application without CF application, Growth stage-based N application, and Farmer's practice in 2014 dry and wet seasons.	23
Table 11. Initial genetic coefficients of PSB Rc82, NSIC Rc160 and Mestiso 20 generated using the Genetic Likelihood (GLUE) program in DSSAT model using data from Nueva Ecija in 2014 dry and wet seasons.	24

List of Tables

Page

Table 12. Grain yield of PSB Rc82 in zero fertilizer plot, nitrogen omission plot or indigenous soil N supply, PhilRice general recommended rate, the four NDTs (i.e., Nutrient Manager or NM, PalayCheck-LCC, Soil Test Kit or STK and Minus-One Element Technique or MOET) and the Farmer's Fertilizer Practice or FFP in 2014 cropping season. 26

Table 14. Some shoot growth and physiological parameters of the rice genotypes IR64 and DRS111 under N treatments and grown under continuously waterlogged (CWL) and draughted (DR) soil conditions. 35

Table 15. Root dry weight, number and length of nodal roots and linear frequency of lateral roots of the rice genotypes IR64 and DRS111 under N treatments and grown under continuously waterlogged (CWL) and droughted (DR) soil conditions. 35

Table 16. Shoot dry weight, transpiration and total root length of the different genotypes grown under transient waterlogged for 14 days followed by progressive drying maintained at 10% SMC at various N sources applied at 80 kg/ha before the onset of drought. 36

Table 17. Grain yield and total biomass of seven genotypes with different N fertilizer treatment grown under CWL and DR conditions in 2013DS. 37

Table 18. Plant dry weight and shoot dry weight of the different genotypes under the raised bed and normal treatment. 41

Table 19. Relationship of plant dry weight, spikelet fertility and root parameters above and below the gravel layer under raised bed. 41

Table 20. Correlation matrices of parameters measured in different genotypes grown under drought (DR) conditions without sand layer embedded at any soil depths (D0). 43

Table 21. Correlation matrices of parameters measured in different genotypes grown under drought (DR) conditions with sand layer embedded at 60cm below the soil surface (D60). 44

List of Tables

	Page
Table 22. Correlation matrices of parameters measured in different genotypes grown under drought (DR) conditions with sand layer embedded at 30cm below the soil surface (D30).	45
Table 23. Grain yields (t/ha) of the main and ratoon crops of transplanted rice (with 40kg seeds/ha) for 8 genotypes in 2014 dry season (DS).	49
Table 24. Grain yields (t/ha) of the main and ratoon crops of direct wet-seeded rice (with 40kg seeds/ha) for 8 genotypes in 2014 dry season (DS).	50
Table 25. Grain yields (t/ha) of the main and ratoon crops of transplanted rice (with 40kg seeds/ha) for 8 genotypes in 2014 wet season (WS).	51
Table 26. Grain yields (t/ha) of the main and ratoon crops of direct wet-seeded rice (with 40kg seeds/ha) for 8 genotypes in 2014 wet season (WS).	51
Table 27. Grain and straw yield and harvest index for the 3 retained SRI practices* (i.e., alternate wetting and drying, 1 seedling/hill and rotary weeding) vs. continuous flooding, 2 and 3 seedlings per hill and hand-weeding in 2014 cropping season for PSB Rc82.	56
Table 28. Grain and straw yield and harvest index for the 3 retained SRI practices* (i.e., alternate wetting and drying, 1 seedling/hill and rotary weeding) vs. continuous flooding, 2 & 3 seedlings per hill and hand-weeding in 2014 cropping season for NSIC Rc222.	57
Table 29. Water productivity (WP) at two water management methods, 2014 DS, PhilRice-CES.	59
Table 30. Water productivity (WP) of selected varieties with high yield potential, 2014 DS, Philrice-CES.	59
Table 31. Irrigation Input Energy (IIE) and Fuel Input Energy (FIE) of selected varieties with high yield potential, 2014 DS, PhilRice-CES.	59
Table 32. Selected sites for the monitoring of the extent of heavy and light metals accumulation.	65

List of Tables

Page

Table 33. Initial characterization of the different selected sites as per their land use or cropping sequences, and farm input levels. 66

Table 34. Concentrations of metals in sediment sample as compared to intervention values. 66

Table 35. Chemical properties of the soil where the set-up was conducted (2014 WS). 68

Table 36. Yield and yield components of M48 as affected by different nitrogen fertilizer level treatments irrigated lowland ecosystems (2014 WS). 69

Table 37. Yield and yield components of M48 as affected by different potassium fertilizer level treatments irrigated lowland ecosystems (2014 WS). 69

Table 38. Grain yield, spikelet number m2, spikelet number panicle^{-1} and filled spikelets, 1000-grain weight and harvest index of rice varieties/lines, PhilRice-CES, 2014 DS. 71

Table 39. 1000-grain weight and harvest index at different N management, PhilRice-CES 2014 DS. 72

Table 40. Panicle number m^{-2}, spikelet number m^{-2}, and spikelet number panicle^{-1}, PhilRice-CES, 2014 WS. 72

Table 41. Grain yield and spikelet number panicle^{-1}, PhilRice-CES, 2014 WS. 72

Table 42. Summary of ANOVA for height and tiller number, WS 2014. 75

Table 43. Summary of ANOVA for yield and yield components, WS 2014. 75

List of Figures

Page

Figure 1. Mean grain yield and AEN of the rice varieties tested as affected by the different fertilizer treatments in the long-term organic fertilizer study (ASD-002-002). 4

Figure 2. The agronomic nitrogen-use efficiency expressed in kg grain produced per kg N applied of the rice varieties tested (average of 3 varieties) in the treatments with N application during the 2014 dry and wet seasons cropping. 8

Figure 3. Agronomic efficiency of applied nitrogen (AEN) of PSB Rc82 applied with different types of organic and inorganic fertilizers in 2014 cropping season. 2014. 11

Figure 4. Agronomic nitrogen-use efficiency (kg grain kg-1 N applied) of PSB Rc82 applied with different types of organic and inorganic fertilizers in 2014 cropping season. 2014. 11

Figure 5. Yield of PSB Rc82 applied with different types of organic and inorganic fertilizers across seasons. Maligaya clay soil series. 12

Figure 6A and 6B. Grain yield (t/ha) of irrigated lowland rice varieties in response to fixed-time N fertilizer application (1A) and LCC-based N application. 15

Figure 7. Agronomic nitrogen use efficiency (AEN) (expressed in kg grain kg N-1 applied) of irrigated lowland rice varieties in response to the fixed-time and LCC-based N fertilizer applications. 16

Figure 8. Grain yield (kg/ha) of NSIC Rc284 applied in 2 water regimes and different nutrient treatments during WS 2014. 20

Figure 9. Comparison of morning and afternoon readings of SPAD 502+ and atLeaf+. 27

Figure 10. Inter-user comparison of SPAD 502+ and atLeaf+ measurements. 28

Figure 11. Comparison between atLeaf+ and SPAF 502+ readings during early panicle initiation (41 DAT) in DS 2014. 28

Figure 12. Variation of SPAD 502+ and atLeaf+ readings over time for PSBRc 82 during DS 2014. 29

List of Figures

Page

Figure 13. Grain yield data during the Dry and Wet Seasons 2014. 30

Figure 14. Shoot dry weight of the different genotypes under N treatments and grown under waterlogged (A) and draughted (B) soil condition. 35

Figure 15. Shoot dry weight of the different genotypes under N treatments and grown under waterlogged (A) and draughted (B) soil condition. TNRL was moderately correlated with shoot dry weight (0.55) with N application under DR condition (data not shown). 36

Figure 16. Total root length of seven genotypes with different N fertilizer treatments grown under CWL and DR conditions. 38

Figure 17. The well-watered bed and raised bed at 74 days after sowing. Images were taken during one of the drought periods in raisedbed. 40

Figure 18. Thermal image analysis of raisedbed and well-watered bed. 42

Figure 19. Soil moisture dynamics of layers above and below the gravel layer in raised bed. 42

Figure 20. Effect of gravel layer on soil moisture contents at different soil depths. D30-gravel layer imposed at depth 30cm, D60-gravel layer imposed at depth 60cm, D0-drought, WW-well-watered. Broken lines in the graph the location of gravel layer. 42

Figure 21. Grain yields of the test rice varieties as affected by the fertilizer treatments (FTR-N: fixed time and rate N application; FTAR-N: fixed time-adjustable rate LCC-based N application). 53

Figure 22. The partial factor productivity (PFP) from the applied N of the test rice varieties. 54

Figure 23. Agronomic nitrogen use efficiency (AEN) of varieties across N management in 2014 DS and WS, PhilRice-CES. 60

Figure 24. Total amount of applied N fertilizer based on Leaf Color Chart (LCC), 2014 DS and WS, PhilRice-CES. 60

List of Figures

Page

Figure 25. Total amount of applied N fertilizer based on LCC-real time (LCC-RT) and LCC-fixed time adjustable rate (LCC-FTAR), PhilRice-CES, 2014 DS. 73

Figure 26. Total amount of applied N fertilizer based on LCC-real time (LCC-RT) and LCC-fixed time adjustable rate (LCC-FTAR), PhilRice-CES, 2014 WS. 73

PhilRice Central Experiment Station, Maligaya, Science City of Muñoz, 3119 Nueva Ecija • Tel: (44) 456-0277 • Direct line/Telefax: (44) 456-0112

Email: prri.mail@philrice.gov.ph • PhilRice Text Center: 0920-911-1398 • Websites: www.philrice.gov.ph; www.pinoyrkb.com
PhilRice Agusan, Basilisa, RTRomualdez, 8611 Agusan del Norte • Tel: (85) 343-0778•Tel/Fax: 343-0768 • Email: agusan.station@philrice.gov.ph
PhilRice Batac, MMSU Campus, Batac City, 2906 Ilocos Norte • Tel/Fax: (77) 670-1887; 670-1867 • Email: batac.station@philrice.gov.ph
PhilRice Bicol, Batang, Ligao City, 4504 Albay • Cell:0905-7352078, 0918-9467493 • bicol.station@philrice.gov.ph
PhilRice Isabela, Malasin, San Mateo, 3318 Isabela • Tel: (78) 664-2954, 2280 • Tel/Fax: 664-2953 • Email: isabela.station@philrice.gov.ph
PhilRice Los Baños, UPLB Campus, Los Baños, 4030 Laguna • Tel: (49) 536-8620•501-1917 • Email: losbanos@philrice.gov.ph
PhilRice Midsayap, Bual Norte, Midsayap, 9410 North Cotabato • Tel: (64) 229-8178 • Tel/Fax: 229-7242 • Email: midsayap.station@philrice.gov.ph
PhilRice Negros, Cansilayan, Murcia, 6129 Negros Occidental • Cell:0928-506-0515 • Email: negros.station@philrice.gov.ph
PhilRice Field Office, CMU Campus, Maramag,8714 Bukidnon • Tel/Fax: (88)222-5744
Liaison Office, 3rd Floor, ATI Bldg, Elliptical Road, Diliman, Quezon City • Tel/Fax:(02)920-5129, Cell:0920-9069052