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Effect of water management schemes on the growth and yield performance of green super rice genotypes

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Abstract

Water is the single most important component for sustainable rice production, especially in the traditional rice growing areas in the Philippines. Producing more rice with less water is therefore a formidable challenge to feed its growing population. The following treatment combinations were used: Factor A – Water Management Schemes (mainplots) which include the following: a_1 - Alternate Wetting and Drying, a_2 - Continuous Flooding, and a_3 – Field Capacity. Factor B –Rice Genotypes assigned as subplots to include: b_1 - GSR 1, b_2 - GSR 5, b_3 - GSR 8, b_4 - GSR 12A and b_5 - NSIC 222. The experiment was laid out using Split-plot Design with three replications from January to May 2016.Water management schemes as a single factor did not show significant effect in almost all the parameters measured, neither was there significant interaction between the two factors tested in the experiment on all the data observed except for the root length which shows significant result. The yield of different rice genotypes as affected by different water management schemes showed significant result ($P>0.01$), where GSR 5 out yielded all the other genotypes tested with a ranged yield of 5.93 – 6.92 tons/ha. The green super rice genotypes like GSR 5, GSR 8 and GSR 12 are recommended since they do not differ significantly from NSIC 222 (check variety) in terms of yield.

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Introduction

Rice, botanically known as *Oryza sativa* Linn*,* a member of Poaceae is one of the two important cereal crops in the Philippines and has a variety of uses. It is one of the most important staple foods for more than half of the world's population (IRRI, 2006). In the past years, plant breeders around the world already initiated the production of climate-resilient rice varieties suitable for countries at risk to climate change. Varieties produced must have resistance to insect pest, efficient nitrogen and phosphorous use, drought resistant and high yielding with superior grain quality.

Green super rice (GSR) is a term coined to describe the characteristics of the variety made through tedious cross-breeding of hundreds of varieties and lines of rice. "Green" does not only signify its color but because it is environmentally friendly as it will grow as much or more grain with fewer inputs. Parental lines used to have been screened through molecular marker-based genetic analyses by which specific locus for specific characteristics were determined. "Super", on the other hand, means the rice is designed to better resist droughts, floods, salty water, insects and diseases. The green super rice was introduced in Africa and Asia to address the rice demand of the growing population of the continent as well as to increase productivity of the farmers. Meanwhile, researchers continue stacking more traits into new varieties to help farmers produce more with less, resources/impacts in order to feed a growing world. Generally, the Philippines is vulnerable to La Niňa or El Niňo phenomenon wherein extreme weather conditions are experienced in the whole country. This phenomenon greatly affect agriculture production specifically rice industry in the country.

Water is one of the limiting factors in rice production. With the onset of climate change and due to the effect of dry spell (El Niňo), rice production in the country has declined. Thus, supply of rice to meet the needs of the increasing population is a problem. Despite efforts of research institutions to address the problem of producing drought tolerant rice varieties, seemingly the scarce supply of rice still beset the countryside. The increasing world's water scarcity problems is brought about by the increasing demands of fresh water for urban and industrial uses, and agricultural production, more particularly irrigated lowland rice production.

The above situation threatens not only the capacity of the agricultural sector to produce the food demands of the escalating human population, but also the sustainability of the irrigated rice production system.

According to Bouman and Tuong (2001) rice production is facing increasing competition with rapid urban and industrial development in terms of freshwater resource. The need for "more rice with less water" is crucial for food security, and irrigation plays a greater role in meeting future food needs than it has in the past (Tuong *et al*., 2004).

The research endeavor will therefore provide indispensable valuable benchmark information to farmers. It is necessary therefore, to evaluate GSR breeding lines and select the best line under different water management schemes for recommendation to farmers. Selections of these lines are based on their tolerance to water stress and climate change to cope up with the needs of the continuously growing population.

Generally, the study aimed to evaluate the growth and yield performance of the different green super rice genotypes under different water management schemes. Specifically, it aimed to: (1) determine the effect of different water management schemes on the growth and yield of the different green super rice genotypes; (2) evaluate the yield and yield components of the different green super rice genotypes under different water management schemes; (3) determine the interaction effect of different green super rice genotypes and water management schemes; and (4) conduct a return of investment analysis on the production of the different green super rice genotypes under different water management schemes.

Materials and methods

Experimental Site, Layout and Design

The study was conducted at the experimental area of Cagayan State University – Piat Campus which is located 17°48' 4.1" North, 121°30'31.3" East. An area of 17 meters × 11 meters was prepared by alternate plowings and harrowing at seven days interval. This was done to allow the weeds to decay. The experiment plots were laid out using the Split-Plot Design with 3 blocks and each block was further subdivided into 15 plots with a dimension of 3m × 3m and the distance between blocks was 2m as alleyways to test the following treatments:

FACTOR A - Main Plot (Water Management)

A_1 – Alternate Wetting and Drying

A_2 – Continuous Flooding

A_3 – Field Capacity

FACTOR B Sub-plot (Rice Genotypes)

B_1 – GSR 1

B_2 - GSR 5

B_3 – GSR 8

B_4 – GSR 12A

B_5 – NSIC 222 (check)

Water Management Schemes

A_1 – Alternate Wetting and Drying:A field water tube "Pani Pipe" was installed using 30-cm long plastic pipe, and with a diameter of 15 cm so that the water level was easily visible, and it is easy to remove the soil inside. The tube was perforated with many holes on all sides, so that water can flow readily in and out of the tube. The perforated tube was buried into the soil until 15 cm protrudes above the soil surface. The tube was placed in every treatment in a readily accessible part of the field close to a bund, so it is easy to monitor the ponded water depth. When the water level has dropped to about 15 cm below the surface of the soil, irrigation was applied to re-flood the field to a depth of about 5 cm (Fig. 1).

*A_2 - Continuous Flooding: T*he depth of water was maintained following the International Rice Research Institute (IRRI) technology viz. 2 cm depth after transplanting up to tillering stage; 5 cm depth during booting stage and 3 cm depth during milking stage to maturity.

*A_3 – Field Capacity: I*rrigation was done after 50% of the field capacity was depleted. Gravimetric method was used to monitor the field capacity.

Statistical Tool

The data were analyzed using STAR, version 2.0.1 2014. Biometrics and Breeding Informatics, PBGB Division, International Rice Research Institute, Los Baños, Laguna following procedures for analysis of variance (ANOVA) for two factorial experiment in a Split-Plot Design to test the significant differences among treatments. The Least Significance Difference (LSD) test was also used to analyze mean comparisons.

Results and discussion

Number of days to 50% flowering

Table 1 shows that plants produced flowers almost at the same time regardless of the water management schemes with means ranging from 76 – 78 days after sowing (DAS) with no significant differences noted.

Results revealed in Table 2 that GSR 1 (b_1) was the earliest to flower with a mean of 71 days followed by GSR 8 (b_3), GSR 12A (b_4), NSIC 222 (b_5) and GSR 5 (b_2) with a corresponding means of 74, 78, 80, and 82 days respectively. Analysis of variance reveals highly significant difference among the genotypes tested. This finding is attributed to the differences in the genetic composition of the rice genotypes, thus, early maturing lines produced flower earlier compared to the other lines with late maturity. This was supported by the study of Rangel *et al.*, (1991) reported 76.00 days to 229.00 days of 50% flowering in rice. However, no interaction exists between the green super rice genotypes and water management schemes (Table 3).

Number of Days to Maturity

As reflected in Table 1, shows the same trend of response with that number of days to flowering. The maturity duration by the different rice genotypes ranged from 107-109 days regardless of the water management applied.

Table 1. Summary of statistical analysis of different water management schemes on rice production under Cagayan State University – Piat Campus Condition.

Treatments (Water)	Days to 50% flowering	Days to maturity	Height at maturity (cm)	Number of tillers	Root length (cm)	Panicle length (cm)	Yield (tons/ha)
A_1 - AWD	76.93	107.53	99.23	12	32.74	25.29	6.52
A_2 - CF	77.73	108.93	102.73	14	30.13	25.73	6.76
A_3 - FC	77.00	108.06	98.56	12	31.00	25.59	6.37
Result:	ns	ns	ns	ns	*	ns	ns
CV (%)	1.98	2.47	11.49	2.54	10.11	5.0	2.2

*not significant - ns significant at 1%

**highly significant at 5%

In terms of the different green super rice genotypes, Table 2 presents that GSR 1 (b_1) was the earliest to mature with an average of 102 days after sowing (DAS), followed by GSR 8 (b_3), GSR 12A (b_4), NSIC 222 (b_5) and GSR 5 (b_2) with a corresponding maturity days of 105, 106, 112 and 115 respectively. Statistical analysis indicates highly significantly difference among the different green super rice genotypes tested. On comparison among treatment means did not register significant difference between b_1, $b_3$and b_4 but significant different exist when these genotypes compared to b_5 and b_2. The ranking followed the number of days to flower as this is the function factor to maturity, i.e. the earliest rice genotypes was also the earliest to mature. Rice crop regardless of varieties have the same reproductive duration which is 30 days and 35 days from panicle initiation to maturity during dry and wet season planting respectively. The maturity duration of the different GSR ranges from 107-109 days regardless of the water management.

Table 2. Summary of statistical analysis on the performance of green super rice under water management schemes.

Treatments (Rice Genotypes)	Days to 50% flowering	Days to maturity	Height at maturity (cm)	Number of tillers	Root length (cm)	Panicle length (cm)	Yield (tons/ha)
B_1 – GSR 1	71.44	102	107.15	11	33.07	26.85	5.93
B_2 – GSR 5	82.11	115	101.82	14	29.97	26.11	6.92
B_3 – GSR 8	74.44	105	96.57	12	30.79	24.64	6.80
B_4 – GSR 12	77.89	106	98.07	12	31.81	24.56	6.53
B_5 – NSIC 222	80.22	112	97.28	13	30.81	25.51	6.58
Result:	**	**	**	**	**	**	**
CV (%)	4.72	5.33	2.47	4.69	12.80	2.14	2.9

*not significant - ns significant at 1%

**highly significant at 5%

No significant interaction was noted on the two factors involved. This implies that the different rice genotypes had the same responses in terms of the number of days to maturity even exposed to different water management schemes (Table 3).

Height at Maturity (cm)

Results revealed that despite numerical variations, analysis of variance did not show significant difference in terms of height of the rice plants tested which ranged from 98.56 cm to 102.73 cm (Table 1).

In Table 2 shows the tallest plants was obtained from GSR 1 (b_1) with a mean of 107.15 cm, followed by GSR 5 (b_2), GSR 12A (b_4) and NSIC 222 (b_5) with a corresponding mean of 101.82cm, 98.03cm, and 97.28cm respectively, while the shortest was recorded in GSR 8 (b_3) with a mean of 96.57cm. Analysis of variance reveals highly significant difference among genotypes tested. However, comparison among means did not show significant difference between b_3, b_4 and b_5, but significant difference exist when these genotypes compared with b_1 and b_2.This means that different lines had different characteristics in term of this parameter. The result of the study conforms to the statement of Mohammad *et al.*, (2002) reported significant variation among the studied cultivars for the trait plant height. In addition, Rajesh *et al.*, (2010) reported a range of 78.80 cm to 217.80 cm and Chakraborty and Chakraborty, (2010) reported a range of 100 cm to 175 cm plant height for rice.

Nevertheless, no significant interaction was noted on the two factors tested on the height at maturity (Table 3).

Table 3. Summary on the interaction effect of water management schemes and green super rice genotypes.

A (Water) x B (Rice Genotypes) Interaction	Days to 50% flowering	Days to maturity	Height at maturity (cm)	Number of tillers	Root length (cm)	Panicle length (cm)	Yield (tons/ha)
T_1	71	101	109.02	11	37.17	26.46	5.88
T_2	82	113	102.37	14	30.23	25.25	6.85
T_3	74	106	95.25	12	31.98	24.87	6.93
T_4	77	106	94.57	11	33.6	24.62	6.38
T_5	80	111	94.93	13	30.73	25.23	6.58
T_6	72	103	109.72	13	30.10	27.08	6.61
T_7	83	116	101.18	15	29.52	26.67	7.11
T_8	75	105	98.63	14	29.83	24.45	7.08
T_9	78	106	104.28	12	30.67	24.63	6.36
T_{10}	81	115	99.83	14	30.55	25.80	6.64
T_{11}	72	102	102.72	10	31.93	27.00	5.31
T_{12}	81	116	101.92	13	30.17	26.40	6.8
T_{13}	74	105	95.83	11	30.56	24.62	6.38
T_{14}	78	106	95.23	13	31.17	24.43	6.84
T_{15}	80	111	97.08	12	31.15	25.5	6.52
Result:	Ns	ns	Ns	ns	*	ns	ns

*not significant - ns significant at 1%

**highly significant at 5%

Number of Productive Tillers/hill

Table 1 it can be observed that despite the numerical disparities, the production of productive tillers did not vary significantly regardless of the water management schemes.

As shown in Table 2, which indicates that GSR 5 (b_2) had the most number of productive tillers with a mean of 14. This was followed by NSIC 222 (b_5), GSR 8 (b_3), GSR 12A (b_4) and GSR 1 (b_1) with a mean of 13, 12, 12, and 11, respectively. Analysis of variance reveals that a highly significant difference exists among rice genotypes tested. Comparison among means show no significant difference between b_1, b_3 and b_4 but significant differences is observed when they are compared with b_2 and b_5. This was supported by the study of Rajesh *et al.*, (2010) reported a range of 7 to 25 tillers per plant and Adeyemi *et al.*, (2011) reported a range of 3 to 23 tillers per plant in rice. Similarly, according to Allah *et al.*, (2010), a highly tillered plants tends to have a short root system and hence a negative relationship with drought resistance. Low tillering capacity appears to be one desirable characteristic when rice plant has to depend on soil moisture retained in the deep soil layers during drought stress.No significant interaction effect was noted between the two factors tested relative to the production of tillers. This implies that the different rice genotypes manifested the similar trend of response on the different water management (Table 3).

Root Length (cm)

Results revealed that despite numerical variations, green super rice genotypes vary significantly with each other which ranged from 31 – 33.74 cm (Table 1).

Table 2 reveals the longest roots was produced by GSR 1(b_1) with a mean of 33.07 cm, followed by GSR 12A (b_4), NSIC 222 (b_5), GSR 8 (b_3) and GSR 5 (b_2) with a mean of 31.81, 30.81, 30.79 and 29.97 cm in the same order. Analysis of variance reveals highly significant difference among the different green super rice genotypes tested. However, comparison among means did not show significant difference between b_4, b_5, and b_3, but these genotypes are statistically different with b_1 and b_2.

Table 4. Summary of the cost and return analysis of GSR genotypes under different water management schemes.

Description	Treatment		
	I	II	III
Total Cost of Production (Php)	35,613.00	38,280.00	36,469.00
Gross Sales (Php)	104,320.00	108,160.00	101,920.00
Net Income (Php)	68,707.00	69,880.00	65,451.00
Return on Investment (Php)	192.93	182.55	179.47
Net Return per Peso Invested	1.92	1.83	1.79

It was observed however that rice plants exposed to lesser water supply produced longer roots. This implies that roots, being an integral part of the rice plant, have various adaptive mechanisms in response to soil water stress conditions in the acquisition of nutrients and water (Yamauchi *et al.*, 1996). Plants tend to produce deep and extensive root system in response to water stress and support extraction of water from deep soils (Fukai and Cooper, 1995; Kamoshita *et al.*, 2004; Kato *et al.*, 2007).

Therefore, deeper root growth is a sign of moisture shortage experienced by rice plants (Fageria *et al.*, 2005). According to Russell, (1959), root development of a plant has long been recognized as an important factor in determining its adaptability to water stress conditions.

When water deficit occurs, the most effective resistance mechanism available to the rice plant is a deep root system consisting of mostly thick roots that enables the plant to avoid the adverse effects of internal water deficit (Chang *et al.*, 1972). Moreover, there is an interaction between the water management and different rice genotypes in term of this parameter. This means that different green super rice genotypes responded differently when exposed to water management regimes (Table 3).

Length of Panicles (cm)

Data revealed that the three water management schemes did not give any effect on the length of panicles of the different green super rice genotypes which recorded a length ranges from 25.29 – 25.73 cm (Table 1).

The graphical data on the length of panicle was presented in Table 2, of different green super rice genotypes. Data shows that GSR 1 (b_1) obtained the longest panicle length of 26.85 cm, followed by GSR 5 (b_2), NSIC 222 (b_5) and GSR 8(b_3) with a mean of 26.11 cm, 25.51 cm, and 24.64 cm respectively. The shortest panicle was observed in GSR 12A (b_4) with a mean of 24.56 cm. Analysis of variance revealed that there is a highly significant difference among the rice genotypes tested. Comparison among means further indicated that b_1 differ significantly with b_3 and b_4 but not with b_2 and b_5. It was observed among the lines tested that, panicle with slender grains and the distance between grains is farther compared to the test lines which had smaller grains closely distanced from each other. Sharma (2002) worked with fine grain rice and reported that there had been significant variation in panicle length. However, Shrirame and Muley (2003) observed that panicle length had no significant difference among the genotypes studied. Singh *et al.*, (2010) and Rajesh *et al.*, (2010) also observed significant differences for this trait. Chakraborty and Chakraborty, (2010) observed a range of 18 cm to 30 cm and Rajesh *et al.*, (2010) observed a range of 24.66 cm to 37.00 cm for this trait.

No significant interaction was noted among all plants exposed to the two factors involved in the experiment (Table 3).

Computed yield (tons/ha)

Data shows that irrespective of the water management schemes, the test plants obtained comparable yields which ranged from 6.37-6.92 tons/ha (Table 1).

Among the different genotypes, GSR 5 (b_2) outyielded the rest of the genotypes with a mean of 6.92 tons per hectare. This was followed by GSR 8 (b_3), NSIC 222 (b_5), GSR 12A (b_4) and GSR 1(b_1) with a yield of 6.8, 6.58, 6.53 and 5.93 tons/ha in the same order.

Statistical analysis indicates that b_2, b_3, b_5, and b_4 did not differ significantly with each other but remarkable difference is observed when these four genotypes was compared to b_1.

The disparities in yield are based from the different yield component parameters e.g. panicle length, number of spiklets per panicle and tiller count (Table 2).Tillering in rice is one of the most important agronomic characters for grain production (Smith and Dilday, 2003), because the tiller number per plant determines the panicle number, a key component of grain yield (Yan *et al.*, 1998). Miller *et al.*, (1991) reported that tillering is a major determinant for production in rice. According to Gallagher and Biscoe (1978), tillering ability affects total yield in rice. Kusutani *et al.*, (2000) and Dutta *et al.*, (2002) suggested that, genotypes producing higher number of effective tillers per hill showed higher grain yield in rice. The alternate irrigation and its suspension ensured deeper growth of the root system and access to water and nutrients uptake which ensuring optimum growth and high grain yield (Zhi, Undated). No significant interaction was noted among all plants exposed to the two factors involved in the experiment Table 3.

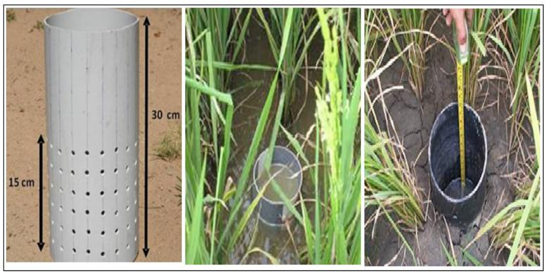

Fig. 1. Installed Pani pipe tube in the Experimental Are.

Cost and Return Analysis

As reflected in Table 4, the highest inputs is a_2 (Continuous Flooding) with ₱38, 280, closely followed by a_3 (Field Capacity) and a_1 (Alternate Wetting and Drying) with ₱36, 469 and ₱35, 613.

The value of yield is ₱108, 160 was obtained in a_2 (Continuous Flooding), ₱104, 320 in a_1 (Alternate Wetting and Drying) and ₱101, 920 in a_3 (Field Capacity). This means that the higher the filed activity (irrigation) the higher is the cost of inputs. Computing the net income, a_2 has ₱69, 880, a_1 has ₱68, 707 and a_3 has ₱65, 451.

On the relative value, the net income per peso invested (NRPI) was 1.93/peso for a_1 followed by a_2 with 1.83/peso and a_3 with 1.79/peso invested. The low net return per peso invested in a_3 is due to high cost of production particularly on labor.

Conclusion and recommendation

It is concluded that water management schemes as a single factor did not show significant effect almost all the parameters, neither was there significant interaction between the two factors tested in the experiment on all the data observed except for the root length which shows significant result.This indicates that the use of the alternate wetting and drying gave slightly higher economic advantage.

The reduction in the frequency of water application in AWD scheme resulted to a corresponding decrease in the cost of irrigation. The application of alternate wetting and drying as a water management scheme is recommended to reduce water input by as much as 15-30% without yield loss.

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