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Yield and physicochemical properties of lowland rice (*Oryza sativa* L. var. NSIC Rc218) as influenced by water and fertilizer applications

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Abstract

Yield and physicochemical properties of lowland rice are affected by several growth factors. This study was conducted to evaluate the yield performance and physicochemical properties of lowland rice NSIC Rc218 variety as influenced by water and fertilizer applications. The experiment was laid out in Split Plot arranged in Randomized Complete Block Design (RCBD) with three replications. Water application (WM_1- Flooded and WM_2- AWD) was designated as the main plot, and fertilizer application (T_1- No fertilizer as control, T_2 - recommended rate of inorganic fertilizer (RRIF) at 100-60-60 kg ha-^{1} N, P_20_5 and K_20, T_3-reccommended rate of vermicast at 10 t ha^{-1} (RRVC), T_4- 75% RRIF + 25% RRVC, T_5 – 50% RRIF + 50% RRVC and T_6 – 25% RRIF + 75% RRVC) was designated as the subplot. Results showed that grain yield of NSIC Rc218 variety was significantly higher by 28% in treatments applied with 100% RRIF (T_1), 75% RRIF + 25% RRVC (T_4), and 50% RRIF + 50% RRVC (T_5), compared to unfertilized plants (T_1), and those applied with RRVC (T_3) and 25% RRIF + 75% RRVC (T_6) regardless of water application. On the other hand, physicochemical properties of NSIC Rc218, particularly grain length (cm) and % Protein Content (P) were markedly enhanced under AWD conditions. ,Percent total milled rice and Protein contents were significantly higher in treatments applied with RRIF at a rate of 100-60-60 kg ha-^{1} N, P_20_5, K_20. Likewise, , volume expansion ratio (VER) and water uptake (WU) of cooked rice were significantly enhanced with the application of pure vermicast at 10 t ha^{-1} or in combination with 50 to 75% inorganic fertilizer.

Key words: *AWD, flooded condition, growth factors, grain yield, physicochemical properties*

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Introduction

Water and fertilizer management are among the important cultural management practices to be considered in the production of any rice variety both in the irrigated lowlands and rainfed uplands and lowlands (Tuong and Bouman, 2002; Cagasan and Tamayo, 2016). According to literature, drought and decreasing water availability for agriculture threaten the productivity of rice both in the irrigated and rainfed ecosystems (Bouman and Toung, 2001; Maclean et al., 2002; Ashsouri, 2014). Tuong and Bouman (2002) reported that by 2025 in Asia, more than two million hectares of irrigated areas during dry season and 13 million hectares of irrigated areas during wet season may experience “physical scarcity” of water. They added that 22 million hectares of irrigated areas during dry season will be hampered by “economic scarcity” of water. To address this problem, new methods of irrigation are urgently needed to save water and sustain good yield of rice (Tuong and Bouman, 2002). A number of research studies have shown that intermittent flooding to keep the soil saturated provides better water-use efficiency (Bouman, 2001; Bouman and Tuong, 2001; Ratilla and Cagasan, 2011; Cagasan and Tamayo, 2016). Alternate wetting and drying (AWD) have been reported to maintain or even increase rice yield. However, there are still few studies that determine the effect of AWD on the physicochemical properties of rice (Belder et al., 2004; Belder, 2005).

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In reality, there are still lots of important concerns in using either organic or inorganic fertilizers in crop production. Some scientists stressed that use of organic fertilizer alone in crop production particularly in cereals will not give good harvest because cereal crops need high amount of nutrients. Thus, farmers are not convinced to use this kind of fertilizer. On the other hand, inorganic fertilizer can give immediate effects in terms of increasing yield, but it has been noted to have negative effects not only to the environment but also to human beings. Despite of these negative effects, farmers continue to use this kind of fertilizer to satisfy the nutrient requirements of rice and to get good yield (Escasinas and Zamora, 2009).

The use of inorganic fertilizers may be reduced if farmers could be convinced to use at least a combination of organic and inorganic fertilizers. But in the case of aromatic rice varieties, there is still lack of information about the effects of fertilizers on the yield as well as on the physicochemical properties (Faylon and Cardona, 2007).

This study y aimed to evaluate the growth and yield performance, as well as the physicochemical properties of lowland rice NSIC Rc218 variety as influenced by water and fertilizer applications.

Methodology

The study on fertilizer and water applications was conducted at the farmer`s area in Barangay Pangasugan, Baybay City, Leyte, Philippines. On the other hand, the study on physicochemical properties determination was done at the Philippine Rootcrops Research and Training Center (PhilRootcrops) and Department of Food Science and Technology, both at the Visayas State University (VSU), Baybay City, Leyte. Milling potentials and some physicochemical attributes were analysed at the Rice Chemistry and Food Science Division of the Philippine Rice Institute (PhilRice) in Maligaya, Munoz, Nueva Ecija.

The experiment was laid out in split-plot Randomized Complete Block Design (RCBD) with three replications. Different water applications (WM_1- Flooded and WM_2- AWD) were designated as the main plot. Fertilizer applications, on the other hand, were designated as the subplot. These fertilizer treatments include: T_1- No fertilizer (control), T_2 –recommended rate of inorganic fertilizer (RRIF) at 100-60-60 kg ha^{-1} N, P_20_5 and K_20, T_3 – recommended rate of Vermicast (RRVC) at 10 t ha^{-1}, T_4- 75% RRIF + 25% RRVC, T_5 – 50% RRIF + 50% RRVC, and T_6 – 25% RRIF + 75% RRVC. Size of each treatment plot was 5m x 4m. Replications and treatment plots were separated by 1.0 m alleyways. Data on the total amount of water received by the rice plant (m^3ha-^{1}), growth and yield of the rice plants, and physicochemical properties of NSIC Rc218 were gathered. Each parameter was analysed using SAS 6.2 split plot design, while mean comparison was done using Honestly Significant Difference (HSD).

Results and Discussion

Amount of water received by the rice plants

The total amounts of water received by the rice plants throughout the growing period were 15,349 m3 ha^{-1} under flooded condition, and 12, 431 m^3 ha^{-1} under AWD conditions (Table 1). These amounts of water came from the rain (9,020 m3) and from the irrigation water added to the field (6,329m^3 in flooded plots and 3,411m^3 in the AWD plots). Under AWD application, the amount of irrigation water added to the field was only 53% of the irrigation water added to the flooded plots. This means that AWD water application was able to save 47% of irrigation water.

Table 1. Total amount of water (m3 ha-1) received by the rice plants in the field from land preparation up to the s second week before harvesting of rice NSIC Rc218 variety

Treatments	Amount of water from the rain (m^3ha^{-1})	Amount of water from irrigation (m^3ha^{-1})	Total water received by the rice plant (m^3ha^{-1})
$WM_{1=}$ Flooded	9,020	6,329	15,349
$WM_{2=}$ AWD	9,020	3,411	12,431
Difference of water applied from irrigation to the rice field		47.45%	
Amount of water saved			19.00%

Yield and yield components

The yield and yield components of rice, except harvest index, were significantly affected by the fertilizer treatments (Table 2). However, only panicle length and number of filled spikelet per panicle were significantly (p<0.05) affected by water applications. It was noted that rice plants under flooded conditions had longer panicle with more number of filled spikelets than plants subjected to AWD condition. These findings are similar with the research results reported by Maclean et al. (2002), which showed that rice plants exhibited significantly higher number of filled grains per panicle and lower percent spikelet sterility when enough water was made available especially during panicle initiation. This is also similar to the findings of Ratilla and Cagasan (2011) which showed that conventional irrigation (i.e., flooding of the paddies) produced longer panicles and more filled grains per panicle but did not cause significant (p<0.05) increase in yield of lowland rice. The other yield components of lowland rice NSIC Rc218 variety did not affect the productive tillers, percent filled spikelet, weight (g) of 1000 grains and total grain yield (tha^{-1}). These results confirmed the findings of Bouman et al. (2007) that rice production does not need excess water or total plant submergence throughout the growing period.

Table 2. Yield, yield components and harvest index of lowland rice NSIC Rc218 variety as influenced by water and fertilizer applications

Treatments	Productive tillers $hill^{-1}$	Panicle length (cm)	No. of filled spikelet $panicle^{-1}$	Percent filled spikelet $panicle^{-1}$	Weight of 1,000 grains (g)	Grain yield (tha^{-1})	Harvest Index (HI)
Water Application							
WM_1 = Flooded	10.19	25.03^a	96.72^a	76.66	27.52	4.15	0.37
WM_2 = AWD	9.73	23.46^b	76.77^b	74.55	27.50	4.33	0.38
CV (%)	10.68	4.51	3.72	2.75	2.95	16.13	20.43
Fertilizer Application							
T_1 = No fertilizer (Control)	7.91c	21.83^c	72.17^b	70.83^b	26.73^b	3.34^b	0.36
T_2= RRIF at 100-60-60 kg N, P_20_5, K_20 ha^{-1}	11.73a	26.71a	95.33^a	80.17^a	29.00^a	5.18^a	0.34
T_3= RRVC (Vermicast at 10 tha^{-1})	8.50^{bc}	24.25^b	85.66^b	73.50^{ab}	29.69^a	3.50^b	0.39
T_4= 75% RRIF + 25% RRVC	10.90^a	5.01^{ab}	89.50^{ab}	79.66^a	28.45^a	5.03^a	0.35
T_5= 50% RRIF + 50% RRVC	10.66^a	24.30^b	90.50^{ab}	73.00^{ab}	28.05^a	4.53^a	0.37
T_6= 25% RRIF + 75% RRVC	10.03^{ab}	3.38^{bc}	77.33^b	76.50^{ab}	28.16^a	3.74^b	0.41
CV (%)	11.36	4.98	12.03	5.73	2.41	8.92	14.62

Means with the same letter in a columns and rows are not significantly different at 5% level, HSD

Results of this study also showed that all yield components of NSIC Rc218 responded significantly (p<0.05) to fertilizer applications. . Treatment plants applied with RRIF at a rate of 100-60-60 kg ha^{-1} N, P_20_5 and K_20 (T_2), and those applied with 75% RRIF + 25% RRIF (T4) and 50% RRIF + 50% RRVC (T5) significantly produced more productive tillers per plant, longer panicle, higher number and percent of filled spikelets, heavier weight (g) of 1000 grains, and consequently total grain yield, compared to the other treatments. This results are similar to the findings of earlier studies (Ratilla and Cagasan, 2011; Cagasan and Tamayo, 2016) which showed that rice produces higher yield when applied with inorganic fertilizer, or a combination of organic and inorganic fertilizers.

The least yield and yield characters were noted in unfertilized plants and those applied with vermicast at 10 t ha^{-1}. This result is attributable to a lesser amount of nutrients available to the untreated plants and to plants applied with pure vermicast. This result also suggests that inorganic fertilizer contributes positively to increase in rice production. The inorganic fertilizer applied at a rate of 100-60-06 kg ha^{-1} N, P_2O_5 and K_2O and the combination of inorganic and organic fertilizers at 75% RRIF + 25% RRVC were able to provide sufficient amounts of nutrients needed by the rice plants during grain formation and filling. Stoop et al. (2002) reported that satisfying the nitrogen requirement for grain development is very critical because during the process of spikelet formation nitrogen deficiency can lead to spikelet degeneration, which eventually results to low number of filled grains per panicle.

Substantial differences were also observed on the interaction effect between water and fertilizer applications (Table 3). Plants applied with RRIF and RRVC significantly (p<0.05) obtained the heaviest weight of 1000 grains both in flooded and AWD conditions. Lightest 1000 grain weight was observed from the unfertilized plants both in the flooded and AWD conditions. This result is attributable to the greater amount of readily available and highly soluble nutrients from inorganic fertilizer which can be used immediately by the rice plants. On the other hand, although vermicast releases nutrients slowly, it's nutrient release is continuous throughout the whole duration of plant growth, thus nutrients are always available when needed by the plants. Soil available nitrogen increased with increasing levels of vermicast and highest nitrogen uptake was obtained resulting to increase in the number of filled spikelet and weight of 1000 grains. On the other hand, treatment with zero fertilizer application gave the lowest weight of 1000 grains regardless of water application. This result was attributed to the insufficient amount of nutrients particularly phosphorus in soil which is needed for grain formation that greatly affects the grain weight, (Haby, Baker, and Feagley, 2012).

Table 3. Weight of 1000 grains of NSIC Rc218 as influenced by the interaction between water and fertilizer applications

Fertilizer Application	Water Application		Mean
	Flooded	AWD	
T_1 = No fertilizer (Control)	26.30[c]	27.17[c]	26.73[b]
T_2= 100-60-60 kg N, P_2O_5, and K_2O ha^{-1} (RRIF)	29.06[a]	28.94[a]	29.00[a]
T_3= Vermicast 10 t ha^{-1} (RRVC)	29.74[a]	29.65[a]	29.69[a]
T_4= 75% RRIF + 25% RRVC	28.37[b]	28.53[b]	28.45[a]
T_5= 50% RRIF + 50% RRVC	28.13[b]	27.98[b]	28.05[a]
T_6= 25% RRIF + 75% RRVC	28.42[b]	28.91[b]	28.16[a]
Mean	27.52	27.50	

Means with the same letter in a column are not significantly different at 5% level, HSD

Physicochemical properties

The physicochemical properties of lowland rice NSIC Rc218 variety were influenced by water and fertilizer applications (Table 4). Grain length (cm), % protein contents and gelatinization temperature (GT) were significantly higher (p<0.05) in treatments subjected to AWD condition. On the other hand, rice plants applied with RRIF at 100-60-60 kg ha^{-1} N, P_2O_5, K_2O had a comparably higher percentage of milled rice recovery and percent protein content to plants applied with 75% RRIF + 25% RRVC. Likewise, , water uptake (WU) and volume expansion ratio (VER) were significantly higher in rice applied with vermicast at 10 t ha^{-1} or in combination with inorganic fertilizer (75% RRIF + 25% RRVC and 50% RRIF + 50% RRVC). This result can be attributed to the presence of high amount of nitrogen from 10 tha^{-1} vermicast and fertilizer combinations with 50 to 75% inorganic fertilizers.

Table 4. Physico-chemical properties of NSIC Rc218 variety as influenced by water and fertilizer applications

Treatments	Milled rice Recovery (%)	Grain length (cm)	Protein content (%)	Gelatinization Temperature (GT)	Water Uptake) WU	Volume Expansion Ratio (VER)
Water Applications						
WM_1 = Flooded	65.60	6.31b	7.19b	7.25b	3.85	3.90
WM_2 = AWD	65.78	6.83a	7.65a	7.81a	3.84	3.87
CV (%)	7.45	3.83	6.73	7.79	9.38	1.53
Fertilizer Applications						
T_1 = No fertilizer (Control)	62.20[c]	6.56	7.25[b]	7.50	3.70[b]	3.49[b]
T_2= 100-60-60 kg ha^{-1} N, P_2O_5, and K_2O (RRIF)	66.62[a]	6.72	7.71[a]	7.61	3.79[b]	3.64[b]
T_3= Vermicast 10 t ha^{-1} (RRVC)	65.88[b]	6.65	7.43[b]	7.58	4.05[a]	4.26[a]
T_4= 75% RRIF + 25% RRVC	66.00[a]	6.56	7.85[a]	7.56	3.83[ab]	3.91[ab]
T_5= 50% RRIF + 50% RRVC	65.20[b]	6.46	6.95[c]	7.49	3.83[ab]	3.98[ab]
T_6= 25% RRIF + 75% RRVC	65.25[b]	6.47	7.36[b]	7.43	3.71[b]	3.69[b]
CV (%)	2.30	11.11	3.42	4.80	3.41	9.23

Means with the same letter in a columns and rows are not significantly different at 5% level, HSD

Significant interaction effect of water and fertilizer applications was also noted on protein content (Table 5). Results indicated that protein content significantly increased (p<0.05) when the rice plants were grown under AWD condition and fertilized with RRIF at 100-60-60 kg N, P_2O_5 and K_2O ha^{-1} or with 75% RRIF + 25% RRVC. The least protein content value (6.69) was noted in rice plants fertilized with 50% RRIF + 50% RRVC and planted under flooded condition.

The higher protein contents of the rice grains under AWD conditions could due to the stress condition brought about by limited water supply on rice plants grown under AWD condition. Juliano (1985) reported that growing rice under stress condition (i.e., drought, high salinity, high or low temperature) increased its protein content. Likewise, rice plants subjected to AWD condition experienced water stress during its development, resulting to increased crude protein (CP) contents. The findings of this study are also similar to the study of Champagne et al. (2007) which showed that protein content was significantly higher ($P < 0.0007$) at higher fertilizer level.

Table 5. Interaction effect on crude protein (%) of NSIC Rc218 as influenced by the water and fertilizer applications

Fertilizer Application	Water Application		Mean
	Flooded	AWD	
T_1 = No fertilizer (Control)	7.18^{bc}	7.32^{bc}	7.25^{b}
T_2= 100-60-60 kg N, P_20_5, and K_20 ha^{-1} (RRIF)	7.23^{bc}	8.19^{a}	7.71^{a}
T_3= Vermicast 10 t ha^{-1} (RRVC)	7.43^{bc}	7.43^{bc}	7.43^{b}
T_4= 75% RRIF + 25% RRVC	7.48^{bc}	8.21^{a}	7.85^{a}
T_5= 50% RRIF + 50% RRVC	6.69^{cd}	7.20^{bc}	6.95^{c}
T_6= 25% RRIF + 75% RRVC	7.14^{bc}	7.57^{b}	7.36^{b}
Mean	7.19^{y}	7.65^{x}	

Means with the same letter in a column and rows are not significantly different at 5% level, HSD

This result indicates that high nitrogen content at the rate of 100-60-60 kg N, P_20_5 and K_20 ha^{-1} RRIF and 75% RRIF was the cause of the increased protein content. Plant converts nitrogen to amino acids as the building blocks of proteins. These amino acids are then used in forming protoplasm, which is used in cell division. These amino acids are also utilized in producing necessary enzymes and structural parts of the plant and can become part of stored proteins in the grain resulting to increase in CP values under this condition, (Juliano, 1985).According to Champagne et al. (2008), grains with high % CP content was observed to be less flavorful than grains with low protein content, as observed by the panelists during sensory evaluation in this study.

Conclusion

Based on the results of this study, the following conclusions can be drawn:

1. Subjecting rice plants to AWD and the application of a combination of inorganic and organic fertilizer did not cause significant reduction on the yield of rice. Panicle length and number of filled spikelet per panicle of NSIC Rc218variety were significantly lower when rice plants were grown under AWD conditions, but subjecting the AWD condition did not cause significant reduction on the total grain yield. Likewise, grain yield was significantly higher by 25% when plants were applied with inorganic fertilizer at rate of 100-60-60 kg ha^{-1} N, P_20_5 and K_20 and with a combination of inorganic fertilizer and vermicast (75% RRIF + 25% RRVC).

2. Growing rice variety NSIC Rc218 under AWD condition and the application of inorganic fertilizer or a combination of inorganic and organic fertilizers could enhance the physicochemical properties of rice. Grain length (cm) and percent protein content of lowland rice NSIC Rc218 variety were significantly enhanced when the crop was planted under AWD conditions. Likewise, percent total milled rice recovery and protein content significantly improved in plants applied with inorganic fertilizer at a rate of 100-60-60 kg N, P_20_5 and K_20 ha^{-1}, or in combination with little amount of organic fertilizer (75% RRIF + 25% RRVC). Also, volume expansion ration (VER) and water uptake (WU) were significantly higher when plants were applied with pure vermicast at 10 t ha^{-1} or with a combination of 50% to 75% inorganic fertilizer and 25% organic fertilizer.

3. Significant interaction effect of the treatments was only noted on protein contents. Protein contents were significantly (p<0.05) increased when rice plants were planted under AWD condition and fertilized with 100-60-60 kg ha^{-1} N, P_20_5 and K_20 RRIF and 75% RRIF + 25% RRVC.

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