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Performance of rice under different water regimes and plant nutrient sources

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ABSTRACT

Field experiment was carried out at the Soil and Irrigation Research Centre, University of Ghana, Kpong in 2015 and 2016 cropping seasons to evaluate the effect of different soil water condition and plant nutrient sources on the growth and yield of rice. The experiment was laid out in a split plot design with three replications. Water regime and nutrient source were the main and sub plot factors, respectively. Water regimes included; continuous flooding (CS), alternate wetting and drying (AWD) and moist soil condition between field capacity and permanent wilting point (MC) while the nutrient fertilizer treatments included no fertilizer (N0), 90 kg N/ha mainly from urea fertilizer (N1), 90 kg N/ha from 12.8 tons of compost (N2) and 45 kg N/ha from urea fertilizer + 45 kg N/ha from 6.4 tons of compost (N3). Results from the study revealed that, keeping the soil periodically in aerobic and anaerobic condition through AWD method of water management, recorded similar growth and grain yield of rice as with complete submergence of paddy field. Combination of inorganic fertilizer and compost for each to supply 45 kg N/ha under AWD produced the highest rice growth and grain yield. There was a positive and significant correlation between grain yield and growth parameters (plant height, chlorophyll content and above ground biomass accumulation).

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Introduction

Rice (*Oryza sativa* L.) is one of the important staple grain crops in the world including Africa. The crop contributes significantly in achieving food security and socio-economic development in Sub-Saharan Africa. It also reduces poverty by creating employment, income generation and improved nutrition. The consumption of rice in the region is estimated to increase from 19.8 to 34 million tons in 2010 and 2020, respectively (Africa Rice Centre, 2011). As a result, about 14 million tons of milled rice will be imported into the region in 2020 to meet the increasing rice demand.

Ghana is self-sufficient in all the major food crops with the exception of rice (MoFA, 2014). Rice production is low due to many factors including poor water and nitrogen management practices. Nitrogen is the most important and limiting nutrient in rice production (Haefele *et al.*, 2006). According to Cassman *et al.*, (1996), nitrogen is highly mobile in the soil and it is subjected to different types of losses. Moreover, the soils in the country are low in nitrogen as a result of their low organic matter content. Farmers burn crop residues after harvesting and threshing which results in nutrient mining as nutrient output exceeds nutrient input. Others also incorporate the fresh crop residues into the soil during land preparation which leads to severe nitrogen immobilization in the soil (Chandra, 2005) and methane (CH_4) emission which contributes to greenhouse gases (Dobermann & Fairhurst, 2002). However, these crop residues can be composted and incorporated into the soil to mitigate these constrains and help increase rice growth and yield. Compost is a rich source of plant nutrients, it improves organic matter status of the soil and decrease water pollution (Sarwar *et al*., 2007). Organic matter (OM) prevents soil degradation and improves the physical, chemical and biological properties of soils (Swift, 2001).

About 85 percent of the available water in the developing countries is used for irrigation purposes (Plusquellec *et al*., 1994). According to Shashidhar (2007), three thousand to five thousand litres of water is required to produce one kilogram of rice. Due to climate change and increasing human population, the amount of fresh water available for irrigation for sustainable rice production is decreasing (Molden, 2007; Zwart, 2013). This implies that, rice production will be adversely affected in the near future. Traditionally, rice is cultivated under flooded conditions which result in high amount of water loss through evaporation, seepage, percolation and transpiration. Numerous water-saving management methods for rice such as non-continuous soil saturation (Borrell *et al*., 1997), control of soil water potential (Yang *et al*., 2007), alternate wetting and drying (Bouman & Tuong, 2001), aerobic rice system (Bouman *et al*., 2005), have been suggested. Information on integrated water and nutrient management in Ghana is inadequate. This study was therefore conducted to assess the influence of integrated water and nutrient management on growth and yield of lowland rice.

Materials and methods

Description of the experimental site

The experiment was carried out at the Soil and Irrigation Research Centre, University of Ghana – Kpong in the Eastern Region of Ghana. The centre is located within the lower Volta basin of the Coastal Savannah agro-ecological zone at latitude 6° 09’ N, longitude 00° 04’ E, and an altitude of 22 m above mean sea level. The soil at the experimental site was tropical black clay and it belongs to the Akuse series. Chemical analysis of the soils used for the field and pot experiments are presented in Table 1.

TABLE 1

Chemical properties of the soil.

Depth (cm)	*TN (%)*	*AP (%)*	*AK (mg kg^{-1})*	*Ca (mg kg^{-1})*	*Mg (mg kg^{-1})*	*pH (H_2O) 1:1*	*OC (%)*	*OM (%)*	*C/N ratio*	*EC dS/m*
0 - 15	0.07	2.09	4.72	22.8	1.26	7.88	1.63	2.81	24.3	0.54

TN: total nitrogen, AP: available phosphorus, AK: available potassium, Ca: exchangeable calcium, exchangeable magnesium, pH: soil reaction, OC: organic carbon, C/N: carbon/nitrogen, OM: organic matter, EC: electrical conductivity.

Land preparation and experimental design The land was cleared and puddled to reduce percolation of water after which 21 days old seedlings of rice variety *Ex Baika* were planted at spacing of 20 cm X 20 cm. 3 m x 2 m metallic barriers with height of 60 cm long were inserted in each unit at a depth of 30 cm to prevent lateral movement of nutrient and water from of the plots. The barriers were sprayed with oil paint to prevent them from rusting. A 3 by 4 factorial experiment was laid out in a split plot design and replicated three times. Water management regime was the main plot factor with three levels; continuous submergence (CS), alternate wetting and drying (AWD) and moist condition of soil between saturation and field capacity (MC). Fertilizer management was the sub plot factor with four levels; 90 kg N/ha of urea fertilizer, 12.8 t/ha (90 kg N/ha) of compost, 45 kg N/ha of urea plus 6.4 t/ha (45 kg N/ha) of compost and a control (no N application). The sub-plot treatments were completely randomized in each main plot while the main plot treatments were also completely randomized in each replication. Description of the treatments is shown in Table 2.

TABLE 2
Description of treatments

Water management	*Fertilizer management*	*Treatment*
Alternate wetting and drying (AWD)	Control (0 kg N/ha)	**N0xAWD**
	Urea 90 kg N/ha	**N1xAWD**
	Compost 12.8 t/ha (90 kg N/ha)	**N2xAWD**
	Compost 6.4 t/ha (45 kg N/ha) + Urea 45 kg N/ha	**N3xAWD**
Moist condition between saturation and field capacity (MC)	Control (0 kg N/ha)	**N0xMC**
	Urea 90 kg N/ha	**N1xMC**
	Compost 12.8 t/ha (90 kg N/ha)	**N2xMC**
	Compost 6.4 t/ha (45 kg N/ha) + Urea 45 kg N/ha	**N3xMC**
Continuous submergence (CS)	Control (0 kg N/ha)	**N0xCS**
	Urea 90 kg N/ha	**N1xCS**
	Compost 12.8 t/ha (90 kg N/ha)	**N2xCS**
	Compost 6.4 t/ha (45 kg N/ha) + Urea 45 kg N/ha	**N3xCS**

Fertilizer application and crop establishment Triple Superphosphate (P_2O_5) and muriate of potash (KCl) were applied at 45 kg N/ha each on all the experimental units at two weeks after transplanting of seedlings. Recommended rate of nitrogen (90 kg N/ha) was applied to all the nitrogen treated plots. Urea fertilizer was split (50%) and applied for both basal (1 week after transplanting) and top-dress (6 weeks after transplanting). 12.8 tons of compost was broadcasted and incorporated as per treatment at one week before transplanting of rice seedlings. Where compost and urea were applied as nitrogen combination, 6.4 tons of compost was incorporated into the soil as basal and 45 kg N/ha from urea was applied as top dress. Compost was prepared with water hyacinth (*Eichhornia crassipes)*, rice straw (*Oryza sativa* L.*),* ash, cow dung, *Leucaena leucocephala* leaves and top soil. The matured compost (12 weeks old) had the following chemical properties; total nitrogen 0.7%, available phosphorus 0.4 mg kg^{-1}, available potassium 0.5 mg kg^{-1}, organic carbon 8.9%, pH 6.5 and C:N ratio of 12.7. Three-week old rice seedlings were transplanted at a spacing of 20 cm × 20 cm and two seedlings per hill.

Water management regimes

Sixty cm long perforated PVC pipes with a diameter of 3 cm were inserted in all the experimental plots except the continuously submerged plots to monitor soil moisture level below the soil surface. A wooden rule was used to measure moisture level below and above the soil surface. Continuous submerged plots were always flooded with water from transplanting to 10 days to harvest. Soil moisture level was kept at 25 cm below the soil surface in the MC plots. For the AWD treatment, the plots were only flooded (5 cm above the soil surface) when soil moisture level dropped to 25 cm below the soil surface. All the treatments were continuously flooded at booting stage to ten days to harvest.

Data collection

Chlorophyll content in leaves was taken with SPAD 502 chlorophyll meter at booting stage. Plants were cut from five hills in each plot at harvest and oven dried at 70°C to a constant weight and used to determine above ground biomass. Grain moisture content was measured for each treatment using a moisture meter and yield was expressed as t/ha at 14% grain moisture. Ten plants were selected at the centre of the plot randomly and used to determine the yield components: test weight, percentage of filled grains, spikelet number per panicle and effective tillers. Grain yield was determined by weighing grains from 5 m^2 at 14% moisture level.

Data analysis

The data collected were subjected to Analysis of Variance using GenStat statistical software package (12th Edition). Where significant differences were observed among treatments, least significant difference (LSD) at 5% was used to separate treatment means. Correlation matrix among grain yield, plant N uptake and growth parameters were also analysed using GenStat statistical software package (12th Edition).

Results

Weather

The climatic condition during the both seasons is showed in Table 3. The total rainfall during the entire period was 343.6 and 269.3 mm in 2015 and 2016 seasons, respectively. October recorded the highest rainfall in 2015 while September had the highest in 2016 season. Monthly maximum temperature ranged from 31 to 33.8°C in 2015 and from 31 to 34.1°C in 2016. November recorded the highest maximum temperature in both seasons. Mean relative humidity during the study ranged from 34.9 to 62.0% and 41.0 to 53.6% in 2015 and 2016 seasons, respectively.

TABLE 3
Total monthly rainfall, mean monthly maximum temperature and humidity of the experimental site during the experiments.

Month	*Rainfall (mm)*		*Maximum temperature (°C)*		*Relative humidity (%)*	
Year	*2015*	*2016*	*2015*	*2016*	*2015*	*2016*
July	97.0	22.3	31.0	31.6	37.4	44.8
August	22.3	50.0	31.0	31.0	34.9	46.5
September	21.9	112.3	32.2	31.6	59.0	53.6
October	106.4	N/A	32.6	32.0	62.0	45.0
November	96.0	84.7	33.8	34.1	60.2	41.0

N/A: not available. Source: Agrometeorological station, SIREC- Kpong.

Effect of water and fertilizer management on the growth of rice

The interaction between water and fertilizer management did not affect plant height significantly ($p > 0.05$) in both seasons (Table 4). Plant height ranged from 70.7 to 97.4 cm in 2015, and 68.4 to 98.0 cm in 2016. N1 x CS and N3 x CS treatment combinations recorded the tallest plants in 2015 and 2016, respectively while N0 x MC treatment combination recorded the shortest plants in both seasons. The main effects of both water and fertilizer management significantly ($p < 0.01$) influenced plant height at harvest. The AWD treatment produced similar plant height as CS treatment while MC treatment produced significantly the shortest plants in both seasons. Treatments N1 and N3 produced the tallest plants in 2015 and 2016 seasons, respectively. The control had significantly the shortest plants in both seasons.

There was a significant ($p < 0.05$) interaction between water and fertilizer management on above ground biomass at harvest in both seasons (Table 4). Above ground biomass ranged from 182.2 to 628.6 kg/m^2 and 165.7 to 640.5 kg/m^2 in 2015 and 2016 seasons, respectively. N1 x CS treatment combination produced the highest above ground biomass in 2015 while N3 x CS produced the highest in 2016 season. N0 x MC produced the lowest above ground biomass in both seasons. The main effects of both water and fertilizer management on above ground biomass was also significant ($p < 0.01$). AWD produced similar above ground biomass as CS treatment while MC had significantly the lowest above ground biomass in both seasons. Fertilizer effect on above ground biomass followed the order: N1 > N3 > N2 > N0 in 2015 season and N3 > N1 > N2 > N0 in 2016 season.

There was a significant ($p < 0.05$) interaction between water and fertilizer management on chlorophyll content at flowering stage in both seasons (Table 4). Chlorophyll content ranged from 30.7 to 42.7 and 30.0 to 43.5 in 2015 and 2016 seasons, respectively. The main effects of water and fertilizer management had a significant ($p < 0.05$) effect on chlorophyll content. AWD recorded similar chlorophyll content as CS treatment in both seasons while MC was significantly lowest. Treatments N1 and N3 recorded the highest chlorophyll content value in 2015 and 2016 seasons, respectively while the control had the lowest value in both seasons.

TABLE 4
Mean plant height, leaf area index, chlorophyll content and above ground biomass of rice under various water and fertilizer management.

Water regime	*Nitrogen sources*	*Plant height (cm)*		*Chlorophyll content*		*Above ground biomass (kg/m²)*	
		2015	*2016*	*2015*	*2016*	*2015*	*2016*
	N0	83.9d	81.5d	33.7d	31.3c	273.4cd	260.5c
	N1	97.4a	97.8a	42.6a	42.9a	582.2a	596.3a
	N2	87.5bc	90.1bc	38.2b	41.0b	418.8b	452.8b
CS	N3	96.7a	98.0a	42.7a	43.5a	628.6a	640.4a
	Average	**91.4A**	**91.9A**	**39.3A**	**39.7A**	**475.8A**	**487.5A**
	N0	75.2e	72.8e	32.6d	30.9c	261.6de	249.9cd
	N1	91.3b	92.5b	39.9ab	40.8b	561.3a	574.2a
	N2	87.5bc	89.9c	37.1c	39.7b	403.6b	438.5b
AWD	N3	91.9b	93.7b	40.7ab	41.4a	602.1a	629.0a
	Average	**86.5B**	**87.2A**	**37.6B**	**38.2B**	**457.2A**	**472.9A**
	N0	70.7e	68.4f	30.7e	30.0c	182.2e	165.7d
	N1	87.9bc	89.2c	39.1b	39.8b	392.5b	403.1bc
	N2	83.6d	86.8cd	39.1b	39.7b	305.7cd	331.3c
MC	N3	86.1cd	90.3bc	41.0ab	41.5a	349.7bc	398.5bc
	Average	**82.1C**	**83.7C**	**37.5B**	**37.8B**	**307.5B**	**324.7B**

Means followed by the same letter within a column are not significant from each other (P > 0.05). AWD: alternate wetting and drying soil condition; MC: moist soil condition between field capacity and permanent wilting point; CS: flooded soil condition; N0: no nitrogen application (control); N1: urea nitrogen application; N2: compost nitrogen application; N3: combined compost and urea nitrogen application.

Effect of water and fertilizer management on grain yield and yield components of rice

The interaction between water and fertilizer management significantly ($p < 0.01$) affected grain yield in both seasons (Fig. 1). Grain yield ranged from 3.0 to 6.7 t/ha in 2015 and 2.7 to 6.9 t/ha in 2016 season. N3 x CS produced the highest grain yield, followed by N3 x AWD, N1 x CS, and N1 x AWD, respectively. However, these treatments did not differ significantly from each other. N0 x MC produced significantly the lowest grain yield. The main effects of water and fertilizer management significantly ($p < 0.01$) influenced grain yield in both seasons. CS produced the highest grain yield, followed by AWD and MC treatments, respectively. Fertilizer management was ranked as: N3 > N1 > N2 > N0.

The interaction between water and fertilizer management had significant ($p < 0.01$) effect on spikelet number per panicle in both seasons (Table 5). The spikelet number per panicle ranged from 93 to 141 in 2015 and 90 to 144 in 2016 season. N3 x CS and N0 x MC treatment combinations produced the highest and lowest spikelet number per panicle in both seasons, respectively. The main effects of water and fertilizer management affected number of spikelet per panicle significantly ($p < 0.01$) in both seasons. CS produced similar number of spikelet per panicle as AWD treatment while MC had the lowest spikelet in both seasons. N3 and N0 treatments produced the highest and lowest number of spikelet per panicle in both seasons.

There was significant ($p < 0.05$) interaction effects of water and fertilizer management on panicles per m^2 in only 2016 season (Table 5). Panicles per m^2 ranged from 245 to 459 and 229 to 476 in 2015 and 2016 seasons, respectively. N3 x AWD and N0 x MC treatment combinations produced significantly the highest and lowest panicles per m^2 in both seasons, respectively while N0 x MC had the lowest. The main effects of both water and fertilizer management significant ($p < 0.05$) influenced panicles per m^2 in both seasons. AWD and MC treatments had significantly the highest and lowest panicles per m^2 in both seasons, respectively. Fertilizer effect on the above ground biomass followed the trend: N3 > N1 > N2 > N0 in both seasons.

There was a significant ($p < 0.01$) interaction between water and fertilizer management on percentage of filled grains in both seasons (Table 5). Percentage of filled grains ranged from 87 to 94% and 86 to 94% in 2015 and 2016 seasons, respectively. Treatment N0 x MC recorded the highest percentage of filled grains while N1 x AWD had the lowest in 2016. The main effect of water management did not significantly ($p > 0.05$) affect percentage of filled grains. However, there was significant ($p < 0.05$) effect of fertilizer management on percentage of filled grains. N0 had the highest percentage of filled grains followed by N2, N3 and N1treatments, respectively.

The main effects of water and fertilizer management and their interactions did not significant ($p > 0.05$) affect thousand (1000) grains weight in both seasons (Table 5). Thousand grains weight ranged from 25.9 to 27.1 and 26.4 to 26.8 in 2015 and 2016 seasons, respectively.

TABLE 5

Effect of water and fertilizer management on spikelets per panicle, panicles per m^2, thousand (1000) grains weight, and percentage of filled grains of rice for 2015 and 2016 seasons.

Water regime	*Nitrogen source*	*Spikelets per panicle*		*Panicles per m^2*		*1000 grain weight (g)*		*Percentage of filled grains*	
		2015	*2016*	*2015*	*2016*	*2015*	*2016*	*2015*	*2016*
CS	N0	109c	104d	281e	263de	26.7a	26.7a	90ab	92a
	N1	140a	142a	417b	425b	26.4a	26.6a	88b	87bc
	N2	121b	131b	323d	371c	26.7a	26.8a	91ab	90ab
	N3	141a	144a	459a	476a	27.1a	26.5a	87b	86c
	Average	**128A**	**130A**	**370A**	**384A**	**26.7A**	**26.7A**	**89A**	**89A**
AWD	N0	101cd	98de	283e	270d	26.4a	26.5a	90a	92a
	N1	138a	140a	426b	431b	26.2a	26.4a	88b	86c
	N2	110c	117c	332d	379c	26.7a	26.8a	89b	88bc
	N3	135a	141a	468a	485a	26.7a	26.6a	88b	86c
	Average	**121A**	**124A**	**377A**	**391A**	**26.5A**	**26.6A**	**89A**	**88A**
MC	N0	93d	90e	245f	229e	25.9a	26.4a	94a	94a
	N1	101cd	105d	419b	421b	26.4a	26.6a	89b	90av
	N2	98d	103d	330de	351c	26.8a	26.7a	93a	92ab
	N3	108c	112c	384c	420b	26.6a	26.5a	90ab	89bc
	Average	**100B**	**102B**	**345B**	**355.B**	**26.4A**	**26.6A**	**91A**	**91A**

Means followed by the same letter within a column are not significant from each other (P > 0.05). AWD: alternate wetting and drying soil condition; MC: moist soil condition between field capacity and permanent wilting point; CS: continuously submerged soil condition; N0: no nitrogen application (control); N1: urea nitrogen application; N2: compost nitrogen application; N3: combined compost and urea nitrogen application.

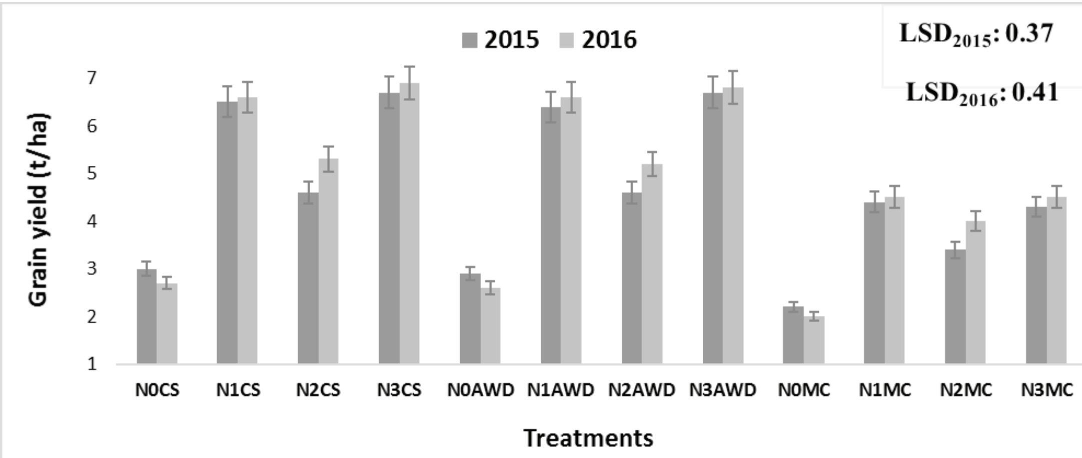

Fig. 1. Interaction effect of water and fertilizer management on grain yield for 2015 and 2016 seasons.

Correlation matrix between grain yield and growth parameters of rice

The relationship between grain yield and growth parameters of rice for both seasons is showed in Table 6a and 6b. Grain yield showed a strong positive and significant correlation with above ground biomass and plant height in both seasons. The association between grain yield and chlorophyll content was positively stronger in 2016.

TABLE 6A

Correlation matrix grain yield and growth parameters of rice under different water and fertilizer treatments in 2015 season.

Traits	*GY*	*CC*	*PH*	*ABM*
GY	-			
CC	0.537**	-		
PH	0.873**	0.701**	-	
ABM	0.942**	0.819**	0.876**	-

GY: grain yield, CC: chlorophyll content at flowering, PH: plant height at booting, ABM: above ground biomass at booting, ** means significant at 1%.

TABLE 6B

Correlation matrix grain yield and growth parameters of rice under different water and nitrogen treatments in 2016 season.

Traits	*GY*	*CC*	*PH*	*ABM*
GY	-			
CC	0.897**	-		
PH	0.923**	0.948**	-	
ABM	0.992**	0.869**	0.918**	-

GY: grain yield, CC: chlorophyll content at flowering, LAI: PH: plant height at booting, ABM: above ground biomass at booting, ** means significant at 1%.

Discussion

Effect of water and fertilizer management on rice growth

Results from both seasons (2015 and 2016) revealed that, above ground biomass, plant height, and chlorophyll content had a strong positive and significant correlation with grain yield. Chlorophyll is a component of photosynthesis, thus the higher the chlorophyll content of a leaf, the higher the production and partition of photosynthate into the grains which in turn increases grain yield. Plants with high above ground biomass and tall height store more assimilate and consequently, lead to higher grain yield. Plants with above ground biomass and tall height produced optimum grain yield as a result of their high rate of photosynthesis and metabolism (El-Refaee *et al*., 2007).

Plants with fertilizer application produced better plant vegetative growth than plants without fertilizer application in both seasons and this might be due to the available nutrients from the fertilizers in addition to the soil. This finding is in line with previous studies (Sarwar *et al*., 2007; Che Lah *et al*., 2011). Among the fertilized treatments, combined organic and inorganic fertilizer (N3) had the highest rice growth and it might be due to the continuous release of both macro-and micronutrients from the organic fertilizer to the plants along with the instant release of nutrients from the inorganic fertilizer (Omar Hattab *et al*., 2000). This finding is in agreement with Sarwar *et al*., (2007) and Che Lah *et al*., (2011) who reported a higher rice growth under combined organic and inorganic fertilization than the application of the fertilizers separately. Treatment N2 recorded the lowest plant growth among the fertilized treatments, and it might be attributed to nutrient immobilization by microorganisms and slow mineralization of nutrients from the organic fertilizer into the soil (Ebid, 2008). The finding confirms the report by Bar-Tat *et al*., (2004) who found that the incorporation of organic fertilizer into the soil has a positive effect on crops only when it is combined with an inorganic fertilizer. Available water between field capacity and permanent wilting point (MC) treatment had lowest rice growth due to reduced soil moisture level from one week after transplanting to booting stage. The movement and absorption of nutrients by plant roots were hindered due to the dryness of the top soil (Kropff & Spitters, 1991; Mannan *et al.,* 2012). Plants under alternate wetting and drying soil condition (AWD) treatment produced similar plant growth as plants under CS since it does not limit soil water availability (Belder *et al*., 2004; Singh *et al*., 2009). Moreover, AWD allows air exchange between soil and the atmosphere which in turn facilitates root growth and nutrient uptake (Yang *et al*., 2009; Tan *et al*., 2013). Treatment N1 and N3 under CS or AWD water management produced the highest rice growth in both seasons and it could be attributed to the unhindered nutrient movement and absorption as a result of the good moisture content of the top soil. It could also be attributed to the additional N from the fertilizers to soil.

Effect of combination of water and fertilizer management on rice yield and yield components

Plants with fertilizer application produced significantly higher number of spikelet per panicle, panicle per m^2 and grain yield than plants without fertilizer application in both seasons. This is in line with Singh *et al*., (2009) and Rahman & Singh (2013) who stated that fertilizer application increased grain yield and yield components of rice. Treatment N3 produced the optimum grain yield and it could be due to its highest above ground biomass, number of spikelet per panicle and panicle per m^2. This is in support of Sarwar *et al*., (2007) who recorded the highest grain yield in plants with integrated organic and inorganic fertilizer application. Treatment N2 had significantly the lowest grain yield among the fertilized treatments due to its lower panicle per m^2 and number of spikelet per panicle.

AWD produced similar grain yield as CS and it might be due to their similar number of spikelet per panicle, percentage of filled grains and panicle per m^2. This could be due to the fact that AWD does not limit soil water availability (Belder *et al*., 2004; Singh *et al*., 2009). Treatment MC had the lowest grain yield as a result of its smallest panicle per m^2 and number of spikelet per panicle. This outcome is in support of Abdul-Ganiyu *et al.,* (2015) who reported that maintaining soil moisture at field capacity significantly reduced grain yield of rice.

As a result of their higher panicles per m^2 and spikelet number per panicle treatment N3 and N1 under CS or AWD water management produced the highest grain yield. Moreover, these treatment combinations had the highest above ground biomass, plant height and chlorophyll content which might have resulted in high production of photosynthate. El-Refaee *et al*., (2007) observed significant increase in grain yield in plants with taller height and larger above ground biomass due to their high rate of photosynthesis and metabolism. The control N under MC, in which soil moisture was at field capacity, had the lowest grain yield, spikelet per panicle and panicles per m^2. This could be due to the reduced production of assimilates and photosynthetic rate as a result of its lower chlorophyll content and biomass accumulation (Akram *et al*., 2013).

Conclusion

Based on the objectives of the study it can be concluded that, alternate wetting and drying soil condition (AWD) produced, statistically, similar rice growth and yield as flooded (CS). Combined organic and inorganic fertilizer application (N3: 45 kg N/ha from urea fertilizer + 45 kg N/ha from 6.4 tons of compost) produced the highest rice growth and yield. Treatment N3 under AWD or CS water management produced the optimum rice growth and yield. There was a strong positive and significant correlation between grain yield and the growth parameters (plant height, chlorophyll content, and above ground biomass).

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