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IMPROVING RICE GROWTH AND YIELD THROUGH INTEGRATED COMPOST AND UREA FERTILIZER APPLICATION IN LOWLAND RICE

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Abstract

There is a spiral increase in inorganic fertilizer prices in Ghana and as a result, most farmers cannot apply inorganic fertilizers at the recommended rate for optimum grain yield. To address this challenge, a study was conducted at the Soil and Irrigation Research Centre, University of Ghana- Kpong, during the 2014 and 2015 cropping seasons, to assess the effect of compost, urea fertilizer and their combinations on growth and yield of rice. The experiment was laid out in a randomized complete block design (RCBD) and replicated three times. The treatments included; T1: Control (no nitrogen application), T2: 100% recommended N rate (Rec N = 90 kgN/ha) from compost, T3: 50% Rec N from compost + 50% Rec N from urea, T4: 70% Rec N from compost + 30% Rec N from urea, T5: 30% Rec N from compost + 70% Rec N from urea, T6: 100% Rec N from urea. Soil incorporation of compost or urea fertilizer significantly affected chlorophyll content, above ground biomass, plant height and grain yield in both seasons. Combined application of compost and Urea N at ratios of 50:50 (T3) and 30:70 (T5) were at par with 100% urea N application in terms of above ground biomass, plant height, chlorophyll content and grain yield in both seasons while 100% N through compost alone (T2) produced the lowest rice growth and yield among the nitrogen fertilizer treatments. Therefore, to reduce heavy dependence on inorganic fertilizer and encourage use of organic waste for rice production, the combination of inorganic fertilizer and compost at the ratio of 50:50 is recommended.

Keywords
Compost, Chlorophyll meter, lowland rice, recommended nitrogen rate, urea fertilizer

Introduction

In Ghana, rice is considered to be the second most important staple grain next to maize and the fifth important source of energy in the diet accounting for 9 percent of total caloric intake (FAOSTAT, 2012). Local production is just about 40% (641,000 t/ha paddyrice) of the demand (MoFA, 2015)(MOFA 2015), which has necessitated importation of large quantity of rice to fill the gap. Per capita consumption of rice rose from 17. 5 to 38.0 kg and it is estimated that by 2018 it will rise to 63 kg due to rapid urbanization (NRDS, 2015)(NRDS, 2010). Therefore, to meet this challenge, rice production needs to increase through intensification and expansion of production area. However, increasing cropping intensity with modern rice varieties, particularly in irrigated rice farming system in Ghana, has resulted in nutrient mining from the soil because nutrient removal has exceeded annual replacement through the usual inorganic fertilizer application. This is because many farmers are unable to afford the recommended rate of application due to spiral increase in fertilizer prices from weakness of local currency on the exchange market and removal of subsidies on fertilizers. Moreover, long-term studies done by Bhandari et al. (2002) attributed the reduced productivity of the rice system to declining soil organic matter (SOM), decreased soil fertility, and occurrence of nutrient imbalances. Nitrogen utilization efficiency of the applied nitrogenous fertilizers (including urea) in lowland rice system is less than 50%, and could be mainly due to losses through volatilization, denitrification and run-off water. Adding organic matter to the paddy soil may increase the soil fertility by suppling some nutrients such as, nitrogen, sulphur and micronutrients to the rice plant. According to Greenland (1997), these are released in plant available form as the organic matter mineralizes. But according to Miah et al. (1994), only one fifth to half of the nutrient supplied from manure was recovered in the first year and the rest released gradually to succeeding crops. Therefore, to improve synchrony between plant demand and supply of plant nutrient, particularly nitrogen from organic nutrient sources, combined application of compost and inorganic fertilizer could be a better option. Diverse studies across different agro-ecological zones have shown importance of organic nutrient sources in improving crop yield and soil quality (Azza et al., 2007; Fening et al., 2011; Osman and AboHassan, 2010). Considering nutrient imbalance in irrigated rice farming systems in Ghana, the present study was undertaken to investigate the effects of compost or urea fertilizer and their combinations on growth, yield and yield contributing characters of irrigated rice.

Materials and Methods

Descriptions of the experimental site

A field experiment was conducted at the Soil and Irrigation Research Center of the University of Ghana, Kpong during 2014 and 2015 cropping seasons. The centre is located within the lower Volta basin of the Coastal Savannah agro-ecological zone on latitude 6° 09' N, longitude 00° 04' E, and at an altitude of 22 m above mean sea level. The site experiences a bi-modal seasonal rainfall distribution with an annual precipitation of about 1200 mm. The major and minor rainfall seasons start from April to July and September to December, respectively. Mean annual temperature is 27.2°C. The soil at the research center is eutric vertisol (FAO, 1991), and belongs to the Akuse series (Amatekpor et al., 1993). The soil is clayey in texture, with pH of 7.8, Organic mater 1.55%, Total Nitrogen 0.07%; Available Phosphorus 1.97%; Available Potassium 2.34 mg/kg; Calcium 22.8 $mgkg^{-1}$; Magnesium 1.26 mg/kg; Electrical conductivity 0.76 dS/m. The chemical composition of the compost used for the experiment: pH (H_2O) 6.5; Electrical conductivity 0.49 dS/m; Total nitrogen 0.7%, Available phosphorus 0.4%; Available potassium 0.5%; Organic matter 15.3%; Organic carbon 8.9% and C/N ratio 12.7.

Experimental design and field management

The experiment was laid out in a randomized complete block design (RCBD) and replicated three times. Six treatments were involved; T1: Control (no nitrogen application), T2: 100% recommended N rate (Rec N = 90 kgN/ha) from 12.8 t compost in dry basis., T3: 50% Rec N from compost + 50% Rec N from urea, T4: 70% Rec N from compost + 30% Rec N from urea, T5: 30% Rec N from compost + 70% Rec N from urea, T6: 100% Rec N from urea. Triple Superphosphate (P_2O_5) and muriate of potash (K_2O) were applied at 45 kgN/ha each on all the experimental units as basal application at a week after transplanting of seedlings. Plot size of 4 m x 5 m was measured out with 1.5 m interval between the plots and 3 m between replications. Compost was prepared with water hyacinth *(Eichhornia crassipes)*, rice straw *(Oryza sativa* L.*)*, ash, cow dung, *Leucaena leucocephala* leaves, and topsoil. The matured compost (14 weeks old) was incorporated into the experimental units one week before transplanting of rice seedlings. Twenty-one day seedlings (Ex Baika variety) were transplanted at a planting distance of 20 cm × 20 cm with two seedlings per a hill on 13th August in 2014 and on 26th March in 2015. Post-emergence herbicide, Propagold (propanil +2,4-D) was applied at 21 days after transplanting to control weeds. The field was fenced with net during flowering stage to prevent birds from eating the grains. Chlorophyll content in leaves was measured with SPAD 502 chlorophyll meter at maximum tillering (55 days after sowing) (DAS) and booting stage. Five plants were cut from each plot at mid-tillering (42 DAS), panicle initiation (65 DAS), booting (84 DAS) and harvest (125 DAS) and oven dried at 70°C to a constant weight and used to determine above ground biomass. Grain yield was determined from 12 m^2 area after removing the border rows in each experimental unit, which was harvested and threshed manually. Grain moisture content was measured for each experimental unit using a moisture meter (after drying of grain) and yield was expressed as tons per hectare at 14% moisture. Five plants were selected at the center of the plot randomly and used to determine the yield components: test weight, sterility percentage, grains per panicle and panicle per m^2. Harvest index was calculated as the ratio of grain yield to the sum of grain yield and straw yield at harvest.

Data analysis

Data collected were subjected to analysis of variance using GenStat statistical software (12th edition, 2011). Where significant difference among treatment means was observed, LSD at 5% was used to separate the means. Correlation between chlorophyll content and grain yield and yield components were evaluated using Pearson's correlation coefficients.

Results

Effect of compost and urea fertilizer treatments on rice growth

Nitrogen fertilizer (compost and/or urea) application increased plant height significantly ($p < 0.05$) in both seasons (Table 1). Plants height ranged from 77 cm to 102.0 cm in 2014, and 75.2 cm to 103.2 cm in 2015. T6 treatment produced the tallest plants in both seasons, however it did not differ significantly ($p > 0.05$) from T5 treatment in 2015 season. The control produced the shortest plants in both seasons. Plant height was ranked in this order; T6 > T5 > T3 > T4 > T2 > T1 in both 2014 and 2015 seasons.

N fertilizer application had significant ($p < 0.05$) effect on chlorophyll content in both 2014 and 2015 cropping seasons (Table 1). Chlorophyll content ranged from 30.8 μmol/m2 to 41.7 *mu*mol/m^2 and 42.0 *mu*mol/m^2 to 28.4 *mu*mol/m^2 at maximum tillering (MT) and booting stages (BT), respectively in 2014, while in 2015, 32.5 *mu*mol/m^2 to 42.1 *mu*mol/m^2 and 27.9 to 42.5 were measured at MT and BT, respectively. T6 treatment had the highest chlorophyll content while the control (T1) recorded the lowest chlorophyll content in both seasons. T6 and T5 treatments had similar chlorophyll content in both seasons while T3 treatment recorded similar chlorophyll content as T6 and T5 treatments at booting stage in both seasons.

The effect of compost and urea treatments had insignificant ($p > 0.05$) effect on days to 50% flowering (Table 1) during both seasons. Days to 50% flowering ranged from 84 to 87 in 2014 and 88 to 91 in 2015. Plants grown in 2014 cropping season flowered earlier than the plants in 2015 however, there was no significant difference between seasons.

Above ground biomass was significantly ($p < 0.01$) affected by N fertilizer application from mid tillering stage to harvest (Figure 1). Biomass accumulation increased from 0.30 and 0.26 kg/m^2 at mid tillering stage to 4.54 and 4.5 kg/m^2 at harvest in 2014 and 2015 seasons, respectively. T6 treatment produced the highest above ground biomass from mid - tillering stage to harvest in 2014 while T5 had the highest above ground biomass from booting stage to harvest in 2015 season. However, both treatments did not differ significantly ($p < 0.05$) from each other. Plants from the control had the lowest above ground biomass throughout the growth stages in both 2014 and 2015 seasons.

Table 1. Effect of compost and urea fertilizer on plant height, days to 50% flowering, chlorophyll content at mid tillering (MT) and booting (BT) stages

Treatment	Plant height (cm)		Days to 50% flowering		Chlorophyll content at MT		Chlorophyll content at BT	
	2014	2015	2014	2015	2014	2015	2014	2015
T1	77.0e	75.2d	84a	89a	30.8d	32.5d	28.4e	27.9e
T2	81.2d	90.5c	86a	90a	35.4c	37.1b	36.8d	38.0cd
T3	95.4b	100.0a	87a	89a	38.6b	39.6b	39.7bc	41.2a
T4	85.9c	93.5.3c	86a	88a	37.2b	38.4b	38.3c	39.5bc
T5	95.6b	101.3a	87a	91a	39.0b	40.9b	40.6b	42.5a
T6	102.0a	103.2a	87a	89a	41.7a	42.1a	42.0ab	42.5a

T1: Control, T2: 100% compost, T3: 50% compost + 50% urea, T4: 70% compost + 30% urea, T5: 30% compost + 70% urea, T6: 100% urea. Means followed by the same letter in a column within a year are not significant (P > 0.05)

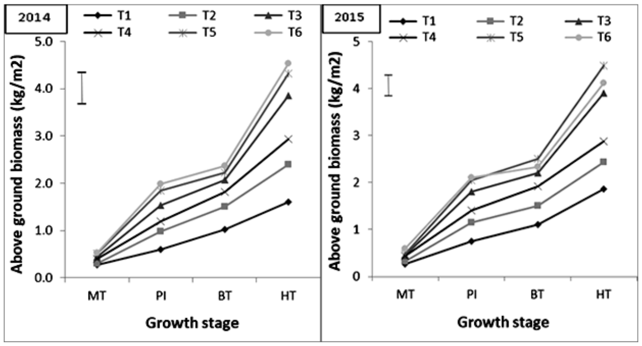

Figure 1. Effect of compost and urea fertilizer treatments on above ground biomass. T1: Control, T2: 100% compost, T3: 50% compost + 50% urea, T4: 70% compost + 30% urea, T5: 30% compost + 70% urea, T6: 100% urea. MT: mid tillering, PI: panicle initiation, BT: booting, HT: harvest. Bars represent ± SEM

Effect of compost and urea fertilizer on grain yield and yield components

Grain yield increased significantly ($p < 0.05$) with N fertilizer application in both seasons (Figure 2). Apart from the control, grain yield was higher in 2015 than 2014. T6 and T5 treatments had the highest grain yield in 2014 and 2015 cropping seasons, respectively. However, T3 treatment produced similar grain yield as T6 and T5 treatments in both seasons. Grain yield ranged from 2.4 to 5.7 t/ha and 2.0 t/ha to 5.8 t/ha in 2014 and 2015 cropping seasons, respectively. Plants from the control produced the lowest grain yield in both seasons.

N fertilizer application significantly ($p < 0.01$) increased panicles per m^2 in both seasons (Table 2). Panicles per m^2 ranged from 183 to 178 and 381 to 383 in 2014 and 2015 cropping seasons, respectively. T6 treatment produced the highest panicles per m^2 in 2014 while T5 treatment produced the highest panicles per m^2 in 2015 seasons. T3 treatment produced similar panicles per m^2 as T5 and T6 treatments in both seasons. The control produced the lowest panicles per m2 in both seasons. T2 treatment produced similar panicles per m^2 as the control (T1) in 2014, however it differed significantly ($p < 0.05$) from T1 treatment in 2015 season.

Grains per panicle increased significantly ($p < 0.05$) with N fertilizer application in both cropping seasons (Table 2). Grains per panicle ranged from 96 and 91 to 123 to 126 in 2014 and 2015 cropping season, respectively. T5 treatment produced higher grains per panicle than T3 and T6, however these treatments did not differ significantly from each other. The control (T1) produced the lowest grains per panicle in both seasons. Plants from 2015 cropping season produced higher grains per panicle marginally than plants from 2014 cropping season.

N fertilizer application had insignificant ($p > 0.05$) effect on test weight in both seasons (Table 2). Test weight (1000 grain weight) ranged from 25.1 g to 26.6 g in 2014, and 25.4 g to 26.3 g in 2015. The control had the lowest test weight in both seasons.

There was a significant ($p < 0.05$) effect of N fertilizer application on sterility percentage in both seasons (Table 2). Sterility percentage ranged from 5.3% to 13.1% in 2014 and 6.6% to 13.5% in 2015. T6 treatment recorded similar sterility percentage with the control, however these treatments had significantly higher sterility percentage than all the compost treatments in 2014 cropping season. Compost treatments did not differ significantly from each other in 2014, however T3 treatment differed significantly from T4 and T5 treatments in 2015. T6 treatment had the highest sterility percentage in both seasons.

The effect of N fertilization had insignificant ($p > 0.05$) effect on harvest index (Table 2). Harvest index ranged from 0.42 to 0.48 in 2014 and 0.45 to 49 in 2015. T3 and T4 treatments had the highest and lowest harvest index of 0.48 and 0.42, respectively in 2014. T6 and T3 treatments produced the highest and lowest harvest index of 0.49 and 0.44 in 2015, respectively.

Correlation matrix between chlorophyll content, and grain yield and yield components

The relationships between chlorophyll content and grain yield and yield components in 2014 and 2015 cropping seasons

Table 2. Effect of compost and urea fertilizers on panicles per m^2, grains per panicle, test weight, sterility percentage and harvest index

Treatment	Panicles/m2		Grains/panicle		Test weight		Sterility %		Harvest index	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
T1	183c	178d	96c	91d	25.1a	25.4a	12.5a	10.9ab	0.44a	0.45a
T2	200c	265c	103c	104c	25.7a	26.3a	6.5b	7.4bc	0.45a	0.48a
T3	363ab	376ab	122a	124a	25.3a	26.0a	5.3b	6.6c	0.47a	0.49a
T4	342b	348b	115b	116b	25.3a	25.5a	8.2b	9.4b	0.42a	0.46a
T5	373a	383a	123a	126a	26.6a	25.7a	7.3b	9.1b	0.48a	0.47a
T6	381a	380a	120a	124a	25.9a	26.1a	13.1a	13.5a	0.45a	0.44a

T1: Control, T2: 100% compost, T3: 50% compost + 50% urea, T4: 70% compost + 30% urea, T5: 30% compost + 70% urea, T6: 100% urea. PI: panicle initiation stage. Means followed by the same letter in a column within a year are not significant ($P > 0.05$).

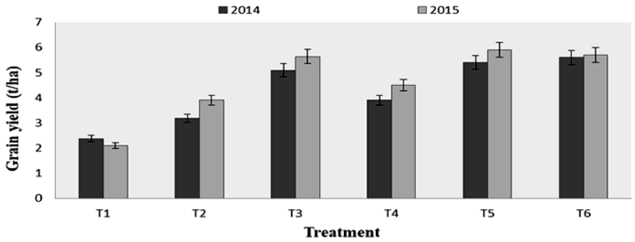

Figure 2. Effect of compost and urea fertilizer treatments on grain yield. T1: Control, T2: 100% compost, T3: 50% compost + 50% urea, T4: 70% compost + 30% urea, T5: 30% compost + 70% urea, T6: 100% urea. Bars represent 5% value

are shown in Table 3 and Table 4, respectively. Chlorophyll content had a strong positive and significant correlation with grain yield, grains per panicle and panicles per m^2 in both cropping seasons. Chlorophyll content showed weak positive and insignificant relations with test weight and sterility percentage in the 2014 season. However, a weak negative and insignificant correlation was recorded between chlorophyll content and sterility percentage in 2015 cropping season.

Discussion

Effect of compost and urea fertilizer on rice growth

Nitrogen fertilization produced higher rice growth than the control in both seasons. The control produced the lowest chlorophyll content, plant height and above ground biomass and it could be attributed to low nitrogen content of the soil. This outcome is in conformity with Bejbaruha et al. (2009) and Che Lah et al. (2011) who asserted that the application of nitrogen to the soil significantly increased rice growth. Plants from 2015 season produced higher vegetative growth than plants from 2014 season with the exception of the control and it might be due to the improvement of the soil properties as a result of the application of the fertilizers especially the compost. Previous studies by Bhattacharyya et al. (2008), Che Lah et al. (2011) and Xin et al. (2016) indicated that the application of compost improved soil properties. Among the N fertilized treatments, T6 treatment produced the highest chlorophyll content and the tallest plants in both seasons. T6 is 100% urea, hence N is readily available as compared to treatments that contained compost (organic material) as previously reported by Bejbaruha et al. (2009). T3 and T5 treatments produced similar above ground biomass, plant height and chlorophyll content as T6 treatment and it could be attributed to faster release of N from the urea fertilizer and the continuous release of plant nutrients from the compost to the plants roots as was observed by Omar Hattab et al. (2000). Lower rice growth characteristics observed under T2 (100% compost application) could be due to the slow and non-synchronous release of N from the organic material to the demand of the rice at critical stages of growth (Odlare and Pell, 2009).

Effect of compost on rice yields and yield components

The control produced lower rice yield than the N fertilized treatments as a results of its lower panicles per m^2 and grains per panicle. Better yield and yield components were recorded in 2015 cropping season than in 2014. This might be due to the gradual improvement in the soil properties or carry-over effect of previous N fertilizer application. T6 (100% N from urea) treatment produced the highest rice yield in 2014 cropping season, whiles in 2015 the highest yield was recorded under T5 (30% N in compost + 70 N in urea) treatment. This observation could be due to improvement of the soil properties by the compost after the 2014 cropping season and gradual mineralization of plant nutrients. Similar observation was made by Ebid et al. (2008) in field trial involving rice residue as organic plant nutrient source. T3 treatment had similar grain yield as T5 and T6 due to their similar grains per panicle and panicles per m2 in both seasons. T2 produced the lowest grain yield among the N fertilized treatments and it could be due to slow release of N during the crop growth period. According to Miah et al. (1994), only one fifth to half of the nutrient supplied from manure was recovered in the first year and the rest released gradually to succeeding crops. This is in

Table 3. Correlation matrix between chlorophyll content and grain yield and yield components in 2014

Trait	GY	GP	TW	PM	SP	CCBT
GY	-					
GP	0.962**	-				
TW	0.412ns	0.469*	-			
PM	0.934**	0.899**	0.319ns	-		
SP	0.165 ns	0.087ns	-0.028 ns	0.352 ns	-	
CCBT	0.922**	0.905**	0.272 ns	0.909**	0.231 ns	-

GY: grain yield, GP: grains per panicle, TW: test weight, PM: panicles per m^2, SP: sterility percentage, CCBT: chlorophyll content at booting stage, ** means significant at 1%, * means significant at 5% and ns: not significant at 5%.

Table 4. Correlation matrix between chlorophyll content and grain yield and yield components in 2015

Trait	GY	GP	TW	PM	SP	CCBT
GY	-					
GP	0.947**	-				
TW	0.314 ns	0.311 ns	-			
PM	0.935**	0.910**	0.288 ns	-		
SP	-0.336 ns	-0.484*	-0.100 ns	-0.276 ns	-	
CCBT	0.892**	0.819**	0.173 ns	0.896**	-0.075ns	-

GY: grain yield, GP: grains per panicle, TW: test weight, PM: panicles per m^2, SP: sterility percentage, CCBT: chlorophyll content at booting stage, ** means significant at 1%, * means significant at 5% and ns: not significant at 5%.

conformity with Bar-Tal et al. (2004) who stated that compost incorporation has a positive effect on crops when it is combined with a urea fertilizer. Test weight was not affected by N fertilization in both seasons since it a genetic trait which is mainly determined by the size of the hull (Mae, 1997; Mannan et al., 2012; Yoshida, 1981).

Relationship between chlorophyll content and grain yield and yield components

Chlorophyll content showed a strong positive and significant correlation with grain yield, grains per panicle, and panicles per m^2 in both seasons. Test weight and sterility percentage showed weak positive and insignificant relation with chlorophyll content in both seasons. Thus, the greener the leaves, the higher the grain yield and yield components. Chlorophyll is a component of photosynthesis, thus the greener the leaves the more the production of photosynthates and therefore the higher the partition of assimilates into the grain, leading to higher grain yield and yield components. Che Lah et al. (2011) similarly reported lower grain yield and yield components in plants with the lowest chlorophyll content.

Conclusion

Results from the study revealed that nitrogen fertilizer (compost or urea) application increased rice growth and yield significantly than the control. Incorporating compost into the soil had more positive effect on rice growth and yield in the second major season (2015) than the first season (2014). Based on the performance of rice under treatments T3 and T5 as compared to T6 (sole urea N source), 30 to 50% of urea N fertilizer could be substituted with compost and thus reduce farm input cost substantially from chemical fertilizers while maintaining good yield level.

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