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Effect of Compost on Agro-Botanical Components Responsible for Rice (*Oryza sativa)*Grain Yield in Southwestern Nigeria

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Abstract. Rice ranks first among cereal food crops with direct human consumption. The production trend is at a far distant behind its demand especially in West Africa sub-region. In spite of dissemination and adoption of diverse improved rice varieties the impact on increase in grain yield on nutrient limiting soil is marginal. Therefore this study was conducted to examine morphological traits that has direct link with sink capacity. The study was conducted over two seasons each in a typical derived savannah and humid rain forest agro-ecologies. The trial was a split plot design laid out in a randomized complete block with three replicates. The main plots were three upland rice cultivars (Ofada, NERICA 1 and NERICA 2) while the sub-plots were four compost rates (0, 4, 8 and 12 t ha^{-1}) and 90kg ha^{-1} NPK (20-10-10) fertilizer. NERICA 1 had the highest grain yield (5.57t ha^{-1}) in plots fertilized with NPK but not significantly ($p > 0.05$) different from yield obtained in NERICA 2 (4.95t ha^{-1})and Ofada (4.52t ha^{-1}) plots augmented with 8t ha^{-1} compost in derived savannah. Similarly in humid rainforest, NERICA 2 had the highest grain yield (7.40t ha^{-1}) on NPK fertilized plots but not significantly different from NERICA 1 and 2 cultivars (5.31 and 5.55t ha^{-1}) augmented with 4t ha^{-1} or Ofada (5.90t ha^{-1}) augmented with 8 t ha^{-1}compost. Number of leaves, plant height and leaf area were significantly associated with grain yield. Three morphological and five sink capacity characters contributed 92% to total grain yield (tha^{-1}). Residual effect of compost had no significant ($p > 0.05$) effect in improving growth or grain yield of upland rice on soil with marginal nutrient.

Keywords: Upland rice, Compost, Morphological characters, Sink capacity.

Introduction

Upland rice production in West Africa especially Nigeria has attained relevant importance considering the fact that about 75% of cultivable rice growing area is planted to upland rice. (Singh, *et al.*1997, WARDA, 2000). Nonetheless, the trend in rice production is behind demand in this region. Among cereal crops, rice is the number one food crop for many people across the globe (Dawe, 2007). Rice has therefore been the focus of recent discussions with the major aim of evolving radical approaches in addressing the need to improve its yield per unit area cultivated (Sage and Sage, 2009). Apart from the fact that diverse improved rice varieties exist, most are producing below the expected yield per hectare (Imolehin and Wada, 2000). A typical African rice cultivar, *Oryza glaberrima* Steud. produces ≤1t ha^{-1} which is below the average yield (3t ha^{-1}) of *Oryza sativa* L.*,* its Asian relative. Nevertheless, *O. glaberrima* survives under several biotic and abiotic stresses which limit yield potentials of *O. sativa* under tropical conditions (Oikeh *et al.,* 2008). Consequently an intraspecific cross was made between the two relatives to produce a genotype that combines some desirable yield related characters for the purpose of increasing upland rice production in the region. This had led to breeding for intraspecific rice genotypes through a specific cross between *O. glaberrima* x *O. sativa* resulting in a genotype known as NERICA (New Rice for Africa). Despite the impressive growth attributes of these intraspecific genotypes the low yield output is of great concern. Several studies have shown that some of the upland NERICA genotypes performed below expectations both in farmers' field and research stations (Saito *et al.*, 2007 and Dada, 2013). Evaluation and characterization of phenotypic diversity among different accessions have been shown to reveal important characters of interest that could be selected for hybridization or introgression by plant breeders (Singh, 1989, Nassir *et al.,* 2006 and Dada *et al.,* 2012). To bridge the production-consumption schism in rice, there is also increasing consciousness that remarkable improvements in yield per unit area cultivated are required especially on marginally fertile field.

Crop response to environmental conditions such as soil types and soil fertility levels varies, particularly with experiments repeated in time and/or space (Morakinyo and Ajibade, 1998 and Sanni *et al.,* 2009). The optimum fertilizer demand by NERICA genotypes for increasing grain yield (t ha^{-1}) under highly weathered soils of tropical region is scanty. It is therefore important also to determine the response of upland NERICA cultivars on highly weather soil of tropical agro-ecosystem augmented with compost. Therefore, this study was carried out to determine agro-botanical components that has direct link with grain yield of both improved and traditional upland rice cultivars on nutrient deficient soil augmented with compost in both derived savannah and humid rainforest agro-ecological zones of Nigeria. The outcome of which would form a working template for breeders in selecting relevant growth and yield traits necessary for increasing grain yield during future breeding efforts.

Materials and methods

Study site

The study was carried out during 2009 through 2011 planting seasons at the Teaching and Research Farm of College of Agricultural Sciences, Olabisi Onabanjo University, Yewa Campus, Ayetoro, Ogun State ($7^0$15'N and 3^0 3'E) and upland rice field of International Institute of Tropical Agriculture (IITA) Ibadan (7^0 33'N and 3^0 56'E) both located in southwestern Nigeria. The average temperature was between 24.90 -28.30^{0}C throughout the period of study. The sites received bimodal rainfall with an average annual rainfall of 220.22mm during the study period. Mean monthly temperature ranged from 25 – 27^{0}C, relative humidity was generally high with a range of 73 – 80%. The soil at Ayetoro and Ibadan respectively is Alfisol (FAO, 1988) with pH (H_2O) (5.1 and 6.5), N (0.8 and 1.1 g kg^{-1}), P (2.0 and 9.7g kg^{-1}), K (0.2 and 0.5 cmol kg^{-1}), organic matter (1.4 and 1.9g kg^{-1}), Ca (1.0 and 1.4g kg^{-1}) and Na (0.5 and 0.8g kg^{-1}). The sandy loam soil contained 782 and 670g kg^{-1}sand, 149 and 166g kg^{-1} silt and 69 and 164g kg^{-1}(clay). The first field trial was carried out between May and August 2009 while the second trial which tested the residual effect of the applied compost was carried out between June and October 2010 in derived savannah zone. At the tropical rainforest-derived savannah transition zone, the first and second trials were carried out between June and November 2010 and May and October 2011 respectively.

Compost was prepared from combination of farmyard manure + maize stover. The proportion of the maize stover to livestock remains was 3:1 on dry weight basis. This was prepared using concrete surface heap method described by Akanbi and Togun (2002) and Dada (2013). Sample of the matured compost was taken for physical and chemical analysis in laboratory using standard methods (IITA, 1990). Soil samples were taken randomly from each of the plot within the depth of 0-15cm and 15cm to 30cm for physico-chemical analysis.

Experimental design and treatments

The experimental design was a split plot fitted into randomized complete block with three replicates. The study was a 3 x 5 factorial combination of three rice cultivars (main plot) and five compost rates (sub-plot). Three rice cultivars: NERICA 1 (WAB 450-1-B-38-HB), NERICA 2 (WAB 450-1-P-28-HB), and Ofada (*Oryza glaberrima* -Traditional upland cultivar) cultivated were obtained from Africa Rice Centre at IITA, Ibadan, Oyo State. Compost was applied and worked into the plots seven days before planting at the rate of 0, 4, 8, 12 t ha^{-1} and 90kg N (NPK 20-15-15) fertilizer was applied at two weeks after sowing.

Land preparation and crop management

The field used in derived savannah was formerly grown to maize and cassava while upland rice cultivar was previously grown on field used at the rainforest agroecology. Both fields had been left fallow for four months. The fields were prepared mechanically. Seeds of rice were planted directly on the field using drilling method with 2 – 4 seeds per hole at the depth of 3 – 4 cm at a spacing of 20cm x 25cm. It was later thinned to two plants per stand to give a population of 550,000 plants per hectare. Other cultural practices were deployed as necessary.

Data collection

Data were collected at physiological maturity on number of leaves, plant height (cm), number of tillers, leaf area (cm^2) and leaf area index (LAI). These were obtained from plants grown at the two middle rows in each plot (excluding two plants at both end of each row). The following yield data were determined: number of spikelets, number and weight of panicles, weights of 100 seed (g), grains per plant (g), grain per stand and grain yield (tha^{-1}). Dry matter of shoot, root and total biomass was also weighed.

Data analyses

Data collected were analysed using ANOVA with Statistical Analysis System (SAS, 2002). The differences in means were separated by Least Significant Difference (LSD) at $p \leq 0.05$. Pearson Product Moment Correlation (PPMC) and simple linear regression were also used to analyse the data.

Results

Growth, dry matter and yield response of upland rice in derived savannah agro-ecosystem.

The effect of varying rates of compost on growth of three upland rice cultivars grown on Alfisol of southwestern Nigeria is presented in Table 1. During the main cropping cycle, there was no significant ($P > 0.05$) difference in the growth performance of the three rice cultivars. In the residual trial, growth performance of Ofada was significantly better than that of NERICA cultivars.

Application of varying compost rate to nutrient deficient soil had significant effect on growth response of the upland rice cultivars. Applying 8 tha^{-1} of compost significantly promoted tallest plants (72.23cm), highest number of leaves (25.72), tillers (5.00) and leaf area index (94.31) during the first planting season. However, the residual effect of applied compost had significant influence only on plant height but not on all other growth parameters.

Interaction between upland rice cultivars and compost rates during main cropping season was significantly ($P< 0.05$) different with respect to growth parameters. Number of leaves formed (28.00) and leaf area index (120.37) were highest in Ofada plots augmented with 8 tha^{-1} of compost but this was not significantly ($P> 0.05$) different from NERICA cultivars augmented with similar compost rate. Height of Ofada genotype was highest (82.00cm) in plots fertilized with NPK, while NERICA 2 had significantly highest tillers (5.83) in plots augmented with 8 tha^{-1} of compost. All the cultivars exhibited poor performances in the control plots where no mineral fertilizer or compost was applied. The residual effect of the interaction showed that Ofada performed better on plots previously amended with 8 tha^{-1} compost with respect to number of leaves (29.83) and leaf area index (100.68). Tiller production by the three upland rice cultivars was not significantly ($P>0.05$) influenced by previously applied compost or NPK fertilizer.

Biomass accumulation by the three upland rice cultivars is presented in Table 2. There was no significant difference in dry matter accumulation by the three upland rice cultivars during the first planting cycle. However residual effect of compost earlier applied had significant ($p< 0.05$) effect on biomass accumulation by the three upland rice cultivars. Ofada strain had significantly highest dry matter partitioned into its shoot (11.63g), root (4.07g) and overall biomass (16.48g). The effect of different levels of compost application on biomass yield revealed that plots augmented with 8 tha^{-1} compost accumulated highest biomass. This had significantly higher values than those of other compost rate.

The interaction between varying compost rates and rice cultivars also revealed a significant ($p< 0.05$) difference in dry matter production. Ofada plots fertilized with mineral fertilizer had significantly highest (23.20g) biomass accumulation. Meanwhile, NERICA cultivars had the highest dry matter on plots augmented with 8 tha^{-1} compost. The results of residual trials showed that Ofada performed better than NERICA cultivars with regard to dry matter production.

Nevertheless, there was no significant ($p > 0.05$) in dry matter accumulation and partitioning by the three cultivars.

There was no significant ($P > 0.05$) difference in yield and yield components of the three upland rice cultivars. Nonetheless, NERICA 2 had the highest grain (3.65g) and 100 seed weight (1.36g) as well as grain yield (3.45t ha^{-1}). Yield and yield components of upland rice cultivars were significantly influenced by varying rates of compost applied. Upland rice cultivars performed better on plots amended with 8 tha^{-1} compost but not significantly different from other plots fertilized with other compost rates or mineral fertilizer. The yield components increased with increasing compost rates from 4 to 8 tha^{-1} but declined beyond this compost level except for weight of 100 seeds (Table 3).

The interaction between varying rates of compost and upland rice cultivars revealed significant ($P < 0.05$) differences in weights of grain and grain yield (t ha^{-1}) whereas, weight of 100 seeds was not significantly influenced by the interaction. All the cultivars performed better on plots amended with compost and are comparable to mineral fertilizer. Highest grain weight (5.30g) was observed in NERICA 1 cultivar fertilized with inorganic fertilizer but was not significantly different from NERICA 2 or Ofada cultivars augmented with 8 tha^{-1} (Table 3). NERICA 1 had the highest grain yield (5.57 tha^{-1}) in plots fertilized with inorganic fertilizer whereas NERICA 2 and Ofada had comparable yield (4.95 tha^{-1} and 4.52 tha^{-1}) in plots augmented with 8 tha^{-1} compost.

The residual effect of earlier applied compost resulted in significant ($p < 0.05$) differences in weights of grains/stand and 100 seed of the three upland rice cultivars. NERICA 2 had the highest grain yield (1.48 tha^{-1}) but not significantly different from other cultivars. Plots previously amended with compost were not significantly different with regard to weight of 100 seed and grain yield (t ha^{-1}). However, grain weight was significantly highest (2.35g) in plots earlier fertilized with 8 tha^{-1} compost.

Also, interaction between cultivar type and compost rates were significantly influenced by previously applied compost (Table 3). Ofada performed significantly better on plots previously amended with 8 tha^{-1}compost with respect to weights of grain (3.72g) and 100 seed (1.42g) than NERICA cultivars. Although, grain yield (t ha^{-1}) was not significantly influenced by residual effect of compost but NERICA 1 plots previously amended with 4 tha^{1}compost had the highest (1.99 tha^{-1}) grain yield.

Growth, dry matter and yield response of upland rice n humid rain forest agro-ecosystem.

In humid rain forest zone, Ofada cultivar had significantly highest number of leaves (26.63), tillers (9.03) and leaf area index (45.00) but not significantly different from NERICA 1 during the main planting trial. However, during the residual trial, growth performance of Ofada was significantly better than NERICA cultivars (Table 1). With respect to compost rates, tallest plant (101.06cm) was observed in plots amended with 4 tha^{-1} of compost. However, plant with highest number of leaves (26.17), tillers (10.17) and leaf area index (48.06) were observed in upland rice cultivars grown on plots fertilized with NPK (Table 1). Although, these were not significantly different from plots augmented with 4 or 8 tha^{-1} compost. Plots previously augmented with compost or mineral fertilizer had no significant ($P> 0.05$) effect on growth of the crop.

Interaction between rates of compost and upland rice cultivars revealed that growing Ofada on plots amended with 4 tha^{-1} of compost promoted better leaf formation (36.42) and leaf area index (81.26). Also, plant with highest tiller formed was observed in Ofada plots fertilized with NPK. Augmenting poor soil with 4 tha^{-1} of compost promoted tallest plant in NERICA 1 field. The residual effect of compost on upland rice cultivar was not significantly different (Table 1).

During the main cropping cycle, Ofada line had significantly highest dry matter than the NERICA cultivars. Application of varying rates of compost had no significant ($P>0.05$) influence on dry matter accumulation of the three upland rice cultivars but applying NPK fertilizer enhanced highest (35.09g) biomass accumulation. Least dry matter was observed in control plots where there was no augmentation (Table 2). Meanwhile, the interaction effect of applying varying rates of compost on upland rice cultivars showed significant difference. Augmentation of NERICA 1 cultivar plot with 8 tha^{-1} of compost significantly promoted highest shoot (41.14g), root (13.43g) and total biomass accumulation (54.56g).

Earlier applied compost had no significant residual effect biomass yield. Results of yield and yield components showed that NERICA 1 had better grain weight (3.98g) but this was not significantly different from that of other cultivars. However, Ofada had the highest grain yield (5.29 tha^{-1}). Also, all the rice cultivars responded differently to varying compost rates in this agro-ecology. Plots augmented with 4 tha^{-1} compost had significantly highest weights of grain (4.49g) and 100 seed (3.09g) weight but these were not significantly different from the effect on the plots amended with NPK fertilizer. Highest grain yield (6.47 tha^{-1}) was observed in plots fertilized with NPK but not significantly different from those augmented with 4 tha^{-1} compost (Table 3).

The interaction revealed that, NERICA 1 grown on plots amended with 4 tha^{-1} compost had highest grain weight (3.46g) but this was not significantly different from Ofada plots amended with 8 to 12 tha^{-1} compost or NPK fertilizer. Highest weight of 100 seed (4.92g) was observed in NERICA 2 line grown on plots augmented with 4 t ha^{-1} compost. For the interaction, highest grain yield (7.40 tha^{-1}) was observed in NERICA 2 plots fertilized with NPK fertilizer although this was not significantly different other plots fertilized with NPK. Nonetheless, applying 4 tha^{-1} compost to NERICA cultivar plots and 8 tha^{-1}compost to Ofada plot had no significant ($p > 0.05$) difference in the effects of mineral fertilizer.
The residual effect of compost application in rainforest zone revealed that there was significant ($P < 0.05$) difference in yield attributes of the three rice cultivars. Ofada had significantly highest grain weight (0.16g) and yield (0.03 t ha^{-1}) but not significantly different from that of NERICA 2 (Table 3). Previous compost or fertilizer application had no significant ($p > 0.05$) influence on yield components of

upland rice cultivars. With respect to interaction, the performance of Ofada was better on plots previously augmented with 8 tha^{-1} compost.

Determinants of contributions of morphological and yield parameters to grain yield in upland rice cultivars in South western Nigeria

The results showed that growth parameters such as number of leaves, plant height as well as leaf area are significantly associated with grain yield of upland rice cultivars. Among the dry matter parameters none except shoot biomass which was significant ($p< 0.05$) but negatively associated with grain yield. Yield components like number of panicles ($r =0.04$), tillers ($r=0.55$), filled grains ($r=0.81$), weight of panicle ($r=0.40$), grain weight/stand ($r=0.96$) and grain weight/stand ($r=0.96$) were significantly associated with grain yield (t ha^{-1}) (Table 4).

Determinant of contribution of growth and yield components to grain yield in upland rice cultivars in south western Nigeria on Alfisol augmented with compost is presented in Table 5. The result revealed that number of leaves, number of tillers, plant height and leaf area are important growth parameters that determine yield in upland rice cultivars. Whereas, yield components like number of filled grains, panicles, 100 seed weight and grain weight/stand are major determinants of grain yield (t ha^{-1}) in upland rice cultivars. These growth parameters and yield components were found to have contributed 92% of the total grain yield (t ha^{-1}).

Discussion

The comparable growth performance of the three cultivars on poor soil amended with compost implies that under adequate nutrient availability optimum potential performance of a crop is usually attained. This agrees with Singh and Rachie (1985), who reported combined effect of seed genetic makeup, environment and field management practices on cowpea morphology. The better growth performance of Ofada over the NERICA cultivar suggests that this cultivar is likely to be well equipped with regards to morphological attributes necessary for building biological structures better than the NERICA lines. The performance of Ofada both during the main and residual trials supports the fact that this cultivar possesses some traits that confer ruggedness to limiting environmental factors especially nutrients occasioned by weed interference or decline soil fertility (Jones 1998 and Oikeh *et al.,* 2008). The superior performance of traditional cultivar Ofada over the improved NERICA cultivars especially during residual study contradicted the reports of Somado *et al.* (2008) that NERICA varieties respond even better than traditional varieties to lower inputs. However, our observation agrees with that of Saito *et al.* (2007).

The response of the crop on compost augmented plots suggests that applied compost contains growth promoting substances with the attribute to promote better growth and development of the three upland cultivars (Myint, *et al.,* 2010). Compost had been shown to act as a good soil conditioner by improving crop rhizopheres for better growth and development (Khan *et al*., 2004).

The crop exhibited poor performance during the residual trials. This implies that one time application on highly weathered soil had suboptimal effect on growth of the upland rice cultivars. Long term or residual benefits of compost application is premised on the level of soil nutrient depletion and crop type. On highly depleted soils like Alfisol used in this study, there will be the need for consistent application of optimum quantity of compost on annual basis to boost grain yield on this soil type. Similar observation had been reported by Myint, *et al.* (2010).

Superior performance of upland rice cultivars at 8 tha^{-1} compost rate means that this quantity of compost will supply nutrients needed for optimal growth performance of upland rice. Applying beyond this rate might create imbalance and affect crop growth negatively. Irrespective of cultivar type, applying 8 tha^{-1} compost appeared to have promoted better growth and development (Buresh and Witt, 2008). This suggests that when soil releases optimal nutrient as supplied by the applied materials, it is most likely that development of better biological architecture needed for assimilate production would be promoted. This is in line with the observation of Antil and Singh, (2007).

Biomass yield by the three cultivars was not significantly different during the first growing cycle. This suggests that compost supplied adequate nutrients necessary for abundant production of plant canopy factors like leaf length, leaf breadth, specific leaf area, tillering ability needed to enhance better radiation use efficiency by these cultivars. This is in line with observations of Shipley and Vu (2002) and Echarte*et al.* (2008). The comparable dry matter yield on plots augmented with 8 tha^{-1} compost and NPK implies that compost can serve as alternative to mineral fertilizer in upland rice cultivation. Similar view had been reported by Myint, *et al.* (2010).

The yield response of the three cultivars followed similar trends as obtained in growth and biomass yield where no significant differences were observed. Since both improved and native cultivars had comparable yield performance, it would appeared that farmers are likely to embrace the improved cultivars especially for its shorter days to maturity advantage which could allow for double cropping cycles as reported by Jones *et al.* (1997) and Nassirou and He (2011). Compost application helped in improving fertility status of Alfisol in this region as the performance of the crop improved significantly on compost augmented soil far better than the unfertilized control plots. Our results in this study agree with Akanbi *et al.* (2009).

The superior yield performance of Ofada could be linked to better growth and dry matter partitioning into grain. The better growth, dry matter and yield response of the crop to lower compost rate in humid rainforest agro-ecology, implies when the native nutrient is fairly low, a suboptimal compost rate would be required to complement crop’s nutrient demand. This probably explains reason why all the cultivars did well at 4 tha^{-1}compost rate. Applying superfluous compost would only promote vegetative growth at the expense of economic yield. NERICA had been reported to responded better to mineral fertilizer than traditional cultivars by Oikeh *et al.* (2008). This was confirmed by this study where NERICA 2 out yielded other cultivars on NPK fertilized field. Effect of compost application was comparable to mineral fertilizer in this study.

The residual effect of compost on growth, dry matter accumulation, yield and yield component of upland rice on Alfisol was negligible in both agro-ecologies. This is supported by the result obtained in the residual trial where grain yield was reduced by 57%. This could be linked to the low fertility status of the fields used for the study. This affirms the fact that inadequate nutrient availability and poor soil nutrient management would constitute constraints to upland rice production. This observation supports the assertion of Bationo *et al*. (2006) that poor crop land soil management practices contributed to the reduced crop yield in tropical Africa.

Ofada cultivar displayed superior performance compared to NERICA lines during the trial on residual effect of compost. This is possibly because of its ability to tolerate minimal nutrient conditions. This is in consonance with the submission of Jones, (1998) and Oikeh *et al.,* (2008).

The residual effect of the compost applied was better in humid rainforest than in the derived savannah in spite of the fact that they belong to similar soil class. This is perhaps because soil in this agro-ecological zone was fairly higher in indigenous nutrient level than that of derived savannah agro-ecology. This observation had also been reported by Sanni *et al.,* (2009).

The ten morphological characters implicated above are very important traits that contributed mostly to the variability in grain yield among these cultivars. Morphological characters such as leaf formation, leaf area, tillering ability and number of panicles are essential characters that have strong influence in determining the sources of assimilate synthate into the sink. It means that a unit increase in quantity of any of these traits will result in direct increase in grain yield. These morphological characters are very vital in photosynthetic activities. Our observation in this study is in congruent with that of Sanni *et al.* (2009). The negative significant association expressed by shoot biomass indicates that this trait should not be considered when selecting sink capacity related traits. On the other hand, number of filled grains, weights of grain, panicle per plant and 100 seed are good sink that greatly influence grain yield in upland rice. Kato and Takeda, (1996) and Nassir *et al.* (2006) had pointed out the importance of yield sink capacity as a good determinant of grain yield.

Conclusion

Recycling and utilization of degradable organic wastes such as farm yard manure and plant residue in form of compost will go a long way in improving nutrient limiting soil. Such marginal soils are thereby made available for crop production. Dissemination and adoption of NERICA 1 and 2 cultivars among rice growers will go a long way in boosting its production in the area. In conclusion, agro-botanical traits such as number of leaves, tillers, plant height, leaf area, number of panicles, filled grains, as well as weights of 100 seeds, grain $plant^{-1}$ and grain $stand^{-1}$ are traits that are directly related to sink capacity. These traits when selected for introgression or hybridization in further breeding efforts, have potential of boosting upland rice production in the region.

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Table 1: Growth response of upland rice cultivars augmented with varying rates of compost in Southwestern Nigeria

Rice cultivars		DERIVED SAVANNAH ZONE								RAIN FORESTH ZONE							
		MAIN CROPPING EFFECT				RESIDUAL EFFECT				MAIN CROPPING EFFECT				RESIDUAL EFFECT			
		NLV	PHT	NTL	LAI	NLV	PHT	NTL	LAI	NLV	PHT	NTL	LAI	NLV	PHT	NTL	LAI
NERICA 1		18.37	63.70	3.23	48.20	16.97	68.00	4.20	24.07	21.65	92.57	8.15	34.84	3.53	32.90	0.62	3.28
NERICA 2		17.47	68.94	3.70	37.18	17.87	68.87	4.77	20.48	21.67	93.67	8.10	23.84	3.43	39.71	0.70	3.63
Ofada		18.53	76.51	3.33	64.41	23.83	92.55	5.20	61.47	26.63	96.35	9.03	45.00	5.38	55.65	1.62	8.63
LSD (p≤0.05)		**5.36**	**8.38**	**1.20**	**38.80**	**6.11**	**9.46**	**1.89**	**26.47**	**4.53**	**5.77**	**1.77**	**18.50**	**1.46**	**9.06**	**0.58**	**3.28**
Compost rate (tha^{-1})																	
0 tha^{-1}		8.28	70.81	1.39	8.00	16.44	74.20	4.06	21.57	16.17	88.34	7.56	48.06	3.92	43.13	0.94	3.88
4 tha^{-1}		19.44	71.64	3.11	58.34	18.11	78.34	4.50	27.56	25.53	101.06	8.14	33.91	4.47	44.84	1.06	6.77
8 tha^{-1}		25.72	72.23	5.00	94.31	23.07	66.07	6.28	44.11	24.92	94.64	9.56	37.87	3.78	46.76	0.83	5.69
12 tha^{-1}		17.94	64.97	3.67	36.09	20.94	76.57	4.06	40.63	25.47	90.79	6.09	18.41	4.28	39.06	0.97	4.53
NPK		19.22	68.93	3.94	52.91	19.22	87.17	4.72	42.83	26.17	96.17	10.17	34.55	4.14	39.97	1.08	5.02
LSD (p≤0.05)		**6.92**	**10.75**	**1.54**	**50.09**	**7.89**	**12.22**	**2.44**	**34.17**	**5.85**	**7.45**	**2.28**	**23.88**	**1.88**	**11.69**	**0.74**	**4.25**
Interactions	**Compost rate tha^{-1}**																
	0	7.67	67.67	1.33	6.11	17.67	67.32	4.50	26.08	19.67	97.01	8.42	68.82	2.67	26.68	0.33	1.15
	4	9.50	74.05	3.17	55.65	16.33	68.08	4.33	26.23	30.42	114.75	6.42	17.55	3.17	31.80	0.83	2.61
NERICA 1	**8**	24.17	59.93	3.83	83.13	17.50	55.43	5.00	18.52	22.58	78.17	9.17	29.83	4.17	39.43	0.97	5.65
	12	18.00	53.52	4.33	24.68	15.83	69.77	3.50	21.85	11.75	80.58	7.00	8.65	5.08	31.21	1.00	5.10
	NPK	22.50	63.35	3.50	71.43	17.50	79.38	3.67	27.65	28.83	92.33	9.75	36.89	2.58	35.39	0.00	1.84
	0	9.33	68.75	1.83	8.97	11.50	62.65	3.33	8.38	23.33	83.58	7.50	30.01	4.50	50.00	1.00	4.68
	4	18.00	69.32	3.67	34.17	17.50	76.47	4.00	24.48	20.50	103.58	7.75	15.35	2.83	44.35	0.33	3.01
NERICA 2	**8**	25.00	76.12	5.83	79.42	21.83	47.52	7.17	13.34	21.83	102.42	8.08	14.74	3.33	38.73	0.50	4.25
	12	16.83	69.08	3.00	24.44	19.00	77.00	3.67	22.04	21.58	83.58	8.17	34.10	3.17	36.22	0.67	3.51
	NPK	18.17	61.43	4.17	38.92	19.50	80.70	5.67	34.17	21.08	95.17	9.00	24.98	3.33	29.23	1.00	2.68
	0	7.83	76.02	1.00	8.91	20.17	92.63	4.33	30.25	22.67	84.37	6.75	32.90	4.58	52.70	1.50	5.81
	4	20.83	71.57	2.50	85.20	20.50	90.48	5.17	31.96	36.42	84.83	10.25	81.26	7.42	58.37	2.00	14.68
Ofada	**8**	28.00	80.63	5.33	120.37	29.83	95.25	6.67	100.48	30.33	103.33	11.42	69.04	3.83	62.13	1.08	7.17
	12	19.00	72.30	3.67	59.17	28.00	82.95	5.00	78.02	15.17	108.21	5.25	12.49	4.58	49.75	1.25	4.98
	NPK	17.00	82.00	4.17	48.38	20.67	101.43	4.83	66.65	28.58	101.00	11.75	41.77	6.50	55.28	2.25	10.51
Mean		**17.46**	**69.72**	**3.42**	**49.93**	**19.56**	**76.47**	**4.72**	**35.34**	**23.65**	**94.19**	**8.45**	**34.56**	**4.12**	**42.75**	**0.98**	**5.18**
LSD (p≤0.05)		**11.99**	**18.62**	**2.67**	**86.75**	**13.67**	**21.16**	**4.22**	**59.18**	**10.14**	**12.91**	**3.95**	**41.36**	**3.26**	**20.25**	**1.29**	**7.35**

NLV= No of leaves, PHT = Plant height (cm), NTL = Number of tillers, LAI= Leaf area index/plant. Data are means of four plants.

Table 2: Biomass accumulation by upland rice cultivars augmented with varying rates of compost in Southwestern Nigeria

Rice cultivars		DERIVED SAVANNAH ZONE						HUMID RAINFOREST ZONE					
		MAIN CROPPING EFFECT			RESIDUAL EFFECT			MAIN CROPPING EFFECT			RESIDUAL EFFECT		
		Dry weight plant^{-1} (g)			Dry weight plant^{-1} (g)			Dry weight plant^{-1} (g)			Dry weight plant^{-1} (g)		
		Shoot	**Root**	**Total**	**Shoot**	**Root**	**Total**	**Shoot**	**Root**	**Total**	**Shoot**	**Root**	**Total**
NERICA 1		7.69	2.27	10.17	7.90	2.77	11.45	24.40	7.37	31.77	1.28	1.02	2.23
NERICA 2		10.03	2.98	13.32	6.75	2.68	10.21	19.16	6.47	25.63	1.12	0.88	2.02
Ofada		9.85	3.46	13.35	11.63	4.07	16.48	29.88	9.07	38.95	1.18	0.86	2.02
LSD (p≤0.05)		**3.60**	**1.45**	**4.79**	**2.75**	**1.30**	**3.74**	**7.27**	**2.70**	**8.89**	**0.54**	**0.57**	**1.04**
Compost rate (tha^{-1})													
0 tha^{-1}		4.09	1.27	5.54	8.36	3.27	12.41	21.12	5.20	26.32	1.20	0.82	1.92
4 tha^{-1}		8.34	2.88	11.34	8.34	2.53	11.67	27.14	7.46	34.60	1.69	1.55	3.27
8 tha^{-1}		14.67	4.35	19.51	9.00	3.50	13.28	28.06	9.44	37.50	0.86	0.53	1.36
12 tha^{-1}		8.72	2.38	11.39	8.38	2.78	11.84	20.47	6.59	27.06	1.04	0.80	1.86
NPK		10.11	3.66	13.99	9.81	3.78	14.36	25.61	9.49	35.09	1.19	0.91	2.04
LSD (p≤0.05)		**4.64**	**1.87**	**6.19**	**3.55**	**1.68**	**4.82**	**9.38**	**3.48**	**11.48**	**0.69**	**0.73**	**1.34**
Interactions	**Compost rate (tha^{-1}**												
	0	5.05	1.52	6.87	7.83	4.17	12.78	18.05	3.97	22.02	1.73	1.20	2.68
	4	7.95	2.87	10.78	7.58	1.75	10.11	19.74	6.52	26.26	1.75	1.93	3.65
NERICA1	**8**	14.65	3.43	18.35	8.00	3.17	11.95	41.14	13.43	54.56	0.92	0.50	1.31
	12	6.18	1.88	8.48	6.25	1.75	8.78	22.16	5.62	27.78	0.93	0.98	1.93
	NPK	4.60	1.65	6.38	9.83	3.00	13.61	20.93	7.32	28.25	1.08	0.48	1.58
	0	4.27	1.10	5.35	5.42	1.82	8.01	17.01	5.36	22.37	0.95	0.60	1.63
	4	8.80	2.90	11.20	6.83	1.92	9.53	22.76	9.16	31.92	1.66	1.30	3.27
NERICA2	**8**	14.95	5.27	21.17	7.00	3.33	11.11	16.56	4.10	20.66	0.93	0.68	1.63
	12	12.28	3.27	15.78	6.00	2.67	9.45	16.73	5.84	22.57	1.10	0.52	1.63
	NPK	9.83	2.35	12.38	8.50	3.67	12.95	22.72	7.90	30.62	0.97	0.98	1.95
	0	2.97	1.18	4.40	11.83	3.83	16.45	28.31	6.26	34.58	0.92	0.65	1.44
	4	8.28	2.88	11.32	10.67	3.92	15.36	38.93	6.70	45.63	1.65	1.08	2.89
Ofada	**8**	14.42	4.35	19.02	12.00	4.00	16.78	26.46	10.81	37.27	0.72	0.40	1.15
	12	7.68	1.98	9.92	12.58	3.97	17.28	22.53	8.30	30.83	1.08	0.90	2.03
	NPK	15.90	6.97	23.20	11.08	4.67	16.53	33.17	13.25	46.42	1.53	1.26	2.03
Mean		**9.19**	**2.91**	**12.31**	**8.76**	**3.18**	**12.71**	**24.48**	**7.64**	**32.12**	**1.19**	**0.90**	**2.05**
LSD (p≤0.05)		**8.04**	**3.24**	**10.72**	**6.15**	**2.90**	**8.36**	**15.73**	**5.63**	**19.05**	**1.20**	**1.27**	**2.32**

NLV= No of leaves, PHT = Plant height (cm), NTL = Number of tillers, LAI= Leaf area index/plant. Data are means of four plants.

Table 3: Yield and yield components of upland rice cultivars augmented with varying rates of compost in Southwestern Nigeria

Rice cultivars		DERIVED SAVANNAH ZONE								HUMID RAINFOREST ZONE						
		MAIN CROPPING EFFECT				RESIDUAL EFFECT				MAIN CROPPING EFFECT				RESIDUAL EFFECT		
		Dry weight (g) plant^{-1}			Grain yield (tha^{-1})	Dry weight (g) plant^{-1}			Grain yield (tha^{-1})	Dry weight (g) plant^{-1}			Grain yield (tha^{-1})	Dry weight (g) plant^{-1}		Grain yield (tha^{-1})
		Panicles	Grain	100 Seeds		Panicles	Grain	100 Seeds		Panicles	Grain	100 Seeds		Panicles	Grain	
NERICA 1		**1.06**	**3.00**	1.19	2.81	0.55	0.96	**0.65**	1.34	3.93	3.98	2.96	4.98	**0.04**	**0.03**	0.01
NERICA 2		**1.15**	**3.65**	1.36	3.45	0.44	1.36	0.50	1.48	3.78	4.08	2.82	4.86	0.15	0.11	0.02
Ofada		1.29	2.94	**1.34**	**1.93**	0.94	1.96	1.06	0.99	3.70	3.91	2.96	**5.29**	0.22	0.16	0.03
LSD ($p \leq 0.05$)		**0.27**	**1.32**	**0.48**	**1.53**	**0.26**	**0.59**	**0.39**	**0.56**	**0.56**	**0.57**	**0.15**	**1.05**	**0.12**	**0.09**	**0.02**
Compost rate (tha^{-1})																
0 tha^{-1}		1.09	1.62	1.15	1.09	0.68	0.85	0.76	1.38	3.69	3.78	2.73	4.65	0.14	0.09	0.02
4 tha^{-1}		1.09	2.78	1.67	2.05	0.71	1.58	0.64	1.41	**4.25**	**4.49**	**3.09**	5.40	0.16	0.13	0.03
8 tha^{-1}		**1.19**	**4.46**	**1.31**	**4.02**	0.66	2.35	0.88	1.11	3.51	3.68	2.88	4.33	0.13	0.11	0.02
12 tha^{-1}		1.15	3.06	**1.47**	2.76	0.55	1.08	0.66	1.28	3.36	3.50	2.81	4.36	0.14	0.11	0.02
NPK		1.33	4.07	1.39	3.73	0.62	1.29	0.76	1.17	4.19	4.51	2.95	**6.47**	0.11	0.07	0.01
LSD ($p \leq 0.05$)		**0.35**	**1.71**	**0.62**	**1.97**	**0.34**	**0.77**	**0.51**	**0.73**	**0.72**	**0.74**	**0.19**	**1.35**	**0.16**	**0.12**	**0.02**
Cultivars	**Compost rate tha^{-1}**															
	0	1.00	1.63	0.93	1.29	0.73	0.92	0.67	0.90	4.58	2.47	2.73	3.75	0.02	0.01	0.00
	4	1.03	2.38	0.83	2.12	0.71	1.14	0.63	1.99	4.25	3.46	3.86	5.31	0.05	0.05	0.01
NERICA1	**8**	1.08	3.03	1.30	2.61	0.38	1.06	0.70	0.89	3.79	2.94	4.50	3.91	0.03	0.03	0.01
	12	1.17	2.65	1.62	2.48	0.65	0.85	0.72	1.44	2.58	2.64	4.34	5.22	0.02	0.02	0.00
	NPK	0.97	5.30	1.25	5.57	0.27	0.84	0.54	1.50	4.42	2.96	4.48	6.70	0.07	0.05	0.01
	0	1.00	1.75	1.02	1.39	0.28	0.54	0.33	1.94	3.33	2.78	2.94	3.20	0.13	0.05	0.01
	4	1.25	3.25	1.17	3.02	0.47	1.50	0.68	1.41	4.50	3.02	4.92	5.55	0.08	0.13	0.03
NERICA2	**8**	1.28	5.15	1.60	4.95	0.69	2.27	0.51	1.41	2.92	2.99	3.77	3.71	0.18	0.07	0.01
	12	1.27	3.98	1.60	3.95	0.30	1.24	0.52	1.57	3.92	2.58	3.94	4.39	0.23	0.20	0.04
	NPK	1.25	4.10	1.37	3.94	0.44	1.25	0.48	1.05	4.25	2.73	4.83	7.40	0.13	0.08	0.02
	0	1.28	1.47	1.45	0.59	1.03	1.09	1.28	1.29	3.16	2.47	3.23	3.55	0.28	0.20	0.04
	4	1.30	2.72	1.50	1.02	0.95	2.11	0.62	0.84	4.00	2.79	4.06	5.35	0.25	0.20	0.04
Ofada	**8**	1.08	5.18	1.02	4.52	0.91	3.72	1.42	1.02	3.83	3.16	4.23	5.90	0.28	0.23	0.05
	12	1.05	2.53	1.18	1.87	0.65	1.14	0.75	0.85	3.58	3.22	3.81	4.94	0.18	0.12	0.02
	NPK	1.00	2.81	1.57	1.68	1.14	1.78	1.25	0.96	3.92	3.17	4.24	6.72	0.12	0.07	0.01
	Mean	**1.13**	**3.20**	**1.29**	**2.73**	**0.64**	**1.43**	**0.74**	**1.27**	**3.80**	**2.89**	**3.99**	**5.04**	**0.14**	**0.10**	**0.02**
LSD ($p \leq 0.05$)		**0.60**	**1.07**	**2.98**	**3.42**	**0.58**	**1.33**	**0.88**	**1.26**	**1.24**	**0.33**	**1.28**	**2.35**	**0.28**	**0.21**	**0.04**

Data are a means of four plants.

Table 4: Correlations among growth and yield parameters of upland rice cultivars grown on augmented with compost in Southwestern Nigeria

Variable	NLV	PH	LA	SBM	RBM	TBM	NPL	NTL	NSP	WPL	100 Seed wt.	GWt. /plant	GWt /std	GY (t/ha)
Number leaves	1.00													
Plant height	0.28**	1.00												
Leaf area	0.90**	0.47**	1.00											
Shoot biomass	-0.27*	-0.20	-0.29**	1.00										
Root biomass	-0.16	-0.14	-0.17	0.81**	1.00									
Total biomass	-0.25*	-0.19	-0.27*	0.98**	0.90**	1.00								
Number of panicles	0.26*	0.17	0.14	-0.03	-0.02	-0.02	1.00							
Number of tillers	0.64**	0.26*	0.56**	-0.16	-0.12	-0.16	0.36**	1.00						
Number of filled grains	0.63**	0.24*	0.46**	-0.17	-0.12	-0.15	0.48**	0.60**	1.00					
Weight of panicle	0.09	0.21*	0.20	-0.13	-0.19	-0.16	-0.05	0.08	-0.08	1.00				
100 seed weight	0.06	0.04	0.04	-0.08	-0.07	-0.08	-0.10	0.07	0.03	0.28**	1.00			
Grain weight/plant	0.60**	0.22*	0.49**	-0.23*	-0.21*	-0.23*	0.38**	0.57**	0.84**	0.38**	0.19	1.00		
Grain weight/stand	0.60**	0.23*	0.50**	-0.24*	-0.21*	-0.24*	0.38**	0.57**	0.84**	0.38**	0.19	0.98**	1.00	
Grain yield (t/ha)	0.59**	0.21*	0.50**	-0.22*	-0.18	-0.21	0.40**	0.55**	0.81**	0.40**	0.19	0.96**	0.96**	1.00

*** Correlation is significant at P< 0.01 level. , * Correlation is significant at P< 0.05 level.*

NLV = No. of Leaves, PH= Plant Height, LA= Leaf Area, SBM = Shoot Biomass, RBM = Root Biomass, Total Biomass, NPL = No. of Panicles, NTL = No. of Tillers, NSP = Number of Spikelets, WPL = Weight of Panicle, GW = Grain Weight, GY = Grain Yield.

Table 5: Regression analysis of contributions of growth and yield components of upland rice to grain yield (t/ha)

Variable	**Coefficient (βi)**	**t**
(Constant)	0.38	1.54
Number of leaves	0.01*	0.70
Plant height	0.00*	1.42
Leaf area	0.00*	1.17
Number of filled grains	0.00*	0.10
Shoot biomass	0.13	1.37
Root biomass	0.11	1.10
Total biomass	0.06	1.32
Number of panicles	0.02*	1.17
Number of tillers	0.01*	0.60
Weight of panicle	0.30	2.29
100 seed weight	0.01*	0.30
Grain weight/plant	0.00*	0.02
Grain weight/stand	0.17	1.75
F	**70.24**	
R^2	**0.96**	
Adjusted R^2	**0.92**	

**Correlation is significant at p< 0.05 level.*