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ORIGINAL ARTICLE

The performance of lowland rice (*Oryza sativa* L.) cultivars on iron toxic soil augmented with compost

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Performance of lowland rice grown on anaerobic wetland soil is greatly affected by iron toxicity disorder in Nigeria. Better nutrient management and cultivation of resistant varieties have been recommended as strategy to manage this nutrient disorder. Information on intraspecific lowland NERICA cultivars grown on iron toxic soil augmented with compost is scanty. Therefore, the effect of different rates of compost on growth, dry matter and grain yield of lowland NERICA cultivars grown on iron toxic soil was investigated. A greenhouse experiment comprising of three (two NERICAs and ITA 212) lowland rice cultivars and four varying rates of compost arranged in completely randomized design with six replicates was conducted in greenhouse of Botany Department, University of Ibadan. Data collected on growth and yield parameters were analysed using ANOVA and LSD at $P \leq 0.05$. Correlation and simple linear regression were used to establish relationship between growth and iron toxicity scores. Results showed that iron toxicity significantly ($p \leq 0.05$) reduced growth and yield of lowland rice. Growth and grain yield of NERICA cultivars were significantly better ($P \leq 0.05$) on soil augmented with compost than control. Grain yield was significantly related to the number of leaves affected by iron toxicity. Cultivating lowland NERICA-L-1 on iron toxic soil augmented with 8t ha^{-1} of compost will enhance better growth, dry matter characteristics and increase lowland NERICA grain yield.

Key words: Iron toxicity, lowland NERICA, compost, wetland, grain yield

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Key words: Iron toxicity, lowland NERICA, compost, wetland, grain yield

Nigeria has a wide range of arable rice growing environments including the inland valleys (Singh *et al*., 1997). The inland valley of West Africa which covers 30% of the total rice producing area is highly prone to iron toxicity (Audebert, 2006; Olaleye *et al* 2009). Low land rice growing environment covers about 75% of Nigerian rice growing ecosystems. Despite being the largest rice producer in West Africa, Nigeria is still a rice-deficit nation (Rahji and Adewunmi 2008). One of the major constraints to rice production in the inland valleys of Nigeria is iron toxicity. Iron toxicity is a nutritional disorder causing poor growth and severe yield loss in West African lowland rice field. This nutritional disorder is often caused by the microbial reduction under flooded conditions of insoluble iron-III (Fe^{3+}) into soluble iron-II (Fe^{2+}), which can be taken up by rice plants in excess amounts. Under the reductive effect of this environment, certain soil bacteria create anaerobic respiration (ATP synthesis) resulting in a large quantity of ferrous ion (Fe^{2+}) solution (Diatta and Sahrawat, 2006, Ayeni, 2011). The sources of the iron could be from the soil solution in the lowland itself or by natural seepage or runoffs from adjoining slopes. The Fe^{2+} solution formed usually causes element disequilibrium in the soil solution, which is translocated into plant.

Iron toxicity is characterized by “bronzing” or “yellowing” of oldest rice leaves which often lead to retardation of growth factors especially plant height, tillering potentials as well as higher level of panicle sterility. Reduction in rice productivity has been reported to be directly proportional to concentration of Fe^{2+} in the solution and the tolerance of the cultivar type (Masajo *et al.*, 1986; Abafarin, 1989 and Audebert *et al.,* 2006). Report of Audebert (2006) revealed that this problem can be solved with the development of tolerant varieties, the use of appropriate cropping systems, fertilizer application and water management. However, there are still a number of challenges that deserve urgent attention in iron toxicity incidence in lowland rice in Nigeria. Diatta and Sharawat (2006) reported that application of nutrients such as N, P, K and Zn could help in controlling harmful effect of iron toxicity on rice field. Nonetheless, fertilizer utilization among poor resource rice growers is still below the recommended rate. Quantity of fertilizer applied especially to arable crops by Nigerian farmers has been generally sub-optimal (Philips *et al.,* 2009). A report has also shown that fertilizer per capita consumption in Nigeria at 9 kg/ha is one of the lowest in sub-Saharan Africa (CARD, 2009). This is premised upon availability and affordability of this input, consequently lowland rice cultivation in Nigeria is still faced with deleterious effect of iron toxicity resulting from deficient nutrient management. Another means of controlling iron toxicity is by cultivating resistant variety. However, the new lowland NERICA lines are yet to be widely tested under iron toxicity stressed environments. If fertilizer uptake as well as planting resistant varieties tends to minimize the toxic effect of excess iron on growth and grain yield; it is not clear if augmentation of iron toxic soil with compost derived from cattle dung + maize stover will help in mitigating the effects of iron toxicity on lowland NERICA cultivars. Therefore this study was conducted to examine the effect of compost on growth, biomass and grain yield of two lowland NERICA and ITA 212 rice cultivars grown on iron toxic soil in Nigeria.

MATERIALS AND METHODS

Study site

The study was a pot experiment carried out in greenhouse of the Department of Botany, Faculty of Science, University of Ibadan, Ibadan between August - December, 2012. The experimental area is located at 7^0 26′ N and 3^0 54′E at an elevation of 215m above the sea level. One hundred and ninety two poly pots of 14 cm diameter with 18.5 cm depth were each filled with 3kg soil collected from a valley bottom known to show iron toxicity features.

Composting

Compost was prepared from combination of cattle dung and maize stover. Cattle dung was collected at the Faculty of Veterinary Medicine while maize stover was collected from teaching and research farm, both sites located in the University of Ibadan, Ibadan. The compost was prepared based on C:N ratio of 3:1using heap method described by Oworu and Dada (2009).

Soil collection

Soil used for the study was collected from valley bottom along Awolowo Hall Stream, University of Ibadan. The soil showing Fe toxicity symptoms (substances that looks like oil spills in the flood water and reddish stains in the soil) was collected with a spade within 0 – 15 cm depth. The soil was air-dried under shade before analysis.

Compost and soil analysis

At 75 days after preparation, matured compost sample was taken to laboratory for physico-chemical analysis after being air-dried at Department of Agronomy, University of Ibadan, Ibadan. Soil and compost samples were analysed for pH as described by McLean (1982); total Nitrogen using micro Kjeldahl procedure followed by distillation described by Bremner and Mulvaney (1982); Organic Carbon using the method described by Walkley (1947); Available potassium and sodium by flame photometry; phosphorus and extractable cations such as Ca^{2+}, Mg^{2+} and Fe^{2+} by Atomic Absorption Spectrophotometer (AAS). Also soil physical properties like sand, silt, clay and bulk density were also determined. Procedures described by IITA (2002) were adopted in determining the physical and chemical properties of the two samples.

Compost application and iron toxicity simulation

Each pot was filled with 3kg of soil and arranged in a completely randomized design. Each designated pot was incorporated with 0g, 6g, 12g and 18g of compost equivalent to 0, 4, 8 and 12t ha^{-1} per treatment a week prior to sowing. To ensure toxicity, 3000mg of $FeSO_4.7H_2O$ was dissolved in 1 litre of distilled water as described by Olaleye *et al.* (2009). The pots were watered to field capacity with 250 ml of the 3000mg L^{-1} of Fe solution 24 hours before sowing. The pots were regularly flooded with the solution every other day.

Planting materials

NERICA-L-1, NERICA-L-2 and ITA 212 were obtained from Africa Rice Centre, Ibadan substation located within International Institute of Tropical Agriculture (IITA), Ibadan. The two NERICA cultivars are lowland rice cultivars with scanty information on their response to iron toxicity whereas ITA 212 is a lowland rice cultivar susceptible to iron toxicity.

Treatments and experimental design

There were 12 treatments derived from combination of three lowland rice cultivars (NERICA-L-1, NERICA-L-2 and ITA 212) and four compost rates (0, 4, 8, and 12 tha^{-1}). The 12 treatments were arranged in completely randomized design (CRD) and replicated six times. There were two plants per treatment in each replicate.

Sowing and pot management

Six seeds were sown per pot through direct drilling. Two Weeks After Sowing (WAS), the seedlings were thinned to two plants per pot. Each pot was kept weed free as weeds were removed regularly.

Data collection

Growth data

Data were collected on number of leaves and tillers formed by visual counting; plant height was determined by measuring from the base to the tip of the tallest leaf at the middle of the plant. Leaf Area (LA) was measured by measuring the length and maximum width of each leaf in the middle tiller and compute the area of each leaf based on the length-width method : $LA = K \times L \times W$. Where LA = Leaf Area, K = 0.75 at vegetative stage and 0.67 at the maturity stage. L = length of leaf and W = maximum width of leaf (Gomez, 1972).

Iron toxicity score (ITS)

The iron toxicity score was based on ITS evaluation score of International Rice Research Institute (IRRI, 1984) on a 9 point scale. Where 1 = Very healthy and 9 = extremely susceptible.

Dry matter

At physiological maturity when 90% of the panicles have turned yellow, each plant was uprooted per pot. The root portion was washed under a flowing tap to remove all soil particles. The plants were separated into shoot and root portions and spread on work bench to air dry for six hours. The air dried plant samples were oven dried at 70^0C to a constant weight.

Yield data

Data were collected on the number of panicles, number of tillers, number of effective tillers and grain yield (g/plant).

Statistical analysis

Analysis of variance (ANOVA) was used to analyse the data and differences in means were separated with least significant difference (LSD) at P ≤ 0.05 using Statistical Analysis System software Version 9. (SAS, 2002). Correlation and simple regression analyses were made by relating grain yield to growth and ITS parameters. The model expressing the relationship between grain yield (Y) and independent variables was as given below:

$Y = f(x_1, x_2, x_3, x_4, x_5, e_1)$, Where: Y= grain yield, x_1 = Number of leaves with iron toxicity symptoms, x_2 = Plant height, x_3 = Number of effective tillers, x_4, = Number of tillers, x_5 = Iron toxicity score, e_1= Error term.

RESULTS

Table 1 show the results of physical and chemical characteristics of compost and soil (0-15cm) used for the study. The compost is rich in organic matter ($46gkg^{-1}$) and plant nutrients especially N ($4.6gkg^{-1}$), P ($15.3\ mgkg^{-1}$) and K ($0.62\ cmolkg^{-1}$) which were higher than those found in the soil used for the study. Growth response of lowland rice on toxic soil amended with compost is presented in Table 2. The results reveal that there were significant differences in the growth responses of the three rice cultivars to varying rates of compost applied to amend the iron toxic soil. NERICA-L-2 had significantly highest number of leaves in soil augmented with 8t ha^{-1} of compost at the vegetative stage while NERICA-L-1 had highest leaves in soil amended with 12t ha^{-1} of compost at the reproductive stage. However at maturity stage ITA 212 cultivar grown on soil augmented with 8t ha^{-1} compost had significantly highest number of leaves but not significantly different from NERICA-L-1 cultivar grown on pot amended with 12t ha^{-1} of compost.

Growth response of the three rice cultivars increased with increase in compost rate where better performance was observed on higher compost rates between 8 – 12t ha^{-1}. Leaf formed was significantly enhanced by augmentation of iron toxic soil with compost as minimal leaf formation was observed in the control plants. Leaf formation appeared directly proportional to the rate of compost applied. At the earlier growth stage, the performance of newly introduced NERICA cultivars was better on compost augmented pots than the susceptible ITA 212 cultivar whose performance peaked at the senescence growth stage (Table 2). This could be linked to early maturity trait of the NERICA cultivars which could have made it possible for these improved cultivars to escape the effect of iron toxicity in such soil environment before it becomes intense.

The performance of the three cultivars with respect to leaf area showed that NERICA-L-1 had highest leaf area across the three growth stages in soils augmented with compost rates ranging from 8 – 12t ha^{-1}. The performance of three cultivars was poor in control plants as it relates to leaf area coverage (Table 2). The results suggest that plants with higher leaf area values are better in performance as a result of the ability to capture solar energy and ultimately serve as an efficient source for assimilate partitioning than those of control with low leaf area. Hence the negative effect of iron toxicity on leaf area may have direct influence in reducing assimilate partitioning into sink of the plant.

Application of compost to lowland rice cultivars grown on toxic soil had no significant influence on plant height of the crop at the vegetative growth phase. However, application of varying compost rates had significant effect on height of the three lowland rice cultivars at reproductive and maturity stages. NERICA-L-2 had tallest plants in soil augmented with 8t ha^{-1} of compost at reproductive. At the early vegetative stage where no significant difference was noticed implies that the iron toxicity effect is not likely to have harmful effect on rice at the logarithmic phase. Shortest plants were observed in control soil which suggests that iron toxicity retards rice growth as reported by Audebert (2006), Olaleye *et al.* (2009). The response of the crop to compost application on iron toxic soil with respect to height suggests that compost possesses some growth promoting substances that tend to enhance stem elongation, which is a very important morphological trait needed for successful rice cultivation in hydromophic environment.

Tiller formation was adversely affected by iron toxicity as observed in the control soil. Tiller production was significantly influenced by compost application. NERICA-L-2 and ITA 212 had the highest tillers in pots amended with 8t ha^{-1}. Highest tiller formation was observed in soil amended with 8t ha^{-1} in all the three cultivars although this observation was not significantly different from that in plants augmented with other compost rates (Table 2). It therefore means that tiller formation in iron toxic soil can be promoted by compost application. This may be linked to the ability of organic matter component of the applied compost to promote better aeration and retention of moisture while increasing buffering and exchange capacity of soils thereby suppressing the deleterious effect of ferrous solution on the plant growth (Weber, 1996, Arancon and Edwards 2005, Herviyanti, 2006).

Effect of compost on biomass yield of the three rice cultivars grown on iron toxic soil is shown in Table 3. The results reveal that compost application had significant effect on biomass yield of the three rice cultivars. Shoot and root biomass yield of ITA 212 was significantly highest in soil augmented with 4t ha^{-1} and 12t $ha^{-1}$of compost respectively. Nonetheless, NERICA-L-1 grown in soil amended with 8t ha^{-1} of compost had significantly highest total biomass yield. Least biomass yield was observed in unfertilized pots in all the three cultivars. Also, NERICA-L-1 soil augmented with 8t ha-1 had the highest relative growth rate of 0.11g day^{-1}(Table 3). The better biomass yield observed on compost amended soil implies that the compost supplies sufficient nutrient for biomass accumulation and partitioning for both biological and economic yield. It also means that the compost possibly serves as buffer in this acidic soil whereby nutrient contained in both soil and compost were possibly made available for necessary plant metabolic process. The steady growth rate observed in NERICA-L-1 plots fertilized with 8t ha^{-1}

compost implies that compost application to iron toxic soil can help reduce the toxicity effect of dissolved Fe^{2+} especially in wetland rice growing environment.

Table 4 presents the effects of compost on yield and yield components of lowland rice cultivated on iron toxic soil. Application of 8t ha^{-1} to NERICA-L-1 had significant effect on effective tiller formation, number of panicles and grain yield. Whereas, highest harvest index was observed in NERICA-L-2 on soil amended with 8t ha^{-1} of compost, NERICA-L-1 had least harvest index in control pots. Application of compost to iron toxic soil enhanced yield and yield components of lowland rice cultivars. Highest grain yield observed in NERICA-L-1 grown in soil amended with 8t ha^{-1}compost indicates that the cultivar will perform optimally under anaerobic wetland soil when 8t ha^{-1} of compost is applied. The compost rate appeared optimal for this cultivar on iron toxic soil environment. Meanwhile highest harvest index obtained from lowland NERICA-L-2 soil and higher harvest index of NERICA-L-1 grown on soil augmented with same rate indicates the superiority of newly developed NERICA cultivars over ITA 212 a susceptible check.

The iron toxicity evaluation score (ITS) as proposed by IRRI (1984) revealed that ITA 212 had significantly highest (6.82) ITS but not significantly different from NERICA-L-2 (6.65) in control pots, while least score (3.76) was observed in NERICA-L-1 pots augmented with 12t ha^{-1} compost (Table 5). Meanwhile the susceptible cultivar, ITA 212 had least ITS on soil amended with 12t ha^{-1} compost. This implies that effects of iron toxicity on lowland rice can be reduced by applying appropriate quantity of compost. The newly released lowland NERICA cultivars tested in this study appeared fairly susceptible to iron toxicity and its growth may be retarded by the influence of dissolved Fe^{2+} solution under anaerobic situation. Nonetheless, augmenting iron toxic soil with compost may be a reliable solution to reduce harmful effects of iron toxicity in flooded rice growing areas as ITS reduced with increase in the rate of compost application. This agrees with the report of Audebert (2006) on lowland rice cultivars.

The relationship between ITS and growth as well as yield factors is presented in Table 6. ITS is significantly related to number of leaves (r = - 0.27) and grain weight (r = 0.24). Thus suggesting that severe ITS will lead to reduction in number of leaves formed. Also, number of leaves formed is significantly related to leaf area (r = 0.63), number of tillers (r = 0.46) and grain weight (r = -0.33). Similarly, plant height is significantly related to number of tillers, grain weight and effective tillering. This implies that the more the tillering and effective tillers the more the grain yield. Since grain yield is significantly related to the number of effective tillers, it is unlikely that improving soil condition to enhance tiller formation will help in improving grain yield in lowland rice production. Therefore reducing iron toxicity effect by applying compost to lowland rice field will help in boosting rice production in inland valleys of Nigeria.

The regression results in Table 7 shows the level of variation in grain yield (Y) explained by the independent variables. The two variables that have statistically significant coefficients are number of leaves with iron toxicity symptoms and number of effective tillers. The two variables are statistically significant at 5% and 1% level of significance respectively. Number of leaves affected is negatively signed indicating that a unit increase in this variable will decrease grain yield. This suggests that the more the leaves formed is affected by iron toxicity the less the grain yield. The number of effective tillers is significantly related to grain yield indicating that the more the number of panicle with fertile spikelets the more the quantity of grain produced by the crop. Thus the lower the effect of iron toxicity on leaf the better fertile tiller production becomes and ultimately, the better the grain yield.

Table 1. Physical and chemical characteristics of compost and soil (0-15cm) used for the study.

Parameters	Compost*	Soil
pH(H_2O)	6.5	6.5
pH(KCl)	5.5	5.4
Silt (%)	Nd	6.1
Clay (%)	Nd	10.8
Sand (%)	Nd	83.1
Bulk Density	Nd	1.7
Organic carbon (g/kg)	46.3	10.2
Total Nitrogen (g/kg)	4.6	1.0
Available P (mg/kg)	15.3	10.1
Exchangeable cations (cmol/kg)		
Na	0.4	0.5
Ca	1.4	1.1
Mg	0.8	0.5
K	0.6	0.5
Extractable micronutrients (mg/kg)		
Fe	167	56

*Dry weight basis Nd: Not determined

Table 2. Growth response of lowland rice grown on iron toxic soil augmented with compost

	Number of leaves plant^{-1}			Leaf area (cm^2) plant^{-1}			Plant height (cm) plant^{-1}			Number of tillers plant^{-1}		
Treatments	**Veg.**	**Rep.**	**Mat.**	**Veg.**	**Rep.**	**Mat.**	**Veg.**	**Rep.**	**Mat.**	**Veg**	**Rep.**	**Mat.**
NERICA-L-1 x 0t/ha	5.10 c	10.00 ab	7.17 c	151.00 b	479.60 c	362.22 abc	14.1 7a	38.03 bcd	45.42 e	1.83 a	2.00 ab	3.33 cd
NERICA-L-1 x 4t/ha	6.00 abc	11.33 ab	8.50 bc	187.75 ab	610.27 abc	397.21 ab	16.5 3a	40.42 bcd	46.37 e	2.17 a	2.17 ab	4.33 a
NERICA-L-1 x 8t/ha	6.17 abc	11.67 a	9.00 bc	199.67 ab	720.79 ab	437.93 a	18.0 7a	41.13 bc	49.50 de	1.83 a	2.33 a	4.33 a
NERICA-L-1 x 12t/ha	5.33 bc	12.00 a	10.1 7ab	246.23 a	750.50 a	421.63 ab	16.2 3a	44.63 ab	50.75 cde	1.67 a	2.00 ab	4.00 abc
NERICA-L-2 x 0t/ha	6.17 abc	10.33 ab	7.33 c	181.46 ab	553.14 bc	234.77 c	17.6 5a	44.08 ab	47.33 e	2.00 a	2.33 a	4.00 abc
NERICA-L-2 x 4t/ha	6.00 abc	10.50 ab	7.33 c	226.91 ab	619.84 abc	271.53 bc	15.2 5a	44.67 ab	47.33 e	1.83 a	2.17 ab	4.17 ab
NERICA-L-2 x 8t/ha	7.00 a	11.33 ab	7.50 c	224.89 ab	722.69 ab	269.70 bc	17.8 5a	48.60 a	54.63 bcd	2.00 a	2.00 ab	4.50 a
NERICA-L-2 x 12t/ha	6.00 abc	10.83 ab	8.33 bc	246.23 a	676.89 ab	314.03 abc	16.2 0a	48.25 a	49.62 cde	1.83 a	1.83 ab	3.50 bcd
ITA 212 x 0t/ha	5.80 abc	8.83 b	7.50 c	178.94 ab	592.33 abc	419.23 ab	17.1 2a	26.25 f	56.03 bc	2.30 a	2.33 a	3.00 d
ITA 212 x 4t/ha	5.67 bc	10.00 ab	10.6 7ab	179.82 ab	632.42 abc	369.35 abc	15.0 3a	28.87 ef	60.00 ab	2.00 a	2.00 ab	4.00 abc
ITA 212 x 8t/ha	6.17 abc	11.50 a	11.8 3a	210.02 ab	669.04 abc	309.71 abc	16.4 0a	33.37 de	63.68 a	2.17 a	1.83 ab	4.50 a
ITA 212 x 12t/ha	6.67 ab	10.17 ab	9.67 abc	202.79 ab	711.44 ab	386.85 abc	16.1 2a	35.27 cde	63.03 a	1.67 a	1.67 b	3.33 cd
Mean	**6.01**	**10.71**	**8.75**	**204.90**	**644.91**	**349.51**	**16.38**	**39.45**	**52.81**	**2.00**	**2.07**	**4.00**
LSD (0.05)	**1.25**	**2.56**	**2.57**	**93.51**	**196.71**	**161.34**	**3.98**	**7.10**	**6.01**	**0.86**	**0.55**	**0.83**

Data are means of four plants from six replicates. Means with similar alphabets are not significantly different at P>0.05 of LSD
Veg. = Vegetative, Rep = Reproductive and Mat = Maturity

Table 3. Biomass yield of lowland rice grown on iron toxic soil augmented with compost

Treatments	Biomass yield (g) $plant^{-1}$			Relative growth rate (g day^{-1})
	Shoot	Root	Total	
NERICA-L-1 x 0t/ha	8.91f	5.37b	13.29c	0.09c
NERICA-L-1 x 4t/ha	9.54efd	5.73b	15.48abc	0.10ab
NERICA-L-1 x 8t/ha	10.64cde	5.86b	19.11a	0.11a
NERICA-L-1 x 12t/ha	10.74bcd	5.91b	14.86abc	0.08d
NERICA-L-2 x 0t/ha	8.69f	5.34b	13.17c	0.09c
NERICA-L-2 x 4t/ha	9.04ef	5.35b	13.13c	0.10ab
NERICA-L-2 x 8t/ha	9.91cdef	5.49b	14.46bc	0.09c
NERICA-L-2 x 12t/ha	9.90cdef	5.55b	12.19c	0.08d
ITA 212 x 0t/ha	11.45bc	5.77b	18.04ab	0.07e
ITA 212 x 4t/ha	13.18a	5.99b	18.71ab	0.10ab
ITA 212 x 8t/ha	12.36ab	6.42ab	18.19ab	0.10ab
ITA 212 x 12t/ha	11.45bc	9.22a	18.22ab	0.10ab
Mean	**10.48**	**6.00**	**15.74**	**0.10**
LSD (0.05)	**1.67**	**2.96**	**4.39**	**0.01**

Data are means of four plants from six replicates. Means with similar alphabets are not significantly different at P>0.05 of LSD

Table 4. Yield and yield components of lowland rice grown on iron toxic soil augmented with compost

Treatments	Number of effective tillers $plant^{-1}$	Number of panicles $plant^{-1}$	Grain yield (g) $plant^{-1}$	Harvest Index $plant^{-1}$
NERICA-L-1 x 0t/ha	2.33a	2.83ab	5.63c	42.83f
NERICA-L-1 x 4t/ha	2.66a	3.00a	9.47ab	60.49abc
NERICA-L-1 x 8t/ha	2.83a	3.33a	11.69a	61.23abc
NERICA-L-1 x 12t/ha	2.33a	3.00a	9.64ab	64.84ab
NERICA-L-2 x 0t/ha	2.50a	3.00a	7.73bc	62.65ab
NERICA-L-2 x 4t/ha	2.83a	2.83ab	8.27bc	58.03abcd
NERICA-L-2 x 8t/ha	2.67a	2.83ab	9.59ab	67.45a
NERICA-L-2 x 12t/ha	2.67a	2.67ab	5.95c	48.87cdef
ITA 212 x 0t/ha	0.67b	1.33d	8.44abc	45.13ef
ITA 212 x 4t/ha	1.33b	1.67cd	8.66abc	46.54def
ITA 212 x 8t/ha	1.00b	1.67cd	10.24ab	53.39bcdef
ITA 212 x 12t/ha	1.17b	2.17bc	9.72ab	12.61g
Mean	**2.08**	**2.53**	**8.75**	**55.64**
LSD (0.05)	**0.81**	**0.76**	**3.26**	**12.61**

Data are means of four plants from six replicates. Means with similar alphabets are not significantly different at P>0.05 of LSD

Table 5. Iron toxic score of lowland rice grown on iron toxic soil augmented with compost

Treatments	Iron Toxic Score	Interpretation
NERICA-L-1 x 0t/ha	5.15b	Tolerant
NERICA-L-1 x 4t/ha	4.50b	Tolerant
NERICA-L-1 x 8t/ha	4.08b	Highly tolerant
NERICA-L-1 x 12t/ha	3.76b	Highly tolerant
NERICA-L-2 x 0t/ha	6.65a	Fairly susceptible
NERICA-L-2 x 4t/ha	4.99ab	Tolerant
NERICA-L-2 x 8t/ha	4.81b	Tolerant
NERICA-L-2 x 12t/ha	4.67b	Tolerant
ITA 212 x 0t/ha	6.82a	Fairly susceptible
ITA 212 x 4t/ha	4.08b	Highly tolerant
ITA 212 x 8t/ha	4.32b	Highly tolerant
ITA 212 x 12t/ha	4.24b	Highly tolerant
Mean	**4.72**	
LSD (0.05)	**1.84**	

Data are means of four plants from six replicates. Means with similar alphabets are not significantly different at P>0.05 of LSD

Table 6. Correlation coefficients (r) among different traits of lowland rice grown on iron toxic soil augmented with compost

	Iron toxicity score	Number of leaves	Plant height (cm)	Leaf area (cm^2)	Number of tillers	Grain yield (g)	Number of effective tillers
Iron toxicity score	1.00						
Number of leaves	- 0.27*	1.00					
Plant height (cm)	0.15	0.06	1.00				
Leaf area (cm^2)	- 0.07	0.63**	0.09	1.00			
Number of tillers	0.01	0.46**	- 0.44**	0.34**	1.00		
Grain yield (g)	0.24*	- 0.33 **	- 0.40**	- 0.06	0.30*	1.00	
Number of effective tillers	0.16	- 0.22	- 0.54**	- 0.13	0.45**	0.71**	1.00

* Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).

Table 7. Regression results of factors affecting grain yield on iron toxic soil augmented with compost

Functional form	B_0	x_1	x_2	x_3	x_4	x_5	R^1	Adj. R^2	F
Linear	1.86	- 2.15*	-0.31	4.72$^+$	1.19	0.99	0.55	0.52	16.28
Standard error	0.86	0.04	0.01	0.10	0.14	0.05			

*Parameter estimator and F value significant at 5%, + Parameter estimator significant at 1%

CONCLUSION

Iron toxicity had significant effect on growth and yield of lowland rice. Growth and yield is significantly related to severity of iron toxicity. Application of compost to iron toxic soil is a good agronomic practice that could be employed in reducing the deleterious effect of dissolved Fe^{2+} in lowland rice growing environments. Applying higher tonne (8-12t ha^{-1}) of compost per unit area will be beneficial to lowland rice cultivation in inland valleys than lower rates. Newly developed interspecific lowland NERICA cultivars appeared a better option than the susceptible ITA 212. In conclusion, this study recommends application of 8t ha^{-1} to lowland NERICAL-L-1in iron toxic environment such as inland valleys, rainfed lowland, irrigated lowland, deepwater and mangrove swamp.

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