ELEMENTAL COMPOSITION OF TWO RICE CULTIVARS UNDER POTENTIALLY TOXIC AN AQUEPT AND AQUENT

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Abstracts: *Iron toxicity is a major nutrient disorder affecting rice production of wetland rice in the irrigated and rainfed ecosystem in West Africa sub-region. Little attention has been paid to evaluating nutrient contents of rice cultivars grown on such soils and their relationship to the iron toxicity scores, grain yield and dry matter yields. A pot experiment was conducted on two potentially Fe-toxic soils (Aeric Fluvaquent and Aeric Tropaquept). The experiment was a 2 x 2 x 4 factorial experiment with three replicates in arranged in a randomized fashion. The factors were two soil types, two rice cultivars (ITA 212) and tolerant (Suakoko 8) and four* Fe^{2+} *levels (control, 1000, 3000 and 4000 mg* L^{-1}*). The result showed that for both susceptible cultivar (ITA 212) and the relatively tolerant (Suakoko 8) cultivar, little or no differences were observed in their elemental composition with regards to micro and macro-nutrients. For the susceptible cultivar, results showed that none of the tissue nutrients significantly relates to iron toxicity scores (ITS), grain yield and dry matter yield on both soil types. However, for the tolerant cultivar, ITS was observed to be significantly related to tissue K and P contents on the two soil types respectively. Tissue Ca and Mg were observed to be significantly related to the dry matter yield (DMY) on Aeric Tropquept. It could be concluded that for these rice cultivars grown on two potentially Fe-toxic soils, different tissue nutrients may trigger the manifestation of bronzing or yellowing symptoms of rice cultivars.*

Key words: Rice, wetlands, iron toxicity, soil, yield, tissue nutrients

INTRODUCTION

Iron toxicity (Fe) may be attributed to high iron content in the soil, low soil pH and soil fertility as well as by accumulation by of harmful organic acids and (or) hydrogen sulphide (Tanaka *et al*. 1966; Tanaka and Yoshida, 1970; Becker and Asch 2005). Plants generally show *bronzing* or *yellowing* symptoms if dissolved iron in the soil solution of the rhizosphere is in the 300 to 500mg/kg range. Excessive tissue Fe content (> 300 mg Fe/kg) is known to be toxic to rice plants. It has been reported that rice plants grown on such soils show little or no differences in their elemental composition with regards to macro and micro-nutrients (Sahrawat *et al*. 1996; Olaleye *et al*. 2000; Sahrawat 2000, Olaleye et al., 2008; Olaleye and Ogunkunle, 2008). Little attention has been given to determining which of the macro and micronutrients significantly relates to the iron toxicity scores, grain and dry matter yields.

If iron toxicity expressed as *bronzing* or *yellowing* is indeed triggered by excessive Fe^{2+} uptake and insufficient supply of several nutrients, then it is expected that several tissue nutrients would be significantly related to the iron toxicity scores (ITS), grain yield (GY) and dry matter yield (DMY) of these two rice cultivars on two iron toxic soil types (Aeric Tropaquept and Aeric Fluvaquent). This hypothesis was tested by the study below.

MATERIAL AND METHOD

Soils

The Soil samples (0-15 cm depth) used for this investigation were randomly collected at C-Hydromorphic plot of the International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State and Edozhigi, Niger State (representing humid forest and derived savannah agro-ecological zones respectively). The soil at Ibadan was classified as an Aeric Fluvaquent, whereas that in Niger State was classified as an Aeric Tropaquept (Olaleye, 1998). Soil samples were composited, air-dried and representative samples taken for laboratory analysis after being crushed to pass a 2-mm sieve and some to further pass a 0.5-mm sieve. Detailed soil analytical procedures were followed as described by Olaleye *et al*. (2000). Selected chemical properties of the soils are presented in Fig 1.

Iron studies

Four iron (Fe) levels (control, 1000, 3000 and 4000-mg Fe L^{-1}) were prepared from $FeS0_4$, to be used with two rice cultivars (ITA 212 and Suakoko 8). The former variety was susceptible whereas the latter was relatively tolerant to Fe^{2+} toxicity.

Pot experiment.

The experiment was a 2 x 2 x 4 factorial experiment with three replicates in arranged in a randomized fashion. The factors were two soil types, two rice cultivars and four Fe^{2+} levels (control, 1000, 3000 and 4000 mg L^{-1}). Soils (4 kg) were placed in 5-liter plastic pots and were thoroughly mixed with a basal fertilizer application. In the Aeric Fluvaquent (Derived Savannah), the fertilizers were applied at the rates of 560-mg N/pot, 48-mg P_2O_5/pot, 100-mg K_2O/pot and 26-mg Zn /pot whereas in the Aeric Tropaquept (Humid forest), 560-mg N/pot, 200-mg P_2O_5/pot and 26-mg Zn /pots were applied. Standing water of about 2-3-cm depth was maintained throughout the crop growth. The water used for irrigation was de-ionized water of good quality having pH ranging between 6.8 and 7.1. Seedlings of about 23 day-old of uniform vigor were transplanted at the rate of four seedlings/pot into the reduced soils where Fe treatments were introduced a week after transplanting.

Plant samplings

Plant samples with different degrees of bronzing symptoms were scored redundant visually using a scale of 1-9 based on the International Rice Research Institute (IRRI) standard evaluation systems for rice (IRRI 1988). A score of 1 suggests normal growth and tillering, while a score of 9 indicated that almost all plants are dead/dying. Plant samplings were carried-out per pot/treatment at 30 60 and 90 days after transplanting (DAT). They were washed with 0.1% teepol solution to avoid contamination especially of Fe and were then rinsed with de-ionized water. The washed plant samples were oven-dried at a temperature of 65 °C for 12 hours, cut and ground using mortal and pestle for easy digestion by a concentrated double acid (2:1 nitric and perchloric acids) mixture. Detailed methodology is described elsewhere (Olaleye *et al.* 2000).

Dry matter and Grain yield

The crops were harvested when most of the panicles turned yellow. The grain yield (GY) and dry matter yield (DMY) were recorded.

Statistical Analysis

Multiple regression analysis was used to evaluate which tissue nutrient contents (dependent variables) significantly relate to ITS, GY and the DMY (independent variables) at P=0.05% using SAS (SAS Inst., 1996).

RESULTS AND DISCUSSION

The soil chemical properties of the two soils are low when compared with the critical values (Tanaka and Yoshida 1970;Senadhira 1994 and Sahrawat *et al.* 1997) (Fig 1). The active Fe content (Fe_H) is very high compared with the critical level of 1.25% (Singh, 1992). This showed that these soils are potentially very iron toxic. The mean tissue nutrient contents showed that no apparent differences exist in the two rice cultivars on both soil types (Fig 2.). Tissue Fe content in both rice cultivars was observed to be in excess of 300mg/kg (i.e. in the toxic range). This was in agreement with the results of Fageria and Rabelo, (1987); Sahrawat *et al.* (1996); Olaleye *et al*. (2000) and Sahrawat, (2000) and Olaleye et al., 2009.

The mean iron toxicity scores (ITS), grain yield (GY) and dry matter yield (DMY) are presented in Fig 3. The tolerant cultivar (Suakoko 8) out-yielded the susceptible check on both soil types in terms of GY (g/pot). Furthermore, results showed that the DMY was much affected by the Fe^{2+} levels on both soil types. This was in agreement with the findings of Fageria and Rabelo, (1987) and Olaleye and Ogunkunle, (2008). In addition, the mean ITS ranged between 2.25 and 2.50, though low, the mean tissue Fe contents ranged between 270 and 322 mg Fe kg^{-1} dry weight.

The result of step-wise multiple regression analysis is presented in Table 1. For the susceptible check (ITA 212) grown on both soil types, none of the tissue nutrients significantly relates to ITS, GY and DMY at P=0.05%. However, on Aeric Fluvaquent, the ITS of a tolerant check (Suakoko 8) was observed to be significantly related to tissue K content (P=0.02%). The regression equation is given as: ITS =

3.109 – 1.13 (K), $R^2 = 0.421$. Similarly, on both soil types, results showed that none of the tissue nutrients significantly relates to GY and DMY on Aeric Fluvaquent. However, on Aeric Tropaquept, the ITS of a tolerant cultivar (Sukoko 8) appeared to be significantly related to the tissue P content, but the R^2=0.276 appeared to be low. In addition, on the same soil type, of all the yield attributes (GY and DMY), only the DMY appeared to be significant related to tissue Ca and Mg with R^2= 0.559.

The results of the regression analysis still points to the fact that deficiencies of P and K in both soil solution and tissues, may trigger bronzing symptoms of rice cultivars grown such soils. This was in agreement with the result of earlier authors that deficiencies of P, K, Zn Ca, and Mg in relation to N would result in excessive Fe^{2+} uptake (Benckiser *et al*. 1984a; Benckiser *et al*. 1984b and Olaleye *et al*. 2000; Olaleye et al., 2009). The importance of P, K and Ca has been demonstrated to improve the oxidizing capacity of rice roots and thus increase its iron excluding capacity rice roots (Wyn Jones and Lunt, 1967).

CONCLUSIONS

The result of this study clearly showed that soil types significantly would influence tissue nutrient contents of rice cultivars grown on it. The *bronzing* symptoms of some rice cultivars on two soil types is a function of different tissue nutrient contents, in this case, K and P contents for the tolerant cultivar (Suakoko 8).

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REFERENCES

1. Benckiser, G., Ottow, J.C.G., Watanabe, I and Santiago, S. (1984b). The mechanisms of excessive iron-uptake (iron toxicity) of wetland rice. *J. Plant Nutr.* 7:177-185.
2. Benckiser, G., Santiago, S., Neue, H.U., Watanabe, I and Ottow, J.C.G. (1984a). Effect of fertilization on exudation, dehydrogenase activity, iron-reducing populations and Fe (II)-formation in the rhizosphere of rice (*Oryza sativa* L.) in relation to iron toxicity. *Plant and soil* 79:305-316.
3. Becker, M., Asch. F.(2005). Iron Toxicity – Conditions and management concepts. J. Plant Nutr. Soil Sci. 168, 558-573.
4. Fageria, N.K. and Rabelo, N.A. (1987). Tolerance of rice cultivars to Iron toxicity. *J. Plant Nutr.* 10 (6): 653-661.
5. International Rice Research Institute (IRRI). (1988). Standard evaluation system for rice. International Rice Research Institute, Los Banos, Philippines.
6. Olaleye A.O,, Tabi, F.O., Ogunkunle, A.O., Singh, B.N. and Sahrawat, K.L., (2000). The effect of toxic iron concentration on the growth of lowland rice. *J. Plant Nutr.* USA. Article accepted on the 22nd May 2000. 24 Issue 2.

7. Olaleye A.O., Ogunkunle, A.O. and Sahrawat, K.L., (2000). Forms and pedogenetic distribution of extractable iron in selected wetland soils in Nigeria. *Commun. Soil Sci. & Plant Anal*. 31 (7-8), 923-941.

8. Olaleye, A.O. (1998). Characterization, evaluation, nutrient dynamics and rice yield of selected wetland soils in Nigeria. Ph.D. Thesis, University of Ibadan. 205p.

9. Olaleye, A.O., A. O. Ogunkunle, B. N. Singh, G. E. Akinbola, F. O. Tabi, O. O. Fayinminu, and M. E. Iji. 2009. Ratios of Nutrients in Lowland Rice Grown on Two Iron Toxic Soils in Nigeria. *J. Plant Nutr*. 32 Issue 8:1-17.

10. Olaleye, A.O and Ogunkunle, A.O. 2008. Management of Two Potentially Iron Toxic Benchmark Wetlands Using Integrated Approach for Rice Production in Nigeria. *J. Agronmy and Crop Science*. Doi: 0.111/j1439-037x.2008.0030.x

11. Olaleye, A.O. and A.O. Ogunkunle and G.E. Akinbola.(2008). Dynamics of iron oxides in two benchmark inland valley soils and rice grain yields in Nigeria. *Communications in Soil Science and Plant Analysis* (USA). Volume 39: Issue (19&20): 2939-2949.

12. Sahrawat K.L; Mulbah, C.K; Diatta, S., Delaune, R.D., Patrick Jr; W.H., Singh, B.N and Jones, M.P. (1996). The role of tolerant genotypes and plant nutrients in the management of iron toxicity in lowland rice. *J. Agric. Sci.* 126, 143-149.

13. Sahrawat, K.L, Jones, M.P. and Diatta, S. (1997). Extractable phosphorus and rice yield in an Ultisol of the humid forest zone in West Africa. Commun. *Soil Sci. Plant Anal.* 28: 9-10, 711-716.

14. Sahrawat, K.L. (2000). Elemental composition of rice plants as affected by iron toxicity under field conditions. *Commn. Soil Sci. Plant Anal.* 31 (17-18): 2819-2827.

15. Statistical Analysis Systems (SAS) Institute Inc. (1996). SAS User's guide: statistics. Version 6th Edition. Cary, North Carolina.

16. Singh, B.P., (1992). Characteristics of Fe-toxic soils and affected plants and their correction in acid Haplaquents of Mehalaya. *IRRI News* 2 (2): 18-19.

17. Tanaka, A. and Yoshida, S. (1970). Nutritional disorders of the rice plant in Asia. Int. Rice Res. *Inst. Tech. Bull.* 10. 51p.

18. Tanaka, A.R., Loe, R. and Navasero, R., (1966). Some mechanisms involved in the development of iron toxicity symptoms in the rice plant. *Soil Sci. Plant Nutr.* 12:158-164.

19. Tanaka, A. and Yoshida, S., (1970). Nutritional disorders of the rice plant in Asia. *IRRI Technical Bull*. 10. IRRI Manila Phillipines

20. Wyn Jones, R.G and Lunt, O.R., (1967). The function of Calcium in plants. *Bot. Rev*.33:407-426.

Table 1

Results of multiple regression analysis of the tolerant check (Suakoko 8) on Aeric Fluvaquent and Aeric Tropaquept

		Aeric Fluvaquent **Independent variable = ITS**		R^2=0.421	
Regression	DF‡	Sum of Squares	Mean squares	F	Prop>F†
Error	1	2.634	2.634	7.28	0.022
Total	10	3.616	0.362		
	11	6.250			
Variables	Parameter estimate	Standard error	Type II sum of squares	F	Prop> F†
K	-1.127	0.417	2.634	7.28	0.022

		Aeric Tropaquept Independent variable = ITS		R^2=0.276	
Regression	DF‡	Sum of Squares	Mean squares	F	Prop>F†
Error	1	1.723	1.723	3.81	0.079
Total	10	4.527	0.453		
	11	6.250			
Variables	Parameter estimate	Standard error	Type II sum of squares	F	Prop> F†
Intercept	3.671	1.004	6.056	13.38	0.004
P	-13.515	6.927	1.723	3.81	0.079

		Aeric Tropaquept Independent variable = Dry matter yield (DMY)		R^2=0.559	
Regression	DF‡	Sum of Squares	Mean squares	F	Prop>F†
Error	2	2523.102	1261.551	5.70	0.025
Total	9	1990.718	221.191		
	11	4513.820			
Variables	Parameter estimate	Standard error	Type II sum of squares	F	Prop > F†
Ca	-73.713	22.190	2440.860	11.04	0.01
Mg	143.387	60.345	1248.841	5.65	0.04

‡DF= degrees of freedom
†Level of significance P=0.05%

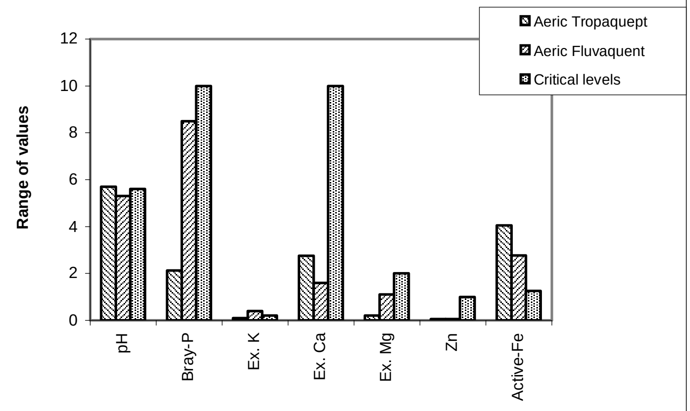

Fig 1. Important soil chemical properties of iron toxic soils

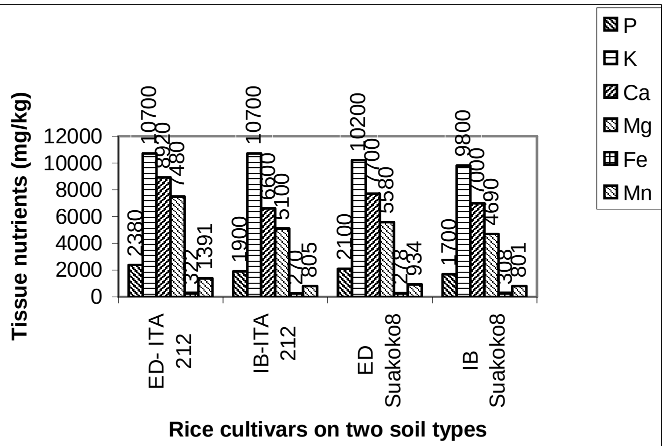

Fig 2. Tissue nutrient contents in two rice cultivars on two soil types