Comparative tolerance of *Oryza sativa* and *O. glaberrima* rice cultivars for iron toxicity in West Africa

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Iron toxicity is a widespread nutrient disorder that affects wetland rice growing in the humid tropical regions of Asia and Africa. It has been estimated that 30–40% of the inland swamps in the humid forest and savanna zones in West Africa are affected by varying degrees of iron toxicity stress. The disorder is caused by the accumulation of excessive amounts of iron in rice plants growing under rainfed and irrigated lowland conditions. In West Africa, iron toxicity causes rice yield losses varying from 12% to 100%, depending on the intensity of the stress and the iron tolerance of the variety (Sahrawat et al 1996).

Rice cultivars differ in their tolerance for iron toxicity and the selection of rice cultivars with superior tolerance for iron toxicity is an important component of research for reducing iron toxicity. However, sustained increased rice productivity on iron-toxic soils can be achieved only through the integrated use of tolerant genotypes with nutrient and water management. Scope for sustained increases in lowland rice yields is especially high under irrigated conditions through a combined use of iron-tolerant cultivars and the application of plant nutrients.

Iron toxicity is a physiological disorder and the application of other plant nutrients plays a physiological role in the rice plant to overcome the stress and grow normally under high concentrations of ferrous iron in soil solution (Yoshida 1981). The high amount of iron in the growing medium causes an imbalance in nutrients such as P, K, and Ca, and applying these nutrients corrects this imbalance, reduces iron toxicity, and increases yield in lowland rice (Ottow et al 1983). However, in irrigated rice on mineral soils, Ca deficiency is rare, except on acid sulfate soils. P, K, and Zn, along with N, therefore play a more important role in reducing iron toxicity (Sahrawat et al 1996).

Recently, we observed that some *Oryza glaberrima* cultivars adapted to lowland rice-growing conditions have a higher tolerance for iron toxicity than their *O. sativa* counterparts. This report describes results of the comparative evaluation of promising *O. sativa* and *O. glaberrima* rice varieties for iron tolerance in field experiments conducted for two seasons at an iron-toxic site at Korhogo in the savanna zone of Côte d'Ivoire. The varieties tested were selected from a large number of cultivars through an initial screening for iron toxicity tolerance.

The soil at the experimental site was an Ultisol (pH water, 5.2; pH KCl, 3.9; organic C, 12 g kg^{-1}; Bray 1 extractable P, 9 mg kg^{-1}; exchangeable K, 0.08 cmol kg^{-1}; exchangeable Mg, 0.30 cmol kg^{-1}; DTPA extractable Fe, 325 mg kg^{-1}; DTPA extractable Zn, 5 mg kg^{-1}). The contribution of ferrous iron through interflow from upper slopes in this gently sloping experimental site was low and less important than the release of ferrous iron in situ in causing iron toxicity in wetland rice. Moreover, the interflow of iron does not occur in the dry season (because of no rain), although iron toxicity intensity is higher in the dry season than in the wet season (Sahrawat and Singh 1998). Following submergence under water, the soil releases ferrous iron concentrations ranging from 50 to 150 mg L^{-1} in soil solution during 3–10 wk after flooding (Narteh and Sahrawat 1999).

Field experiments were conducted under irrigated conditions in the 2000 dry (Jan-May) and wet (Jul-Nov) seasons. The lowland rice varieties tested were CK4, an iron-tolerant variety; Bouaké 189, an iron-susceptible cultivar; and CG14, a tolerant variety that does not show iron toxicity symptoms. While CK4 and Bouaké 189 belong to *O. sativa*, CG14 belongs to *O. glaberrima* and is native to Africa. Each season, the effects of nine nutrient treatments (no fertilizer, N, N + P, N + K, N + Zn, N + P + Zn, N + K + Zn, N + P + K, N + P + K + Zn) were tested in a randomized complete block design with four replications. The plot size was 24 m^2. Nitrogen was applied at 100 kg N ha^{-1} as urea in three splits; P at 50 kg P ha^{-1} as triple superphosphate; K at 80 kg K ha^{-1} as potassium chloride; and Zn at 10 kg Zn ha^{-1} as zinc oxide.

All nutrients, except N, were added as basal applications. Rice seedlings (3–4 wk old) were transplanted using a spacing of 0.25 × 0.25 m. For this paper, only nutrient treatments with no fertilizer and N + P + K + Zn were used.

During the two seasons of evaluation, although CK4 and Bouaké 189 plants showed iron toxicity symptoms in varying degrees, CG14 plants did not show any iron toxicity symptoms at all as measured by iron toxicity scores (ITS). The intensity of iron toxicity based on the extent of bronzing symptoms on leaves 60 d after transplanting (DAT) was higher without nutrient application. Applying nutrients reduced iron toxicity as indicated by a lower ITS.

In general, rice yields were higher in the wet season than in the dry season, and the application of P, K, or Zn with N increased grain yield and total biomass production over the control (no nutrient). The combined application of N + P + K + Zn significantly increased grain and total biomass (grain plus straw) yields in the three varieties. Without the application of nutrients, CK4 had the highest biomass and grain yield, followed by CG14 and Bouaké 189. With the application of nutrients, CK4 had the highest biomass and grain yield, followed by Bouaké 189 and CG14 (see table). A comparison of the performance of the three varieties based on the two seasons' pooled data showed that, without applying nutrients, all varieties had similar grain yields, but, with the application of plant nutrients, CK4 and Bouaké 189 had significantly higher yields than CG14. The grain yields of CK4 and Bouaké 189 were on a par.

Although CG14 did not have high grain yields because of its lower harvest index, lodging of the crop, especially under the application of nutrients, and shattering of seeds at maturity, the variety showed remarkable tolerance for iron toxicity stress. Results show that CG14 has a high tolerance for iron toxicity and remains an obvious choice as a donor for iron tolerance in a breeding program. An integrated use of a tolerant variety and plant nutrients is needed for sustained productivity in irrigated lowland rice on soils where iron toxicity exists.

References

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Iron toxicity scores (ITS) of rice plants at 60 d after transplanting, and grain and grain plus straw yields.

Treatment	CK4			Bouaké 189			CG14		
	Grain ($t\ ha^{-1}$)	Biomass ($t\ ha^{-1}$)	ITS[a]	Grain ($t\ ha^{-1}$)	Biomass ($t\ ha^{-1}$)	ITS	Grain ($t\ ha^{-1}$)	Biomass ($t\ ha^{-1}$)	ITS
2000 dry season									
No nutrients	2.0	5.4	5	1.6	3.9	6	1.8	3.7	1
N + P + K + Zn	3.2	8.5	2	2.6	5.9	3	2.0	6.0	1
Mean	2.6	6.9		2.1	4.9		1.9	4.8	
LSD (0.05)	0.42	1.60		0.41	1.65		0.31	1.15	
2000 wet season									
No nutrients	2.9	5.6	5	2.4	5.0	5	2.8	5.6	1
N + P + K + Zn	5.9	11.0	2	5.9	12.2	3	3.7	7.8	1
Mean	4.4	8.3		4.2	8.6		3.3	6.7	
LSD (0.05)	1.11	2.01		0.75	1.95		0.67	2.11	
Av of dry and wet seasons									
No nutrients	2.5	5.5	5	2.0	4.4	6	2.3	4.7	1
N + P + K + Zn	4.5	9.8	2	4.2	9.1	3	2.9	6.9	1
LSD (0.05)	0.77	1.91		0.58	1.80		0.50	1.63	

[a]The iron toxicity scoring system is based on the extent of bronzing symptoms on rice plant leaves and uses a scale from 1 to 9. A score of 1 indicates normal growth and 9 indicates that most plants are dead or dying.