Iron tolerance of some rice varieties (*Oryza sativa* L.) commonly grown in Nigeria.

E.O. AJAYI and J.A. ADEPETU,
Department of Soil Science,
University of Ife,
Ile-Ife, Nigeria.

Abstract

A green house study was conducted to determine the Fe tolerance of six rice varieties commonly grown in Nigeria. The varieties were grown on a soil to which variable levels (0 - 150ppm) of Fe were applied as Fe-EDTA.

Increasing concentration of Fe up to 150ppm did not affect tiller number at 8 weeks after seeding. Similarly, plant height did not improve except for slight increases in the variety, FARO 17 up to 25ppm. In terms of dry matter yield within the range of Fe applied, the order of tolerance of the varieties to Fe-deficiency was FARO 25> FARO 15 > FARO 8 > FARO 11 > FARO 12 >FARO 17, while the order of resistance to Fe toxicity was FARO 15 > FARO-8 > FARO-12 > FARO-17 > FARO-11 > FARO-25. Therefore, FARO 15 should thrive very well over a wide range (high to low) of available soil Fe. FARO 8 would yield well on soils high in soluble Fe which may be toxic to other varieties. FARO 17 and FARO 12 will require moderately high level of available Fe for optimum yield whereas a relatively low level of Fe will be required to give optimum yields in FARO 11 and FARO 25.

Introduction

Erratic response of rice-crop to application of primary nutrients N, P, K could be due to micronutrient problems such as toxicity or deficiency of Iron (Fe). A survey of nutritional disorders of rice across Nigeria indicated Fe deficiency in some localised upland conditions and Fe toxicity in lowland acid soils with low macronutrient status (NAFPP, 1975).

In Borno State of Nigeria, the type of chlorosis that usually appears on young leaves of rice grown on calcareous or alkaline vertisols to which recommended levels of macronutrient fertilizer have been applied, suggests mainly Fe deficiency. At Edozhighi (Niger State), Bakura (Sokoto State), Ajaokuta (Kwara State) and Itoikin (Lagos State), Fe toxicity has been suspencted to be involved in reducing the growth and yield potentials of promising rice varieties; and some varieties are known to be tolerant (Njoku, 1977; Ayotade, 1979).

The growth of upland rice is affected by fluctuating annual precipitation and distribution of rain and temperature (De Datta *et al.,* 1974). That of swamp rice is affected by changes in chemical and electrochemical properties prevailing in the submerged condition (Savant and Kibe, 1969). These changes will also affect the ionic concentration of soil solution available to the plant. When there is excess soluble Fe in soil solution, oxidation of the Fe^{2+} to Fe^{3+} occurs in the rhizosphere of rice; but when solution Fe is low, reduction of Fe^{3+} to Fe^{2+} occurs. The ability to oxidise or reduce the Fe forms probably vary among rice varieties; hence, the tolerance of rice to high or low reduction potential in the environment should vary with varieties.

The objective of this study was to evaluate some commonly grown varieties of rice for their relative tolerance to Fe deficiency and/or toxicity in soil, with a view to optimising rice production in areas where Fe level in soil may constitute a limiting factor to rice cultivation and yield.

Materials and methods

The study was carried out in the greehouse. Six varieities of rice viz:- FARO 11, FARO 25, FARO 8, FARO 12, FARO 15 and FARO 17 were used in the experiment. The first two varieties are upland while the others are lowland varieties. The soil used was collected from the University of Ife Teaching and Research Farm low fertility plots (i.e. cropped continuously for 10 years without fertilization). It belongs to the Iwo soil series and has: 6.1 ppm available P (Bray-1), 34ppm exchangeable K, 165 ppm exchangeable Ca, pH 5.8 ($CaCl_2$), 12.7 ppm Na-EDTA-extractable Fe, 1.4% OM, 17.0% clay and 76.0% sand. 4 kg of the soil was weighed in each 5l. plastic pot before directly seeding each rice variety. The seedlings were thinned to 10 per pot three weeks after seeding. Fe was then applied as Fe-EDTA at the rates of 0, 5, 10, 25, 50, 75, 100 and 150 ppm per pot. Also, equivalents of 120kg N/ha, 35kg P/ha and 60kg K/ha were applied to each pot. Treatments were replicated thrice for each variety.

For FARO 8, FARO 12, FARO 15 and FARO 17, the soil was submerged while FARO 11 and FARO 25 were grown under upland condition. All the varieties were allowed to grow for additional five weeks.

Plant height and tiller number were recorded for all varieties at 8 weeks. Whole plants per pot were also harvested, washed in deionized distilled water and oven-dried at 80°C before the dry weights were recorded.

Results and Discussions

Treatments with less than 25ppm Fe in soil showed severe interveinal chlorosis on FARO 12 and FARO 17. The chlorosis was mild on FARO 8 and FARO 15, hardly noticeable on FARO 11 and none on FARO 20. Except in FARO 12 and FARO 17, the chlorosis had eseentially disappeared at the end of the experiment (8 weeks after seeding).

Table 1 shows that increasing rates of applied Fe up to 150 ppm, did not influence the tiller number of any of the varieties during the 8 weeks of plant growth. Poor response of tiller to Fe treatments may be due to the short duration (8 weeks after seeding) of the experiment. On the other hand, plant height was influenced by the concentration of Fe applied. Maximum plant heights were attained at 25ppm for FARO 11, FARO 8 and FARO 17; at 10ppm for FARO 25 and FARO 12; and at 0ppm for FARO 15 (Table 2). The plant heights decreased thereafter as concentration of Fe increased. Over the whole range of Fe applied however, the differences in plant height were not much except for FARO 17. Unappreciable change of heights in five of the varieties. may be due to their ability to tolerate higher concentrations of Fe than the variety (FARO 17) whose height was markedly affected.

TABLE 1 – MEAN TILLER NUMBER OF SIX RICE VARIETIES AT 8 WEEKS AFTER SEEDING.

Fe Applied (ppm)	*FARO 11*	*FARO 25*	*FARO 8*	*FARO 12*	*FARO 15*	*FARO 17*	*Average*
0	10	10	10	10	10	11	10
5	10	9	10	10	10	12	10
10	11	9	11	11	10	11	11
25	10	10	10	11	10	11	10
50	11	9	10	11	10	10	10
75	9	9	10	10	10	10	10
100	9	10	12	10	10	11	10
150	9	8	10	11	10	10	10
Average	10	9	10	10	10	11	10

TABLE 2 – MEAN PLANT HEIGHTS (cm) OF SIX RICE VARIETIES AT 8 WEEKS AFTER SEEDING.

Fe Applied (ppm)	*FARO 11*	*FARO 25*	*FARO 8*	*FARO 12*	*FARO 15*	*FARO 17*
0	58.0	64.3	102.8	95.7	89.3	68.0
5	62.3	61.6	100.7	99.3	88.3	82.7
10	60.7	65.5	100.3	101.0	87.0	81.0
25	63.0	64.0	105.3	98.3	88.3	84.3
50	60.3	58.3	98.0	99.7	83.0	78.0
75	54.3	61.3	95.3	95.0	85.0	74.7
100	52.0	61.3	94.3	93.7	86.0	80.7
150	57.0	52.3	93.0	82.7	83.3	80.7

TABLE 3 – DRY MATTER YIELD (g) AT 8 WEEKS AFTER SEEDING OF SIX VARIETIES OF RICE SUPPLIED WITH VARYING CONCENTRATIONS OF Fe

	FARO 11	*FARO 25*	*FARO 8*	*FARO 12*	*FARO 15*	*FARO 17*
Level of Fe applied			*Dry Matter yield (g)*			
0	2.01	3.04	6.06	5.02	7.74	6.39
5	2.20	2.60	6.91	5.95	8.42	9.24
10	2.57	2.63	7.06	6.96	8.90	9.93
25	1.96	2.66	6.24	6.99	8.65	8.65
50	1.62	1.98	5.92	6.53	7.72	8.02
75	1.61	1.98	5.86	5.09	7.46	7.20
100	1.30	1.98	5.92	4.48	7.44	6.76
150	1.27	1.34	4.91	4.07	6.33	4.92

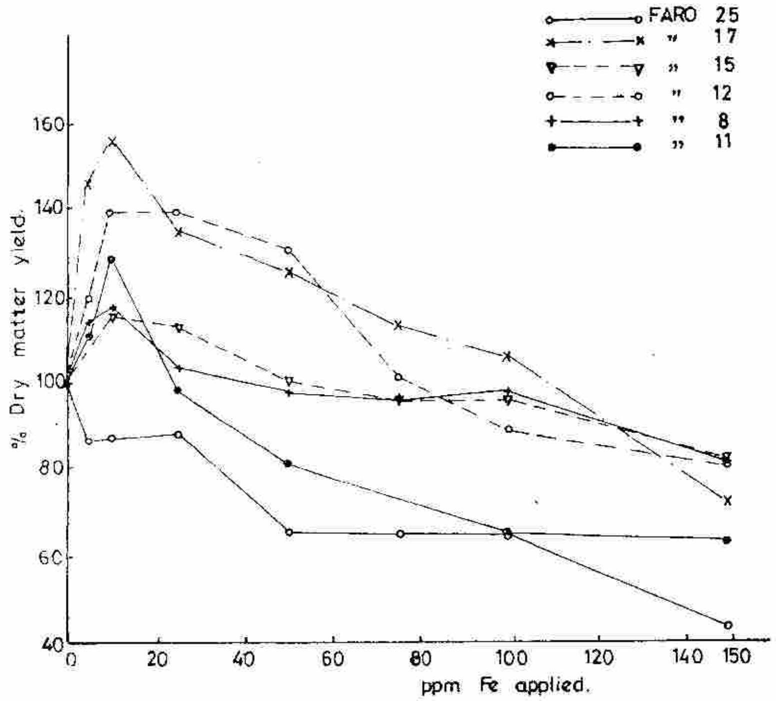

Fig. 1. Dry matter yield of six varieties of rice subjected to varying levels of Fe.

Table 3 and Fig. 1 respectively show the dry matter yield and percent dry matter yield of the six varieties (i.e. yield at other Fe treatments relative to yield at 0ppm Fe) at varying concentrations of Fe. The maximum dry matter yield of FARO 11 at 10ppm Fe amounted to 28% above the yield at 0ppm Fe, while 150 ppm Fe decreased yield of FARO 11 by 37%. FARO 25 had its highest yield when no Fe was applied; this means that application of Fe decreased yield of this variety in this soil. 150 ppm Fe reduced yield by 56% when compared with zero Fe treatment. Maximum yield of FARO 12 was at 10ppm Fe. Application of Fe up to 25ppm and 50ppm increased yield of FARO 12 by 37% and 30% respectively. Toxic effect of Fe on this variety became suspect at 100ppm and 150ppm where yield depressions of about 10% and 19% respectively were found. Maximum yield for FARO 17 was at 10ppm where there was an increase of 56% over the yield of rice receiving no Fe. Application of Fe up to 100ppm did not affect dry matter yield appreciably. However, 150ppm Fe reduced yield by 23%. The maximum dry matter yield of FARO 8 also at 10ppm was 16% greater than the zero treatment. Application of Fe up to 100ppm did not affect its yield appreciably, but 150ppm Fe reduced yield by 18%.

Marked yield reduction (37% and 56%) at 150ppm of the upland varieties (FARO 11 and FARO 25) indicate that these varieties cannot tolerate high levels of Fe in the soil. FARO 25 seemed to be especially susceptible to Fe toxicity. Highest yield of FARO 25 was at 0ppm Fe, suggesting that native Fe available in the soil used in this study (12.7ppm extractable Fe) was sufficient for optimum growth of the variety. It also indicates that FARO 25 was more tolerant of low level of Fe in the soil than FARO 11. A higher statistical F-ratio of the effect of Fe on the dry matter yield in FARO-25 than FARO-11 further indicates the greater susceptibility of FARO 25 to Fe toxicity.

The F-tests of the effect of increasing Fe concentration on dry matter yield of the swamp varieties were significant at 5% level for FARO 8 and at 1% level for FARO 15, FARO 17 and FARO 12. The effect of Fe was more apparent at the deficient range where increasing application of Fe up to the optimum level markedly increased dry matter yield.

The dry matter yield at 0ppm and 150 ppm Fe levels expressed as a percentage of the dry matter yield at the optimum Fe level for each variety, is presented in Table 4.

TABLE 4 – DRY MATTER YIELD AT 0ppm AND 150 ppm Fe EXPRESSED AS PERCENTAGE OF DRY MATTER YIELD AT OPTIMUM LEVELS OF Fe IN SIX VARIETIES OF RICE.

Rice Variety	*Fe applied (optimum level)*	*Dry matter yield (g) at optimum Fe*	*at 0ppm Fe*	*at 150ppm Fe*	*% Dry Matter Yield*[1]	*% Dry Matter yield*[2]
FARO 11	10 ppm	2.57	2.01	1.27	78.21	49.42
FARO 25	0 ppm	3.04	3.04	1.34	100.00	44.08
FARO 8	10 ppm	7.06	6.06	4.91	85.83	69.55
FARO 12	25 ppm	6.99	5.02	4.07	71.82	58.23
FARO 15	10 ppm	8.90	7.74	6.33	86.97	71.12
FARO 17	10 ppm	9.93	6.39	4.92	64.35	49.55

1 = Dry matter yield at 0ppm Fe expressed as % yield at optimum Fe level.

2 = Dry matter yield at 150 ppm Fe expressed as % yield at optimum Fe level.

The higher the percentage yield at 0ppm Fe, (which was assumed deficient) the closer is the yield to the optimum yield, and the more likely is the variety to tolerate Fe deficiency. The order of tolerance of low level of Fe by the four swamp varieties was therefore FARO 15 > FARO 8 > FARO 12 > FARO 17. In a similar manner, high value of percent dry matter yield at 150ppm would suggest relatively marked tolerance of Fe toxicity by the varieties. The order of tolerance of Fe toxicity by the varieties was therefore FARO 15 > FARO 8 > FARO 12 > FARO 17.

The differences in varietal tolerance of Fe toxicity and/or Fe deficiency are probably related to the morphological properties and biochemical activities of the rice root. The cortex and shoot of rice consist of continuous air space systems which permit gaseous diffusion between the atmosphere and the rhizosphere (Mitsui, 1964; John, 1979). Young rice roots have been shown to secrete oxygen through the glycolic pathway of respiration (Mitsui, 1955). Diffusion and secretion of oxygen by the root oxidise the rhizosphere, ensure oxidative uptake of nutrients and protect rice from toxic concentrations of Fe in soil solution. It has been found that riboflavin production and release of reducing substances by roots along with Fe accumulation and translocation capacity of plants enhance the ability of plants to utilize Fe under conditions of Fe stress (Kashirad and Maschner, 1974). Van Egmond and Aktas (1977) also found that under Fe stress, Fe efficient plants excrete relatively low amount of OH^- or high amount of HCO_3^- and lower anion uptake.

The extent to which the air space system is developed, the degree of oxidising power of the roots, the ability of the roots to excrete reducing substances and the capacity to produce riboflavin will influence uptake of Fe. The extent to which these characteristics are developed in each variety probably accounted for the differences in the varieties' tolerance of Fe deficiency and/or toxicity.

Comparison of all the varieties over the range of Fe concentration applied indicated the order of resistance to deficiency as FARO 25 > FARO 8 > FARO 11 > FARO 12 > FARO 17 and the order of resistance to Fe toxicity as FARO 15 > FARO 8 > FARO 12 > FARO 17 > FARO 11 > FARO 25. In terms of adaptability, the above orders seem to suggest that FARO 15 can thrive well over a wide range of available soil Fe levels. FARO 8 and FARO 15 will be the suitable lowland varieties for rice farmers operating on soils high in soluble Fe. FARO 17 and FARO 12 could be grown with good performance in areas where soil solution Fe is moderately high while FARO 11 and FARO 25 will be suitable for areas with low concentration of soil solution Fe.

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