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Assessment of extractants for available Fe and soil factors affecting iron chlorosis in upland rice in Southwestern Nigeria.

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Abstract

Available Fe in 23 surface soils from southwestern Nigeria was determined with five extractants, namely:
(1) 1N NH_4OAc + 0.01 M EDTA, pH 7.0; (2) 1N NH_4OAc, pH 4.8; (3) 0.01M EDTA; (4) 1N NaOAC, pH 4.8 and (5) 0.005M DTPA and correlated with Fe uptake by rice plants (CV. ART 8) grown under upland conditions in pot trials in the glasshouse. 0.005 M DTPA showed the highest correlation ($r = 0.54^{**}$) and 1N NH_4OAc pH 4.8 showed the least correlation ($r = 0.35$), with plant Fe uptake. The range of available Fe extracted by 0.005 M DTPA and 1N NH_4OAc + 0.01M EDTA was 1.8 — 6.7 ppm and 3.3 — 10.5 ppm respectively.

Regression analysis indicated that soil pH is a strong factor controlling both Fe availability and Fe uptake by upland rice in the moderately acid tropical soils. Organic carbon accounted for 17.4% and 15.0% of available FE extracted by 1N NH_4OAc + 0.01 M EDTA, pH 7.0 and 0.005 M DTPA respectively. 0.005 M DTPA extractant appeared the best of the five extractants for assessing the availability of Fe in the moderately acid tropical soils. Incorporation of organic manures — poultry and brewer's grain wastes, improved Fe uptake by the upland rice plants in a pot trial.

Introduction

Iron deficiency is most often associated with high pH (Okajima *et al,* 1970). In Nigeria, Moore and Adetunji (1966) observed iron chlorosis in a variety of plants grown on old dye boiling sites where a large quantity of ash had accumulated and soil pH had gone up to 8.2 Kang *et al* (1976) reported that although high soil pH associated with burnt spots or previous village refuse dumps could explain most of the iron deficiency symptoms observed on upland rice in Western Nigeria, high soil pH is not the only cause of Fe deficiency in the upland.

Field observations in southwestern Nigeria revealed that iron deficiency in upland rice generally shows up in patches when the crop is grown on a piece of land that has been under continuous cropping for more than two years after it was opened from bush fallow. This observation appears to justify the local farmers' practice of growing upland rice as the first crop after bush fallow, and also lends credence to the suggestion that iron deficiency in upland rice in moderately acid, highly weathered soils (pH5.0 — 6.5) of Western Nigeria may be related to the degree of degradation of organic matter in the soils. Parsa *et al* (1979) reported that incorporation of plant materials into the soil enhanced iron availability and significantly increased Fe uptake by sorghum.

Bole-Jones (1955) reported that the deficiency of K or high contents of P, Mn and

Cu in soils could cause anomalies in Fe uptake by plants. Moore and Adetunji (1966) observed that centrosema plants showing iron chlorosis were exceptionally high in P ($\geq$ 2.4%). They suggested the possibility of iron inactivation by P within the plant. Olsen (1972) has since demonstrated the importance of the negative interaction between P and Fe for several crops.

The objectives of the study were (1) to identify the most suitable extractants for available Fe in the upland, (2) to determine soil chemical factors that will reliably predict the availability and uptake of Fe by upland rice and (3) to determine the effect of organic manures of Fe uptake by upland rice.

Materials and Methods

Bulk surface (0—15cm) soil samples were taken from 23 sites with a wide range in parent materials, cropping history, physical and chemical properties. The soils were air-dried and passed through 2mm sieves. Five kilogrammes of each soil were weighed into 5-liter plastic pots in triplicates.

Reagent grade chemicals were used to supply 200 ppm N as urea, 50 ppm P as $NaH_2PO_4.2H_2O$, 80 ppm K as KCl, 20ppm Mg as $MgSO_4.7H_2O$, 10 ppm Zn as Zn chelate, 1 ppm B as H_3BO_3 and 5 ppm Cu as $CuSO_4$. All the reagents were applied to the soils as solutions and were thoroughly mixed with the soils before planting. The soils were watered to a pre-calculated field capacity level and allowed to stay for 24 hours before planting four upland rice seeds (cultivar ART 8) into each pot.

The pots were arranged in a randomized complete block design and watered regularly to field capacity with distilled water. The severity of chlorosis was scored six weeks after planting. The top growths of the plants were harvested at 8 weeks, dried at 70°C in a forced-air oven, weighed and analysed for Fe, K, P and Mn. Five extractants (1) 1N NH_4OAc + 0.01 M EDTA, pH 7.0, (2) 1N NH_4OAc, pH 4.8, (3) 0.01 M EDTA, pH 7.0, (4) 1N NaOAc, pH 4.8 and (5) 0.005 M DTPA, pH 7.3 were used to assess Fe availability in the soils.

One of the soils (Alagba series, Oxic Paleustalf from Ikenne) in which the plants showed severe chlorosis in this experiment was used in the second experiment to study the effects of organic manure addition on Fe uptake by upland rice. Soil incorporation of poultry manure and dried brewer's waste were compared with soil and seed application of Fe. The treatments consisted of (1) control, (2) 50 ppm Fe soil application, (3) seeds soaked for 24 hours in 1% Fe solution ($FeSO_4$), (4) soil plus poultry manure plus 50 ppm Fe, (6) soil plus brewer's waste ratio 20:1, (7 soil plus brewer's waste plus 50 ppm Fe. The treatments were replicated five times in randomized complete block design.

Nutrient supplementation in the soil, planting and watering procedures were as described in experiment one. Observations were taken on the severity of iron chlorosis, plant height and time of flowering. The Y-leaf (second leaf from top) was sampled at full heading for mineral analysis. The leaf tissue samples were digested with a tertiary mixture of perchloric-nitric-sulphuric acids (Jackson, 1958). The digest was analysed for P, K, Mn, Fe, Zn, Ca and Mg.

TABLE 1: THE MEAN AND THE RANGE OF PHYSICAL AND CHEMICAL PARAMETERS OF SOILS USED IN THE TRIAL

	Mean	*Range*
pH	6.2	5.1 — 6.7
CEC	4.1	2.1 — 13.2
Organic Carbon, %	1.4	0.4 — 2.6
Available P, ppm	5.4	1.9 — 12.9
Sand, %	77.5	55.4 — 87.4
Silt, %	14.7	7.0 — 39.0
Clay, %	7.9	5.0 — 13.6

TABLE 2: AMOUNTS OF AVAILABLE Fe EXTRACTED BY THE FIVE EXTRACTION METHODS

EXTRACTION METHOD	*Available Fe extracted (ppm)*	
	Mean	*Range*
IN NH_4OAc + 0.01M EDTA, pH 7.0	5.8	3.3 — 10.5
0.01M EDTA, pH 7.0	12.3	4.6 — 17.9
IN NH_4OAc, pH 4.8	1.1	0.6 — 6.8
IN NaOAc, pH 4.8	0.8	0.4 — 2.7
0.005 M DTPA, pH 7.3	3.5	1.8 — 6.7

Results and Discussion

Relationship between soil properties, rice growth characteristics, Fe uptake and Fe extracted by different methods

The average values and ranges of the physical and chemical characteristics of the soils used in the study are shown in Table 1. Table 2 shows the amounts of available Fe extracted by the five extraction methods.

Correlation data for the relationships between Fe uptake by the rice plants and other parameters are shown in Table 3. The number of tillers per pot, dry weight of top growth and Mn uptake showed significant correlations with Fe uptake (r = 0.57**, 0.62** and 0.55** respectively). While soil pH showed a significant negative correlation (r = -0.53**) with Fe uptake, soil organic carbon was very poorly correlated (r = 0.14).

Among the extractants 0.005 M DTPA had the strongest correlation with Fe uptake (r = 0.54**). 1N NH_4OAc + 0.01 M EDTA pH 7.0, 0.01 M EDTA and IN NaOAc pH 4.8 were rather similar in their relationships with Fe uptake (r = 0.45*;

TABLE 3: CORRELATION ANALYSIS BETWEEN Fe UPTAKE AND OTHER PLANT PARAMETERS.

Correlation		*Coefficient of simple correlation, r*	
No of tillers vs Fe uptake		0.5**	
Dry wit (top)	,,	0.62***	
Dry wt (roots)	,,	0.28	NS
Deficiency score	,,	-0.42*	
K uptake	,,	-0.23	NS
P uptake	,,	0.23	NS
Mn uptake	,,	0.55**	
IN NH_4OAc + 0.01M EDTA pH 7.0	uptake	0.45*	
0.01 M EDTA, pH 7.0	,,	0.45*	
IN NH_4OAc, pH 4.8	,,	0.35	
IN NaOAc, pH 4.8	,,	0.44*	
0.005 M DTPA, pH 7.3	,,	0.54**	
Soil pH	,,	-0.53**	
Organic Carbon	,,	0.14	NS

*, ** Significant at 0.05 and 0.01 probability level respectively.

NS Not significant.

TABLE 4: CORRELATION BETWEEN EXTRACTANTS, pH AND SOIL ORGANIC CARBON CONTENT

	IN HN_4OAc + 0.01M EDTA	*0.01M EDTA*	*IN NH_4OAc pH 4.8*	*IN NaOAc pH 4.8*	*0.005M DTPA*	*SOIL pH*
0.01M EDTA	0.42					
IN NH_4OAc, pH 4.8	0.94***	0.36				
IN NaOAc, pH 4.8	0.79**	0.47*	0.83***			
O.005M DTPA	0.97***	0.45*	0.91***	0.76***		
Soil pH	-0.53***	-0.27	-0.42	-0.19	-0.61***	
Soil Org. Carbon	-0.46*	0.14	0.26	0.19	0.44	-0.08

* Significant at 0.05 probability level
** ·Significant at 0.01 probability level
*** Significant at 0.001 probability level.

0.45* and 0.44* respectively. IN NH_4OAc pH 4.8 was not suitable for assessing available Fe in the highly weathered soils of Western Nigeria. With the exception of 0.01 M EDTA, all the extractants were strongly correlated with one another (Table 4).

All the extractants were negatively correlated with soil pH but only the r values for 0.005 M DTPA and IN NH_4OAc + 0.01 M EDTA pH 7.0 attained significance

TABLE 5: REGRESSION DATA RELATING: Fe UPTAKE BY UPLAND RICE (DEPENDENT VARIABLE) WITH EXTRACTANTS AND SOIL PROPERTIES

	Coefficient of determination R^2				
	IN HN$_4$OAc + 0.01M EDTA pH 7.0	0.01M EDTA	IN HN$_4$OAc pH 4.8	IN NaOAc pH 4.8	0.005M DTPA
Soil pH	0.278*	0.278*	0.278*	0.278*	—
Extractant	—	—	—	—	0.296*
Extractant + pH	0.321*	0.378%	0.300NS	0.396*	0.357*
Extractant + pH + Org. C.	0.321*	0.382*	0.303NS	0.397*	0.359*

* Significant at 0.05 probability level
NS not significant.

(r = 0.61** and —0.53** respectively). The correlation between extractants and soil organic carbon was generally not as strong as that with soil pH. Only 0.005M DTPA (r = 0.44**) and IN NH_4OAc + 0.01M EDTA pH 7.0 (r = 0.46* showed significant correlation with soil organic carbon.

The results of the multiple regression analysis relating soil pH, extractants and soil organic carbon (independent variables) to Fe uptake (Table 5) showed that with the exeeption of 0.005 M DTPA, the effect of pH was dominant over that of the extractant. However, the inclusion of both pH and extractants in the regression equations improved the R^2 value coming from 0.01 M EDTA (10%) and IN NaOAc pH4.8 (12%), and interpreted as being related to the ability of the two extractants to extract only the most readily absorbable Fe in soil solution. Inclusion of soil organic carbon in the regression equations yielded insignificant changes in the R^2 values for all the extractants.

The regression analysis relating extractable Fe (dependent variable) to soil pH and soil organic carbon (Table 6), showed that soil pH significantly influenced extractable Fe by IN NH_4OAc + 0.01 M EDTA, pH 7.0 and 0.005 M DTPA (R^2 = 0.281* and 0.374** respectively). The inclusion of soil organic carbon in the regression equation improved the R^2 values by 17.4% and 15% respectively for the two extractants. It appears that besides extracting readily available Fe, IN NH_4OAc + 0.01 M EDTA pH 7.0 and 0.005 M DTPA extractants were also capable of assessing the capacity factor which controls the concentration of available Fe in soil solution.

Effect of organic manures on growth, severity of chlorosis, Fe uptake and Fe extracted by different methods

The results of the chemical analysis of both the poultry manure and the brewer's grains used in the experiment are shown in Table 7. Except for Mn content, the poultry manure was higher in all the elements analysed.

Leaf Chlorosis suspected to be Fe deficiency started to show on the plants 10 days after germination. The chlorosis was rated as very severe on the control plants, severe on both seed treated and soil applied Fe, slight on poultry manure treatments

TABLE 6: REGRESSION DATA RELATING EXTRACTABLE Fe (DEPENDENT VARIABLE) WITH SOIL pH AND SOIL ORGANIC CARBON CONTENT.

Independent variables	IN NH_4OAc 0.01M EDTA pH 7.0	0.01M EDTA	IN NH_4OAc pH 4.8	IN NaOAc Ph 4.8	0.005M DTPA
Soil pH	0.281*	0.71^{NA}	0.176^{NS}	0.038^{N}	0.374**
pH + % Org. C.	0.455**	0.086^{NS}	0.229^{NS}	0.068^{NS}	0.524**
R^2 Change	0.174	0.014	0.053	0.030	0150

* ** Significant at 0.05 and 0.01 probability levels respectively.

NS No Significant.

TABLE 7: CHEMICAL ANALYSIS OF POULTRY AND BREWER'S GRAIN MANURES

	Chemical Components							
	Ca %	Mg %	K %	P %	Mn ppm	Zn ppm	Fe ppm	Cu ppm
Poulry manure	3.11	1.04	0.93	2.65	860	580	503	84
Brewer's waste	0.68	0.32	0.20	0.52	927	525	431	61

and none on the brewer's grains treatments. The status of the chlorosis in the poultry manure treatments became progressively more severe with plant age. Although the brewer's grains treatments showed no chlorosis throughout the trial, initial growth rate was much slower than the poultry manure treatments as shown by both plant height and number of tillers per pot at six weeks after planting (Table 8). There was a strong relationship between the severity of chlorosis and the number of tillers flowering per pot by the 13th week of growth. While the brewer's grains treatments maintained between 84% and 92% of the total number of tillers originally formed as productive tillers (i.e. panicle bearing tillers) the percentages for other treatments ranged from 39% to 61%.

The effects of Fe or organic manure application were not as dramatic on plant height as on the number of tillers that survived to bear panicles. Plant heights in the organic manure treatments were generally greater than in other treatments (Table 8).

The nutrient composition of the Y-leaf is presented in Table 9. There were no treatment effects on Ca, K, Mn and Cu contents. The effects of treatments on Mg and Zn contents were not well defined. The higher tissue P content of the poultry manure treatments appears to be a direct reflection of the high total P content of the poultry manure used in the trial, but did not seem to have influenced tissue Fe content. Organic manure application was however, higher in the brewer's grains treatments even though the poultry manure was richer in total Fe than the Brewer's

TABLE 8: EFFECT OF TREATMENTS ON TILLERING AND PLANT HEIGHT

	No. of Tillers		Plant Height, cm	
Treatments	6 Weeks	13 Weeks	6 Weeks	13 Weeks
Control	14.5 c	6.8 d	73.5 c	97.5 bc
Seed Fe application	27.6 b	10.8 cd	80.3 ab	90.8 c
Soil Fe application	20.3 bc	8.3 cd	76.0 bc	89.5 c
Poultry manure + Fe	34.0 a	14.8 cd	83.3 a	108.3 ab
Brewer's grains + Fe	26.0 b	24.0 A	75.5 c	108.0 ab
Poultry manure only	35.8 a	15.8 bc	85.0 a	105.5 ab
Brewer's grains only	25.5 b	21.5 ab	75.5 c	110.5 a

TABLE 9: CHEMICAL ANALYSIS OF THE Y-LEAF SAMPLE AT FULL HEADING

Treatments	Nutrient Composition							
	Ca %	Mg %	K %	P %	Mn ppm	Zn ppm	Fe ppm	Cu ppm
Control	0.21	0.24	1.27	0.21	250	68	100	28
Seed Fe application	0.21	0.16	1.15	0.20	202	60	106	29
Poultry manure + Fe	0.22	0.23	1.31	0.35	210	71	146	29
Brewer's grains + Fe	0.22	0.20	091	0.19	226	53	186	23
Poultry manure only	0.23	026	1.11	0.43	267	58	155	30
Brewer's grains only	0.21	0.16	1.01	0.18	194	70	180	20

grains (Table 7). The imposition of Fe application on the organic manure treatments did not improve tissue Fe content. Tissue Fe content from the seed or soil Fe application was not substantially better than the control. Sobulo (1982) reported that the lack of response of upland rice to Fe application at Aha on a soil of pH above 7 could be due to conversion of the applied Fe into less soluble form in the soil.

The results presented herein have shown that even within soil pH range of 5.0 to 6.5 pH was still a strong factor influencing Fe availability in the soil and uptake by upland rice. The identification of goethite peaks in the X-ray diffraction analysis of many of the important soils of southwestern Nigeria (Oladimeji and Ojo-Atere, 1977) indicate that the soils in the region contain sizeable amount of highly insoluble iron minerals, with the result that Fe may be deficient for plants even when the soils are moderately acid.

The R^2 from the regression equation relating Fe uptake to extractants and soil pH are fairly comparable for all the extractants (Table 5). All the extractants appear therefore to have good affinity for Fe in soil solution. However, a similar regression analysis relating the amount of Fe extracted by the extractants to soil pH and organic carbon showed that the R^2 values for I$\underline{n}$ NH_4OAc + 0.01 $\underline{M}$ EDTA pH 7.0 and 0.005 $\underline{M}$ DTPA were highly superior to those of other extractants (Table 6). Besides assessing available Fe in soil solution, these two extractants seem capable of assessing potentially absorbable Fe from crystalline and organic complex sources. In this regard, 0.005 M DTPA is the best among the extractants compared for assessing Fe availability for upland rice in the highly weathered tropical soils of southwestern Nigeria. The regression equation predicting Fe uptake is: Y = 11.12 + 0.046 (0.005 M DTPA-FE) — 1.47 (pH) — 0.22 (Org. Carbon), R^2 = 0.36*.

Enrichment of the moderately acid soil with poultry manure and brewer's grains increased rice Fe uptake and effectively reduced Fe deficiency symptoms. Parsa *et al* (1979) have observed similar effects of increased Fe uptake by sorghum as a result of organic matter incorporation into calcareous soils. The role of soil organic matter appears to be that of maintaining a labile pool of available Fe through the formation of organic Fe complexes. However, the concentration of organic complexing agents is a function of the quantity of organic matter, its composition and state of decomposition among other factors. Under the condition of rapid degradation of soil organic matter, as is the case in tropical soils, the concentration of organic complexing agents and consequently the labile pool of available Fe, is expected to drop rapidly as soil organic matter decreases under continuous cropping. In mineral, moderately acid soils, this situation may cause Fe deficiency in sensitive crops like upland rice. It is therefore suggested that use of organic manures or residues as source of available iron to upland rice in depleted soil should be further studied.

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References

Bole-Jones, E.W., 1955. The interrelationships of iron and potassium in the potato plant. *Plant and Soil* 6: 129—173.

Kang, B.T., A.O. Abifarin and A. Sajjapongse, 1976. Iron deficiency problems with upland rice in Western Nigeria. *Niger. Agric. J.* 13: 3—9.

Moore, A.W. and S.A. Adetunji, 1966. Chlorosis in plants growing in Latosolic soil. *Plant and Soil* 25: 309—312.

Okajima, H., N.D. Mannikar and M.J. Rao, 1970. Iron chlorosis of rice seedlings in calcareous soil under upland conditions. *Soil Sci. and Plant Nutrition* 16: 128—131.

Oladimeji, O.M. and J.O. Ojo-Atere, 1978. Clay mineralogy of some forest soils in the humid tropics and their genetic implications. *Niger. Agric. J.* 15: 1—15.

Olsen, S.R., 1972. Micronutrient interactions. In Proceedings Symposium on Micronutrients in Agriculture. Mortvedt, J.J. (Editor), *Am. Soil Sci. Soc. Wisconsin, U.S.A.:* 243—264.

Parsa, A.A., A. Wallace and J.P. Martin, 1979. Enhancement of iron availability by some organic materials. *J. Agric. Sci. Camb.* 93: 115—120.

Sobulo, R.A. (1982). Response of upland rice to N, P, K, Fe and Zn in southwestern Nigeria. *Niger. J. Soil Sci.* 3: 14—27.