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*Research Paper*

# Effect of Iron Fertilization on the Growth and Yield of Rice (*Oryza sativa*) in Makurdi, Benue State, Nigeria

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A pot experiment was carried out at the Agronomy Teaching and Research Farm of the University of Agriculture Makurdi, in the Southern Guinea Savanna Zone of Nigeria. This study was to determine the response of rice to Fe fertilization. Surface soil sample (0-20 cm) was collected from the Research farm. Sub samples of the soil were analyzed for physico-chemical properties using soil analytical procedures and the remaining samples kept for pot experiment. Four (4) Kg of the soils were weighed into perforated plastic pots of 5 L capacity. Treatment consists of five levels of Fe (0 kg ha$^{-1}$, 15 kg ha$^{-1}$, 30 kg ha$^{-1}$, 45 kg ha$^{-1}$ and 60 kg ha$^{-1}$) in the form of $FeSO_4$. The treatments were laid out in a Completely Randomized Design (CRD) with three replications. Ten (10) seeds of rice (FARO 44 variety) were planted per pot and later thinned to 5 plants per pot two weeks after planting. Fertilizer equivalent to 80 kg N, 30 kg $P_2O_5$ and $K_2O$ were applied to all the pots as basal application and the Fe rates distributed accordingly to the pots at planting with the control treatment pots without Fe application. The crops were grown to maturity and all agronomic practices carried out as at when due. Data was collected on selected growth and yield parameters. Response of rice to the application of Fe fertilizer was obtained with 30 kg ha$^{-1}$ giving the best results in all parameters studied. For optimum yield of rice on this soil, 30 kg ha$^{-1}$ of Fe is recommended to farmers.

**Keywords:** Fertilization, growth, iron, Nigeria, rice, yield

## INTRODUCTION

Micronutrients, though required in small quantities, are essential for the growth and development of crops. They play many complex roles in plant nutrition (Brady and Weil, 2014). While most of the micronutrients participate in the functioning of a number of enzyme systems, there is considerable variation in the specific functions of the micronutrients in plants and microbial growth processes, for instance copper, iron and molybdenum are capable of acting as electron carriers in the enzyme systems that brings about oxidation-reduction reactions in plants. Such reactions are essential steps in photosynthesis metabolic processes (Brady and Weil, 2014). Iron (Fe) is one of the essential elements required for plant growth and reproduction. Of the 7 micronutrients, Fe has the highest plant requirement (Jones and Benton, 2012). It is involved in chlorophyll formation and degradation and in the synthesis of proteins and nucleic acids (FFTC, 2001).

It is the fourth abundant element, constituting about 5 % of all the elements composing the earth's crust, yet Fe deficiency is not of uncommon occurrence among some plant species and/or on the certain types of soils (Jones and Benton, 2012). Studies have revealed micronutrients deficiency in some Nigerian Savanna Soils (Lombin, 1983a, 1983b, 1985; Enwezor *et al.,* 1990; Oyinlola and Chude, 2010). This has been associated with the use of improved high yielding crop varieties which are nutrient demanding (Mustapha and Loks, 2005), intensive continuous cultivation of soils thereby placing considerable stress on the micronutrient supplying powers of the soils. In addition, the current fertilizer of one or two macronutrients may in due course deplete the soil reserve of other nutrients and limits crop performance (Oyinlola and Chude, 2010). Also, increased knowledge of plant nutrition and improved methods of analysis in the laboratory are helping in the diagnosis of micronutrient deficiencies that might have formerly gone unnoticed (Brady and Weil, 2014).

Rice is a staple food for more than 3 billion people in the world (IRRI, 2005) In Nigeria, an estimated 3 million hectares is under rice annually out of the potential land of

4.6 - 4.9 million hectares for rice production (Chude *et al.,* 2012) Farmers' yields range between 1,200 and 3,000 kg $ha^{-1}$ for swamp rice and 1,000 -1,500 kg $ha^{-1}$ for upland rice (Chude *et al.,* 2012). Micronutrients deficiency is considered one of the major causes of declining productivity trends in rice growing countries (Johnson *et al.,* 2005). With improved practices yields of up to 5,000 – 6,000 kg and 2,500 - 3,000 kg $ha^{-1}$ of paddy are possible for swamp and upland rice, respectively (Chude *et al.,* 2012). Despite its role and that of other micronutrients in soil fertility and plant nutrition, studies on micronutrients status of Nigerian soil and their effect on crop production have been neglected in the past (Kparmwang *et al.,* 1995; Adeboye, 2003). The current study was carried out to determine the effect of Fe fertilization on the growth and yield of rice.

## MATERIALS AND METHODS

The study was made up of laboratory studies and pot experiment. The laboratory studies included routine soil analysis and micronutrient determination. The routine analysis and micronutrient determinations were carried out at the Advanced Analytical Service Laboratory of the Department of Soil Science, University of Agriculture Makurdi while the pot experiment was conducted at the Agronomy Teaching and Research Farm of the same University located on Latitude 7° 47' N and Longitude 8° 36' East at an elevation of 82 m above sea level

### Soil sample collection and analysis

Surface soil samples were collected using shovel and bags at a depth of 0-20 cm from the Teaching and Research Farm of the University of Agriculture, Makurdi, Nigeria for laboratory studies and pot experiment. Sub-samples of the collected soil was air dried and ground to pass a 2 mm sieve for routine analysis and micronutrient determination while the remaining samples were kept for the pot experiment.

### Soil analysis

The soil samples were analyzed for selected physical and chemical properties using standard soil analytical procedures. Soil pH was determined in a 1:1 soil-water suspension by the glass electrode method using a pH meter, particle size distribution by the hydrometer method of Bouyoucos, (1951) using sodium hexametaphosphate (calgon) as the dispersing agent and the textural class obtained using the textural triangle. Total organic carbon was determined by the chromic acid oxidation procedure of Walkley and Black, (1934). Exchangeable bases were brought into solution by repeated extraction procedure with neutral 1 M $NH_4OAC$ (pH 7) solution (IITA, 1979); Na and K were read on a flame photometer while Ca and Mg were read on Atomic Absorption Spectrophotometer (AAS) Buck scientific model 210 VGP, USA. Exchangeable acidity by the 1 N KCl extraction and 0.01 M NaOH titration method. Nitrogen in the samples was determined by the Macro-Kjeldahl method. The DTPA extractant was used to extract available micronutrients and the values read on an Atomic Absorption Spectrophotometer (Lindsay and Norwell, 1978)

### Pot experiment

A pot experiment was conducted at the North Core Teaching and Research Farm of the University of Agriculture Makurdi, using soils collected from the farm. Four (4) Kg of the soils were weighed into perforated plastic pots of 5 l capacity.Treatment consists of five levels of Fe (0 kg $ha^{-1}$, 15 kg $ha^{-1}$, 30 kg $ha^{-1}$, 45 kg $ha^{-1}$ and 60 kg $ha^{-1}$) in the form of $FeSO_4$ designated as T1, T2, T3, T4 and T5 respectively. The treatments were laid out in a Completely Randomized Design (CRD) with three replications. Ten (10) seeds of rice (FARO 44 variety) obtained from Olam rice farm, Rukubi Nasarawa state, Nigeria were planted per pot and later thinned to 5 plants per pot two weeks after planting. Fertilizer equivalent to 80 kg N, 30 kg $P_2O_5$ and $K_2O$ were applied to all the pots as basal application (Chude et al., 2012) and the Fe rates distributed accordingly to the pots at planting with the control treatment pots having no Fe application. The crops were grown to maturity and all agronomic practices carried out as at when due.

### Data collection

Data was collected on the following parameters:

(i) Number of tillers at 4 and 6 weeks after planting
(ii) Plant height at 4, 6, 8 and 10 weeks after planting
(iii) Root weight at 4 and 8 weeks after planting
(iv) Leaf area at 4, 6, 8 and 10 weeks after planting
(v) Number of grains per panicle at harvest
(vi) Grain yield at harvest
(vii) Dry matter weight

### Data analysis

Data collected was subjected to the analysis of variance using the discovery edition 4 of Genstat statistical package. Where significant differences were observed means were separated using Fischers least significant differences (F-LSD)

## RESULTS

### Physical and chemical properties of the experimental soils

The physical and chemical properties of the experimental soils are presented in (Table 1).The soil was slightly acidic with a pH of 6.29. Textural class was clay loam with 56 g kg$^{-1}$ sand, 36 g kg$^{-1}$ silt and 74 g kg$^{-1}$ clay. The soil organic carbon was low (1.79 g kg$^{-1}$), as well as the organic matter content (3.08 g kg$^{-1}$). Nitrogen content was low (0.02 %), the available P was very low (3.54 mg kg$^{-1}$). The soil was low in exchangeable bases with 0.12 cmol kg$^{-1}$ K, 0.36 cmol kg$^{-1}$ Na, 1.36 cmolkg$^{-1}$and 3.33 cmol kg$^{-1}$ Ca. The CEC (5.17 cmol kg$^{-1}$) was low. The micronutrient status reveals that the soil has 0.22 mg kg$^{-1}$ Zn, 3.50 mg kg$^{-1}$ Fe, 0.72 mg kg$^{-1}$ Cu and 0.7 mg kg$^{-1}$ Mn.

### Effect of iron fertilization on the growth of rice

The effect of Fe on the growth of rice presented in (Table 2) indicated that there were significant differences in the growth parameters measured with the exception of plant height at 8 weeks after planting. The highest plant height at 4 weeks after planting was obtained using T3 which is significantly ($P \leq 0.05$) different from T1, T2, T4 and T5. At 6 weeks after planting, the tallest plants were obtained using T2, which is also significantly different from T1, T4 and T5. At 10 weeks after planting, the highest plant height was obtained using T3 which is significantly different from T1, T2, T4 and T5 respectively.

The second highest plant height at the same 10 weeks after planting was obtained using T2 which is significantly different from T1 and T5. The result also indicated that there were no significant differences in the leaf area and in the number of tillers with exception of the leaf area at 6 WAP. The highest leaf area was obtained using T3 which is significantly different from T1, T2, T4 and T5, respectively.

### Effect of iron fertilization on rice yield

The effect of Fe fertilization on rice yield (Table 3) showed that there were significant differences ($P \leq 0.05$) in all the parameters measured. The highest number of grain per panicle was obtained using T3 which is significantly different from T1, T2, T4 and T5 respectively. However the second highest number was obtained using T4.

The highest dry matter weight was obtained with T3 and was significantly different from that obtained with the other treatments. The second highest dry matter weight was obtained using T4 which is significantly different from T1.The highest root weight at 4 weeks after planting was obtained using T5 which is significantly different from T1, T2, T3 and T4. The second highest root weight at the same 4 weeks after planting was obtained using T4 which is also significantly different from T1, T2 and T3. The highest root weight at 8 weeks after planting was obtained using T4 which is significantly different from T1, T2, T3 and T4. The second highest root weight at the 8 weeks after planting was obtained using T2. The highest grain yield was obtained using T3 and this was significantly different from grain yield obtained with T1, T2, T4 and T5 respectively. The second highest grain yield was obtained using T4.

## DISCUSSION

The pre-cropping analysis indicated that the soil was clay loam and slightly acidic. The soil was therefore suitable for the production of rice as earlier reported by James and Tufekcioglu, (2000). The soil was deficient in most of the mineral nutrients, especially N, P and K the major macronutrient elements. The low mineral content of the soil was probably due to its depletion as a result of continuous cropping over time and the slash and burn practice carried out in the study area. The low nitrogen (N) content of the soil could be as a result of leaching, denitrification, volatilization, crop removal, soil erosion and runoff. Other factors affecting the availability of nitrogen in the soil include temperature (Basu *et al.,* 2010; Carson and Ozore-Hampton, 2012; Dai *et al.,* 2008), soil moisture (Kochba *et al.,* 1990), soil pH (Basu *et al.,* 2010) and soil texture (Ahmed *et al.,* 1963).

The P level was low when compared with 10 – 16 mg kg$^{-1}$ critical levels for tropical soils as indicated by Agboola and Corey, (1972) and Adeoye and Agboola, (1985). This might be attributed to the nature of parent material and the colloidal system present in the soil (Fox and Kang, 1978; Adepetu, 1981). Phosphorus fixation has been suggested as one of the major limiting factors for agricultural production (Osodeke, 2005; Rowe *et al.,* 2016). Low mobility and high fixation of P can restrict its availability and biological utilization by plants (Cessa *et al.,* 2009; Yi-Halla, 2016).

Almeida *et al.* (2003), Cessa *et al.* (2009) and Osodeke (2005), attributed lack of available phosphorus to its strong adsorption by mineral surfaces, making the part of the total P unavailable to plants.

Exchangeable K was low when compared with critical levels of 0.16 – 0.2 cmol kg$^{-1}$ reported by Babajide *et al.* (2008) and Akanbi, (2002). The low exchangeable K content may be due to leaching and fixation into clay lattices (Danahue *et al.,* 1977). With the nature of this soil, application of fertilizer both organic and inorganic will be required to enhance and sustain crop productivity.

The soils were low in available micronutrients. For Cu and Zn the results are in alignment with the report of Kparmwang *et al.* (2000) that these nutrient values are low but contrary to their reports for Fe and Mn. They reported that the soils of middle belt and the Northern part of Nigeria were above the critical levels of 4.5 and 1 mg kg$^{-1}$.The low micronutrient status of the soil may be attributed to the fact that micronutrients are not applied regularly to the soil in conjunction with common fertilizers, the intensification of cropping practices and adoption of

**Table 1.** Physical and chemical properties of soil.

| Parameters | Values |
|---|---|
| pH(1:1) | 6.29 |
| Sand (g $kg^{-1}$) | 56 |
| Silt (g $kg^{-1}$) | 36 |
| Clay (g $kg^{-1}$) | 74 |
| Textural class | CL |
| Organic C (g $kg^{-1}$) | 1.79 |
| Organic matter (g $kg^{-1}$) | 3.08 |
| N (%) | 0.02 |
| Available P (mg $kg^{-1}$) | 3.54 |
| Ca (cmol $kg^{-1}$) | 3.33 |
| Mg (cmol $kg^{-1}$) | 1.36 |
| K (cmol $kg^{-1}$) | 0.12 |
| Na (cmol $kg^{-1}$) | 0.36 |
| CEC (cmol $kg^{-1}$) | 5.17 |
| B.S (%) | 84.00 |
| Exch A | 0.83 |
| Cu (mg $kg^{-1}$) | 0.72 |
| Fe(mg $kg^{-1}$) | 3.50 |
| Mn(mg $kg^{-1}$) | 0.70 |
| Zn(mg $kg^{-1}$) | 0.22 |

**Table 2.** Effect of Fe fertilization on rice growth.

| | Plant height (cm) | | | | Leaf area ($cm^2$) | | | Number of tillers | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Treatment** | **4 WAP** | **6 WAP** | **8 WAP** | **10 WAP** | **4 WAP** | **6 WAP** | **8 WAP** | **10 WAP** | **4 WAP** | **6 WAP** |
| T1 | 29.33 | 35.20 | 39.40 | 44.43 | 8.17 | 11.07 | 13.07 | 16.50 | 2.67 | 2.33 |
| T2 | 32.33 | 44.17 | 49.10 | 49.97 | 8.27 | 8.43 | 9.67 | 10.60 | 3.00 | 3.00 |
| T3 | 36.30 | 42.53 | 50.77 | 59.50 | 11.50 | 15.53 | 17.20 | 18.07 | 3.67 | 4.00 |
| T4 | 25.47 | 32.50 | 41.93 | 46.83 | 8.47 | 10.70 | 11.87 | 17.93 | 3.00 | 3.33 |
| T5 | 25.50 | 31.37 | 38.47 | 44.17 | 7.63 | 9.07 | 11.07 | 13.33 | 3.00 | 3.00 |
| LSD($P \leq 0.05$) | 3.55 | 5.69 | NS | 33.93 | NS | 4.611 | NS | NS | NS | NS |

*WAP = Weeks after Planting, LSD = Least Significant Difference.

Table 3. Effect of Fe fertilization on the yield of rice.

| Treatment | NGPP | DMW (g) | RW-4WAP | RW-8WAP | Grain yield (t $ha^{-1}$) |
|---|---|---|---|---|---|
| T1 | 58.33 | 0.63 | 0.02 | 0.04 | 1.20 |
| T2 | 56.67 | 0.67 | 0.02 | 0.12 | 1.33 |
| T3 | 125.33 | 2.00 | 0.20 | 0.04 | 3.00 |
| T4 | 85.67 | 1.33 | 0.30 | 0.39 | 2.03 |
| T5 | 63.00 | 0.67 | 0.38 | 0.07 | 1.47 |
| LSD($P \leq 0.05$) | 33.93 | 0.54 | 0.02 | 0.09 | 0.83 |

*NGPP = Number of Grain per Panicle; DMW = Dry Matter Weight; RW = Root Weight, WAP = Weeks after Planting.

high yielding cultivars which have high micronutrients demand could have led to low levels of micronutrients). Also the reduction in fallow period could also be responsible for low levels of micronutrients in this soil (Kparmwang *et al*., 1998; Adeboye, 2011). No significant differences was observed in the number of tillers per plant; this is in line with the report of Hussain *et al*. (2005) also who observed non-significant difference in total number of tillers per plant and number of fertile tillers per plant in response to applied micronutrients. Response to the application of Fe fertilizer was observed both in the yield and growth parameters observed. This could be attributed to the low level of available Fe in the soil as Fe is considered adequate for plant growth only when available Fe is more than 4.5 mg $kg^{-1}$ (Agbenin, 2003; Ibrahim *et al.,* 2011). The response of rice to Fe fertilization might be due to the fact that iron is required for electron transport in photosynthesis and is a constituent of iron porphyrins and ferredoxins, both of which are essential components of photosynthetic process. As a micronutrient iron is required in trace quantities hence above certain level it becomes toxic to the plant giving rise to a decline in growth and yield; this was observed with treatments above 30 kg $ha^{-1}$ in this study.

## Conclusion

From the results obtained in this study, it could be concluded that the experimental soil was generally poor in available plant nutrients; micronutrients inclusive and that there was crop response to the application of Fe fertilizer. These responses occurred both in the growth and yield parameters studied. 30 kg $ha^{-1}$ Fe resulted in optimum results for all the varieties under study. Generally, growth and yield increased steadily with increasing Fe fertilization, peaked at 30 kg $ha^{-1}$ and declined thereafter. It is therefore recommended that micronutrients should be included in fertilization programmes for crops grown in this area. For optimum yield of rice on this soil; it is recommended that 30 kg $ha^{-1}$ Fe should be included in its fertilization programmes.

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