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# Iron toxicity symptoms in yams (*Dioscorea* spp.) grown in water culture

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**Abstract** *Growth of varieties of* Dioscorea alata *and* D. rotundata *were stunted when they were grown in nutrient solutions containing 5 to 60 mg l*$^{-1}$ *Fe. In* D. alata *variety TDa 95/00361, plants grown in 60 mg l*$^{-1}$ *Fe solution exhibited reductions of 29–65% in plant height, leaf length and width, number of leaves, stems and roots, and root length compared to the control. The corresponding values for* D. rotundata *variety TDr 89/02565 were 34–59%. Tuber weight in* D. rotundata *variety TDr 89/02565 was increased by the iron treatments but the foliar symptoms of iron toxicity reported for other crops were not observed.*


**Key words:** *Dioscorea*, iron toxicity, water culture, yams

## Introduction

Three main species of yams, white Guinea yam (*Dioscorea rotundata*), yellow Guinea yam (*D. cayenensis*) and water yam (*D. alata*) are grown by farmers in West and Central Africa, the dominant zone for the world's production of the crop (Otoo 2003). Cultivation of yams has been expanding (Manyong et al. 1996) but the traditional production systems are under increasing pressure to adapt to short fallow periods owing to limited availability of new land to support shifting cultivation. Traditionally yams are grown first after clearing new land in order to meet the requirement for a relatively rich soil, in particular in terms of organic matter (Degras 1993). To meet the greater demand for food yams due to increasing population, more intensive production systems are now necessary. Agronomic research must provide effective strategies for improving soil fertility and managing pests, including weeds, in yam-based cropping systems (Ekanayake and Asiedu 2003).

In studies on nutrient deficiencies, the omission of N, K, Ca or S led to poor growth of *D. rotundata* in sand culture (Gaztambide and Cibes 1975). Shiwachi et al. (2004) reported heavily stunted growth of *D. alata* and *D. rotundata* in water culture due to the omission of N, P or Ca. The optimal pH for yam growth is between 6 and 7 and problems of aluminium toxicity can occur below pH 5.5 that would require calcium enrichment (Gaztambide and Cibes 1975).

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Soils in the equatorial forest and Guinea savanna zones in West Africa have low available potassium content (Wakatsuki 2002). Yamauchi (1989) reported iron toxicity in rice plants in West Africa following application of potassium sulphate. Symptoms of iron toxicity in yams have not been reported and generally there are few reports that would guide efficient use of fertilizers in yam-based systems. The objective of this study was to describe the impact of iron toxicity on the growth of *D. alata* and *D. rotundata* plants grown in water culture.

## Materials and methods

The study was carried out in a screen house using virus-tested stocks of *D. alata* variety TDa 95/00361 and *D. rotundata* variety TDr 89/02565 at IITA. The stocks were propagated *in vitro* to generate plantlets (Ng, 1994), which were transplanted into peat moss pellets (4.5 cm diameter) and kept in isolation in a screen house until transplanted into a water culture system. Plastic pots (22 cm diameter, 23 cm height, 7 l capacity) with a 2 cm thick polystyrene foam cover that had a planting hole in the centre were used. A spherical air stone, also 2 cm diameter was put into each pot and connected to an air compressor set to produce a continuous supply of oxygen to the water.

The solution with a full complement of nutrients, 0.81 g $l^{-1}$ $KNO_3$, 0.94 g $l^{-1}$ $Ca(NO_3)_2.4H_2O$, 0.49 g $l^{-1}$ $MgSO_4.7H_2O$, 0.21 g $l^{-1}$ $NaH_2PO_4.2H_2O$, 3 mg $l^{-1}$ $H_3BO_3$, 0.22 mg $l^{-1}$ $ZnSO_4.7H_2O$, 2 mg $l^{-1}$ $MnSO_4.4H_2O$, 0.05 mg $l^{-1}$ $CuSO_4.5H_2O$, 0.02 mg $l^{-1}$ $Na_2MoO_4.2H_2O$ and 15.1 mg $l^{-1}$ Fe-EDTA (3 mg $l^{-1}$ of Fe) used for water culture in yams (Shiwachi et al. 2004) served as the control. It had pH 6.5 and EC 2.2 mmho. Treatment was made up of eight test solutions containing 5, 10, 15, 20, 30, 40, 50 and 60 mg $l^{-1}$ of Fe. These were arranged in a completely randomised design with three replicates. Each pot was filled with tap water one day before the nutrients were added in order to release chlorine from the water. Each solution was changed every 5 days. Each pot was placed in a polystyrene foam box (23 × 23 × 21 cm) kept at 24 ± 2 °C. The water used contained 3.7 ± 0.3 mg $l^{-1}$ K, 2.2 ± 0.7 mg $l^{-1}$ Ca, 2.1 ± 0.7 mg $l^{-1}$ Mg and 34.5 ± 0.2 mg $l^{-1}$ Na. N and P were not detected. The pH of the water was 6.6 and the EC was 0.4 mmho.

Each plantlet was transplanted into a plastic pot 4 weeks after it had been put into peat moss pellets for TDa 95/00361 and 6 weeks for TDr 89/02565. Each seedling was suspended with a wire to keep only the roots submerged in the water. Fe treatments were applied 5 days after transplanting. Measurements were made 30 days after transplanting for TDa 95/00361 and and 45 days for TDr 89/02565.

Leaf (lamina with petiole) samples were taken from three plants in each treatment, air dried for 20 days in a screen house, and then ground into powder. They were analysed for N and P by the Tecnicon auto analyzer and for K, Ca, Mg, Zn, Fe, Mn and Cu by atomic absorption spectrophotometry.

## Results and discussion

The growth of TDa 95/00361 (*D. alata*) plants in solutions containing 5 to 60 mg $l^{-1}$ Fe are in Table 1. No symptoms of iron toxicity were observed on the leaves, and the plants survived



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**Table 1.** Mean (SD) plant growth of *Dioscorea alata* variety TDa 95/00361 before and 30 days after transplanting into solutions with different quantities of iron

| Treatment Fe ($mg\,l^{-1}$) | Height (cm) | No. of leaves | Leaf size (cm) | | No. of stems | No. of roots | Root length (cm) | Tuber wt. (g) |
|---|---|---|---|---|---|---|---|---|
| | | | Length | Width | | | | |
| Before Fe treatments | 6.9 (0.4) | 4.2 (0.4) | 3.8 (0.3) | 3.9 (0.4) | 1.8 (0.8) | 6.8 (1.9) | 4.2 (0.4) | – |
| Control | 100.3 (15.0) | 30.3 (2.5) | 13.4 (1.4) | 8.0 (0.6) | 6.3 (2.1) | 31.0 (4.0) | 42.7 (5.0) | 0.3 (0.3) |
| 5 | 70.3 (7.6) | 31.3 (5.9) | 12.1 (1.6) | 7.1 (0.6) | 6.7 (2.1) | 33.7 (4.7) | 42.3 (6.4) | 0.0 (0.0) |
| 10 | 61.3 (13.6) | 29.7 (5.0) | 11.5 (1.4) | 6.5 (0.7) | 7.0 (2.0) | 31.7 (1.5) | 39.0 (3.0) | 0.3 (0.2) |
| 15 | 63.3 (21.1) | 35.0 (10.0) | 11.6 (1.8) | 6.8 (1.0) | 6.7 (1.2) | 31.0 (9.6) | 38.0 (2.0) | 0.0 (0.0) |
| 20 | 44.3 (12.7) | 24.7 (4.0) | 10.1 (1.5) | 6.0 (1.0) | 5.0 (1.0) | 32.7 (4.2) | 29.3 (2.3) | 0.0 (0.0) |
| 30 | 42.3 (13.1) | 23.0 (3.6) | 9.4 (1.3) | 5.6 (0.6) | 4.7 (0.6) | 29.7 (2.5) | 25.0 (2.0) | 0.1 (0.2) |
| 40 | 37.3 (8.3) | 22.0 (2.6) | 8.5 (0.8) | 5.6 (0.7) | 4.0 (1.0) | 27.7 (2.1) | 22.3 (1.5) | 0.2 (0.3) |
| 50 | 35.7 (5.9) | 21.0 (3.6) | 7.6 (0.9) | 4.8 (0.6) | 3.7 (0.6) | 25.3 (3.8) | 20.0 (1.0) | 0.0 (0.0) |
| 60 | 35.3 (8.1) | 19.0 (3.6) | 6.8 (0.8) | 4.8 (0.5) | 3.0 (0.0) | 22.0 (4.0) | 18.7 (1.5) | 0.0 (0.0) |



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**Table 2.** Mean (SD) plant growth of *Dioscorea rotundata* variety TDr 89/02565 before and 45 days after transplanting into solutions with different quantities of iron

| Treatment Fe ($mg\,l^{-1}$) | Height (cm) | No. of leaves | Leaf size (cm) | | No. of stems | No. of roots | Root length (cm) | Tuber wt. (g) |
|---|---|---|---|---|---|---|---|---|
| | | | Length | Width | | | | |
| Before Fe treatments | 7.1 (0.7) | 6.8 (0.8) | 3.7 (0.3) | 4.0 (0.4) | 1.6 (0.5) | 5.0 (0.7) | 5.2 (0.7) | – |
| Control | 103.0 (24.3) | 39.3 (15.5) | 11.7 (2.6) | 7.4 (1.0) | 5.0 (1.0) | 31.0 (4.6) | 43.0 (5.0) | 0.2 (0.1) |
| 5 | 74.7 (16.5) | 20.7 (8.7) | 8.2 (0.5) | 4.9 (0.5) | 5.3 (2.5) | 24.3 (6.8) | 39.0 (10.0) | 4.3 (2.9) |
| 10 | 72.0 (25.2) | 27.3 (11.8) | 9.4 (1.0) | 5.4 (0.5) | 4.3 (0.6) | 24.3 (5.9) | 43.3 (6.4) | 5.4 (1.3) |
| 15 | 74.7 (30.7) | 31.7 (6.1) | 9.4 (1.2) | 5.5 (0.7) | 5.3 (1.2) | 33.7 (5.7) | 44.7 (5.5) | 6.4 (2.4) |
| 20 | 98.3 (29.2) | 33.3 (7.5) | 10.0 (0.8) | 6.2 (0.9) | 5.7 (2.5) | 25.0 (5.0) | 45.7 (2.9) | 8.9 (2.8) |
| 30 | 53.7 (30.9) | 25.0 (14.8) | 8.0 (0.8) | 5.3 (0.5) | 3.0 (1.0) | 15.7 (9.0) | 29.3 (6.7) | 2.8 (2.5) |
| 40 | 66.0 (27.6) | 23.7 (6.0) | 6.6 (0.8) | 4.4 (0.5) | 3.7 (2.1) | 14.0 (3.0) | 27.7 (2.5) | 2.0 (1.0) |
| 50 | 42.7 (24.8) | 22.0 (8.2) | 5.9 (0.9) | 4.6 (0.4) | 3.0 (1.0) | 13.7 (3.5) | 25.0 (7.0) | 2.3 (1.1) |
| 60 | 42.7 (25.0) | 17.0 (5.6) | 6.0 (0.5) | 4.6 (0.6) | 3.3 (1.5) | 12.7 (1.5) | 24.3 (7.6) | 2.2 (0.7) |




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at all the concentrations of Fe used. Plant growth in the 5 mg l$^{-1}$ Fe solution was not different from the control but stunting was observed for plants growing 10 to 60 mg l$^{-1}$ Fe. The plants grown in 60 mg l$^{-1}$ Fe exhibited reductions of 65% in plant height, 37% in the number of leaves, 49% in leaf length, 40% in leaf width, 52% in the number of stems, 29% in the number of roots and 56% in root length compared to the control. Tuber development was minimal in all the plants. Fe did not affect the development of tubers in *D. alata* but this may be related to the level of development (age) of the plants when the experiment was terminated.

The growth of TDr 89/02565 (*D. rotundata*) plants under the different Fe treatments are in Table 2. As for TDa 95/00361, no symptoms were observed on the leaves. Plant heights with up to 5 to 40 mg l$^{-1}$ Fe, the number of roots and root length at Fe 5 to 10 mg l$^{-1}$, and the numbers of leaves and stems at all concentrations were similar to the control. Leaf sizes decreased with increasing Fe concentration. With 60 mg l$^{-1}$ Fe there were reductions of 59% in plant height, 56% in the number of leaves, 45% in leaf length, 38% in leaf width, 34% in the number of stems, 59% in the number of roots and 44% in root length compared with the control. Unlike *D. alata*, tuber weights at all treatment levels were greater than the control, especially at 5 to 20 mg l$^{-1}$ Fe.

Thus high concentrations of Fe stunted plant growth in both *D. alata* and *D. rotundata,* but the visual symptoms such as leaf necrosis related to Fe toxicity reported for other crops (Yamasaki et al., 1976) were not observed in either species.

The results of leaf analysis are in Tables 3 and 4. At 15 to 60 mg l$^{-1}$ leaves of TDa 95/00361 contained high levels of Fe and TDr 89/02565 leaves had high levels at 40 to 60 mg l$^{-1}$ Fe. The levels of N, P, K, Ca, Mg, Zn, Mn and Cu in the leaves of *D. alata* and *D. rotundata* were similar to those reported by Shiwachi et al. (2004). Fe accumulation in the leaves was higher in *D. alata* and lower in *D. rotundata* leaves than in previous report when Fe was applied at high concentration (Shiwachi et al. 2004).

**Table 3.** Composition of leaves from *Dioscorea alata* variety TDa 95/00361 grown in solutions with at different concentrations of iron

| Treatment Fe (mg l$^{-1}$) | N | P | K | Ca | Mg | Zn | Fe | Mn | Cu |
|---|---|---|---|---|---|---|---|---|---|
| | (%) | | | | | (μg g$^{-1}$) | | | |
| Control | 3.80 | 0.34 | 7.13 | 6.07 | 0.41 | 38.8 | 226.7 | 191.4 | 9.9 |
| 5 | 3.67 | 0.30 | 6.03 | 3.76 | 0.41 | 46.7 | 210.3 | 170.0 | 15.6 |
| 10 | 3.36 | 0.28 | 5.63 | 4.99 | 0.56 | 57.3 | 271.0 | 290.8 | 13.7 |
| 15 | 3.73 | 0.34 | 7.06 | 4.00 | 0.59 | 31.0 | 314.4 | 205.2 | 7.9 |
| 20 | 3.57 | 0.31 | 4.59 | 4.17 | 0.48 | 61.0 | 306.5 | 283.5 | 16.5 |
| 30 | 3.54 | 0.29 | 6.68 | 4.58 | 0.63 | 40.3 | 345.5 | 184.4 | 10.6 |
| 40 | 3.58 | 0.28 | 4.95 | 3.83 | 0.47 | 50.5 | 344.6 | 388.9 | 17.7 |
| 50 | 3.71 | 0.33 | 4.82 | 3.95 | 0.52 | 66.7 | 433.1 | 266.8 | 11.0 |
| 60 | 2.90 | 0.29 | 5.45 | 5.25 | 0.59 | 83.2 | 537.4 | 398.1 | 19.0 |



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**Table 4.** Composition of leaves from *Dioscorea rotundata* variety TDr 89/02565 grown in solutions with different concentrations of iron

| Treatment Fe ($mg\,l^{-1}$) | N | P | K | Ca | Mg | Zn | Fe | Mn | Cu |
|---|---|---|---|---|---|---|---|---|---|
| | (%) | | | | | ($\mu g\,g^{-1}$) | | | |
| Control | 2.90 | 0.32 | 7.23 | 2.80 | 0.39 | 56.2 | 233.1 | 223.4 | 5.1 |
| 5 | 3.15 | 0.39 | 6.12 | 1.95 | 0.37 | 50.5 | 175.5 | 215.4 | 4.7 |
| 10 | 3.43 | 0.32 | 6.68 | 2.02 | 0.37 | 47.6 | 160.6 | 199.1 | 4.5 |
| 15 | 3.12 | 0.38 | 5.57 | 1.97 | 0.35 | 46.9 | 165.9 | 211.8 | 5.1 |
| 20 | 3.14 | 0.34 | 6.56 | 3.51 | 0.95 | 90.7 | 204.4 | 243.8 | 10.5 |
| 30 | 3.43 | 0.32 | 6.68 | 3.82 | 0.49 | 83.7 | 263.9 | 264.0 | 7.9 |
| 40 | 4.22 | 0.45 | 6.87 | 5.73 | 0.33 | 61.4 | 323.6 | 250.5 | 10.7 |
| 50 | 3.60 | 0.37 | 6.14 | 4.77 | 0.56 | 47.9 | 339.5 | 181.0 | 8.4 |
| 60 | 3.14 | 0.34 | 2.57 | 5.58 | 1.32 | 54.2 | 338.5 | 226.2 | 12.6 |

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