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Nutrient deficiency symptoms in yams (*Dioscorea* spp.)

H Shiwachi, CC Okonkwo and R Asiedu*
International Institute of Tropical Agriculture, Ibadan, Nigeria. *Present address: Faculty of International Agriculture and Food Studies, Tokyo University of Agriculture, Tokyo, Japan

Abstract *Symptoms of nutritional deficiencies in* D. alata *and* D. rotundata *were observed when yam plants were grown in nutrient solutions from which any of the following had been omitted: N, P, K, Ca, Mg, Zn, Fe, B, Mn, Cu and Mo. The symptoms of deficiency of major elements were visible on plants of both species. The omission of Fe, B and Mo produced characteristic symptoms on the leaves of* D. rotundata*, but* D. alata *showed symptoms only in response to Fe deficiency. The omission of minor elements led to poor growth of the leaves, stems and roots. Nutrient deficiencies in yam plants could be diagnosed by visual symptoms in the field.*

Keywords: *Dioscorea*, yams, nutrient deficiency, diagnosis, leaf symptoms.

Introduction

Yam production in West Africa has usually been by traditional techniques including shifting cultivation with little or no fertilizer application. Farmers cultivate yams on cleared forest or after long fallow periods. Urbanization has increased the demand for yams and traditional production is adapting to this, but moving yam cultivation to productive short fallow or a mono-intensive system with mineral restitution and biological balance is a big challenge. Yam requires a relatively rich soil, in particular in terms of organic matter (Degras 1993).

A positive response to N P K fertilization was found in water yam (*D. alata*) (Igwilo 1989), but there was either a response to nitrogen (Lyonga 1984; Kayode 1985) or no response to fertilizer in white Guinea yam (*D. rotundata*) (Igwilo 1989). In the few studies on nutrient deficiencies in *D. rotundata*, the omission of N, K, Ca or S led to poor growth in sand culture (Gaztambide and Cibes 1975). The optimal pH is between 6 and 7 for yam, and below pH 5.5 problems of aluminium toxicity can occur, which means that calcium enrichment is required. Nutrient deficiency symptoms such as mosaic are sometimes similar to those caused by viruses or fungi (Winsor and Adams 1987) leading to confusion in the diagnosis. This study describes the visual symptoms produced on *D. alata* and *D. rotundata* plants by the omission of major and minor elements from nutrient solution in water culture.

Materials and methods

The work was carried out in a screen house using virus-tested stocks (Ng 1994) of *D. alata* variety TDa 95/00361 and *D. rotundata* variety TDr 89/02565. The stocks were propagated

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in vitro to generate plantlets, which were transplanted into peat moss pellets (4.5 cm in diameter) and kept at isolation in a screen house until transplanting into the water culture set-up. Plastic pots (22 cm diameter, 23 cm height, 7 l capacity) with a polystyrene foam cover 2 cm thick with 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 used for cultivation of cucumber in hydroponics (Njwaba 1988; Yamasaki et al. 1976) was the control; it had pH 6.7 and EC 2.3 m.mho units. Eleven test solutions were used, each lacking one of N, P, K, Ca, Mg, Zn, Fe, B, Mn, Cu and Mo. The composition of the solutions is in Table 1. The treatments were arranged in a completely randomized design with three replicates. Each pot was filled with tap water one day before nutrients were added in order to release chlorine from the water. The solution was changed every 5 days, six times for TDa 95/00361 and nine times for TDr 89/02565, using 5 l for the first and second changes, 4.5 l for the third and fourth, and 4 l for the fifth. The pots were each put into a polystyrene foam box (23 × 23 × 21 cm) kept at 25 ± 2°C. The water used contained 3.9 ± 0.5 mg/l K, 2.1 ± 0.4 mg/l Ca, 2.3 ± 0.6 mg/l Mg and 36.5 ± 0.2 mg/l Na. N and P were not found. The pH and EC of the water were 6.9 and 0.42 m.mho units, respectively.

The plantlets were transplanted into plastic pots (one plantlet per pot) without nutrient solutions after 4 weeks for TDa 95/00361 and 7 weeks for TDr 89/02565. Sizes of plantlets are in Table 2. Each seedling was suspended with a wire to keep only the roots submerged in the water. Nutrient deficiency treatments were applied 5 days after transplanting. Observations and measurments were made 30 and 40 days after planting for TDa 95/00361 and TDr 89/02565 respectively.

Table 1. Preparation of nutrient solutions for the experiment

Treatment	Control	– N	– P	– K	– Ca	– Mg	– B	– Zn	– Mn	– Cu	– Mo	– Fe
Chemical	Major elements g/l											
KNO_3	0.81	0	0.81	0	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
$Ca(NO_3)_2.4H_2O$	0.94	0	0.94	0.94	0	0.94	0.94	0.94	0.94	0.94	0.94	0.94
$MgSO_4.7H_2O$	0.49	0.49	0.49	0.49	0.49	0	0.49	0.49	0.49	0.49	0.49	0.49
$NaH_2PO_4.2H_2O$	0.21	0.21	0	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
K_2SO_4	0	0.70	0	0	0	0	0	0	0	0	0	0
$CaSO_4.2H_2O$	0	0.69	0	0	0	0	0	0	0	0	0	0
$NaNO_3$	0	0	0	0.67	0.67	0	0	0	0	0	0	0
	Minor elements mg/l											
H_3BO_3	3.00	3.00	3.00	3.00	3.00	3.00	0	3.00	3.00	3.00	3.00	3.00
$ZnSO_4.7H_2O$	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0	0.22	0.22	0.22	0.22
$MnSO_4.4H_2O$	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	0	2.00	2.00	2.00
$CuSO_4.5H_2O$	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0	0.05	0.05
$Na_2MoO_4.2H_2O$	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0	0.02
Fe-EDTA	15.10	15.10	15.10	15.10	15.10	15.10	15.10	15.10	15.10	15.10	15.10	0

Table 2. Plant growth of TDa 95/00361 (*D. alata*) before and after 30 days (s.d.)

Treatment	Height (cm)	No. of leaves	Leaf (cm)		No. of stems	No. of roots	Root length (cm)	Tuber wt (g)
			Length	Width				
Before culture	9.6 (1.5)	7.8 (1.1)	3.5 (0.5)	2.8 (0.4)	2.9 (0.3)	5.8 (0.8)	4.2 (0.4)	–
Control	61.3 (5.9)	31.7 (1.5)	11.3 (1.0)	6.7 (0.5)	5.3 (0.6)	79.0 (2.6)	34.0 (1.7)	2.2 (0.3)
– N	11.8 (1.8)	8.3 (1.5)	7.6 (1.3)	5.2 (0.7)	3.3 (0.6)	46.7 (6.1)	17.3 (6.7)	2.7 (0.9)
– P	16.3 (2.8)	22.3 (2.1)	6.1 (0.8)	4.5 (0.5)	5.7 (0.6)	49.7 (8.5)	16.3 (1.2)	2.6 (1.2)
– K	59.7 (11.2)	23.7 (3.8)	10.6 (1.0)	6.1 (0.6)	4.7 (1.2)	49.3 (8.1)	36.0 (5.3)	2.1 (0.9)
– Ca	28.7 (6.5)	23.3 (2.1)	8.0 (0.9)	5.1 (0.5)	5.7 (0.6)	63.7 (5.7)	28.0 (5.0)	3.3 (1.0)
– Mg	43.7 (5.5)	47.0 (8.9)	8.1 (0.6)	4.4 (0.3)	5.3 (0.6)	45.0 (5.2)	32.7 (2.1)	3.3 (0.9)
– Zn	33.0 (2.0)	46.0 (12.1)	7.3 (0.9)	4.0 (0.6)	5.7 (1.2)	42.3 (4.5)	32.0 (2.6)	2.9 (1.0)
– Fe	35.7 (5.7)	20.3 (1.5)	7.6 (2.0)	4.4 (0.9)	4.0 (1.0)	41.7 (3.8)	35.7 (2.1)	2.6 (0.2)
– B	66.7 (5.0)	31.3 (4.0)	8.5 (1.0)	5.1 (0.4)	5.3 (0.6)	43.3 (7.1)	34.7 (0.6)	3.0 (1.4)
– Mn	67.0 (3.6)	24.0 (2.6)	8.7 (0.8)	5.3 (0.3)	3.3 (0.6)	26.7 (1.5)	41.0 (4.4)	2.2 (0.5)
– Cu	64.7 (4.2)	26.3 (3.8)	9.0 (0.7)	5.2 (0.3)	3.0 (0.0)	24.7 (3.5)	35.0 (1.0)	2.5 (0.6)
– Mo	64.0 (4.0)	25.3 (2.5)	8.3 (0.8)	5.0 (0.3)	3.3 (0.6)	31.3 (4.7)	36.7 (3.2)	2.3 (1.2)

Leaf (lamina with petiole) samples for analysis of nutrient levels 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 spectrophotometery.

Results

Visual symptoms related to omission of major and some minor elements from the solutions were evident on TDa 95/00361 (*D. alata*) by 20 days (Table 2 and Figure 1). The symptoms associated with omission of specified elements nutrients were:

- N – stunted plants; no increase in number of leaves; yellowish leaves (Figure 1a).
- P – stunted shoot and roots; brownish roots and purple stem; smaller and deeper purple leaves than the control (Figure 1a).
- K – plant height, leaf size and number of vines similar to control, but reduced number of leaves and roots; slender stems and branches; inter-veinal chlorosis on lamina of leaves in the middle to lower positions (Figure 1a).
- Ca – chlorotic new leaves; inter-veinal chlorosis and necrosis on old leaves (Figure 1b); stunted plant; shorter plants; fewer and smaller leaves than the control; slender stems and branches.
- Mg – chlorosis between veins on the lower leaves (Figure 1c); brownish spots on leaves after 30 days of treatment (Figure 1d); shorter plants and fewer roots than the control; more but narrower leaves than the control; slender branches and roots.
- Zn – plant growth similar to plants growing in the absence of Mg; smaller, narrower but more leaves than the control; no chlorosis and necrosis.

- Fe – small new leaves; necrotic spots along or on the veins of the new leaves; distorted leaf shape (Figure 1e); poorly developed and brownish roots 20 days after start of treatment.
- B – plant height, number of leaves and vines similar to control, but smaller leaves and retarded root growth.
- Mn – plant height similar to control; fewer leaves and vines, and smaller leaves than the control; roots were retarded and burnish colour.
- Cu – plant growth was similar to the Mn deficient plants; poorly developed and brownish roots.
- Mo – plant growth was similar with Mn and Cu deficient plants. Tuber weights of all treatments were similar to the control.

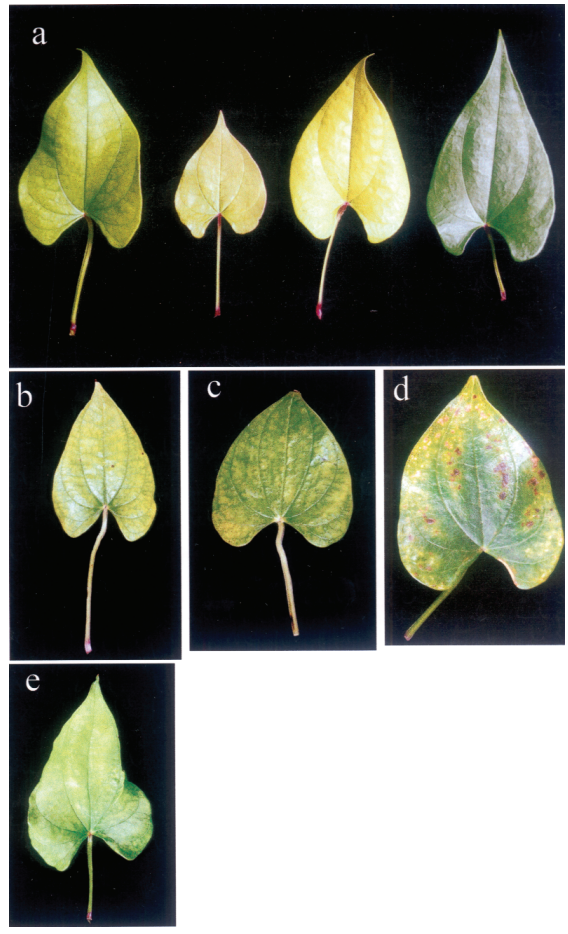

Figure 1. Symptoms on the leaves of *D. alata* clone TDa 95/00361 associated with deficiencies of: (a) L to R - K, P and N compared to control on far R; (b) Ca, inter-veinal chlorosis and necrotic spots; (c) Mg, inter-veinal chlorosis at early stage; (d) Mg, 30 days after treatment; (e) Fe, abnormal shape with chlorosis.

The response to the omission of specified nutrients by TDr 89/02565 (*D. rotundata*) was slower than *D. alata*. The visual symptoms of deficiency of major and some minor elements were evident after 20 and 30 days, respectively (Table 3 and Figure 2).

- N – stunted plants and no increase in number of stems; yellowish leaves (Figure 2a).
- P – stunted plants; short and few with brownish roots; small leaves with yellowish or purplish colour (Figure 2a).
- K – shorter plant and fewer roots than the control, but number of leaves, leaf size, number of stems and length of roots were similar to the control; inter-veinal chlorosis on leaves in the middle to lower positions (Figure 2a).
- Ca – chlorotic new leaves; inter-veinal chlorosis and necrosis in old leaves as in *D. alata* (Figure 2b); stunted plant with growth rate similar to the P deficient plant; slender stems and branches.
- Mg – no characteristic symptoms on the leaves; plant growth similar to the control except for fewer leaves.
- Zn – stunted plants, but similar number of roots to the control; chlorosis and necrosis not observed on the leaves.
- Fe – small new leaves; necrotic spots along or on the veins of new leaves and distorted leaf shape as in *D. alata* (Figure 2c); stunted plant, growth similar to P and Ca deficient plants; poorly developed and brownish roots.
- B – yellowish colour on the lower leaves (Figure 2d); number of leaves, number of stems and root 1ength were similar to the control; shorter plants, smaller leaves and fewer roots than the control.
- Mn – stunted plant; shorter plant, fewer and smaller leaves, and shorter roots than the control; stunted and brownish roots as in *D. alata*.

Table 3. Plant growth of TDr 89/02565 (*D. rotundata*) before and after 45 days (s.d.)

Treatment	Height (cm)	No. of leaves	Leaf (cm)		No. of stems	No. of roots	Root length (cm)	Tuber wt (g)
			Length	Width				
Before culture	13.7 (2.0)	9.3 (2.1)	6.5 (1.0)	5.0 (1.3)	2.7 (0.9)	8.5 (1.7)	5.2 (0.7)	–
Control	209.0 (31.2)	78.0 (2.0)	10.5 (0.9)	6.1 (0.6)	5.0 (1.7)	40.7 (1.5)	50.3 (6.8)	3.6 (2.2)
– N	62.7 (15.7)	17.0 (1.0)	5.4 (0.6)	4.4 (0.2)	2.7 (0.6)	12.7 (3.5)	40.0 (2.0)	5.6 (1.2)
– P	45.3 (6.1)	28.7 (11.2)	5.2 (0.8)	4.4 (0.5)	2.7 (0.6)	19.7 (2.9)	26.3 (3.5)	4.2 (3.9)
– K	160.7 (11.2)	76.3 (4.0)	9.5 (0.6)	5.8 (0.5)	4.0 (1.0)	33.7 (3.8)	48.0 (3.6)	4.2 (2.6)
– Ca	46.7 (7.6)	26.3 (5.1)	6.6 (1.3)	4.3 (1.0)	3.3 (0.6)	19.0 (2.6)	28.3 (3.5)	5.3 (1.4)
– Mg	132.7 (50.0)	35.0 (7.9)	9.5 (0.8)	6.5 (0.6)	4.3 (1.5)	39.7 (1.5)	43.3 (13.1)	4.5 (2.6)
– Zn	82.3 (4.5)	44.7 (13.7)	6.1 (0.9)	4.1 (0.6)	5.3 (1.5)	39.3 (2.1)	21.7 (1.5)	3.4 (0.9)
– Fe	42.0 (6.0)	25.0 (3.0)	5.2 (0.4)	3.9 (0.2)	4.0 (1.0)	19.7 (1.5)	24.7 (3.1)	4.3 (2.2)
– B	106.3 (15.9)	76.3 (9.3)	7.9 (0.4)	4.7 (0.4)	6.3 (1.5)	26.7 (3.8)	45.3 (1.5)	4.7 (1.6)
– Mn	64.7 (22.5)	44.0 (8.7)	6.4 (0.5)	3.7 (0.3)	4.7 (0.6)	37.0 (2.6)	25.3 (3.1)	4.4 (2.0)
– Cu	97.3 (12.9)	58.7 (12.2)	6.5 (0.7)	4.2 (0.8)	4.0 (1.0)	41.0 (4.4)	31.3 (2.9)	3.9 (1.0)
– Mo	97.0 (11.5)	39.3 (3.8)	6.6 (0.9)	3.9 (0.6)	3.3 (0.6)	35.7 (0.6)	29.0 (1.7)	3.8 (1.0)

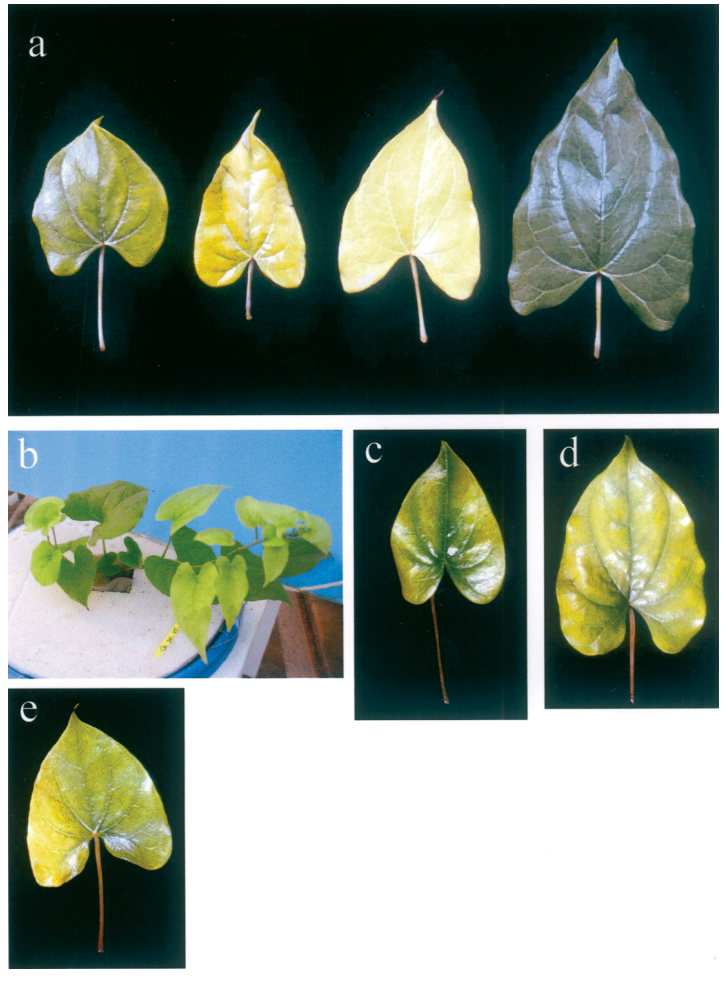

Figure 2. Symptoms on the leaves of *D. rotundata* clone TDr 89/02565 associated with deficiencies of: (a) L to R - K, P and N compared to control on far R; (b) Ca, plant showing chlorosis on new leaves; (c) Fe, clorosis on new leaf; (d) B, abnormal shape with clorosis; (e) Mo, chlorosis.

- Cu – no characteristic symptom observed on the plants; shorter plants and roots, fewer and smaller leaves than the control.
- Mo – plant growth similar to Mn and Cu deficient plants; chlorosis along the entire leaf margin on the lower leaves (Figure 2e). Tuber weights of all treatments were similar to the control.

The results of leaf analysis of TDa 95/00361 and TDr 89/02565 are in Tables 4 and 5 respectively. The omission of each element reduced the leaf content of that element. Leaves of the control of TDa 95/00361 had similar N, P, K, Ca and Mg to those of TDr 89/02565. Leaves

from Fe deficient plants contained the highest level of Zn, Mn and Cu, and the Fe content was high in Mo and Cu deficient plants. The control of TDr 89/02565 had more Zn, Fe and Mn, and less Cu than TDa 95/00361.

Discussion

The visual symptoms related to the omission of major elements were similar in *D. alata* and *D. rotundata* and similar to those reported by Gaztambide and Cibes (1975). Omitting N, P or Ca heavily stunted growth compared to the omission of K and Mg in both species. The minor elements, leaves of *D. rotundata* showed symptoms of deficiency of Fe, B and Mo but *D. alata* showed symptom only of Fe deficiency. However, the omission of minor elements

Table 4. Chemical composition of TDa 95/00361 (*D. alata*) leaves from the omission of selected elements in water culture

Treatment	N	P	K	Ca	Mg	Zn	Fe	Mn	Cu
			(%)				(μg/g)		
Control	3.67	0.30	6.03	3.88	0.48	30.52	260.32	170.03	15.61
– N	0.98	0.25	5.75	2.04	0.43	35.12	249.23	200.58	15.64
– P	3.85	0.10	6.29	2.19	0.41	28.44	232.21	195.71	14.83
– K	3.79	0.37	1.94	4.85	0.51	32.86	218.55	211.38	16.47
– Ca	3.35	0.31	5.88	0.98	0.57	30.87	216.32	186.29	17.24
– Mg	3.78	0.34	8.69	8.01	0.26	33.42	212.19	241.11	11.66
– Zn	3.54	0.34	5.01	3.87	0.43	12.59	284.21	169.71	14.25
– Fe	2.90	0.29	5.45	5.25	0.59	83.17	51.84	398.13	19.02
– B	3.36	0.28	5.63	4.99	0.56	57.26	270.99	290.79	13.66
– Mn	3.76	0.33	5.19	4.04	0.54	55.41	237.10	144.28	13.53
– Cu	3.56	0.30	5.64	4.38	0.56	50.63	326.02	184.86	9.52
– Mo	3.66	0.31	6.01	3.92	0.53	40.74	329.47	222.03	12.79

Table 5. Chemical composition of TDr 89/02565 (*D. rotundata*) leaves from the omission of selected elements in water culture

Treatment	N	P	K	Ca	Mg	Zn	Fe	Mn	Cu
			(%)				(μg/g)		
Control	3.44	0.41	7.23	5.09	0.61	47.06	349.71	323.33	9.45
– N	1.22	0.24	5.16	2.97	0.57	60.47	282.26	195.24	8.82
– P	3.43	0.12	6.68	3.82	0.49	43.73	263.89	189.06	7.85
– K	3.97	0.56	2.57	8.58	1.32	54.18	204.44	419.84	10.48
– Ca	3.14	0.34	6.56	1.51	0.95	48.74	204.44	253.89	10.48
– Mg	4.22	0.45	6.87	5.73	0.33	61.44	323.60	365.30	10.67
– Zn	3.10	0.73	5.71	4.80	0.57	20.70	363.87	360.50	9.99
– Fe	2.16	0.22	4.55	4.42	0.75	62.72	77.02	261.30	9.66
– B	3.36	0.28	9.18	5.26	0.67	42.91	216.85	326.02	9.86
– Mn	2.87	0.32	5.61	4.45	0.74	52.94	358.86	118.86	9.42
– Cu	2.70	0.33	4.30	4.42	0.58	36.05	321.34	319.93	7.30
– Mo	3.06	0.37	6.65	4.90	0.65	52.94	299.70	303.37	8.49

led to poor growth of the leaves, stems and roots of yam plants. The omission of Zn or Fe stunted plant growth more than the other minor elements in both species. The Fe deficiency symptoms were again in line with those observed by Gaztambide and Cibes (1975). The omission of major or minor elements did not seem to affect development of tubers but this may due to the rather short duration of these experiments.

The levels of N, Mg, Zn, Fe and Cu in the leaves of *D. alata* were similar to those reported by Vander Zaag et al. (1980) and the P level was similar to that of Obigbesan and Agboola (1978). For *D. rotundata*, the N, P, Ca, Mg, Fe and Mn levels in the leaves were similar to those obtained by Gaztambide and Cibes (1975). However, the level of K in both species was twice that reported earthier. The symptoms observed in this experiment would be useful for diagnosis in the field of nutrient deficiencies in yam plants.

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