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The influence of zinc on early growth and nutrient uptake by pumpkin (*Telfairia occidentalis* Hook F) in an ultisol

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Abstract: The study investigated the influence of zinc on some growth parameters of *Telfairia occidentalis* as well as its effect on some soil chemical properties in field experiment carried out at the experimental farm of Faculty of Agriculture, University of Benin, Benin City, Nigeria. Four levels of treatment namely 0, 20, 40 and 80kg ZnSO4 ha^{-1} were used in an experiment laid out in a randomized complete block design with 3 replicates. Results showed that the soil Zn, N, P, K, Mg, exchangeable acidity, increased inconsistently from 0.002 $mgkg^{-1}$, 0.60 gkg^{-1}, 2.70 $mgkg^{-1}$, 0.09 $cmolkg^{-1}$, 0.30 $cmolkg^{-1}$, 2.40 $cmolkg^{-1}$ to 154.18 $mgkg^{-1}$, in 80 $kgZnha^{-1}$, 0.63 gkg^{-1} in 0 $kgZnha^{-1}$, 3.86 $mgkg^{-1}$ in 0 $kgZnha^{-1}$, 0.12 $cmolkg^{-1}$ in 80 $kgZnha^{-1}$, 0.41 $cmolkg^{-1}$ in 0 $kgZnha^{-1}$, 2.50 $cmolkg^{-1}$ in 80 $kgZnha^{-1}$ respectively. The free Fe oxide, free Al oxide, amorphous Fe oxide and amorphous Al oxide also increased from 5.92%, 0.74%, 0.07%, 0.03% to 6.18% in 0 $kgZnha^{-1}$, 1.98% in 80 $kgZnha^{-1}$, 0.74% in 80 $kgZnha^{-1}$, 0.35% in 80 $kgZnha^{-1}$ respectively. While the soil pH, organic carbon, Ca and Na also inconsistently decreased from 5.70, 10.70 gkg^{-1}, 1.60 $cmolkg^{-1}$, and 0.06 $cmolkg^{-1}$ to 5.09 in 20 $kgZnha^{-1}$, 10.30 gkg^{-1} in 20 $kgZnha^{-1}$, 0.36 $cmolkg^{-1}$ in 80 $kgZnha^{-1}$ and 0.041 $cmolkg^{-1}$ in 20 $kgZnha^{-1}$ respectively. The K, Mg and Zn content of the root increased with increase in Zn treatment whereas the Na decreased with increase in Zn application. The root Ca and P were however not consistent. In the shoot, the Mg, N, K, Ca, Na and Zn minerals also increased with increase in Zn application. The P content of the shoot was however not consistent. With the exception of Na uptake by the root, which decreased with Zn treatment, the entire nutrients uptake, plant height, number of leaves and the dry matter yield increased with increased Zn treatments. The leaf area and stem girth were however not consistent with increase in Zn application.

Keywords: Zinc, Uptake, Growth, Metals indicator

INTRODUCTION

Zinc is an essential micronutrient needed for biological system with higher attendant toxicity in plants and humans at higher concentration. It is a known constituent of metallo enzyme or a co-factor for several enzymes such as anhydrases, dehydrogenase, oxidase, peroxidase. Zn plays an important role in regulating the nitrogen metabolism, cell multiplication photosynthesis and auxin synthesis in plants (Rout and Das, 2003).

It has been estimated that nearly 2800 human proteins are capable of binding Zn, which corresponds to 10% of human proteome, and almost 40% of the Zn-binding protein are transcription factors needed for gene regulation and the 60% enzymes and proteins involved in ion transport (Andreine *et al.,* 2006). This micronutrient is needed for structural and functional integrity of biological membranes and for detoxification of highly aggressive free radicals (Calmak, 2000). Any alteration of Zn homeostasis or any reduction in Zn concentration of human body may results in number of cellular disturbances and impairment of immense dysfunctions and high susceptibility to infections diseases, retardation of mental development as well as stunted growth of children (Black, 2003).

Omotoso and Falade (2007) while citing Rengh *et al.* (1999) reported that the application of Zn fertilizers could effectively increase Zn concentration in the edible portions of crops. Yadav and Shukler (1983) reported increase in number of nodules and Leghaemogblobin content of nodules with increased Zn application up to 7.5 *ugg*$^{-1}$ in chicken pea. It has been reported that Zn positively influenced the shoot dry matter yield of maize plant (Nyaki *et al.*, 1983) and that of rice and common beans, Frageria (2007). The increased Zn concentration in the soil significantly improved uptake of Zn in rice as well as common beans (Frageria, 2007). However, the availability of this Zn in soil and their uptake by plants not only depends on the total metal content in the soil but also upon the other factors such as soil organic matter, cation exchange capacity, oxides, soil moisture and soil pH.

The test crop *Telfairia occidentalis* is a herbaceous

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annual creeping or climbing plant that grows to about 6m in length. The soft round stems have large leaves that are trifoliate. The plant can produce up to 3-6 pods and the number of seeds per pod depends on the size of the pod. Both the seeds and the leaves widely consumed in tropical Africa and the plant is highly nutritive. This study was carried out to determine Zn uptake by *Telfairia occidentalis* in an ultisol.

MATERIALS AND METHODS

The experiment was conducted in the experimental field at the Faculty of Agriculture University of Benin, Benin City, Nigeria. The field used was left fallow for about 5 years. The experimental area was 10.20 m x 8.4 m giving a total area of 85.68 m^2. The following 0, 20, 40, 80 kg$ZnSO_4$ha^{-1} levels of treatment were used. Each treatment was represented by a bed size of 1.8 m x 1.8 m separated by 50 cm space while each replicate was separated by 1m alley. The various levels of treatment were uniformly applied with the aid of a spreader mixed thoroughly and then left for 7 days to enable the Zn equilibrate with the soil before transplanting the seedlings. The experiment was organized in randomize complete block design with three replicates. Seedlings were transplanted at a spacing of 1m x 1m. Each bed had a plant population of 4 plants per bed. Weeding and watering were carried out regularly. The experiment lasted for 60 days when the plants were harvested and the plant height, number of leaves, stem girth and leaf area were determined. The shoots and roots were separated, oven dried in a draft oven at 70^{0}C for 48 hours to a stable dry weight used for calculating nutrient uptake. Soil analysis was carried out prior and after the experiment.

Soil pH was determined by using pH meter while the soil particle size was done by hydrometer method of Bouyoucos (1951) as modified by Day (1965). The organic carbon was determined by chromic acid wet oxidation procedure of Walkey and Black (1934) as modified by Black (1965). The total N was determine by micro-kjeldal procedure as described by Jackson (1962) whereas the available P was extracted by using Bray No 1 P solution, and the P in the extract assayed calorimetrically by molybdenum blue colour method of Murphy and Riley (1962). The exchangeable bases were extracted using 1 N neutral ammonium acetate solution. The Ca and Na content of the extract were determined volumetrically by EDTA titration procedure (Black, 1965). The K and Na were determined by flame photometry and Mg content obtained by difference. The exchangeable acidity was determined by methods of McLean (1965) while the heavy metals and oxides were determined by methods Soon and Abboud (1993). The data generated were analysed by Genstat statistical version 6.1.0 234 (Payne, 2002).

RESULTS

The properties of soil used: The properties of soil used before and after the trial is shown in Table 1. The textural class revealed that the soil is sandy loam and also acidic which is typical of an ultisol.

After the trial, The soil Zn, N, P, K, Mg, exchangeable acidity, increased inconsistently from 0.002 mgkg^{-1}, 0.60 gkg^{-1}, 2.70 mgkg^{-1}, 0.09 cmolkg^{-1}, 0.30 cmolkg^{-1}, 2.40 cmolkg^{-1} to 154.18 mgkg^{-1}, in 80 kgZnha^{-1}, 0.63 gkg^{-1} in 0 kgZnha^{-1}, 3.86 mgkg^{-1} in 0 kgZnha^{-1}, 0.12 cmolkg^{-1} in 80 kgZnha^{-1}, 0.41 cmolkg^{-1} in 0 kgZnha^{-1}, 2.50 cmolkg^{-1} in 80 kgZnha^{-1} respectively. In addition, free Fe oxide, free Al oxide, amorphous Fe oxide and amorphous Al oxide increased from 5.92%, 0.74%, 0.07%, 0.03% to 6.18% in 0 kgZnha^{-1}, 1.98% in 80 kgZnha^{-1}, 0.74% in 80 kgZnha^{-1}, 0.35% in 80 kgZnha^{-1} respectively. While the soil pH , organic carbon, Ca and Na also inconsistently decreased from 5.70, 10.70 gkg^{-1}, 1.60 cmolkg^{-1}, and 0.06 cmolkg^{-1} to 5.09 in 20 kgZnha^{-1}, 10.30 gkg^{-1} in 20 kgZnha^{-1}, 0.36 cmolkg^{-1} in 80 kgZnha^{-1} and 0.041 cmolkg^{-1} in 20 kgZnha^{-1} respectively. However, the treatments were not significantly different from one another in soil pH, organic carbon, N, Na, exchangeable acidity, free Al oxide and amorphous Fe oxide. In P, Mg and Ca, the control treatment was significantly higher than other treatments whereas in amorphous Al oxide and Zn components of the soil, 80 kgZnha^{-1} was higher than other treatments. The control and 80 kgZnha^{-1} treatments were significantly higher in free Fe oxide while 40 kgZnha^{-1} and 80 kgZnha^{-1} treatments were significantly higher in K content of the soil.

Mineral ions in the shoot and root (Table 2):

Shoot: In the shoot, the N, K, Na, Ca and Zn content increased with increased Zn application with 80 kgZnha^{-1} treatments significantly higher than other treatments. In the Mg component, the 40 kgZnha^{-1} and 80 kgZnha^{-1} treatments were not significantly different from each other but were significantly higher than other treatments. While in the P content, no treatments were significantly different from one another. However, the values of P were not consistent with the increase in Zn application.

Root: In the root, N, K, Mg and Zn minerals increased with increase in Zn treatments with the 80kgZnha^{-1} significantly higher than other treatments. In Ca and P, there were no significant differences among the various treatments. The Ca and P content also not consistent with the increase in Zn treatment. There was a decrease in Na content with increase in Zn application with 0 kgZnha^{-1} significantly higher than other treatments. However, the values of mineral ions in the root were lower than that of the shoot.

Uptake of some minerals by the shoot and root (Table 3):

Root: With the exception of Na uptake by the root, which decreased with increase in Zn application, the N, P, K, Mg, Ca and Zn uptake increased with increased Zn

Table 1. Some chemical properties of the soil used before and after the trial.

Treatment kg ha^{-1}	Soil:H_2O (1:1)	Org C gkg^{-1}	N gkg^{-1}	Av P mgkg^{-1}	K	Mg	Ca	Na	Exch acidity	Free Oxides Fe	Free Oxides Al	Amorphous Oxides Fe	Amorphous Oxides Al
					Cmolkg^{-1}					(%)			
Before Zn treatment													
	5.70	10.70	0.60	2.70	0.09	0.30	1.60	0.06	2.40	5.92	0.74	0.07	0.03
After Harvest													
0	5.68a	10.60a	0.63a	3.86a	0.09b	0.41a	0.56a	0.051a	2.23a	6.18a	1.78a	0.55a	0.19c
20	5.09a	10.30a	0.50a	3.10b	0.09b	0.36b	0.46b	0.041a	2.31a	4.91b	1.72a	0.65a	0.19c
40	5.17a	10.63a	0.50a	2.29c	0.11a	0.36b	0.44c	0.050a	2.33a	4.87b	1.48a	0.66a	0.25b
80	5.51a	10.60a	0.30b	2.03d	0.12a	0.24c	0.36d	0.052a	2.50a	5.79a	1.93a	0.74a	0.35a

Mean values with the same letter in the column are not significantly different from one another at $P \leq 0.05$.

treatment. In the uptake of P, Mg and Ca, there were no significant differences among the various treatments while in Zn uptake, 80 kgZnha^{-1} was significantly higher than other treatments. The 40 kgZnha^{-1} and 80 kgZnha^{-1} treatments were not significantly different from each other in K and N uptake but higher than other treatments.

Shoot: The uptake of N, P, K, Mg, Ca, Na and Zn by the shoot also increased with increased Zn treatment with 80kgZnha^{-1} treatment significantly higher than other treatments in K, Na, Ca and Zn. In the uptake of Mg and N, the 40 kgZnha^{-1} and 80 Znha^{-1} treatments were not significantly different from each other but were higher than other treatment whereas in P uptake, the 20 kgZnha^{-1}, 40 kgZnha^{-1} and 80 kgZnha^{-1} were not significantly different from one another but higher than the control treatment.

Effect of Zn on some growth parameters and dry matter yield (Table 4): The plant height and number of leaves increased with increased Zn application. In the plant height, 80 kgZnha^{-1} though not significantly different from 40 kgZnha^{-1} treatment but were higher than other treatments. While in number of leaves, stem girth and leaf area, the 20 kgZnha^{-1}, 40 kgZnha^{-1} and 80 kgZnha^{-1} treatments were not significantly different from one another but higher than control. The stem girth and leaf area were however not consistent with increase in Zn application. The shoot and root dry matter yield also increased with increased Zn application with 80kgZnha^{-1} significantly higher than other treatments.

DISCUSSION

The nutrient components of the soil were low. For instance, the N, P, K values before the experiment were less than critical level of 1.5 gkg^{-1} (Enwenzor *et al.*, 1979) 10-15 mgkg^{-1} (Adeoye and Agboola, 1985) and 0.18-20 cmolkg^{-1} (Agboola and Obigbesan, 1974) respectively. The Zn value was also below the critical level of 0.003mgkg^{-1} as earlier reported by WHO (1984). The fluctuations in some of the soil nutrients may be attributed to their uptake by the plant at various levels of Zn application. However, the decrease in organic carbon may be due to the decomposition of the organic matter that helped to supplement other soil nutrients in the trial. Hence, increase in some of the nutrient. The increase in oxides may be attributed to their insolubility. Generally, oxides solubility is very low at the pH range of soils and depends on the particle size, crystallinity and percent of Al substitution (Schwertmann, 1991). The quantification of oxides in soils and sediments is often complicated by a considerable variation in crystallinity (Schwertmann, *et al.*, 1985) but it is estimated that iron oxides concentration in various soils vary from <0.1 to >50% and they may be evenly distributed in horizons, concretion mottles, bands or clay minerals coating (Schwertmnn, 1991). The values of the iron oxides

Table 2. Effect of Zn on some mineral content (%) and uptake (mgkg^{-1}) by *Telfairia occidentalis*.

Treatment kgha^{-1}	Mineral content						Mineral uptake					
	N	P	K	Mg	Ca	Na	N	P	K	Mg	Ca	Na
0	2.52d	0.27a	1.71d	0.83b	2.55d	2.77d	1.00c	0.10b	0.73d	0.35c	1.07d	1.21d
20	2.67c	0.29a	2.63c	0.87b	2.58c	2.80c	1.73b	0.19a	1.72c	0.56b	1.68c	1.90c
40	2.85b	0.25a	2.78b	0.92a	2.64b	2.86b	2.00ab	0.20a	1.92b	0.64a	1.82b	2.05b
80	2.87.a	0.27a	3.29a	0.93a	2.74a	2.93a	2.12a	0.21a	2.31a	0.66a	1.93a	2.12a

Mean values with the same letter in the column are not significantly different from one another at $P \leq 0.05$.

Table 3. Zn content and its uptake by *Telfairia occidentalis.*

Treatment Kgha^{-1}	Shoot Zn content (%)	Shoot Zn uptake (mgkg^{-1})	Root Zn content (%)	Root Zn uptake (mgkg^{-1})
0	18.06d	7.35c	6.97b	0.21c
20	22.00c	14.07b	7.72b	0.26bc
40	23.00b	15.62b	9.67b	0.32b
80	27.33a	18.71a	13.33a	0.47a

Mean values with the same letter in the column are not significantly different from one another at $P \leq 0.05$.

obtained in the trial compared well with that of Schwertmann above. The zinc increase in the soil is because of the increase in the amount or concentration of the Zn applied to the soil. Similarly, Gundermann and Hutchinson (1995) and Orhue (2008) also found elevated heavy metals in soil contaminated with heavy metals. The increase in minerals and their uptake in root and shoot is due to the fact that Zn is not known to an antagonist at the primary point or absorption site to these nutrients except P, which have been reported by Summer and Farina (1983) and Wilkinson *et al.* (2000) to interact with Zn either positively or negatively. The P content in the plant in the presence of Zn was not consistent. The increase in these mineral content as well their uptake with Zn application have earlier been reported by Rout and Das (2003) and Frageria (2007) in rice and common bean plant. The performance of the growth parameters in Zn treated plants when compared with control is because of the higher uptake of the nutrients due to synergism influence of Zn application. The Zn indeed is needed as co-factor for several enzymes or metallo-enzymes resulting in the overall increase in the physiological process for growth. Frageria (2007) has earlier reported similar results in rice and common bean plant and Mohammed and Hemmatollah (2008) in wheat.

There was a difference between the shoot and root organs of the plant with respect to applied Zn and resultant accumulation trend of Zn. In the result, more Zn was found in the shoot than the root making the plant *Telfairia occidentalis* a Zn metal indicator. The metal indicator plant according to Raskin *et al.* (1994) actively accumulate metal in their cereal tissue and generally reflect metal level in the soil and they tolerate the existing concentration level of metals by producing intracellular metal bind compounds (chelator) or alter metal compartmentalization pattern by storing metals in non-sensitive parts.

In conclusion, Zn application significantly affected the growth parameters positively with increase in the nutrient content and uptake by the shoot and root. The application of Zn had no negative influence on the soil chemical properties determined.

Table 4. Effect of Zn on some growth parameters and dry matter of *Telfairia occidentalis.*

Treatment kg ha^{-1}	Plant height (cm)	Stem girth (cm)	No of leaves	Leaf area (cm^2)	Shoot dry weight (g)	Root dry weight (g)
0	78.90c	2.28a	65.00b	25.22a	42.2d	2.88c
20	121.30b	3.03a	117.02a	29.56a	65.27c	3.17b
40	148.10ab	3.44a	117.02a	33.66a	69.03b	3.24b
80	158.80a	3.09a	136.23a	33.44a	70.17a	3.40a

Mean values with the same letter in the column are not significantly different from one another at $P \leq 0.05$.

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