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Response of Fluted Pumpkin (*Telfairia occidentalis* Hook F) to Sodium Chloride (NaCl) Application

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Abstract: The influence of NaCl on the early growth of fluted pumpkin (*Telfairia occidentalis* Hook F) and some soil chemical properties was studied in a green house and field experiment at the University of Benin, Teaching and Research Farm. The levels of NaCl used in the greenhouse were 0, 0.5, 1, 2, 3 g/10 kg soil organized in completely randomize design while in the field trial, the 0, 100, 200, 300, 400 kg ha^{-1} equivalent to those of green house trial were tested in a randomized complete block design. Result revealed that the N, P, K, Mg and Ca content and their uptake by the plant and the ionic balance (K:Na, Ca:Na, Mg:Ca) decreased significantly with increasing NaCl applications. The Na and Cl content and their uptake by the plant increased significantly ($p<0.05$) with increasing Nacl concentrations. The result further showed that the N, P and pH components of the soil were not consistent with increasing NaCl treatments while the K, Na, Ca, Cl, Sodium Absorption Radio (SAR), exchangeable acidity, organic carbon and effective cation exchange capacity increased significantly with increasing NaCl levels. As the NaCl concentrations increased, the plant height, stem girth, number of leaves and shoot dry matter yield significantly ($p<0.05$) decreased.

Key words: Influence, ionic balance, sodium absorption ratio, uptake, increasing, decreasing

INTRODUCTION

Soil salinity is one of the main environmental and abiotic factors responsible for decreasing crop productivity in many areas of the world, especially in arid and semi-arid regions (De Pascale and Barbieri, 1997). According to Carter *et al*. (2005), approximately one-third of the world irrigated soils and a large proportion of soils in dry land have been estimated to be saline due to uncontrolled irrigation and use of poor quality water. The commonest predominant form of salt in saline soils is sodium chloride (NaCl).

The presence of sodium salts in the soil influences most of the physical and chemical characteristics of the soils such as soil pH, soil electrical conductivity, soluble ions and Sodium Absorption Ratio (SAR) (Mostafa *et al*., 2004). As salinity increased the Ca^{2+}, Mg^{2+}, K^{+}, Na and Cl sharply increased in the soil. It was also reported by Mostafa *et al*. (1992) that the use of 400 ppm of NaCl led to concentration of Cl and SO_4 in soil. Excess Cl also has been reported to hinder NO_3 uptakes by plants and destroys the ionic balance in plants (Mer *et al*., 2000).

Soils laden with Nacl constitute serious production problems for vegetable crop as these are known to suppress plant growth (Turan *et al*., 2007). Heavy environmental concentration of salts unleashes various types of physical and chemical stress in plants provoking complex responses that involve changes in plant morphology, physiology and metabolism resulting in decline of growth and yields. An over whelming amount of NaCl induced salinity have been known to increase uptake of Na and Cl by plants and increased NaCl in the soil have also been reported to significantly reduced the uptake of Ca and K by plants as a result of intracellular influx of both ions (Cerda *et al*., 1995). The total chlorophyll concentration of lentil and *Phaseolus vulgaris* (Petolino and Leone, 1980) rice (Yeo and Flowers, 1983), wheat and bean plants (Turan *et al*., 2007) leaves have been reported decreased with increased NaCl appreciation.

Reduced germination percentage and root growth in three Medicago crops (Amipour and Aghaee, 1997), reduced plant height, stem growth, number of leaves, fresh and dry matter yield have been reported by Adiloglu *et al*. (2007) in wheat, Huang *et al*. (2006) in barley, Mer *et al*. (2000) in *Brassica juncea* and Tjera *et al*. (2005) in common bean plants. The test plant, fluted pumpkin (*Telfairia occidentalis*) is commonly grown as home garden and commercial crop in Nigeria. This vegetable crop is found in daily diet of an average Nigerian due to its nutritive value. This plant when grown

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in off season is often irrigated with poor quality water. In the home gardens, poor quality salty water are always used to keep this plant alive. This progressive irrigation with poor quality water could result in progressive changes in the soil chemical properties as well as the growth of the crop. Therefore, this study was aimed at determining the influence of NaCl on some soil chemical properties and some agronomic characters of *Telfairia occidentalis*.

MATERIALS AND METHODS

The trials were conducted in the greenhouse and field at the University of Benin. Teaching and Research Farm, Benin city, Nigeria.

Greenhouse trial: Soil sample was obtained from 0-15 cm depth in a plot left fallow for about 3 years. The soil sample taken was thoroughly mixed, air-dried and sieved to remove debris. Thereafter, 10 kg soil was weighed into each polythene pot perforated below. Each polythene pot was however place on sizeable saucer to prevent inter replicate pollution. The NaCl rates of 0, 0.5, 1, 2, 3 g/10 kg soil were applied a week before transplanting one seedling per pot. The polythene pots were arranged in a completely randomized design and replicated three times. The 1 week interval prior transplanting was to enable the NaCl equilibrate with the soil. Watering and weeding was carried out regularly while the experiment lasted for 46 days. Just before the final harvest, the plant height, number of leaves and stem girth were determined. At final harvest, the shoots were separated from the roots and the shoots oven dried at 70°C for 48 h to a constant dry weight used in computing the nutrient uptake.

Field trial: The field trial was conducted to validate the greenhouse trial result. The field trial was sited where the greenhouse soil was obtained and it occupied an area measuring 12×13 m. The field experiment was organized in a randomized complete block design with 3 replicates and each replicate had five beds. Each bed with a dimension of 2×2 m represented a treatment The beds were separated from one another by 50 cm alley while the replicates were separated from one another by 1 m alley. The moistened beds were treated with the following rates of 0, 100, 200, 300, 400 kg NaCl ha^{-1}. The NaCl were thoroughly mixed with the soil a week before transplanting four seedlings per bed at a spacing of 60×60 cm. Weeding and watering was carried out. The field trial also lasted 46 days. The mode of data collection used in the .greenhouse was also adopted in the field trial.

Soil analysis: Soil samples were taken prior and after the trials for analysis. The soil pH was determined at a soil to water ratio of 1:1 using a glass electrode pH meter. Particle size analysis was determined by the hydrometer method as modified by Day (1965). The organic carbon content of the soil was determined by using the chromic acid wet oxidation procedure as described by Jackson (1962). The nitrogen was determined by micro-kjeldal procedure as described by Jackson (1962). Phosphorus was extracted by using Bray no. 1 P solution (Bray and Kurtz, 1945) and the P in the extract assayed colorimetrically by the Molybdenum blue colour method of Murphy and Riley (1962).

The exchangeable bases were extracted using IN neutral ammonium acetate solution. The Ca and Mg content of the extract were determined volumetrically by the 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 KCl extraction and titration methods of Mclean (1965). The effective cation exchange capacity was calculated as the sum of exchangeable bases (Ca, Mg, K and Na) and exchangeable acidity. The Cl was determined by methods of Ademoroti (1996). The Sodium Absorption Ratio (SAR) was calculated by using this equation:

$$SAR= [Na^{+}]/\{(\{Ca^{2+}]+\{Mg^{2+}\})/2\}^{1/2}$$

The data generated were analyzed by Genstat statistical Version 6.1.0.234 (Payne, 2002).

Plant analysis: The plant materials were ground (<1 mm) and then digested with a mixture of HNO_3, H_2SO_4 and $HClO_4$ acids (IITA, 1979). The Na, K, Ca, Mg were determined by atomic absorption spectrophotometer (AAS UNICAM 969). For P content (AOAC, 1970), Perchloric acid digestion (wet oxidation) method was used while the Micro-kjeldal method of Jackson (1962) was used for N determination. The Cl content was determined by methods of Udo and Ogunkule (1986).

RESULTS AND DISCUSSION

Pre-trial soil properties: Table 1 shows the soil properties used in both trials. The soil is acidic and texturally sandy loam with low fertility. The N, P and K for instance were below the critical level of 1.5 g kg^{-1} (Enwenzor *et al.*, 1979), 10-15 mg kg^{-1} (Adeoye and Agboola, 1985) and 0.18-20 cmol kg^{-1} (Agboola and Obigbesan, 1974), respectively.

Post-harvest soil properties: The post-harvest soil properties for both trials are shown in Table 2. The N, P and soil pH were not consistent with increasing NaCl

Table 1: Some physico-chemical properties of the soil used in the trials

Properties	Greenhouse values	Field values
pH (1:1)	5.08	4.97
Organic carbon (g kg^{-1})	0.80	0.72
Total N (g kg^{-1})	0.86	0.88
Av P (mg kg^{-1})	3.00	3.25
Ca (cmol kg^{-1})	0.80	0.81
Mg (cmol kg^{-1})	0.35	0.37
K (cmol kg^{-1})	0.06	0.04
Na (cmol kg^{-1})	0.01	0.02
Exchangeable acidity (cmol kg^{-1})	0.04	0.3
Ecec (cmol kg^{-1})	1.24	1.84
Cl (mg kg^{-1})	1.02	1.20
Sodium Absorption Ratio (SAR)	0.03	0.03
Sand (g kg^{-1})	876	876
Silt (g kg^{-1})	39.50	39.50
Clay (g kg^{-1})	84.50	84.50
Textural class	Sandy loam	Sandy loam

Table 2: Some chemical properties of the soil used after the greenhouse and field trials

Rate NaCl g/10 kg soil	pH (H_20 1:1)	Org C (g kg^{-1})	Av P (mg kg^{-1})	Total N (g kg^{-1})	Ca	Mg	K	Na	Exch acidity	Ecec	Cl (mg kg^{-1})	SAR
					----------------(cmol kg^{-1})----------------							
Greenhouse trial												
0	5.01^a	0.75^c	2.80^a	0.69^b	0.20^d	0.03^c	0.007^c	0.02^e	0.45^a	1.55^c	0.62^d	0.06^e
0.5	4.84^b	0.99^b	1.92^b	0.69^b	0.41^c	0.05^c	0.02^{bc}	0.82^d	0.48^a	2.15	17.40^c	1.71^d
1	4.40^d	1.29^a	1.81^c	0.74^b	0.55^b	0.10^b	0.02^{bc}	1.02^c	0.49^a	2.19^b	20.01^{bc}	1.79^c
2	4.43^d	1.39^a	1.10^d	0.80^a	0.70^a	0.11^b	0.03^b	2.03^b	0.50^a	2.86^a	22.63^b	2.03^b
3	4.53^c	1.40^a	1.03^e	0.73^b	0.74^a	0.29^a	0.05^a	3.10^a	0.53^a	3.00^a	33.67^a	4.31^a
Field trial (kg ha^{-1})												
0	4.61^c	0.81	2.69^b	0.76^a	0.31e	0.06^d	0.03^a	0.03e	0.40^d	1.62^d	1.08^e	0.07^e
100	4.88^a	0.80	3.00^a	0.75^a	0.54^d	0.08^{cd}	0.04^a	0.30^d	0.50^c	1.66^d	10.37^d	0.54^d
200	4.58^c	0.99	3.00^a	0.75^a	0.61^c	0.10^{bc}	0.06^a	0.64^c	1.20^b	2.64^c	21.39^c	1.07^c
300	4.62^{bc}	1.90	2.69^b	0.76^a	0.72^b	0.12^b	0.07^a	1.35^b	1.30^a	3.33^b	27.13^b	2.11^b
400	4.67^b	1.35	2.60^b	0.78^a	0.80^a	0.36^a	0.07^a	2.51^a	1.30^a	4.25^a	35.08^a	3.30^a

Mean values with the same letter in the column are not significantly different from one another at $p<0.05$

treatments while the Na, K, Mg, Ca, Cl, Sodium Absorption Ratio (SAR), exchangeable acidity, effective cation exchange capacity, organic carbon on the other hand significantly ($p<0.05$) increased with increasing NaCl application. The fluctuation in some of these soil mineral components such as N and P may be due to selective uptake by the plant as earlier reported by Mostafa *et al.* (2004) while the higher accumulations of K, Mg and Ca may be due to the antagonism initiated by NaCl as earlier reported by Abd E-nour.

The soil pH, one of the most important parameters which pinpoint the over all changes in soil chemical properties may have decreased due to H ions released from the exchange complex by the influence of other soluble cations in the soil system as reported earlier by Mahrous *et al.* (1983).

The higher accumulations of Na and Cl were due to increased NaCl applied. This result is similar to earlier report of Mostafa *et al.* (2004). The exchangeable acidity also increased due to reduced Mg and Ca component of the soil. The highest Sodium Absorption Ratio (SAR) was significantly associated with the highest NaCl treatments in the greenhouse and field trials. These high values of SAR is attributed to the high NaCl treatments as earlier reported by Seelig (2000) that the SAR is based on the concentration of Na^+, Ca^{2+} and Mg^{2+}. The increased organic carbon in both trials may be attributed to mineralization of the organic matter earlier incorporated into the soil.

Nutrient content and uptake by the plant: The nutrient content and uptake by the plant are shown in Table 3 and 4, respectively. The P content of the plant in both trials and Mg content in the greenhouse were not consistent with increasing NaCl application but significant differences ($p<0.05$) was recorded among the various NaCl treatments. With the exception of K content in the greenhouse which increased with increasing NaCl treatment, the N, Ca, Mg and the ratios of K:Na, Ca:Na and Mg:Na components of the plant declined significantly ($p<0.05$) with increasing NaCl treatments.

As the NaCl treatments increased in the entire trials, the Na and Cl content of the plant increased with the highest NaCl treatments significantly

Table 3: Shoot mineral content and ionic balance as influenced by various levels of sodium chloride in the greenhouse and field trials

	N	P	K	Mg	Ca	Na	Cl			
NaCl g/10 kg soil	----------	----------	----------	----(%)----	----------	----------	----------	K:Na	Ca:Na	Mg:Na
Greenhouse trial										
0	2.35^{a}	0.050^{a}	0.080^{b}	0.07^{b}	0.030^{a}	0.04^{e}	0.04^{e}	2.330^{a}	0.81^{a}	2.030^{a}
0.5	2.10^{b}	0.002^{b}	0.090^{ab}	0.09^{ab}	0.020^{a}	0.06^{d}	0.13	1.580^{a}	0.32^{b}	1.770^{a}
1	2.05^{b}	0.006^{b}	0.090^{ab}	0.10^{a}	0.020^{a}	0.29^{c}	0.99^{c}	0.320^{b}	0.07^{c}	0.340^{b}
2	2.00^{b}	0.002^{b}	0.100^{ab}	0.01^{c}	0.020^{a}	0.42^{b}	1.29^{b}	0.240^{b}	0.03^{c}	0.230^{b}
3	1.82^{c}	0.020^{b}	0.110^{a}	0.01^{c}	0.020^{a}	2.16^{a}	2.97^{a}	0.040^{b}	0.01^{c}	0.003^{b}
Field trial (kg ha^{-1})										
0	3.21^{a}	0.020^{a}	0.070^{a}	0.05^{a}	0.030^{a}	0.02e	0.01e	3.830^{a}	1.61^{a}	2.830^{a}
100	3.10^{a}	0.004^{b}	0.004^{b}	0.04^{ab}	0.020^{b}	0.13^{d}	0.05^{d}	0.030^{b}	0.15^{b}	0.300^{b}
200	2.55^{b}	0.004^{b}	0.001^{b}	0.03^{bc}	0.020^{b}	0.25^{c}	0.09^{c}	0.030^{b}	0.08^{b}	0.120^{b}
300	1.35^{c}	0.002^{b}	0.001^{b}	0.03^{bc}	0.007^{b}	1.34^{b}	0.12^{b}	0.010^{b}	0.01^{b}	0.020^{b}
400	1.00^{d}	0.002^{b}	0.001^{b}	0.01^{c}	0.007^{b}	2.52^{a}	0.22^{a}	0.0002^{b}	0.01^{b}	0.003^{b}

Table 4: Shoot mineral uptake as influenced by various levels of sodium chloride in the greenhouse and field trials (mg kg^{-1})

NaCl g/10 kg soil	N	P	K	Mg	Ca	Na	Cl
Greenhouse trial							
0	220.70^{a}	4.69^{a}	7.52^{a}	6.58^{a}	2.82^{a}	3.77^{e}	3.75^{d}
0.5	138.00^{b}	0.13^{b}	5.94^{b}	5.92^{a}	0.90^{b}	3.94^{d}	8.31^{c}
1	37.94^{c}	0.11^{b}	1.66^{c}	1.86^{b}	0.37^{b}	5.38^{c}	18.23^{b}
2	30.56^{d}	0.04^{b}	1.53^{c}	0.15^{c}	0.17^{b}	6.41^{b}	19.61^{ab}
3	12.75^{e}	0.01^{b}	0.77^{c}	0.08^{c}	0.15^{b}	15.04^{a}	20.82^{a}
Field trial (kg ha^{-1})							
0	1616.30^{a}	10.10^{a}	35.30^{a}	25.19^{a}	15.13^{a}	10.01^{b}	4.88e
100	1050.00^{b}	1.56^{b}	1.36^{b}	13.70^{b}	6.81^{b}	44.60^{b}	18.33^{d}
200	751.80^{c}	1.38^{b}	0.21^{b}	8.85^{bc}	5.90^{b}	73.70^{b}	25.70^{c}
300	339.90^{d}	0.45^{b}	0.12^{b}	7.60^{bc}	1.90^{b}	335.70^{a}	30.01^{b}
400	164.50^{d}	0.28^{b}	0.11^{b}	2.39^{c}	1.19^{b}	403.40^{a}	35.87^{a}

Mean values with the same letter in the column are not significantly different from one another at $p<0.05$

higher ($p<0.05$) than other treatments including control. This result confirmed earlier report of Harsharn *et al.* (2004). The uptake of N, P, K, Mg and Ca (Table 4) by the plant significantly ($p<0.05$) decreased with increasing NaCl concentrations while the Na and Cl increased significantly ($p<0.05$) with increasing NaCl treatments. The low N status of salt affected soil may be the main cause of low N uptake from the soil. In the case of P, K, Mg and Ca, the antagonism by Na may be the cause of their low uptake from the soil as earlier reported by Harsharn *et al.* (2004).

Effect of NaCl on the plant height, number of leaves, stem girth and shoot dry matter yield: The effect of NaCl on growth parameters is shown in Table 5. The plant height in both trials decreased with increasing NaCl treatments with the control significantly higher ($p<0.05$) than other treatments. The decline in plant height may be attributed to the increased osmotic pressure caused by NaCl which lessens the available water and nutrients to plant. Similar results of decreased plant height in barley and wheat have earlier been recorded by Huang *et al.* (2006) and Iqbal *et al.* (2006), respectively. The average number of leaves per plant also decreased with increasing NaCl treatments in both greenhouse and field trials with the control treatment significantly higher ($p<0.05$) than other treatments. The reason for the decrease in number of leaves may be explained by the decrease in the uptake of nutrient elements and water availability and ionic imbalance in the plants treated with higher NaCl concentrations. The decrease in number of leaves is similar to the earlier report of Mer *et al.* (2000), Carter *et al.* (2005) and Pessarakli *et al.* (2005) in *Hordeum vulgaris*, *Limonium perezii* and Desert salt grass, respectively. General, the appropriate ratio of mono and divalent cations particularly in saline conditions is essential for a satisfactory crop growth and when such a ratio is upset in the plant its effect is reflected in the form of reduced

Table 5: Effect of sodium chloride on plant height, stem girth, number of leaves and shoot dry matter yield of *Telfairia occidentalis* in greenhouse and field trials

NaCl g/10 kg soil	Plant height	Stem girth	No. of leaves	Shoot dry weight (g)
	------(cm)------			
Greenhouse trial				
0	69.46^{a}	3.41^{a}	25.00	9.39^{a}
0.5	49.82^{b}	2.35^{b}	21.11	6.57^{b}
1	39.98^{b}	1.50^{c}	14.56	1.85^{c}
2	28.61^{c}	0.76^{d}	7.89	1.53^{d}
3	5.47^{d}	0.74^{d}	3.11	0.70^{e}
Field trial (kg ha^{-1})				
0	136.20^{a}	4.90^{a}	90.22^{a}	50.35^{a}
100	111.80^{b}	3.68^{b}	61.06^{b}	34.48^{b}
200	96.20^{bc}	2.08^{c}	54.39^{b}	29.48^{b}
300	91.00^{c}	1.98^{c}	50.40^{b}	25.07^{bc}
400	81.60^{c}	1.86^{c}	45.34^{b}	16.48^{c}

Mean values with the same letter in the column are not significantly different from one another at $p<0.05$

growth as demonstrated by *Telfairia occidentalis*. The stem girth also decreased significantly ($p<0.05$) with increasing NaCl levels probably due to the decreased nutrient uptake and water availability. Similar decrease in stem girth have earlier been reported by Tjera *et al*. (2005) in common bean plant, Chang and Randle (2005) in onion plant and Elkhatib *et al*. (2004) in potato plant.

As the NaCl concentration increased, the average shoot dry matter yield decreased significantly ($p<0.05$). The reduced average short dry matter yield may be tied up to higher osmotic pressure which reduced the uptake of nutrient elements, water and the reduced ionic balance between nutrient elements in plants especially in the NaCl treated plants. This result further strengthens the earlier report of Ashraf and Khanum (1997) in wheat plant.

CONCLUSION

This study reveals that the K, Mg, Ca, Na and Cl exchangeable acidity, effective cation exchange capacity, organic carbon, SAR components of the soil increased with NaCl application while the N and P were not consistent with increasing NaCl treatments. The nutrient content and uptake by the plant were reduced by the presence of NaCl. In addition, the ionic balance of the plant was destroyed leading to reduce growth of the plant. From the foregoing, it is therefore founded that *Telfairia occientalis* crop should not be grown in soils laden with sodium salts.

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