International Journal of Botany

ISSN: 1811-9700

International Journal of Botany 6 (1): 53-58, 2010
ISSN 1811-9700

Growth, Yield, Water Status and Ionic Distribution Response of three Bambara Groundnut (*Vigna subterranea* (L.) Verdc.) Landraces Grown under Saline Conditions

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Abstract: The effects of NaCl salinity of the growth, yield, water status and ion partitioning response of three bambara groundnut (*Vigna subterranea* L. Verdc., landraces: White Seed Coat (WSC), Black Seed Coat (BSC) and Light Red Seed Coat (RSC)) were investigated with the long-term aim of extending the cultivation in the environments with varying salinity. A laboratory experiment was conducted where four NaCl applications (0, 50, 100 and 200 mM) were applied to a sandy soil. Na^+, K^+ concentrations and water content were determined. A similar study was conducted in the field at University of Douala research farm. The agronomic parameters evaluated during vegetative and harvesting phases were dry weight, number of pods per plant, number of seeds per pods, 1000 grains weight, total chlorophyll concentrations, grains yield and pods yield. The addition of NaCl resulted in a decrease of the K/Na ratio, water content partitioning of BSC and RSC landraces. Na^+ concentration was significantly increased by NaCl treatment, while K^+ concentration significantly decreased in all bambara groundnut landraces. NaCl had a negative effect on growth and yield component in BSC and RSC cultivars. There were a significant decrease in the dry weight of whole plant, the number of pods per plant, the number of seeds per pods, the 1000 grains weight, the chlorophyll content, the pods and grains yield. In the analysis of combining growth and yield components of the parameters measured, the results suggested that WSC cultivar was relatively more tolerant to salinity than others; suggesting that WSC cultivar could be cultivated in the coastal and semi-arid saline soils and studied further as a source of genes for salt tolerance.

Key words: Ion partitioning, salinity, tolerance, *Vigna subterranea*, yield

INTRODUCTION

Bambara groundnut (*Vigna subterranea* L. Verdc.), is a food legume mainly cultivated by women for whom it represents a source of income for the household. In Cameroon, the cultivation of bambara groundnut is located in the Northern parts of the country. This zone is characterized by agro ecological contrasted including dry savana, with low levels of soil fertility due to sandy texture. In these zones, bambara groundnut plays a key role in both food and culture of peoples (Dje *et al*., 2005). Bambara groundnut cultivars are important sources of proteins of subsistence farmers, especially in semi-arid Africa (National Academy of Sciences, 1979). This crop is currently receiving sustained scientific attention in the literature because of its tremendous potential (European Union, 1997).

Salinity is the main environmental factor accountable for decreasing crop productivity in many areas of the world especially in arid and semi-arid regions (De Pascale and Barbieri, 1997; Foolad, 2004; Taffouo *et al*., 2004, 2006). Despite the advanced management technology today, salinization of millions of hectares of land continues to reduce crop production severely world-wide (Alam *et al*., 2004). High salt concentration in root medium affects the growth and economic yield of many important crops (Munns, 2002; Alam *et al*., 2004; Hajer *et al*., 2006). Salinity reduces growth and yield of non halophytes plants by decreasing the availability of water to the roots due to the osmotic effects of external salt and by toxic effects of excessive salt accumulation within the plant (Turan *et al*., 2007a). Thus excessive uptake of Na and Cl may lead ionic disturbance of whole plants. Although most salt-tolerant species control the accumulation of inorganic ions as the basic mechanism to adjust their internal tissue osmotic potential against external salinity, they differ widely in the extent to which they accumulate inorganic ions (Munns, 1993).

NaCl toxicity, the predominant form of salt in most saline soils, enhances the Na and Cl^- contents and consequently affects the absorption of other mineral elements (Carvajal *et al*., 2000; Al-Khateeb, 2006; Turan *et al*., 2007a). It stated that high levels of Na

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inhibits Ca^+ and K^+ absorption, which results in a Na/K antagonism (Al-Karaki, 1997) and net photosynthesis is affected strongly by NaCl saline conditions, which is related directly to the closure of stoma as well as to low intercellular CO_2 levels (Turan *et al*., 2007b).

The basis of successful bambara groundnut production on salt affected soils lies in identifying the landraces most tolerant of specific problem situation. In addition to the development of salt tolerant cultivars, growers require an understanding of how plants respond to salinity, the relative tolerance of different crop cultivars and their sensitivity at different stage of grow to soil and environmental conditions. During vegetative growth, plant height, shoot weight, dry weight of roots, stems and leaves are all affected by salinity (Alam *et al*., 2004; Taffouo *et al*., 2004, 2006, 2008, 2009; Hajer *et al*., 2006). But not all growth parameters are similarly affected by salinity. Strategic responses involve the selection of salt tolerant lines. There have been few such studies available on bambara groundnut.

This research was initiated with the long-term aim of extending the cultivation of bambara groundnut landraces in the environments with varying salinity. Therefore, this study was undertaken to evaluate the effect of salinity on the growth, yield, water status and ionic distribution of three bambara groundnut landraces grown in controlled and field conditions.

MATERIALS AND METHODS

The study was conducted in Faculty of Science, University of Douala, Cameroon, between August, 2007 to May, 2008. Three bambara groundnut (*Vigna subterranea* L. Verdc.) landraces were used in this experiment: White Seed Coat (WSC), Black Seed Coat (BSC) and light Red Seed Coat (RSC). Seeds were obtained from Agronomic Institute for Research and Development (IRAD, Dschang). Seeds were sterilized in 3% sodium hypochlorite for 20 min and then washed twice with distilled water. They were germinated in Petri-dishes on wet No. 1 Watman filter paper. Germination was carried out during 1, 2, 3, 4 and 5 days, seedlings developing their first couple of leaves were separated in four groups of 15 individuals each. For each group, five seedlings were randomly selected and sowed together in the same pot. Pots were kept in laboratory (temperature: 26±3°C, light: 5000 lux for 12 h alternating periods and relative humidity of 51-70%)and supplied every three days with nutrient solution containing 0.4 mM of KNO_3, 0.2 mM of KH_2PO_4, 1.0 mM of Ca_2NO_3 and 0.4 mM of $MgSO_4$ (Wacquant, 1974). Pots filled with clean sand (1000 g) were irrigated with NaCl solutions of different concentrations of 0, 50, 100 and 200 mM. The plants were irrigated with the de-ionized water. Roots, stems and leaves were harvested six weeks after sowing and weighed. The fresh material, plants were washed and 2.0 g of samples were taken for total chlorophyll determination. The remaining plants were oven dried at 70°C and digested with a mixture of HNO_3 and $HClO_4$ acid (4:1) in order to assess the water content and Na^+ and K^+ concentrations (Turan *et al*., 2007b).

Sodium and potassium concentrations were determined by flame photometer (Jenway), as described by Taffouo *et al*. (2008).

Total chlorophyll of plants was extracted in 80% (v/v) aqueous acetone and absorption was measured in Thermospertronic Heλios β model spectrophotometer at 645 and 663 nm (Arnon, 1949).

Parameters assessed under field conditions were dry weight, number of pods per plant, number of seeds per pods, 1000 grains weight, grains and pods yield. The trial was conducted in the experimental field of the University of Douala (4°01 N, 9°44 E, altitude: 13 m above sea level, with total annual rainfall of 3597 mm and average temperature of 27°C). The soil of experimental site has a sandy soil. Its chemical and physical soil properties are shown in Table 1. The experimental design was a complete randomized block design with two treatments and three replicates. Plots were 8 x 8 m surfaced. The experimental plots were supplied with 50 mM NaCl and the control with simple distilled water (0 mM NaCl). The trials were carried out in pure culture without fertilization. Plants were watered once a week at a rate of 20 L m^{-2} (Taffouo *et al*., 2009).

Data are presented in term of mean (±standard deviation). Multiple comparisons of several means was set up using analysis of variance (ANOVA) and the post-hoc pairwise analysis was set up using the Student-Newman-Keuls procedure when the normality and equal variance conditions passed. Multiple comparisons of data noted in experimental groups *versus* those recorded in the single control group were set up using the Dunnett's procedure (Sigma Stat software 2.03).

Table 1: Physical and chemical properties of the experimental sites (0-20 cm of depth)

Elements	Contents
Clay (%)	14.20
Coarse sand (%)	27.90
Fine sand (%)	25.60
Coarse silt (%)	26.00
Fine silt (%)	5.40
Carbon (%)	0.28
Nitrogen (%)	0.80
Ratio C/N	0.35
Available phosphorous (ppm)	4.83
Exchangeable potassium (g kg^{-1})	0.23
Exchangeable sodium (g kg^{-1})	0.11
Exchangeable calcium (g kg^{-1})	0.45
pH- water	5.72

RESULTS

Ionic distribution of bambara groundnut landraces organs

Sodium, potassium concentrations and K/Na ratio: NaCl affected ion concentrations of roots, aerial parts (stems and leaves) of three Bambara groundnut landraces (Table 2). K^+ uptake and transport to the aerial part of the Bambara groundnut were significantly ($p<0.001$) reduced with the increased NaCl concentration. In this experiment, salt stress, induced by increasing NaCl in the soil solution, resulted in an increase in Na^+ concentrations. K/Na ratio was significantly decreased as NaCl concentration increased in aerial parts (Table 2).

Water content of bambara groundnut landraces organs: Water content was significantly reduced ($p<0.001$) in roots, stems and leaves of BSC and RSC landraces on contrary to increased amount of NaCl applied (Fig. 1a-d). The highest reduction at both landraces was observed at 200 mM NaCl treatment. Water content of WSC landrace organs grown under saline conditions was not significantly different from that of control plants (Fig. 1).

Growth and yield of Bambara groundnut landraces: Sodium chloride has a depressive effect on growth and yield component in BSC and RSC landraces (Table 3). For these species, it decreased significantly ($p<0.001$) dry weight of whole plant, the number of pods per plant, the number of seeds per pods, the 1000 grains weight, the chlorophyll content, the pods yield and grains yield (Table 3). Nevertheless, WSC landrace was observed to have relatively higher tolerance average of all parameters than others (Table 2). For this plant species, the depressive effect of salt was less marked on dry weight and yield component ($p>0.001$) except total leaf chlorophyll content.

Table 2: Distribution of Na, K and their ratio K/Na in roots, aerial parts (stems and leaves) of three Bambara groundnut seedlings as affected by sodium chloride rates

Landrace	Treatments (mmol L^{-1} of NaCl)	Na^+ roots content	Na^+ aerial parts content	K^+ roots content	K^+ aerial parts content	K^+/Na^+ aerial parts ratio
		(μeq g^{-1} DM)				
White seed coat (WSC)	0	29.1±1.2	75.2±3.5	749.5±21.3	1437.3±42.6	19.16
	50	252.5±12.3*	173.9±8.7*	636.6±19.7*	1217.8±25.5*	7.03*
	100	365.3±15.4*	236.1±14.2*	523.4±16.4*	884.1±17.6*	3.75*
	200	445.4±15.7*	264.8±10.6*	287.9±11.6*	586.6±21.1*	2.22*
	ANOVA	305.03	276.57	178.59	160.32	76.29
	$F_{(3,16)}$	***	***	***	***	**
Black seed coat (BSC)	0	30.1±0.8	81.3±3.4	718.1±23.1	1422.9±37.6	17.56
	50	219.2±8.9*	318.6±14.1*	615.4±15.2*	1170.3±23.7*	3.68*
	100	253.7±13.4*	351.7±17.8*	482.6±9.6*	657.5±11.3*	1.87*
	200	261.5±8.6*	371.9±12.5*	256.2±7.6*	403.5±9.8*	1.09*
	ANOVA	167.65	112.02	136.49	367.42	126.44
	$F_{(3,16)}$	***	***	***	***	***
Light red seed coat (RSC)	0	37.4±0.8	90.5±8.3	618.7±13.4	1395.0±35.1	15.50
	50	126.6±7.5*	229.2±11.9*	546.6±12.7*	785.6±12.4*	3.43*
	100	178.3±7.1*	291.1±9.7*	472.2±7.1*	510.8±11.7*	1.75*
	200	237.9±10.2*	302.6±10.8*	236.6±8.4*	291.3±9.2*	0.96*
	ANOVA	294.09	234.47	194.54	178.59	87.99
	$F_{(3,16)}$	***	***	***	***	**

Based on Dunnett's test, values headed by differ significantly (*$p<0.05$; **$p<0.01$; ***$p<0.001$). Values are Mean±SE

Table 3: Comparisons of growth parameter (Plant dry weight (g $plant^{-2}$)) and Yield components (number of pods per plant, number of seeds per pods, 1000 grains weight (kg), total chlorophyll concentrations (mg g MS^{-1}), grains yield (t ha^{-1}) and pods yield (t ha^{-1}) of three bambara groundnut under salt stress. n =10 for each landrace

Landrace	Treatments (g L^{-1} NaCl)	Dry weight (g $plant^{-2}$)	No. of pods per plant	No. of seeds per pods	1000 grains weight (kg)	Foliar chl (a+b) content (mg gMS^{-1})	Grains yield (t ha^{-1})	Pods yield (t ha^{-1})
White seed coat (WSC)	0	782.1±25.2	21.2±1.8	5.8±1.2	2.08±0.01	46.6±1.3	5.92±0.04	8.11±0.08
	3	769.2±15.6	22.3±1.5	6. 4±0.8	2.04±0.04	36.2±1.7*	6.17±0.02	8.46±0.04
	ANOVA	2.03	2.13	1.39	1.12	90.65	1.95	2.19
	$F_{(3,16)}$	ns	ns	ns	ns	***	ns	ns
Black seed coat (BSC)	0	649.8±17.6	19.1±1.4	4.7±0.5	2.03±0.01	45.8±1.6	5.80±0.05	7.15±0.06
	3	420.1±8.9*	13.4±1.1*	2.6±0.3*	1.18±0.03*	12.2±0.7*	2.62±0.02*	3.73±0.03*
	ANOVA	20.75	22.36	123.46	112.09	296.33	96.47	97.77
	$F_{(3,16)}$	***	**	***	***	***	**	***
Light red seed coat (RSC)	0	830.3±23.1	22.9±1.4	5.2±1.6	2.20±0.06	49.1±1.2	7.86±0.05	5.69±0.03
	3	352.5±11.5*	14.6±1.2*	2.3±0.8*	1.07±0.01*	20.3±0.6*	4.25±0.01*	3.48±0.04*
	ANOVA	85.57	71.25	163.83	85.77	196.49	104.09	95.54
	$F_{(3,16)}$	***	***	***	***	***	***	***

Based on Dunnett's test, values headed by differ significantly (*$p<0.05$; **:$p<0.01$; ***$p<0.001$), ns = $p>0.05$. Values are Mean±SE

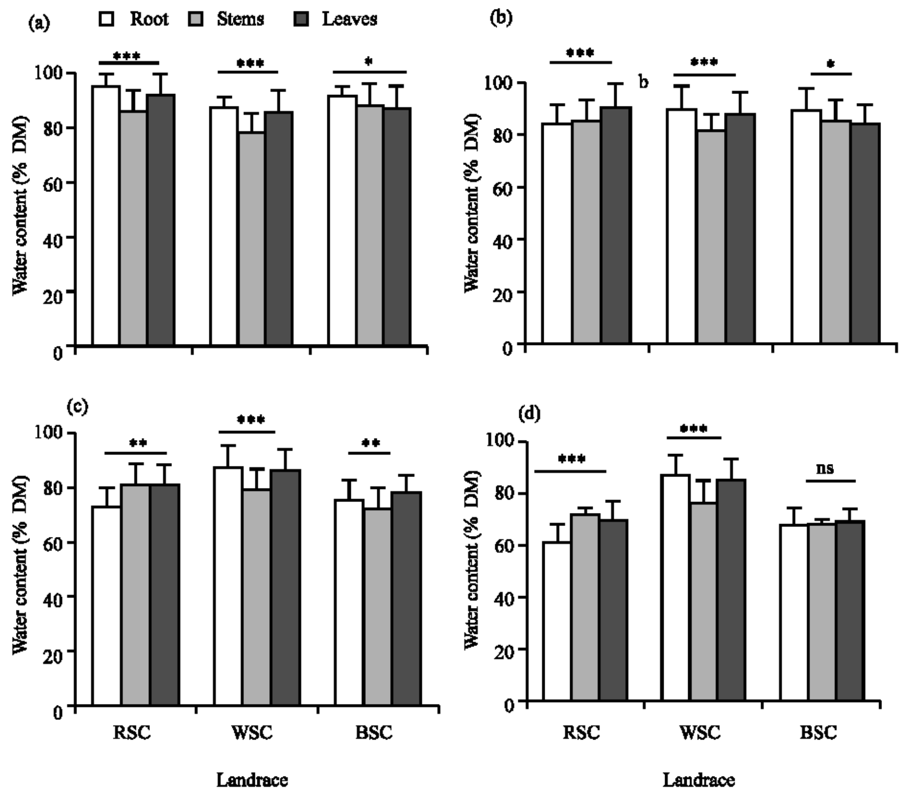

Fig. 1: Salt effects on the water content of organs of three Bambara groundnut seedlings. (a): Control medium (0 mM NaCl); (b): 50 mM NaCl; (c): 100 mM NaCl and (d): 200 mM NaCl; n = 5 for each landrace; White Seed Coat (WSC), Black Seed Coat (BSC) and Light Red Seed Coat (RSC). ns = $p>0.05$; *:$p<0.05$; *$p<0.01$; ***$p<0.001$

DISCUSSION

NaCl affected ion concentrations of roots, aerial parts (stems and leaves) of three bambara groundnut landraces (Table 2). The data have shown that K^+ uptake and transport to the aerial part of bambara groundnut landraces were significantly ($p<0.001$) reduced with increased NaCl concentration. Similar results were reported by Carvajal *et al.* (2000), Taffouo *et al.* (2004, 2008, 2009), Al-Khateeb (2006) and Turan *et al.* (2007b). This implies a competition between Na^+ and K^+ absorption in bambara groundnut plant, resulting in a Na/K antagonism (Al-Karaki, 1997; Mezni *et al.*, 2002). The reduction of K^+ uptake caused by Na^+ is likely to be the result of the competitive intracellular influx of both ions (Cerda *et al.*, 1995). It is well established that many K^+ transport systems have significant affinity for Na^+ (Schachtman and Liu, 1999). Wolf and Jeschke (1987) reported that in shoot of salt stressed barley there was recirculation of K^+ through phloem from shoot to root. Part of this recirculated K^+ was transferred from phloem to xylem within the root and returned to the shoot through xylem. In this experiment, salt stress, induced by increasing NaCl in the soil solution, resulted in an increase in Na concentrations. There is an overwhelming amount of evidence to indicate that NaCl induced salinity increases Na uptake by plants (Taffouo *et al.*, 2004, 2006, 2008; Al-Khateeb, 2006; Turan *et al.*, 2007a, b). K/Na ratio was significantly decreased as NaCl concentration increased in aerial parts (Table 2). Similar results were reported in *Medicago sativa* (Al-Khateeb, 2006).

Water content values were decreased significantly ($p<0.001$) in roots, stems and leaves of BSC and RSC landraces on contrary to increased amount of NaCl applied (Fig. 1). The highest reduction at both landraces was observed at 200 mM NaCl treatment. Similar results for decreased water content values of plants organs were reported by Taffouo *et al.* (2004) in two salt-sensitive species (*Phaseolus vulgaris* and *Glycine max*). Water content values of WSC landrace organs grown under saline conditions were not significantly different from the control plants (Fig. 1). Similar results were found in organs of *Phaseolus adenanthus* and *Avicennia germinans*, two natural halophytes (Taffouo *et al.*, 2004, 2007) and *Lagenaria siceraria*, salt-tolerant plant (Taffouo *et al.*, 2008). It is attributed to the significant storage of monovalent cations in leaves, facilitated by the increase in Na^+ concentrations from roots to leaves.

The present study showed that sodium chloride has a depressive effect on growth and yield component in BSC and RSC landraces (Table 3). For these species, it decreased significantly ($p<0.001$) dry weight of whole plant, the number of pods per plant, the number of seeds per pods, the 1000 grains weight, the chlorophyll content, the pods yield and grains yield (Table 3). These results showed that BSC and RSC landraces, in common with certain other plant leguminous (e.g., beans), is highly sensitive to salt with severe effects even at 50 mM NaCl (Levitt, 1980). For these species, salinity may reduce the growth and crop yield by upsetting water and nutritional balance of plant (Alam *et al*., 2004; Khan *et al*., 2007; Zadeh and Naeini, 2007) and loss of photosynthetic capacity (Alam *et al*., 2004). In the presence of salt, the available of nutrients to plant is restricted and the plant has to spend more energy to sustain itself. According to Munns (2002) this unfavourable effect of salt could be due to the deficiency in calcium, nitrate, phosphate and sulphate. Similar results were found in two salt-sensitive species of tropical cucurbit, *Cucurbita lanatus* and *Cucurbita moshata* (Taffouo *et al*., 2008) and two salt-sensitive leguminous plants, *Phaseolus vulgaris* and *Glycine max* (Taffouo *et al*., 2004). Nevertheless, WSC landrace was observed to have relatively higher tolerance on average of all parameters than others (Table 3). For this plant species, the depressive effect of salt was less marked on dry weight and yield component ($p>0.001$) except total leaf chlorophyll content. Similar observations for dry weight were reported in two halophytes, *Ceriops roxburghiana* (Rajest Arumugam and Venkatesalu, 1998) and *Phaseolus adenanthus* (Taffouo *et al*., 2004) and in *Lagenaria siceraria*, salt-tolerant plant species (Taffouo *et al*., 2008). There are a great number of plant species which are regarded as salt tolerant, the most competitive being those that are able to become established, grow to maturity and survive until they are able to reproduce (Turan *et al*., 2007a). Salinity decreased the total leaf chlorophyll concentration of all Bambara groundnut landraces. This effect of salt was attributed to a salt-induced weakening of protein-pigment-lipid complex (Strogonove *et al*., 1970) or increased chlorophyllase enzyme activity (Stivesev *et al*., 1973). Similar results were reported for total leaf chlorophyll concentration of three tropical cucurbite (Taffouo *et al*., 2008) and wheat and lentil plants (Turan *et al*., 2007a, b).

The present findings showed that two landraces of bambara groundnut, BSC and RSC are less sensitive to salt stress at vegetative and harvesting phases. For these landraces, reduced growth and yield may be the result of disturbed water consumption and K^+ uptake within saline medium. An analysis combining growth and yield components parameters measured, suggested that WSC cultivar was relatively more tolerant to salinity than others. WSC cultivars could be grown in the coastal and semi-arid saline soils. This cultivar could be studied further as a source of genes for salt tolerance that could be exploited in breeding programs. The addition of NaCl resulted in a decrease of the K/Na ratio, water content partitioning of BSC and RSC landraces, Na^+ was increased by treatment with NaCl, while K^+ and total chlorophyll concentrations were decreased in all bambara groundnut landraces.

ACKNOWLEDGMENTS

This research was supported by the International Foundation of Science (IFS), Stockholm, Sweden and Swedish International Development Cooperation Agency Department for Natural Resources and the environment (SIDA NATUR), Stockholm, Sweden through a grant No. C/3817-1 to Dr Victor Désiré TAFFOUO.

REFERENCES

Al-Karaki, G.N., 1997. Barley response to salt stress at varied levels of phosphorous. J. Plant Nutr., 20: 1635-1643.

Al-Khateeb, S.A., 2006. Effect of calcium/sodium ratio on growth and ion relations of Alfalfa (*Medicago sativa* L.) seedling grown under saline condition. J. Agron., 5: 175-181.

Alam, M.Z., T. Stuchbury, R.E.L. Naylor and M.A. Rashid, 2004. Effect of salinity on growth of some modern rice cultivars. J. Agron., 3: 1-10.

Arnon, D.I., 1949. Copper enzymes in isolated chloroplasts: Polyphenyl peroxidase in *Beta vulgaris*. Plant Physiol., 24: 1-15.

Carvajal, M., A. Cerda and V. Martinez, 2000. Modification of the response of saline stressed tomato plants by the correction of cation disorders. Plant Growth Regul., 30: 37-47.

Cerda, A., J. Pardines, M.A. Botella and V. Martinez, 1995. Effect of potassium on growth, water relations and the organic solute contents for two maize grown under saline conditions. J. Plant Nutr., 18: 839-851.

De Pascale, S. and G. Barbieri, 1997. Effect of soil salinity and top removal on growth and yield of broad bean as green vegetable. Sci. Hortic., 71: 147-165.

Dje, Y., S. Beke and A.Z.B. Irie, 2005. Preliminary variability observations between some bambara groundnut landraces(*Vigna subterranea* L. Verdc, Fabaceae) of Ivory Coast. Biotechnol. Agron. Soc. Environ., 9: 1-16.

European Union (EU), 1997. Bambara groundnut project final report, EU STD3. Nottingham, UK, University of Nottingham.

Foolad, M.R., 2004. Recent advances in genetics of salt tolerance in tomato. Plant Cell, Tissue and Organ Culture, 76: 101-119.

Hajer, A.S., A.A. Malibari, H.S. Al-Zahrani and O.A. Almaghrabi, 2006. Responses of three tomato cultivars to sea water salinity 1. Effect of salinity on the seedling growth. Afr. J. Biotechnol., 5: 855-861.

Khan, M.A., A. Qayyum and E. Noor, 2007. Assessment of wheat genotypes for salinity tolerance. Proceedings of 8th African Crop Science Conference, Octo.27-31, El-Minia, Egypt, pp: 75-78.

Levitt, J., 1980. Responses of Plants to Environmental Stresses, Vol. 1, Chilling Freezing and High Temperature Stresses. 2nd Edn., Academic Press, New York.

Mezni, M., A. Albouchi, E. Bizid and M. Hamza, 2002. Effects of salt water irrigation on mineral uptake in three Alfalfa varieties (*Medicago sativa*). Agronomie, 22: 283-291.

Munns, R., 1993. Physiological processes limiting plant growth in saline soil: Some dogmas and hypotheses. Plant Cell Environ., 16: 15-24.

Munns, R., 2002. Comparative physiology of salt and water stress. Plant Cell Environ., 25: 239-250.

National Academy of Sciences, 1979. Tropical Legumes: Resources for the Future. NAS, Washington, DC., USA., pp: 1-264.

Rajest Arumugam, A.R. and V. Venkatesalu, 1998. Growth and photosynthetic characteristic of *Ceriops roxburghiana* under NaCl stress. Photosynthetica, 35: 285-287.

Schachtman, D. and W. Liu, 1999. Molecular pieces to the puzzle of the interaction between potassium and sodium uptake in plants. Trends. Plant Sci., 4: 281-287.

Stivesev, M.V., S.A. Ponnamoreva and E.A. Kuzenstova, 1973. Effect of salinization and herbicides on chlorophyllase activity in tomato leaves. Fiziol. Rast., 20: 62-65.

Strogonove, B.P., V.V. Kabanov, L.P. Lapina and L.S. Prykhodko, 1970. Structure and Function of Plant Cells under Salinity Conditions. 1st Edn., Nauka Publishing House, Moscow.

Taffouo, V.D., M. Kenne, R. Fokam Tasse, W.O. Fotsop, T. Fonkou, Z. Vondo and A. Amougou, 2004. Salt stress variation response in five leguminous plants. Agron. Afr., 16: 33-44.

Taffouo, V.D., M. Kenne, O. Wamba Fotsop, M.L. Sameza, M. Ndomou and A. Amougou, 2006. Salinity effects on growth, ionic distribution and water content in salt-tolerant species: *Gossypium hirsutum* (Malvaceae). J. Cam. Acad. Sci., 6: 167-174.

Taffouo, V.D., M. Kenne, O.W. Fotsop and A. Akoa, 2007. Salinity effect on seedling growth, water, sodium and potassium distributions in the mangrove species (*Avicennia germinans* L. (Avicenniaceae)) in semi-controlled conditions. Agron. Afr., 29: 263-270.

Taffouo, V.D., N.L. Djiotie, M. Kenne, N. Din, J.R. Priso, S. Dibong and A. Akoa, 2008. Effects on salt stress on physiological and agronomic characteristics of three tropical cucurbit species. J. Applied Biosci., 10: 434-441.

Taffouo, V.D., J.K. Kouamou, L.M.T. Ngalangue, B.A.N. Ndjeudji and A. Akoa, 2009. Effects of salinity stress on growth, ions partitioning and yield of some cowpea (*Vigna unguiculata* L. Walp.) cultivars. Int. J. Bot., 5: 135-143.

Turan, M.A., N. Turkmen and N. Taban, 2007a. Effect of NaCl on stomacal resistance and proline, chlorophyll, Na, Cl and K concentrations of Lentil Plants. J. Agron., 6: 378-381.

Turan, M.A., V. Kathat and S. Taban, 2007b. Variations in proline, chlorophyll and mineral elements contents of wheat plants grown under salinity stress. J. Agron., 6: 137-141.

Wacquant, J.P., 1974. Research on cations roots properties uptake. Physiological and ecological role. Ph.D. Thesis, University of Montpellier, Montpellier, France, pp: 155.

Wolf, O. and W.D. Jeschke, 1987. Modeling of sodium and potassium flow via phloem and xylem in the shoot of salt stressed barley. J. Plant Physiol., 128: 371-386.

Zadeh, H.M. and M.B. Naeini, 2007. Effects of salinity stress on the morphology and yield of two cultivars of canola (*Brassica napus* L.). J. Agron., 6: 409-414.