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Relationship between Salt (NaCl) Stress and Yield Components in Three Varieties of African Yam Bean (*Sphenostylis stenocarpa*)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Salinity has threatened the existence of many useful and multipurpose legumes such as *Sphenostylis stenocarpa.* To revert this situation effort must be made towards its sustainable use by encouraging domestication of improved varieties that can thrive in salt stress region. This research study was aimed at establishing the effect of salt-stress on seed germination, morphological attributes and yield response of three varieties *Sphenostylis stenocarpa.* Data were collected from the third-weekly for a period of three months (12 weeks) on plant height and number of leaves. At 12 weeks, data were collected on the following traits: number of flowers per plant, number of pods per plant, length of pod and number of seeds per pod. The data on number of seed germinated was also taken. Data collected were subjected to analysis of variance (ANOVA) and mean were separated using Least Significant Difference (LSD) test. Results obtained revealed that sodium chloride ($NaCl^{+}$) significantly affected some important morphological traits of *Sphenostylis stenocarpa* evaluated. All varieties treated at various levels (1 kg/l, 2 kg/l and 3 kg/l) with NaCl performed poorly than those without treatment (control). This study revealed that there was no significant difference amongst all varieties of African yam been treated at 1 kg/l levels of NaCl.

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There was no significant different ($p<0.05$) among varieties of African yam bean at 0 kg/l in different morphological parameters evaluated. Salt stress significantly reduced ($p<0.05$) the germination of African yam bean.

Keywords: Salt stress; salinity; Sphenostylis stenocarpa; sodium chloride; tolerance.

1. INTRODUCTION

Salt-stress is a threat to crop yield especially in countries like Nigeria that practice irrigated agriculture. Salt-stress involves osmotic stress, ionic imbalances and secondary stresses such as nutritional imbalances and oxidative stress for glycophytes [1,2]. Salinity is one major abiotic factor litigating the growth of several legumes. One of such legumes is African Yam Bean. African yam bean *Sphenostylis stenocarpa* is a multipurpose tuberous legume, producing good yield of edible seeds above ground and small edible tubers below ground [3]. African yam bean is a good source of plant protein [4]. African yam bean seed contains high Vitamin C, dietary fibre, Vitamin B_6, potassium and manganese; but low in saturated fat and sodium. In Southern Nigeria, many low-income and resource poor people especially in the rural areas cherish African yam bean because its products are delicious and very nutritious. African yam bean is cultivated mainly for home consumption and only about 30% of the dry grain produced is sold [5].

African yam bean tolerates a wide range of climatic, geographical and edaphic ecologies. It is capable of growth in marginal areas where other pulses fail to thrive. It survives well in weathered soils where rainfall could be extremely high, tolerates acidic, leached and infertile soil. African yam bean as a legume has a huge biomass and can fix nitrogen [6,7].

In spite of the huge potentials of this crop, it is faced with some challenges that have greatly limited its cultivation and eventually led to its neglect and underutilization. One of such challenges is lack of improved varieties [3] and information on the agronomic management practices of the crop is very scanty in literature. Genetic improvement of this crop would among others, require that variations in seed yield and related characters among local accessions be understood for effective hybridization [8]. There is presently no much information on agronomic management practices of this crop species especially in salt-affected soils in Nigeria.

Salinity disturbs overall plant growth in legumes [9] by influencing the complex interaction of hormones, nutritional imbalances, specific ion toxicity and osmotic effects (Yadav *et al.,* 1989) [10]. Salinity has a strong adverse effect on plant growth, grain yield, and quality and composition of grains [11,12]. It is reported that plants growing under saline condition are affected in three ways: reduced water potential in root zone causing water deficit, phytotoxicity of ions such as Na^+ and Cl^- and nutrient imbalance depressing uptake and transport of nutrients [13]. Sodium is the primarily toxic ion, because it interferes with K^+ uptake as well as disturbs stomatal regulation which ultimately causes water loss and necrosis [14] Cl^- induces chlorotic symptoms due to impaired production of chlorophyll. In plant cell, Cl^- is required for the regulation of some enzymes activities in the cytoplasm [15,16]. It is a co-factor photosynthesis and is involved in turgor and pH regulation. The aim of this research is to establish the effect of salt-stress on seed germination, physiology, morphological attributes and yield response of three varieties of *Sphenostylis stenocarpa.*

2. MATERIALS AND METHODS

2.1 Experimental Site and Collection of Experimental Materials

The experiment was conducted at the experimental field of the Faculty of Biological Science, University of Calabar, Nigeria. In 2017 three varieties of African yam bean seeds (*Sphenostylis stenocarpa*) were purchased from Ogoja market, Cross River State, Nigeria, sundried and checked for viability by soaking in water.

Pure sodium chloride (NaCl) salt was obtained from the market and dissolved in distilled water to give the following concentrations: 1kg/l, 2kg/l, 3kg/l of water. These salt solutions were later used to water the soil on which the African yam bean plants were grown.

2.2 Planting

Planting was done in polythene bags filled with homogenous rich humus soil measuring 4 kg/bag. The bags were perforated black polythene of 28.30 cm in diameter and 30.00 cm in depth. Sixty of these bags filled with 4 kg of soil were used to raise the African yam bean seeds. Weeding was done weekly and staking was done to aid growth of African yam bean.

2.3 Experimental Design

The experimental was a 4 x 3 (4 concentrations of salt, 3 varieties of seed) factorial laid out in RCBD (Randomized Complete Block Design) with 5 replicating, five of experimental seeds were planted in soil pre-soaked with the various concentration of sodium chloride. The soil presoaked with distilled water serve as control.

2.4 Data Collection

Data were collected from third-weekly for a period of three months (12 weeks) on plant height, and number of leaves. At 12 weeks, at maturity data was collected on the following: number of flowers per plant, number of pods per plant, length of pod and number of seeds per pod. Data on number of seeds germinated was also taken.

2.5 Data Analysis

Data collected were subjected to Analysis of Variance (ANOVA) and mean were separated using Least Significant Difference (LSD) test.

3. RESULTS

The results obtained from the experiment are summarized in Table 1 and 2. Table 1 shows the mean ± standard error of the various parameters studied in three varieties (white, black and brown) African yam bean planted under salt stress. The number of seeds germinated showed significant difference ($p<0.05$). Their percentages are: 56%, for white, 36% for black and 32% for brown for 1 kg/l test; 24% for white, 24% for black, 28% for brown for 2 kg/l; and 28% for white 24% for black, 24% for brown for 3 kg/l.

The mean number of plant height at 3 weeks for 0 kg/l, 1 kg/l, 2 kg/l and 3 kg/l were 53.5±2.91, 39.38±3.04, 46.5±1.73 and 21.52±1.25 cm for white variety; 61.0±3.56, 43.24±2.55, 48.78±2.40, 21.3±1.10 cm for black variety, and 56.05+2.64, 48.25+2.23, 43.51+2.23 and 10.5+0.62 cm for brown variety, respectively. There was significant difference in plant height between the concentrations and the varieties ($p<0.05$). The plant height at 6 weeks were 61.42+2.88, 45.58+2.88, 55.18±2.96, 25.32±1.70 cm for white, 64.45+3.76, 51.03±1.71, 66.31±1.65, 26.68±3.35 cm for black, 60.37±2.61, 55.66±2.02, 56±2.02 and 15.21±1.19 cm for brown variety. They did show significant difference. However, there was also significant difference ($p<0.05$) at 12 weeks, 35.57±2.53, 15.2±1.31, 10.67±2.056, 11.14±0.40 for white, 57.09±4.91, 14.88±1.38, 5.76±0.98, 11.67±0.65 for black, 35.32±2.91, 15.1.81, 10.43±0.86 and 10.67±0.33 for brown variety.

A notable observation was in the flower colour. The colour ranged from white to purple or pink with yellowish centre. Each variety produced a number of each of these colours. Flower colours were not peculiar to any of the varieties which mean that any of the varieties could produce any flower colour. There was no significant difference in the number of flowers in all the concentrations and varieties.

The number of pods per plant was 23.78±0.61, 19.2±0.25, 18.33±0.33, 18.28±0.39 for white, 2.54±1.77, 18.55±0.14, 18.16±0.47, 18.0±0.36 for black, 21.78±0.40, 19.0±0.55, 17.71±0.31, 17.66±0.33 for brown variety. There was significant difference ($p<0.05$).

The number of seed/pod were 26.0±0.39, 25.1±0.375, 23.67±0.46, 22.4±0.29 for white, 27.72±0.43, 24.89±0.35, 23.83±0.40, 22.66±0.21 for black, 26.9±0.21, 24.63±0.41, 23.57±0.29, 23.83±0.21, 24.63±0.41, 23.57±0.29, 23.83±0.83 for brown. There was significant difference ($p<0.05$). (Table 3,4 and 5).

The pod length was significantly different. Their mean values were 29.14±0.21, 27.8±0.38, 25.17±0.16, 24.28±0.29 for white, 29.54±0.16, 26.55±0.44, 25.55±0.44, 25.66±0.33, 24.66±0.49 for black and 29.21±0.21, 26.86±0.39, 25.85±0.34, 24.5±0.22 for brown variety (Table 3, 4 and 5).

4. DISCUSSION

Effect of salt stress in three varieties of African yam bean were determined in the number of seeds germinated, plant height, number of leaves, number of flowers, number of seed/pod, pod length and number of pod/plant. The yield of *Sphenostylis stenocarpa* was limited by salt stress, since salinity stress leads to loss in productivity of plant. Salt stress reduced the yield of African yam bean and contributed to the loss of productivity.

Table 1. Mean ± SE of morphological attributes of 3 varieties of *Sphenostylis stenocarpa* (Fabaceae) planted under salt-stress for 12 weeks

		Plant height (cm)				No. of leaves				No. of flowers	No. of seeds/pod	Pod length (cm) 12 wks	No. of pods 12 wks	No. of seeds germinated
Varieties	NaCl	3 wks	6 wks	9 wks	12 wks	3 wks	6 wks	9 wks	12 wks	9 wks				
White	0g/kg	53.5±2.91^{c}	61.42±2.88^{b}	147.07±2.19^{c}	180.89±18.01^{c}	11.07±1.05^{a}	16.0±1.08^{b}	16.78±1.08^{c}	35.57±2.53^{a}	3.43±025^{a}	26.0±0.30^{c}	29.14±0.21^{a}	23.78±0.61^{b}	2.8±0.37^{b}
	1g/kg	39.38±3.64^{c}	45.58±2.88^{c}	56.66±2.02^{b}	56.66±2.02^{a}	3.7±0.51^{b}	4.9±0.48^{c}	9.5±0.87^{a}	15.2±1.31^{b}	2.7±0.21^{a}	25.1±0.378^{a}	27.8±0.38^{a}	19.2±0.33^{c}	2.0±0.31$_{c}$
	2g/kg	46.5±1.73	55.18±2.96^{b}	78.06±4.89^{c}	93.78±2.89^{c}	3.66±0.13^{b}	5.33±0.33^{a}	7.83±0.31^{b}	10.67±2.06^{a}	2.27±0.21^{a}	23.67±0.46	25.17±0.16^{c}	18.33±0.33^{a}	1.2±0.20^{c}
	3g/kg	21.52±1.25^{a}	25.32±1.70^{c}	24.72±1.72^{a}	49.8±2.64^{b}	3.6±0.20^{a}	4.3±0.28^{c}	6.37±0.29^{c}	11.14±0.40^{b}	2.71±0.29^{a}	22.4±0.29^{a}	24.28±0.29^{b}	18.28±0.39^{c}	1.4±0.48^{c}
Black	0g/kg	61.0±3.56^{a}	64.45±3.76^{b}	230.9±15.65	258.44±14.14^{a}	12.8±0.91^{c}	16.54±0.94^{c}	29.72±3.32^{a}	57.09±4.91^{b}	3.18±0.33^{a}	27.72±0.43^{b}	29.54±0.16^{c}	24.54±1.77^{a}	2.2±0.58
	1g/kg	43.24±2.55^{c}	51.03±1.71^{b}	59.83±1.06^{c}	68.75±1.74^{b}	2.66±0.24^{c}	3.7±0.32^{b}	9.88±1.06^{b}	14.88±1.38^{c}	2.89±0.22^{a}	24.89±0.35^{b}	26.55±0.44^{b}	18.55±0.14^{a}	1.8±0.74^{b}
	2g/kg	48.78±2.40^{a}	66.31±1.65^{a}	88.35±2.07^{a}	105.5±3.88^{a}	3.83±0.31^{a}	5.0±0.36^{b}	7.33±0.49^{c}	5.76±0.98^{c}	2.66±0.42^{a}	23.83±0.40^{a}	25.66±0.33^{a}	18.16±0.47^{b}	1.2±0.39^{c}
	3g/kg	21.3±1.10^{b}	26.68±3.35^{a}	37.1±1.53^{b}	52.36±1.89^{c}	3.3±0.21^{b}	3.33±0.21^{a}	7.5±0.34^{a}	11.67±0.65^{a}	3.0±0.25^{a}	22.66±0.21^{c}	24.66±0.49^{a}	18.0±0.36^{a}	1.2±0.73^{c}
Brown	0g/kg	56.05±2.64^{c}	60.37±2.61^{c}	156.82±12.57^{b}	243.63±18.69^{b}	11.31±1.14^{b}	14.05±1.05^{a}	18.21±1.51^{b}	35.3±2.91^{a}	3.05±0.22^{a}	26.21±0.21^{b}	29.21±0.21^{b}	21.78±0.4^{c}	3.2±0.73^{c}
	1g/kg	48.25±2.23^{a}	55.66±2.02^{a}	59.85±3.36^{b}	72.53±2.93^{c}	4.0±0.45^{c}	5.75±0.74^{a}	10.0±1.53^{c}	15.88±1.81^{c}	2.63±0.32^{a}	24.63±0.41^{c}	26.86±0.39^{c}	19.0±0.55^{b}	1.6±0.24^{a}
	2g/kg	43.51±2.68^{b}	56.58±2.08^{c}	74.98±3.05^{b}	102.35±3.76^{b}	3.5±0.2^{b}	4.28±0.28^{c}	8.29±0.42^{c}	10.43±0.86^{b}	2.85±0.26^{a}	23.57±0.29^{b}	25.85±3.4^{b}	17.71±0.31^{c}	1.4±0.19^{c}
	3g/kg	10.5±0.62^{c}	15.21±1.19^{b}	33.1±2.38^{c}	52.63±3.20^{a}	3.2±0.31^{c}	3.83±0.47^{a}	7.83±0.47^{c}	10.67±0.33^{a}	3.0±0.36^{a}	23.83±0.83^{c}	24.5±0.22^{c}	17.66±0.33^{a}	1.2±0.19^{a}
	LSD	43.99	28.86	311.66	306.46	1.73	2.03	37.29	57.96		4.97	0.86	1.16	144.71

Mean using LSD, alphabet with the same letter means there is no significant difference while alphabet with different letter means there is significant difference

Table 2. Analysis of variance for all the parameters of S. stenocarpa (Fabaceae)

Error	Interaction	Factor 2 SS varieties	Factor 1 SS concentration	Combination	Treatment	Total		SOURCES OF VARIATION
44	**6**	**2**	**3**	**11**	**4**	**59**		**Degree of freedom**
77.19 -	114.72 1.48^{NS}	118.2 1.53^{NS}	4344.93 56.29**	1269.05 -	55.98 0.73*	282.29 -	MS VR	PLANT HEIGHT AT 3 WKS
50.63 2.06^{NS}	104.2 3.62*	183.4 -	5208.03 102.86*	1510.56 -	69.25 1.37^{NS}	324.08 -	MS VR	PLANT HEIGHT AT 6 WKS
546.84-	3033.825.55**	4470.158.17**	60315.23110.29**	18917.17-	261.580.48*	3952.48-	MS VR	PLANT HEIGHT AT 9 WKS
220.32-	3387.615.38**	4920.5522.33**	102180.2463.78**	30609.78-	173740.7788.55**	6236.42-	MS VR	PLANT HEIGHT AT 12 WKS
3.03-	2.330.76^{NS}	0.80.26^{NS}	227.8620.97**	63.56-	52.050.67^{NS}	14.23-	MSVR	NO. OF LEAVES AT 3 WKS
3.57-	4.181.17^{NS}	1.200.34^{NS}	439.27123.04**	122.3-	0.230.064^{NS}	25.48-	MSVR	NO. OF LEAVES AT 6 WKS
65.43-	62.470.95^{NS}	77.61.19^{NS}	616.539.42*	216.33-	648.789.92**	52.44-	MSVR	NO. OF LEAVES AT 9 WKS
101.69-	405.63.98**	766.857.56**	4191.541.22**	1224.58-	181.351.78^{NS}	316.45-	MS VR	NO. OF LEAVES AT 12 WKS
0.43-	0.1380.32^{NS}	0.3730.87^{NS}	0.8752.03^{NS}	0.382-	0.7151.66^{NS}	0.44-	MS VR	NO. OF FLOWERS AT 9 WKS
0.83-	2.783.35**	2.63.13^{NS}	45.0817.34**	14,29-	2.693.42*	3.46-	MS VR	NO. OF SEEDS/POD
0.46-	1.63.17*	1.914.15*	88.58192.57**	25.29-	0.631.37^{NS}	5.09-	MS VR	POD LENGTH
15.211-0	27.3151.796^{NS}	64.7154.254*	151.91.987	44.563-	41.2732.713*	5.83-	MS VR	NO. OF PODS
253.9-	372.111.46^{NS}	326.671.29^{NS}	1010.303.98*	1272.12-	406.671.60^{NS}	454.12-	MS VR	NO. OF SEEDS GERMINATION

NS – Not significant; - Significant;** - Very significant*

Table 3. Correlation between salt concentration and growth parameters in white accessions of *Sphenostylis stenocarpa*

	Plant height	No. of leaves	No. of flowers	No. of seeds/pod	Pod length	No. of pods	No. of seeds germinated
Plant height	1	0.900	0.639	0.790	0.744	0.884	0.736
No. of leaves	0.900	1	0.910	0.801	0.830	0.999**	0.928
No. of flowers	0.63	0.910	1	0.654	0.750	0.923	0.934
No. of seeds/pod	0.790	0.801	0.654	1	0.985	0.810	0.878
Pod length	0.744	0.83	0.750	0.985*	1	0.845	0.937
No. of pods	0.884	0.999**	0.923	0.810	0.845	1	0.943
No. seeds germinated	0.736	0.928	0.934	0.878	0.937	0.943	1

***Correlation is significant at 0.01 level (2-tailed);*Correlation is significant at 0.05 level (2-tailed)*

Table 4. Correlation between salt concentration and growth parameters in black accessions of *Sphenostylis stenocarpa*

	Plant height	No. of leaves	No. of flowers	No. of seeds/pod	Pod length	No. of pods	No. of seed germinated
Plant height	1	0.926	0.499	0.928	-0.237	0.946	0.768
No. of leaves	0.926	1	0.788	0.923	0.072	0.998**	0.857
No. of flowers	0.499	0.788	1	0.594	0.578	0.753	0.675
No. of seeds/pod	0.928	0.923	0.594	1	-0.285	0.934	0.948
Pod length	-0.237	0.072	0.58	-0.288	1	0.024	-0.183
No. of pods	-0.946	0.998**	0.753	0.934	0.024	1	0.855
No. seeds germinated	0.768	0.857	0.695	0.948	-0.183	0.855	1

***Correlation is significant at 0.01 level (2-tailed); *Correlation is significant at 0.05 level (2-tailed)*

Table 5. Correlation between salt concentration and growth parameters in brown accessions of *Sphenostylis stenocarpa*

	Plant height	No. of leaves	No. of flowers	No. of seeds/pod	Pod length	No. of pods	No. of seeds germinated
Plant height	1	0.922	0.323	0.849	0.952*	0.918	0.948
No. of leaves	0.922	1	0.445	0.975	0.936	0.999**	0.997*
No. of flowers	0.323	0.445	1	0.305	0.133	0.492	0.440
No. of seeds/pod	0.849	0.975	0.305	1	0.931	0.964	0.959*
Pod length	0.952	0.936	0.133	0.931	1	0.919	0.946
No. of pods	0.918	0.999**	0.492	0.964	0.919	1	0.996**
No. seeds germinated	0.948	0.997**	0.440	0.959*	0.946	0.996**	1

***Correlation is significant at 0.01 level (2-tailed);*Correlation is significant at 0.05 level (2-tailed)*

The control (0 kg/l) produced more than the other concentrations which are 1 kg/l and 3 kg/l. The salt stress affects these concentrations more compared to the control. There was great significant difference between the control (0kg/l) and other concentrations. In plant height, number of leaves, number of pod, pod length, number of seeds, and number of seeds germinated. The Salt stress response of species differ, as such, efforts must be made to identify and select the appropriate variety preference of any species. The inherent characteristics of species and genotypes within species play an important role in their tolerance to salt stress.Results obtained from this study revealed that there was no significant difference among all varieties of African yam bean treated at 1 kg/l levels of NaCl. This result is in support of Onyebuchi et al. [14] who reported that African yam bean is less sensitive to salt stress at lower salt (NaCl) concentration. African yam bean was able to adjust its physiological activities to salt stress condition [17, 18], which would result in improved plant growth. There was no significant difference ($p<0.05$) among varieties of African yam bean at 0 kg/l in different morphological parameters evaluated. This is in line with the findings of Onyebuchi *et al.* who reported a no significant difference among varieties of African yam bean studies. It is probable that this may have been that all varieties studied were from a single ancestor.

Sodium chloride ($NaCl^+$) significantly affected some important morphological traits of *Sphenostylis stenocarpa* evaluated. In this study our result is in agreement with the earlier findings of Onyebuchi et al. [14] who reported that high concentrations of sodium chloride (NaCl) significantly ($P<0.05$) reduced the growth parameters of African yam bean seedling. All varieties treated at various levels with NaCl performed poorly than those without treatment (control). These investigations are in agreement with similar studies in different plants [17, 19, 20]. The number of seed germinated, plant height, flower colour, number of pod per plant, number of seed per pod and pod length were significantly ($p<0.05$) reduced at 12 weeks of treatment. This is in agreement with the findings of Onyebuchi et al. [14] who states that the mechanism by which salinity affects growth of plant depends on the time scale over which the plant is exposed.

Salt stress significantly reduced ($p<0.05$) the germination of African yam bean. This observation is in agreement with the works of other researchers on the effect of salt stress on seed germination of various crops like *Oriza sativa* [21], *Triticum aestivum* [22], *Zea mays* (Carpi *et al.,* 2009). *Brassica* spp. [23, 18] and *Glycine max* [24]. Salt induced inhibition of seed germination could be attributed to osmotic stress or to specific ion toxicity (Huang & Redman, 1995).

5. CONCLUSION

Salt stress is one factor that greatly influences the production of *Sphenostylis stenocarpa.* The result obtained from this study revealed that salt stress affected the yield performance of this crop, there was significant difference among level (1 kg/l, 2 kg/l, 3 kg/l) of NaCl concentrations on parameters studied. There was however, no significant difference observed among varieties at 0 kg/l. From the result obtained, it could be said that 0kg/l had the best results in most parameters evaluated.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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