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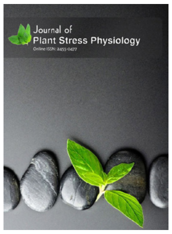
Research Article



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Growth and biomass yield responses of *Sphenostylis stenocarpa* (Hochst. Ex A. Rich.) Harms accessions to waterlogging stress

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ABSTRACT

Effects of waterlogging on the growth of six accessions of *Sphenostylis stenocarpa* were investigated. There accessions were TSs-5, TSs-7, TSs-8, TSs-9 TSs-10 and TSs-11. After growing *S. stenocarpa* for 4 weeks, results indicated that waterlogging significantly (p=0.05) reduced its growth parameters of *S. stenocarpa*. For shoot length; TSs-9 recorded the highest value (48.27±2.92 cm) above its control while TSs-11 (17.96±1.13 cm) had the lowest value. For petiole length, TSs-9 (3.62±0.33 cm) recorded the highest value while TSs-8 (0.93±0.93 cm) recorded the lowest value. Internode length had TSs-7 (6.10±0.78 cm) had the highest value while TSs-8 (2.87±2.87 cm) had the lowest value. The total photosynthetic pigment measurement showed that TSs-5 (45.0±0.65 mg/kg) with the highest value and TSs-8 (33.37±14.00 mg/kg) had the lowest value. For leaf area, TSs-7 (25.73±4.21 cm^2) had the highest value while TSs-11 (16.13±2.82 cm^2) recorded the lowest value. Total Fresh Weight (TFW), TSs-7 recorded the highest value (4.96 g) while TSs-8 recorded the lowest value (1.75 g). Root Fresh Weight (RFW), Tss-5 was observed to have the highest value (1.44 g) while Tss-11 recorded the lowest value (0.56 g). However, at 2 weeks after planting the effect of waterlogging stress on the growth parameter was not significant. The reduction in the growth of *S. stenocarpa* as a result of waterlogging stress might be due to the detrimental effect of flooding on O_2 availability for plant cells and other plant metabolic activities of the plant. In areas with waterlogged soil conditions, *S. stenocarpa* should not be cultivated as it has poor and relatively low tolerance towards withstanding the impact of waterlogging; however, accession TSs-9 showed promising waterlogging tolerance ability.

KEYWORDS: African yam bean, Photosynthetic pigment, Stress, *Sphenostylis stenocarpa*, Waterlogging

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INTRODUCTION

Waterlogging of the soil or deeper submergence (referred to collectively as flooding when a distinction is not necessary) occurs when water enters the soil faster than it can drain away under gravity. There is mounting evidence that, in several parts of the World, inputs of water are growing. One cause may be climate change. A factor contributing to increased rainfall will be faster sea water evaporation at warmer temperatures that, in turn, may produce more rains. Abiotic stress from waterlogging and flooding affect large areas of the world (Martínez-Alcántara *et al*., 2012). This stress is caused by reduced O_2 availability for plant cells, induced by waterlogging or soil compaction (Bailey-Serres & Voesenek, 2008). Flood water fills soil pores, thereby reducing oxygen availability, and the diffusion of dissolved O_2 in stagnant water is so slow that only a thin layer of soil near the surface can contains oxygen (Taiz & Zeiger, 2010). Prolonged flooding conditions may result in crop losses >10% (Bange *et al*., 2004). As a result of this disturbance the physiological functioning of plants, and the vegetative and reproductive growth is negatively affected (Gibbs & Greenway, 2003).

The first symptom of flooding damage is stomatal closure, which affects not only gas exchange, but also decreases the passive absorption of water, which is also negatively influenced by anaerobic conditions in the rhizosphere (Kozlowski & Pallardy, 1997). A decrease in transpiration leads to leaf wilting and early senescence, finally resulting in foliar abscission (Kozlowski & Pallardy, 1997; Ashraf, 2012). The respiration of roots in waterlogged soils that are poorly (hypoxia) or not at all aerated (anoxia), in which gas diffusion is severely inhibited (Armstrong *et al*., 1994) causing changes from aerobic to anaerobic conditions, being very detrimental to the development of plants.

However, in tropical and subtropical regions, excessive rainfall is the major constraint for crop production in which elevated levels of water in the soil create hypoxic conditions (decrease in the level of oxygen) within a short period. As a result, plant roots suffer from anoxia, complete absence of oxygen (Gambrell & Patrick, 1978). Hence, plants tolerant to waterlogging (flooding) stress exhibit certain adaptations which include the formation of aerenchyma and adventitious roots. Furthermore, the formation of adventitious roots is due to the interaction of plant hormones, auxin and ethylene (McNamara & Mitchell, 1989).

Thus, this research was carried out to assess the effects of waterlogging stress on the growth of different accessions of *S. stenocarpa* (African yam bean) and also to investigate the water tolerance level of AYB accessions.

MATERIALS AND METHODS

Physicochemical Properties of the Experimental Soil

The soil samples were air-dried at room temperature and stored in labelled bags. The soil sample was taken for physicochemical properties analysis. All analysis was carried out in soil science Department of Akwa Ibom State University. Soil samples were analysed following the standard procedure by the Association of Official Analytical Chemistry (AOAC, 2005).

Source of Experimental Materials

Six (6) accessions *Sphenostylis stenocarpa* were collected from the International Institute for Tropical Agriculture (IITA), Ibada,n Oyo State, Nigeria. Seed coat colour was physically observed and documented. The experiment was carried out at the Department of Botany Greenhouse, Akwa Ibom State University Ikot Akpaden, Akwa Ibom State, Nigeria.

Planting

About Six (6) seeds of *S. stenocarpa* were sown in their respective planting bucket filled with sterilized sandy-loamy soil. Three replicates were made for each accession, with labels and laid out using Completely Block Design (CBD). After two weeks, waterlogging stress was induced on each accession using a 2 cm measurement of water. Thereafter, no inducement of additional water took place as it occurred just once.

Determination of Growth Parameters

The characters considered and evaluated after two weeks of germination included; Shoot length, Leaf Area, Petiole length, Internode length and Number of nodes.

The percentage germination was calculated using the formula:

Percentage germination = (Number of seeds germinated)/(Number of seeds sown) x 100

Determination of Leaf Area

The leaf area (LA) was determined some days after the sprouting measurement was obtained using the measuring rule, the Area (A) of the Leaf was determined by tracing the outline, and the activities of the leaf on the measuring tape. The area covered by the outline was then calculated. The correlation factor (K) was determined by dividing the area (A) by the product of length x breadth of the leaf, therefore, the leaf area for each plant was determined using the formula:

$$A = L \times B$$

Where: A = the traced area;
L = Leaf length
B = Leaf width

Determination of Shoot Length

The shoot length was obtained by measuring the heights of plants in each accession using a measuring tape to take a written record of the actual length per plant.

Determination of Petiole Length

The petiole length was obtained by taking measurements from the leaf base to the stem of the plant.

Estimation of Total Photosynthetic Pigments

The atLeaf chlorophyll meter was used for non-destructive estimation of the total photosynthetic pigment (TPP) contents of *S. stenocarpa*. The atLeaf chlorophyll meter was pinned on the leaf surface and the readings were taken in triplicates.

Determination of Internodes Length

The internodes length was obtained by taking measurements from the portion of the plant stem between two nodes, using a measuring tape as an aid to carry out the record of the outlined space.

Determination of Number of Nodes

The number of nodes was obtained by simply counting the total number of leaves per plant in each accession.

Determination of Leaf Dry Weight

Leaf dry weight was determined after oven drying to constant weight at 70 ^oC.

Determination of Root Length

A plate was prepared as follows: a transparent plastic plate/tray (296 x 210 x 1 mm) was placed on a paper where the appropriate size of the grids was drawn. The grids were masked with 1 mm wide adhesive tape. The grid size was determined depending on the sample size, and the number of intersections between the grid lines and roots, which appeared as black dots or short lines were counted. To obtain the best estimation, counting of dots that did not reach the centre of the grid width was avoided.

Leaf Turgid Weight (LTW)

To determine the turgid weight (TW), leaves were soaked in distilled water inside a closed petri dish. Leaf samples were weighed periodically after gently wiping the water off the leaf surface with tissue paper until a steady state was achieved. The turgid weight of the leaves was then determined by weighing the soaked leaves on a weighing balance and weight recorded.

RESULTS AND DISCUSSION

Physicochemical Properties of the Soil

The analysis of the physicochemical properties of the experimental soil indicated a pH value of (5.6), total nitrogen (1.16%), available phosphorous (13.10 mg/kg), silt, clay and sand (70, 100 and 30 g/kg), Ex. Ca (0.66 cmol/kg), Base saturation (60), Texture (LS), EC (0.067 dS/m), Organic matter (4.32%), Organic carbon (2.50) (Table 1).

Effect of Water Logging Stress on some Growth Parameters of *S. stenocarpa* Grown for 2 Weeks

The result from the research showed that waterlogging significantly (p=0.05) reduced the growth parameters of *S. stenocarpa* at 2 weeks after germination when compared to their controls. In shoot length, TSs-9 (34.83±4.06 cm) recorded the highest value while TSs-11 (16.67±0.83 cm) had the lowest shoot length value. For Petiole length, TSs-9 had the highest value (3.03±0.23 cm) while TSs-8 (0.97±0.97 cm) recorded the lowest value. Internode length values showed that TSs-5 (6.33±0.67 cm) had the highest value, followed by TSs-7 (6.13±0.17 cm) while TSs-11 (3.60± 0.49 cm) showed the lowest value. Results from the estimation of total photosynthetic pigment recorded showed that TSs-11 (55.16±3.80 mg/kg) recorded the highest value while TSs-9 (46.53±1.07 mg/kg) recorded the lowest value. Numbers of nodes were highest in TSs-9 (8.00±0.00), while TSs-5 (2.00±0.00) showed the lowest value of number of nodes. Lastly, the leaf area of *S. stenocarpa* at two weeks indicated that TSs-10 (24.28±1.94 cm^2) had the highest value while TSs-11 (15.52±2.76 cm^2) recorded the lowest value of leaf area at two weeks of germination as shown in Table 2.

Table 1: Physicochemical properties of the experimental soil

S. No.	Parameters	Result (values)
1	pH	5.6
2	Organic matter (%)	4.32
3	Total nitrogen (%)	1.16
4	Available P. (mg/kg)	13.10
5	Ex. Ca (Cmol/kg)	0.66
6	Silt (g/kg)	70
7	Clay (g/kg)	100
8	Ex. Mg. (Cmol/kg)	0.30
9	Organic carbon	2.50
10	Ex. Na. (Cmol/kg)	0.11
11	Ex. K. (Cmol/kg)	0.40
12	Texture	LS
13	ECEC (Cmol/kg)	2.50
14	Bases saturation	60
15	OM (%)	4.32
16	Sand (g/kg)	30
17	EC (dS/m)	0.067
18	TEA	1.03
19	BD (%)	1.47

Ex-Exchange, ECEC-Effective cation exchange capacity, EC-Electrical conductivity, TEA-Total Exchangeable Acidity, BD-Bulk Density, OM-Organic Matter, Ex. Ca-Exchangeable Calcium, Ex. Na- Exchangeable Sodium, Ex. K- Exchangeable Potassium, Ex. Mg-Exchangeable Magnesium

Effect of Waterlogging Stress on some Growth Parameters of *S. stenocarpa* Grown for 3 Weeks

The result from the research showed that at 3 weeks after planting, waterlogging significantly (p=0.05) reduced the growth parameters of *S. stenocarpa* at 3 weeks after planting when compared to their controls. For shoot length TSs-9 (48.17±3.00 cm) recorded the highest value of growth above the control while TSs-11 (17.50±1.10 cm) showed the lowest value. For Petiole length; TSs-9 (3.23±0.34 cm) recorded the highest value while TSs-5 (2.40±0.10 cm) recorded the lowest value in petiole length. Internode length at values showed that TSs-10 (6.76±1.19 cm) with the highest value while TSs-11 (3.67±0.49 cm) showed the lowest value of internode length. For the number of nodes; TSs-9 (8.00±0.00) had the highest value and TSs-5 (5.00±0.00) had the lowest value. For leaf area; TSs-10 (25.72±1.28 cm^2) had the highest value while TSs-11 (15.35±3.26 cm^2) recorded the lowest value as shown in Table 3.

Effect of Waterlogging Stress on Growth Parameters of *S. stenocarpa* Grown for 4 Weeks after Planting

After growing *S. stenocarpa* for 4 weeks, the result indicated that waterlogging significantly (p=0.05) reduced its growth parameters. For shoot length; TSs-9 recorded the highest value (48.27±2.92 cm) above its control while TSs-11 (17.96±1.13 cm) had the lowest value. For petiole length, TSs-9 (3.62±0.33 cm) recorded the highest value while TSs-8 (0.93±0.93 cm) recorded the lowest value. Internode length had TSs-7 (6.10±0.78 cm) with the highest value while TSs-8 (2.87±2.87 cm) had the lowest value. The total photosynthetic pigment measurement showed that TSs-5 (45.0±0.65 mg/kg) had the highest value and TSs-8 (33.37±14.00 mg/kg) had the lowest value. For estimation of the number of nodes; TSs-9 (8.00±0.00) maintained the highest value and TSs-10 (1.67±1.67) had the lowest value. For leaf area, TSs-7 (25.73±4.21 cm^2) had the highest value while TSs-11 (16.13±2.82 cm^2) recorded the lowest value of leaf area as shown in Table 4.

Effect of Waterlogging Stress on the Biomass Yield of *S. stenocarpa*

The results of biomass yield observed in *S. stenocarpa* under waterlogging stress indicated that in Total Fresh Weight

Table 2: Effect of waterlogging stress on some growth parameters of *S. stenocarpa* grown for 2 weeks

ACCESSIONS	Shoot Length (cm)	Petiole Length (cm)	Internode Length (cm)	Total Photosynthetic Pigment (mg/kg)	Number of nodes	Leaf area (cm²)
Tss-5 (Treatment)	31.93±3.59	1.73±0.20	6.33±0.67	51.40±1.53	2.00±0.00	21.96±3.60
Tss-5 (Control)	37.10±4.16	2.86±0.13	7.93±1.37	48.43±1.31	2.00±0.00	38.65±10.48
TSs-7 (Treatment)	31.47±4.77	2.97±0.20	6.13±0.76	49.67±1.98	5.00±0.00	20.72±2.89
TSs-7 (Control)	26.30±5.64	18.00±0.87	6.40±1.32	47.30±4.28	5.00±0.00	20.55±4.00
TSs-8 (Treatment)	21.37±3.78	0.97±0.97	4.50±0.25	48.30±4.28	6.00±1.00	15.89±0.71
TSs-8 (Control)	26.25±3.25	2.35±0.55	6.80±1.70	48.30±4.22	8.00±0.00	19.28±0.15
TSs-9 (Treatment)	34.83±4.06	3.03±0.23	5.10±0.57	46.53±1.07	8.00±0.00	21.81±3.99
TSs-9 (Control)	20.70±3.10	1.19±0.03	4.80±0.13	47.53±1.07	6.00±1.00	19.95±3.61
Tss-10 (Treatment)	31.60±3.71	2.23±0.57	4.70±0.89	52.80±2.38	4.00±1.00	24.28±1.94
Tss-10 (Control)	29.96±2.58	3.76±0.14	5.17±0.20	54.16±2.04	5.00±0.00	25.42±1.35
Tss-11 (Treatment)	16.67±0.83	1.67±0.42	3.60±0.49	55.16±3.80	3.00±1.00	15.52±2.76
Tss-11 (Control)	9.03±1.83	1.00±0.00	1.23±0.15	48.83±0.46	2.00±0.00	6.17±1.67

Data were processed and expressed as±SEM of three replicates

Table 3: Effect of waterlogging stress on some growth parameters of *S. stenocarpa* grown for 3 weeks

ACCESSIONS	Shoot length (cm)	Petiole length (cm)	Internode length (cm)	Number of nodes	Leaf area (cm²)
Tss-5 (Treatment)	45.03±6.31	2.40±0.10	6.43±0.62	5.00±0.00	24.97±4.34
Tss-5 (Control)	45.86±7.78	3.03±0.18	8.10±1.30	7.00±0.00	28.40±2.17
TSs-7 (Treatment)	44.07±1.49	3.13±0.13	6.37±0.90	5.00±0.00	25.19±4.18
TSs-7 (Control	34.03±6.78	2.83±0.49	6.40±0.95	5.00±0.00	23.07±2.90
TSs-8 (Treatment)	36.30±6.58	2.63±0.32	5.87±1.39	6.00±1.00	20.00±0.99
TSs-8 (Control)	52.55±1.05	3.20±0.50	7.20±1.70	8.00±0.00	21.09±0.28
TSs-9 (Treatment)	48.17±3.00	3.23±0.34	5.11±0.45	8.00±0.00	23.33±2.55
TSs-9 (Control)	32.57±10.13	2.63±0.24	4.60±0.17	6.00±1.00	21.12±2.36
Tss-10 (Treatment)	44.46±3.49	2.96±0.15	6.76±1.19	5.00±0.00	25.72±1.28
Tss-10 (Control)	48.96±5.49	3.93±0.12	5.27±0.22	7.00±1.00	26.29±0.71
Tss-11 (Treatment)	17.50±1.10	2.63±0.17	3.67±0.49	6.00±1.00	15.35±3.26
Tss-11 (Control)	10.20±2.00	2.30±0.25	2.03±0.33	5.00±1.00	6.52±1.57

Data were processed and expressed as mean±SEM of three replicates

(TFW), TSs-7 recorded the highest value (4.96 g) while TSs-8 recorded the lowest value (1.75 g). Root Fresh Weight (RFW), Tss-5 was observed to have the highest value (1.44 g) while Tss-11 recorded the lowest value (0.56 g). Shoot Fresh Weight (SFW); TSs-9 recorded the highest value (3.19 g), while TSs-8 showed the lowest value (1.32 g). Leaf Fresh Weight (LFW); TSs-9 recorded the highest value (0.33 g) while TSs-7 (0.13 g) recorded the lowest value. Leaf Turgid Weight (LTW), TSs-5 recorded the highest value (0.73 g) while TSs-7 recorded (0.51 g) as the lowest value under leaf turgid weight. Root Dry Weight (RDW), TSs-9 recorded the highest value (0.33 g) while TSs-5 (0.13 g) showed the lowest value. Shoot Dry Weight (SDW), TSs-7 recorded the highest value (1.18 g) while TSs-8 (0.35 g) recorded the lowest value. Leaf Dry Weight (LDW), Tss-5, TSs-8 and TSs-10 recorded equal values (0.11 g) while TSs-7, TSs-9 and TSs-11 recorded equal values (0.09 g). Root length

(RL), Tss-5 recorded the highest value of (22.50±1.91 cm) while Tss-11 showed the lowest value (8.16±1.79 cm) (Table 5). Plant growth and biomass production an integral measure of plant response to stress conditions; however a pronounced reduction in biomass yield and a significant increase in biomass yield were observed in the different accessions that had suitable tolerance towards the inducement of water stress (Table 5 & Figure 1).

The surface soil recorded high levels of organic matter (4.32). The high levels of organic matter may be due to luxuriant vegetation, mainly grasses and shrubs, and the slow rate of microbial decomposition of the vegetation. The soil organic matter content agrees with the report findings of (Uduak *et al.*, 2014) who gave values of organic matter to range from 2.46 to 4.97% for Cross River floodplain soils. The high organic matter

Table 4: Effect of Waterlogging Stress on Growth Parameters of *S. stenocarpa* Grown for 4 weeks

Accessions	Shoot length (cm)	Petiole length (cm)	Internode length (cm)	Total photosynthetic pigment (mg/kg)	Number of nodes	Leaf area (cm^2)
Tss-5 (Treatment)	44.50±5.66	2.33±0.20	4.20±2.15	45.0±0.65	3.00±1.53	17.30±3.31
Tss-5 (Control)	46.73±9.34	2.83±0.22	7.97±1.29	49.83±0.81	7.00±1.00	27.16±1.57
TSs-7 (Treatment)	43.17±2.07	2.50±1.25	6.1±0.78	42.00±4.90	5.00±1.73	25.73±4.21
TSs-7 (Control)	36.80±6.37	3.20±0.38	6.43±1.10	49.87±2.13	8.00±0.00	23.40±3.04
TSs-8 (Treatment)	36.47±6.19	0.93±0.93	2.87±2.87	33.37±14.00	2.67±1.20	20.39±1.07
TSs-8 (Control)	41.97±14.16	2.10±1.12	6.23±3.13	47.73±0.84	6.00±2.00	23.88±2.50
TSs-9 (Treatment)	48.27±2.92	3.62±0.33	5.33±0.50	40.83±1.04	8.00±0.00	23.85±2.33
TSs-9 (Control)	35.57±20.03	2.57±0.22	4.87±0.58	46.23±2.80	6.00±1.00	21.60±2.16
Tss-10 (Treatment)	43.50±3.61	2.33±0.43	5.50±0.29	38.30±4.35	1.67±1.67	24.56±3.97
Tss-10 (Control)	51.33±4.80	3.10±0.51	6.63±1.39	53.76±0.81	7.00±1.00	25.87±0.85
Tss-11 (Treatment)	17.96±1.13	2.53±0.33	3.70±0.47	38.67±10.80	6.00±1.00	16.13±2.82
Tss-11 (Control)	10.56±2.22	2.96±0.26	1.60±0.45	46.63±1.44	5.00±0.00	6.15±1.67

Data were processed and expressed as mean±SE of three replicates

Table 5: Effect of waterlogging stress on the biomass yield of *S. stenocarpa*

Accessions	Total Fresh Weight (g)	Root Fresh Weight (g)	Shoot Fresh Weight (g)	Fresh Leaf Weight (g)	Leaf Turgid Weight (g)	Root Dry Weight (g)	Shoot Dry Weight (g)	Leaf Dry Weight (g)	Root length (cm)
Tss-5 (Treatment)	4.83	1.44	2.94	0.21	0.73	0.13	0.66	0.11	22.50±1.91
Tss-5 (Control)	8.80	4.16	4.43	0.24	0.63	0.51	0.15	0.12	10.57±0.52
TSs-7 (Treatment)	4.96	1.40	2.88	0.13	0.51	0.31	1.18	0.09	14.97±1.70
TSs-7 (Control)	6.31	1.11	4.44	0.21	0.57	0.29	1.43	0.11	12.7±1.06
TSs-8 (Treatment)	1.75	0.76	1.32	0.21	0.54	0.22	0.35	0.11	15.90±3.58
TSs-8 (Control)	5.24	1.27	2.68	0.21	0.52	0.36	0.20	0.10	14.97±2.58
TSs-9 (Treatment)	4.55	1.32	3.17	0.33	0.66	0.33	1.11	0.09	22.00±4.16
TSs-9 (Control)	5.33	1.29	1.86	0.19	0.47	0.37	0.70	0.01	19.83±1.01
Tss-10 (Treatment)	3.10	1.10	1.75	0.28	0.55	0.18	0.39	0.11	14.43±0.83
Tss-10 (Control)	5.63	4.35	1.86	0.26	0.60	0.28	0.26	0.11	16.93±2.67
Tss-11 (Treatment)	1.94	0.56	1.66	0.19	0.55	0.14	0.36	0.09	8.16±1.79
Tss-11 (Control)	1.02	0.16	0.33	0.08	0.25	0.08	0.15	0.05	3.00±2.29

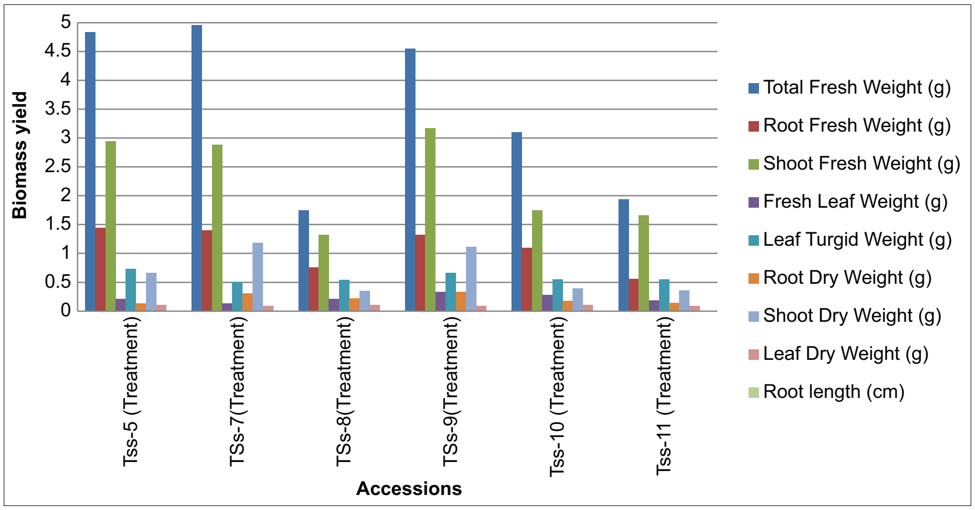

Figure 1: Effect of waterlogging treatments on the biomass yield of *S. stenocarpa*

content contributes to soil tilt and nutrient holding capacity (Tisdale *et al.*, 1993). Electrical conductivity (EC) of the soil recorded a value of (0.067 dS/m), EC is a measure of total cations and anions in soil solution and is usually determined mainly by calcium and magnesium ions, depending on the soil type. Total nitrogen content (1.16), the N content was low as values were below the critical limit of 0.15% (FMANR, 1999). The low level of total N could be attributed to the leaching of nitrates due to excessive rainfall and plant removal. The low N status of the soil will have serious implications on the fertility of the soil, as crop plants need this nutrient in large quantities for growth. Available phosphorous content (13.10mg/kg) indicates the high level of available P in the soil. Exchangeable Ca, Mg, N and K ranged from 0.66 Cmol/kg, 0.30 Cmol/kg, 0.11 Cmol/kg, and 0.40 Cmol/kg respectively. Ca content was at the moderate value which was lower than 4 cmol/kg regarded as the critical value for fertile soils (FAO, 1976). The exchangeable Mg content in the soil was at a low level, the value recorded was below the critical value of 0.50 Cmol/kg (FAO, 1976). Exchangeable sodium content was low whilst exchangeable potassium fell above the critical level of 0.2 Cmol/kg reported by Chude *et al.* (2011). The effective cation exchange capacity (ECEC) had a value of 2.50 Cmol/kg. The values obtained were below the critical value of 20 Cmol/kg regarded to be suitable for crop production (FAO, 1976). The percent base saturation had its value (60). High values of base saturation could be attributed to the high levels of calcium and magnesium in the adsorption complex, indicating the availability of some basic cations which are important indices of fertile soil. Based on the FAO soil fertility evaluation standard (FAO, 1976) and FPDD rating of soil fertility based on soil testing values (FPDD, 1989), all the soil types in Akwa Ibom State are rated low in fertility and will need adequate fertilizer applications to obtain high yields of arable crops. The optimum rate of fertilizers should be applied to crops, if the rate applied is below what is required; the optimal yield of crops will not be achieved. Excess application of fertilizer may lead to a reduction in crop yield, poor quality of the crop, reduction in the availability of some nutrients, especially micronutrients and pollution of the surrounding environments, particularly water bodies near the affected area. Soil testing should be carried out before any fertilizer is applied.

The effect of waterlogging stress on the growth of different accessions of *S. stenocarpa* using specifically six different accessions of was investigated. The characteristics considered and evaluated after two to four weeks of planting include; leaf area, total photosynthetic pigment, petiole length, internode length, shoot length, and number of nodes. This study observed little or no significant decrease ($p=0.05$) in morphological characters at two weeks of planting. The result of this study showed that waterlogging significantly decreased the selected growth parameters of *S. stenocarpa* at four weeks of plant growth in comparison with their controls which showed a reduction in the plant growth. This shows that the plants lacked adaptive features to help them thrive amidst the waterlogging stress as observed in the accessions. This research is in line with the work of Gibbs and Greenway (2003), who reported that as a result of the disturbance of the physiological functioning of plants, vegetative and reproductive growth is negatively affected. Similarly, Wu and Yang (2016) also reported that under prolonged waterlogging conditions, the enzyme activities related to photosynthesis were inhibited; the chlorophyll synthesis ability of leaves decreased, leading to leaf senescence, yellowing, and peeling; the formation of new leaves was blocked, and then the photosynthetic rate decreased, finally leading to the death of the plants which are all in line with the observations of this study.

CONCLUSION

African yam bean has been reported as one of the underutilized legumes in Africa. However, AYB holds greater potentials in improving food security globally. Studies indicate that AYB is rich in protein, minerals and antioxidants with low GI and therefore, can serve as a nutraceutical. It is of great importance to explore its starch, flour and composite flour in producing functional food such as AYB paste called "Amala", bread, and biscuits, as a dietary intervention for the prevention and management of diet-related diseases like diabetics, obesity and kwashiorkor. Feeding infants with the blended flour of AYB will contribute to preventing infant malnutrition problems in developing countries. Also extract of mashed cooked AYB can be used to induce lactation after childbirth and the fried ground seed coat to treat strokes. The reviewed papers revealed that pre-treatment of AYB by soaking, parboiling, before other processing like cooking and roasting has great improvement on its hard-to-cook and anti-nutritional factors. From this research, it was observed that *S. stenocarpa* has low tolerance towards waterlogging stress, the plant has no adaptive features enabling it to thrive within a waterlogged soil condition. This study revealed that waterlogging stress negatively affected the growth parameters of AYB, by reducing its growth and quality. The crop requires moderate water conditions in order for it to survive and yield growth without wilting off. In areas with waterlogged soil conditions, the African yam bean should not be cultivated as it has a poor and relatively low tolerance towards withstanding the impact of water stress, this is because the African yam bean cannot thrive adequately with oxygen shortage and other damaging features of waterlogged soil. Thus, more studies should be conducted to look into ways of improving stress tolerance in different accessions of *S. stenocarpa*.

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