



Effect of Salinity on the Growth Characteristics of *Solanum aethiopicum* L. (Solanaceae)

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SIM designed the study and supervised the work. Authors CE and MU performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Salinity affects various morphological and anatomical characters of plants thereby reducing the yield of the plant in the long run. *Solanum aethiopicum* L. is an economic plant that is versatile for human use ranging from food to traditional medicine. Experiment was conducted to assay the impact of saline irrigation on some growth parameters (plant height, leaf area, fresh weight, dry weight and size of stomatal complex). Results of the experiment showed that for most parameters studied that the values obtained for the treatments are reduced compared to the control, thereby establishing that saline water harmed *S. aethiopicum* L. There is no significant difference in the plant from week 5 (i.e. 2 weeks after application of saline water) but at week 6 and 7 (i.e. 3 and 4 weeks after application of saline water respectively), there was significant difference in the parameters. Therefore it is advised that *S. aethiopicum* L. be grown on soils with low or no content of salinity to maintain optimum growth and development of the plant.

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1. INTRODUCTION

Salinity is a worldwide problem that affects approximately 20% of irrigated land and reduces crop yields significantly [1]. Salinity poses two major threats to plant growth namely osmotic stress and ionic stress [2]. These stresses can interfere with the physiological and metabolic processes of plants thus making the plant exhibit symptoms such as a decrease in leaf area, increase in leaf thickness and succulence, necrosis of the root and shoot, abscission of leaves and decrease in internode length [3-5]. Saline irrigation water can have many negative effects on greenhouse crops. High salinity level in overhead irrigation leads to precipitation of the salt during evaporation and results to salt uptake and phytotoxicity. This, in turn, can result in foliar uptake and phytotoxicity [6]. The irrigation water may also cause salt to accumulate in the substrate, which may lead to salt uptake by the plants. When excessive concentrations of NaCl are present in the soil, water uptake may be inhibited [7], causing physiological drought stress.

In Nigeria, *Solanum aethiopicum* is an economic plant that is cultivated by people in the riverine areas for medicinal and food production. Though this plant has lots of economic importance, there is no report on the effect of salinity on the growth and yield of this species. This work aims to determine the effect of salinity on growth characteristics (height, leaf area, fresh weight, dry weight, and stomatal complex) of *S. aethiopicum*.

2. MATERIALS AND METHODS

2.1 Study Site

The experiment was conducted in 2018 at the Centre for Ecological Studies, University of Port Harcourt, Rivers State, Nigeria (N04⁰ 53' 51.70"; E006⁰ 55' 18.45").

2.2 Source of Planting Materials

The seeds were obtained from the Agricultural Development Programme (ADP), Rumuodumaya, Obio-Akpor, Rivers State, Nigeria. The variety of the seeds of *S. aethiopicum* used was YALO.

2.3 Viability Test

The seeds were tested to know their germination percentage. Twenty seeds were put in a petri dish in four replicates, lined with filter paper and inspected every day for germination. After the seeds have germinated, the germination percentage was then calculated.

2.4 Planting of Seeds

Five seeds were planted directly into buckets containing 8.0 kg of soil and thinned to two plants per buckets after germination.

2.5 Application of Saline Water Treatment

The stock saline water was obtained from the New Calabar River along Iwofe road, Port Harcourt. The salinity of the water was determined with standard salinity meter and titrimetric methods and average salinity (15523 mg/L) used as the stock solution. The distilled water was used as control (treatment-1) and the stock solution was further diluted to have treatment-2 (T₂, 1328 mg/L), treatment-3 (T₃, 4657 mg/L), treatment 4 (T₄, 9313 mg/L) and treatment 5 (T₅, 13970 mg/L). 500 ml of the solutions were added to the respective buckets weekly beginning at 3 weeks after planting and care was taken not to allow the saltwater to touch the leaves of the plant.

2.6 Measurement of Parameters

The measurement of parameters was carried out every week for five weeks following the addition of the saline water. The parameters measured were: plant height, leaf number, leaf area index, fresh weight, dry weight, and stomatal complex.

2.7 Leaf Area Index (LAI)

The leaf area index was calculated using the equation; $LAI = 0.75 \times L \times B$ where LAI is the leaf area index, 0.75 is a constant, L is the length of the leaf and B is the breadth of the leaf which were both measured with a ruler (Issifu et al. 2017).

2.8 Stomata Complex

The area stomata complex of the specimen studied were measured at week 7 after planting.

The lower epidermis of the plant was peeled and a temporary slide prepared. The slide was viewed under the microscope at x100 magnification and the sizes of 50 stomatal complexes measured with an eyepiece graticule. The average area of the stomatal complex was recorded in micrometre squared (μm^2).

2.9 Statistical Analysis

The data obtained were analysed using one-way Analysis of Variance (One-way ANOVA) using Microsoft Excel 2010.

3. RESULTS

The results of the study on the effect of saline irrigation water on height, number of leaves, leaf area, guard cells stomata and dry weight of *S.*

aethiopicum L. over 4 weeks are presented in (Tables 1-5). The seeds used for this had an average germination percentage of 98.75%.

3.1 Plant Height

The mean plant height measured from three to seven weeks after planting is recorded in Table 1. A linear progressive increase in shoot length was observed in each of the treatments. The highest values were recorded at seven weeks after planting for all the treatments. Treatment-1 with a mean height of 12.3 ± 2.680 cm and treatment 5 with a mean height of 14.0 ± 8.245 cm were the highest plant height recorded. There is no significant difference in the plant from week 3 to 6 but at week 7 (i.e. 4 weeks after application of saline water), there was a significant difference in the plant (Table 4).

Table 1. Effect of salinity on the height (cm) of *S. aethiopicum*

Week	T ₁ (Control)	T ₂	T ₃	T ₄	T ₅
3	3.6 ± 0.856	3.7 ± 0.991	3.7 ± 0.401	4.6 ± 1.917	4.0 ± 1.282
4	5.5 ± 1.205	5.7 ± 1.348	5.5 ± 0.381	5.9 ± 0.807	5.9 ± 1.917
5	7.9 ± 1.678	8.1 ± 2.423	7.8 ± 1.484	7.7 ± 1.033	8.2 ± 3.581
6	9.4 ± 2.627	9.5 ± 2.209	9.6 ± 1.484	9.0 ± 1.462	10.8 ± 6.552
7	12.3 ± 2.680	10.8 ± 2.913	12.2 ± 5.22	10.6 ± 1.948	14.0 ± 8.245

Table 2. Effect of salinity on the number of leaves in *S. aethiopicum*

Week	T ₁ (Control)	T ₂	T ₃	T ₄	T ₅
3	2.8 ± 0.289	3.5 ± 0.408	3.6 ± 0.250	3.8 ± 0.645	3.9 ± 0.250
4	3.4 ± 0.25	3.9 ± 0.750	4.0 ± 0.707	4.0 ± 0.912	4.4 ± 0.250
5	3.5 ± 1.225	2.9 ± 1.031	3.5 ± 0.577	3.5 ± 0.707	3.8 ± 1.323
6	3.9 ± 0.629	4.0 ± 0.913	2.3 ± 1.708	2.6 ± 0.750	2.3 ± 1.848
7	4.8 ± 0.646	4.4 ± 0.750	2.9 ± 2.097	3.9 ± 1.315	3.1 ± 2.174

Table 3. Effect salinity on leaf area index of *S. aethiopicum*

Week	T ₁ (Control)	T ₂	T ₃	T ₄	T ₅
3	1.80 ± 0.787	1.90 ± 0.991	1.71 ± 0.140	2.48 ± 1.101	1.77 ± 1.207
4	3.91 ± 2.150	3.83 ± 2.211	3.67 ± 0.869	4.60 ± 0.980	4.11 ± 2.429
5	7.62 ± 4.295	7.70 ± 6.636	7.15 ± 2.204	7.80 ± 2.241	8.84 ± 6.372
6	12.76 ± 6.590	11.78 ± 10.879	11.96 ± 7.979	12.88 ± 5.660	12.91 ± 11.856
7	24.27 ± 10.675	17.85 ± 12.814	17.74 ± 22.734	15.11 ± 7.015	21.88 ± 20.097

Table 4. Effect salinity on leaf area index, plant height and leaf number of *S. aethiopicum*

Treatment	LAI at week 7	Plant height (cm) at week 7	Number of leaves at week 6	Number of leaves at week 7
T1	24.27 ± 10.675^a	12.3 ± 2.680^a	3.9 ± 0.629^c	4.8 ± 0.646^a
T2	17.85 ± 12.814^b	10.8 ± 2.913^b	4.0 ± 0.913^d	4.4 ± 0.750^b
T3	17.74 ± 22.734^c	12.2 ± 5.22^c	2.3 ± 1.708^a	2.9 ± 2.097^c
T4	15.11 ± 7.015^d	10.6 ± 1.948^d	2.6 ± 0.750^b	3.9 ± 1.315^d
T5	21.88 ± 20.097^e	14.0 ± 8.245^e	2.3 ± 1.848^a	3.1 ± 2.174^e
LSD at $P \leq 0.05$	0.00866	0.03899	0.02439	0.00894

Table 5. Effect salinity on stomata area, fresh weight and dry weight of *S. aethiopicum*

Treatment	Stomata area (μm^2)	Fresh weight (g)	Dry weight (g)
T1	173.44 \pm 40.882 ^a	6.54 \pm 3.946	1.06 \pm 0.622 ^b
T2	139.84 \pm 30.240 ^b	5.07 \pm 2.36	0.703 \pm 0.312 ^c
T3	160.16 \pm 35.972 ^c	5.33 \pm 1.669	0.64 \pm 0.349 ^c
T4	92.97 \pm 18.431 ^d	3.76 \pm 2.37	0.40 \pm 0.275 ^a
T5	104.69 \pm 50.419 ^e	4.33 \pm 1.866	0.48 \pm 0.242 ^b
LSD at P \leq 0.05	7.354	-	0.0769

3.2 Number of Leaves

The mean number of leaves counted from three to seven weeks after planting is presented in Table 2. This indicated that the control recorded the highest number of leaves compared to other treatments. There is a progressive increase in the number of leaves counted for control but the other treatments, there are gradual increase and decrease in the number of leaves. For T₂ the average number of leaves reduced at week 5 after planting and thereafter increased progressively to week 7. For T₃, T₄ and T₅ there is a decrease in weeks 5 and 6, thereafter leaf number started to increase again. These fluctuations could be a result of uptake of salt by the plant and at weeks 6 and 7 (i.e. 3 and 4 weeks after application of saline water respectively), there was a significant difference in the plant (Table 4).

3.3 Leaf Area Index (LAI)

The mean leaf area measured from three weeks after planting is presented in Table 3. Generally, all the treatments when compared to the control had reduced area. The mean leaf area of *S. aethiopicum* at different salinity levels from three weeks after planting. This result showed a progressive increase in leaf area from week 3 to 7. The highest leaf area indices were observed at week 7 for all the treatments. Treatment-1 was 24.27 \pm 10.675 cm², treatment-2 was 17.84 \pm 12.814 cm², treatment-3 was 17.74 \pm 22.734 cm², treatment-4 was 15.11 \pm 7.015 cm² and treatment-5 was 21.88 \pm 20.097 cm².

3.4 Dry Weight

The mean dry weight of *S. aethiopicum* measured at week 7 after planting (ie 4 weeks after application of saline water) is presented in Table 5. Treatment-1 gave the highest value for dry weight (1.06 \pm 0.622 g), followed by treatment-2 (0.703 \pm 0.312 g); treatment-3 (0.64 \pm 0.349 g); treatment 4 (0.40 \pm 0.275 g) with a slight increase in treatment-5 (0.48 \pm 0.242 g). Generally, the

trend showed a decrease in dry weight values as the salinity increased and there is a significant difference in weight across the treatments.

3.5 Stomatal Area

The stomatal area on the lower epidermis of *S. aethiopicum* measured at week 7 after planting (ie 4 weeks after application of saline water) is presented in Table 4. The mean guard cells are from treatment 1 (control) to treatment 5 (90%). The control treatment recorded the highest guard cell value (173.44 \pm 40.882 μm^2) with a decrease in treatment 2(139.84 \pm 30.240 μm^2), then an increase in treatment 3(160.16 \pm 35.972 μm^2), followed by a decrease in treatment 4(92.97 \pm 18.431 μm^2) and an increase in treatment 5 (104.69 \pm 50.419 μm^2). Generally, there is a reduction in guard cell area when compared to the control. It is noticed that for the salinity treatments, no definite trend in reduction was observed.

4. DISCUSSION

Generally, for the parameters studied (plant height, number of leaves, leaf area, fresh weight, dry weight and stomatal complex), there was a progressive decrease in the values of the treatments compared to the control. The results of this experiment revealed that there is no significant difference on most of the parameters studied the within the first three weeks of the application of the saline water. However, from the third week, the plant height showed significant difference. Also, at 7 weeks after planting (4 weeks after application of saline water), there was a significant difference in all the parameters measured. This decrease is in line with Gucci and Tattini [3]; Kozlowski [4]; and Parida and Das [5] who stated that salinity stress can interfere with the physiological and metabolic processes of plants thus making the plant exhibits symptoms such as the decrease in leaf area, increase in leaf thickness and succulence, necrosis of the root and shoot of the plant, abscission of leaves and decrease in internode

length. Also, our findings agreed with the work of Chartzoulakis and Klapaki [8] who stated that plant height *Capsicum annuum* L. decreased by as much as 49% and total leaf area by 82% with NaCl concentrations above 2.92 g/L. Though the plant height did not follow a progressive decrease with increasing saline concentration, the reason for this deviation is unaccounted for but could be due to the movement of the plant roots in the soil and accessibility of the saline water to the roots.

We observed a gradual decrease in plant height, number of leaves, leaf area index, fresh weight, dry weight and stomatal complex without significant difference within the first weeks of saline water application and thereafter, there was a significant difference. This is basically because the shoot ion-dependent response occurs first within minutes to days and is thought to be related to Na⁺ sensing and signalling [9,10]. During this period, the effects of salinity on plant water relations cause stomatal closure and the inhibition of leaf expansion [11]. Over a longer period (days to weeks), the build-up of ions in the shoots to toxic concentration particularly in old leaves, causing premature senescence of leaves and ultimately reduced yield or even death of the plant [12]. This was observed from the second week after the application of the saline water when the leaves of the plants reduced in number. The stomata complex showed a significant reduction in size with increasing saline concentration compared to the control. Similar results were obtained by Brugnoli and Lauteri [13] on salinity using *Gossypium hirsutum* and *Phaseolus vulgaris*. They concluded that salinity results in the heterogeneity of the stomata on the leaf surface.

5. CONCLUSION

From the experiment conducted, salinity harmed the parameters of *S. aethiopicum* studied. Further work is planned on the effect of salinity of the guard cell area of *S. aethiopicum* and on investigating the reason for the increase in treatment 3 which had a 30% saline water solution to ascertain whether that level of salinity is the optimum level of tolerance for *S. aethiopicum*.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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