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Morphological Response of *Solanum lycopersicum* L (Tomato) to Salt ($NaCl$ and Na_2SO_4)Stress

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Abstract:

Soil salinity is regarded as the major factor affecting crop productivity. To evaluate the effect of NaCl and Na_2SO_4 at different concentrations on the morphological features of Tomato plant, a variety of tomato was grown in green house condition subjected to varying concentrations of NaCl and Na_2SO_4. All experimental units were laid out in Completely Randomized Design (CRD) with three replications. The result obtained from the study showed a significant decline in plants height and number of leaves in stressed plants. Tomato plants subjected to high salinity (120 and 160mM Na_2SO_4) died off after 2weeks of treatment while plants treated with 160 mM of NaCl had the least biomass (0.82g). Fresh weight of *Solanum lycopersicum* declined with increase in NaCl and Na_2SO_4 where Na_2SO_4 had least biomass and recorded crop mortality at 120 mM and 160mM concentration. This study, revealed that despite the ability of tomato plant to tolerate salinity stress at low concentration, a significantly decline in growth and biomass at higher salt concentration can occur. Both NaCl and Na_2SO_4 inhibited growth, metabolic activity, and ionic uptake. However, Na_2SO_4 affected plant growth more adversely than NaCl. Furthermore, tomato plants can die off at prolong subjection to salinity especially Na_2SO_4 stress.

Keywords **—**Salinity,NaCl, Na_2SO_4, *Solanum lycopersicum,* growth, morphology**.**

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I. INTRODUCTION

Soil Salinity is considered a major factor threatening crop production in arid and semi – arid regions, where soil salt content is naturally high and precipitation can be insufficient for leaching [1,2]. Salt accumulation in agrarian soil has been aggravated by the requirement of irrigation for crop production in arid and semi-arid environments. Salinity problems increasesas salt in the soil increases due to irrigation [3]. It is estimated that at least 20% of all irrigated lands are salt–affected [4]. Even though only around 17% of the land used for cultivation is irrigated, irrigated agriculture accounts for more than 30% of all agricultural production. [5].

Salinity decreases the productivity of agricultural land and jeopardizes the sustainability of agriculture [6].Complex morphological, physiological, and metabolic changes occur in plants as a result of high salinity [7,8]. The higher ratios of toxic salts in the leaf can lead to dehydration and turgor loss, and death of leaf cells and tissues [9].

Tomato (*Solanum lycopersicum* L) is edible, often red fruit/berry of the night shade family Solanaceae [10] Renato Vicario, 2014).Tomato is an important agricultural commodity worldwide. More than 80% of tomatoes are consumed in the form of processed products such as tomato juice, paste, ketchup, sauce, and salsa or as a salad or as cooked. Lycopene is responsible for the characteristic deep–red colour of ripe tomato fruits and tomato products [11]. Tomato is rich in vitamins [12], minerals and lycopene, an excellent antioxidant [13] that helps to reduce the risk of prostate and breast cancer [14].

A comprehensive review of research carried out up to 1999 on the responses of tomato to salinity has been presented by Cuartero and Munoz (1999) [15]. As indicated in previous investigations, the tomato plant is moderately sensitive to salinity [16] (Maas and Hoffman, 1977). The effect of salinity on the germination, vegetative growth, and yield of Tomato has been studied by a number of researchers [17-19; 15, 20]. Although extensive work has been carried out on the effects of salinity on tomato (*Solanum lycopersicum*) using NaCl as a source of salinity. However, little or no researched has been carried out using Na_2SO_4 in some cultivated tomato plants. This work, therefore, aim to analyze the effect of NaCl and Na_2SO_4 at different concentrations on the morphological features of Tomato plant.

II. Materials and Methods

The Experiment was conducted at theGreenhouse of Department of Botany, Faculty of Science, University of Ibadan, located at Lat. 003^0 53^1 47.1^{11} and Long. 07^0 26^1 35.0^{11}N. Tomato seeds were planted in experimental pots of 15cm diameter and 17 cm depth; each pot was filled with 5.0 kg of soil.

NaCl and Na_2SO_4 with varied equimolar concentration (0 mM, 40 mM, 80 mM, 120 mM, and 160 mM) were applied twice a week except for the control (0 mM) that was only watered occasionally with distilled water. After approximately nine weeks of treatment, plant were harvested and analyzed for various growth characters.

2.1 Plant Morphology and Biomass

Plant morphological characters such as plant height and number of leaves were monitored at weekly interval; Root length, Shoot and root fresh weight were obtained at end of the experiment. Plant height was determined using a meter rule while the number of leaves were counted and recorded on weekly basis.

Plant shoots and roots were recorded at the time of harvest. For fresh shoot weight, plants were washed with distilled water and prior to weighing: excess water was removed with paper towels. For fresh root weight, roots were removed from soil with running tap water: excess moisture was absorbed in paper towels prior to weighing. Shoot and root dry weights were determined after drying them at 80^0C till constant weight in air dried oven.

2.2 Determination of Relative Growth Rate

Relative growth rate (RGR) which is the change in relative growth over time was determined using the formula propose by Wareing and Philips (1981) [21]

$$RGR = \frac{Log\ n_2 - Log\ n_1}{t_2 - t_1}$$

Where n_2-final plant height (cm) at t_2 – final time (day) and n_1 –initial plant height (cm) at t_1 – initial time (day).

2.3 Experimental Design and Statistical Analysis

All experiments were laid out in Completely Randomized Design (CRD) with three replications. The data collected were analyzed using Analysis of Variance with Statistical Analysis System (SAS). The means were compared by Duncan Multiple Range Test (DMRT) at 95% level of pr3.

3.0 RESULTS

3.1 Effect of varying concentrations of NaCl and Na_2SO_4 on plant Morphology.

The effects of salinity on the plant height and number of leaves are summarized in Tables 1 and 2.

The results in Table 1 showed that Tomato height was significantly affected by different salt treatments. Plant height decreased significantly with increase in the concentrations of the salts applied. One week after treatment, there was no significant difference in the tomato treated with NaCl and control (0mM) but significant difference was observed in both tomatoes treated with Na_2SO_4. Control pots had the tallest plants (17.87cm). However, tomato treated with 120mM and 160mM Na_2SO_4 had significantly shortest (12.37cm and 12.83cm) plants respectively. Two weeks after treatment, control (0 mM) had the tallest plant height (25.10cm) followed by plants treated with 40mMNaCl (22.63cm) while the shortest (13.20 and 13.77cm) was observed in plants treated with 120mM and 160mMNa_2SO_4. Third week after treatment, control (0 mM) had the tallest (32.63 cm). No significant difference was observed in both plants treated with NaCl concentrations and 40 mM Na_2SO_4 compare to control (0 mM) although significant difference was observed in plants treated with 80 mM, 120 mM and 160 mM Na_2SO_4 compare to control (0 mM). Fourth week after treatment, height of the tomatoes were significantly affected by both salt treatments. Application of 120mM and 160mM of Na_2SO_4 resulted in stunted growth and death of the plants (4.27cm and 4.67cm). No significant difference was observed in plants treated with 160mM NaCl with those treated with 40 mM and 80 mM of Na_2SO_4. Fifth week after treatment, control (0 mM) had the tallest (49.67 cm) while the shortest (26.00 cm) was observed in plants treated with 80 mM Na_2SO_4. There is no significant difference between plants of pot treated with 160 mM of NaCl and 40 mM Na_2SO_4. Application of 120 mM and 160 mM of Na_2SO_4 resulted in total elimination of treated tomatoes. So, it is clear that highest salinity level 120 mM and 160 mM exerted the maximum drastic effects on plant height as compared to the other salinity levels.

Table 2 shows the effect of different concentrations of NaCl and Na_2SO_4 applications on number of leaves of tomato.

After the first week of NaCl and Na2SO4 application, there was no significant difference in the number of leaves in all salt treatments. However, on the second week, The plants treated with 160mM Na2SO4 had the fewest leaves (13.00), but the control (0mM) had the highest average number (26.67) of leaves. Both plants treated with various NaCl and 40mM Na2SO4 concentrations showed no significant difference by the third week following treatment. Although the control pot (0 mM) had the most leaves on average (40.00), 120 and 160 mM of Na_2SO_4 killed several duplicate plants, leaving the plants treated with those concentrations with the fewest leaves (3.67 and 2.33). In comparison to the control (0 mM), both plants treated with varying amounts of NaCl and Na_2SO_4 showed significant differences at the fourth week post-treatment. The plant treated with 120mM Na_2SO_4 had the least amount of leaves (2.67) whereas the control (0mM) plant had the most (50.00). On the fifth week following treatment, the control (0 mM) had the most leaves (63.67), while Na2SO4 at 80 mM had the fewest leaves (26.00). Salt concentrations of NaCl and Na_2SO_4 were not significantly different. 120 mM and 160 mM of Na_2SO4 caused complete defoliation and plant death in plants.

Figure 1 shows the effect of NaCl and Na_2SO_4 salinity on relative growth rate of tomato plants. The relative growth rates (RGR) in the two salts declined significantly compare to control (0mM). The relative growth rate of tomato was highest in plants grown at 0mM followed by plants grown at 40mMNaCl. The lowest growth rate was in plants grown at 160mMNaCl and 80mM Na_2SO_4 respectively (Figure 1). Further increase in salinity caused a decreased in RGR to a low value at higher salinities compared to control.

Effect of varying concentration of NaCl and Na_2SO_4 on biomass of tomato plant is presented in (Table 3). Reduction in fresh and dry weights of root and shoot was observed with the increase in salts stress, as the concentrations of NaCl and Na_2SO_4 increased, dry and fresh weight decreased also. The control showed the highest (5.13g) shoot dry mass, followed by 40mMNaCl (2.54g), while 160 mMNaCl (0.82g) had the lowest value. Salt stress also exerted a drastic effect on root growth and development by reducing its mass. All the two salt concentrations caused reduction in root dry weight compared to the control. The plants grown under control (0 mM) exhibited the maximum value (6.73g) for total dry weight as compared to remaining treatments, which indicated that salinity is responsible for the reduction.

Fresh mass of shoots and roots was decreased significantly ($p>0.05$) by all salt treatment (Table 3). The highest shoot fresh weight was obtained from control treatment (24.51g) and lowest shoot fresh weight (6.96 g) was obtained from 160 mMNaCl. Table 3, showed that shoot fresh weight decreased as salt concentration increased in tomato plant. It was also found that as the salt concentration increased, the root fresh weight decreases (Table 3). The highest root fresh weight was obtained in control (11.01g) and the lowest (1.07g) in 160 mMNaCl.

As the concentration of NaCl and Na_2SO_4 increased, dry and fresh weight decreased. The decreased was more pronounced due to Na_2SO_4 treatments compare to NaCl of the same concentrations.

Table 1.Effect of varying concentrations of NaCl and Na_2SO_4 on height cm) of *Solanum lycopersicum* L

Salts	Concentrations (mM)	1ST	2ND	3rd	4TH	5TH
		WEEKS AFTER TREATMENT				
	0	17.87 a	25.10 a	32.63 a	41.00 a	49.67 a
NaCl	40	17.33 a	22.63 a	28.33 a	37.00 ab	42.17 ab
	80	13.70 a	18.33 a	21.17 a	28.17 ab	38.00 ab
	120	15.27 a	18.83 a	23.50 a	28.67 ab	34.67 b
	160	13.87 a	17.33 a	20.00 a	24.67 b	27.43 b
Na_2SO_4	40	14.87 b	17.43 b	21.33 b	25.17 b	33.17 b
	80	13.20 c	14.93 bc	17.83 b	22.50 b	26.00 c
	120	12.37 c	13. c	13.83 bc	4.27 c	0.00 d
	160	12.83 c	13.77 c	9.17 c	4.67 c	0.00 d

Each value is a mean of three replicates. Values in the same column with the same letter(s) were not significantly different at P>0.05 using Duncan's Multiple Range Test (DMRT).

Table 2: Effect of varying concentrations of NaCl and Na_2SO_4 on Number of Leaves *Solanum lycopersicum*L

Salts	Concentrations (mM)	1ST	2ND	3RD	4TH	5TH
		WEEKS AFTER TREATMENT				
	0	17.00 a	26.67 a	40.00 a	50.00 a	63.67 a
NaCl	40	18.00 a	26.67 a	36.33 a	40.33 ab	45.33 b
	80	14.67 a	22.66 a	30.00 a	42.67 ab	44.00 b
	120	18.33 a	29.00 a	37.33 a	45.00 ab	44.00 b
	160	13.33 a	18.33 a	23.67 a	31.00 b	36.33 b
Na_2SO_4	40	11.33 b	16.67 b	23.00 b	33.67 b	29.67 b
	80	11.33 b	16.33 b	21.00 b	28.67 b	26.00 b
	120	11.00 b	13.67 b	3.67 c	2.67 c	0.00 c
	160	10.00 b	13.00 b	2.33 c	0.00 c	0.00 c

Each value is a mean of three replicates. Values in the same column with the same letter(s) were not significantly different at P>0.05 using Duncan's Multiple Range Test (DMRT

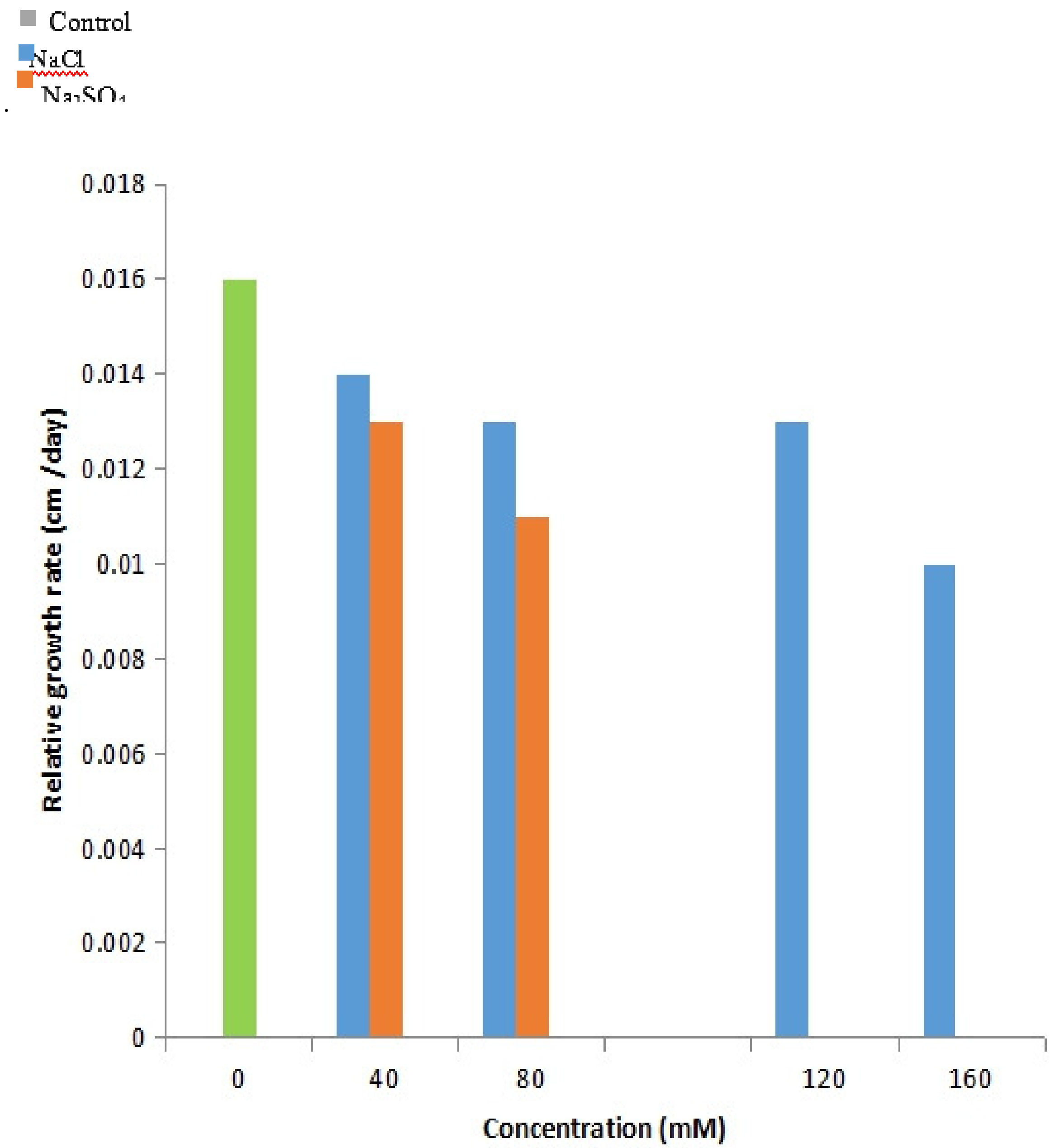

Figure 1 Effect of varying concentrations of NaCl and Na_2SO_4 on Relative GrowthRate of *Solanum lycopersicum*L

Table 3.Effect of varying concentrations of NaCl and Na_2SO_4 on Biomass components of *Solanum lycopersicum* L.

Salts	Concentration (mM)	RFW	SFW	TFW (g)	RDW	SDW	TDW
	0	11.01^{a}	24.51^{a}	35.52^{a}	1.60^{a}	5.13^{a}	6.73^{a}
	40	8.55^{b}	18.66^{b}	27.21^{b}	1.05^{b}	2.54^{b}	3.60^{b}
	80	6.55^{c}	15.42^{bc}	21.97^{bc}	0.92^{b}	1.90^{bc}	2.82^{bc}
NaCl	120	6.32^{c}	10.06^{cd}	16.38^{c}	0.89^{b}	1.40^{cd}	2.29^{c}
	160	1.07^{d}	6.96^{d}	8.03^{d}	0.30^{c}	0.82^{d}	1.12^{d}
Na_2SO_4	40	27.16^{a}	18.02^{a}	25.01^{a}	0.95^{a}	2.14^{a}	3.09^{a}
	80	5.74^{a}	13.34^{b}	19.08^{b}	0.79^{b}	1.52^{b}	2.31^{b}

Each value is a mean of three replicates. Values in the same column with the same letter(s) were not significantly different at P>0.05 using Duncan's Multiple Range Test (DMRT).

RFW: Root fresh weightSFW:Shoot fresh weightTFW: Total fresh weightRDW:Root dried weightSDW: Shoot dried weight TDW:Total dried weight

4. Discussion

Salinity causes several and specific structural changes that affects plant water balance [22, 23]. These structural changes include fewer and smaller leaves, less number of stomata per unit leaf area, thickening of leaf cuticle and wax deposition on leaf surface [24,25].

The continuous increase in the number of leaves in this study agrees with finding of other workers who suggested

Salinity inhibits plant growth for two reasons: first, water deficit and second due to salt-specific or ion-excess effects [26]. In this work, reductions in plants height and number of leaves in stressed plants were observed, plants subjected to high salinity (120 and 160mM Na_2SO_4) died off after 2weeks of treatment. Corroborating the results obtained by Neves et al., 2004 [27], in Umbu plants. These negative effects of salt stress may be due to reduction of both cell division and cell enlargement [28, 29]. Otherwise, inhibition of shoot growth has been considered a whole plant adaptation to salt stress [30,31]. The suppression of growth under salt-stress may also be due to direct effects on ion toxicity especially Na^{+} or indirect effects of saline ions that cause soil/plant osmotic imbalance [1, 32]. These results supports those obtained by other researchers [33,34,35, 36].

Although plant height is genetically controlled, environmental factors also have strong influence on the expression of genes as it is very clear from the current work that all salt treatments significantly influenced the plant. Salinity has been reported to negatively limit germination, plant vigor and yield [37]. Salt tolerance has usually been assessed as the percentage biomass production in saline versus control conditions over a prolonged period of time [38]. It is reported that salt stress affects the plant growth and development by influencing fresh and dry weights of roots, shoots along with shoot length development [39]. Salinity causes stunted growth in glycophytes which results in the reduction in shoot and root fresh weight [40, 41]. The decrease in dry weight of tomato in response to salt stress might be due to several factors like adverse effects of salinity on photosynthesis, reduction in turgor pressure of expanding tissues and salinity response of root to down regulate shoot growth through a long distance signal [40]. These results are in accordance with previous findings where it is reported that decrease in shoot and root fresh weight might be due to decrease in uptake and accumulation of nutrients in the plant body [42].

5. Conclusions

From the results of this study, it could be concluded that salinity stress significantly reduced tomato growth and its biomass. Both NaCl and Na_2SO_4 inhibit growth, metabolic activity, and ion uptake. However, Na_2SO_4 affected plant growth more adversely than NaCl. In addition, the longer the duration of salt stress on *Solanumlycopersicum*, the severe the damage.

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