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Original Article

Assessment of Salinity Effect on Germination, Growth and Yield of *Solanum lycopersicum* (L.)

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Abstract

This study was aimed at unraveling the morphological effect of salinity on germination, growth and yield of *S. lycopersicum,* through inducement of salinity (0, 4, 6, 8, and 10 g NaCl). All the parameters considered: germination percentage, leaves number, stem girth, plant height and fruit quality, were significantly affected by NaCl treatments (salinity) compared with the control (no salinity). 100% germination was recorded only in control and 4 g NaCl concentration, though the percentage of germination was faster in control than within the 4 g NaCl. 'Tomato UC-83-B' plants' growth till maturity, shed leaves, chlorosis and leaf burns around edges occurred due to osmotic imbalance and water deficit caused by salinity, which invariably had effect on leaf area, although the reduction in leaf area varied among tested NaCl concentrations. Fruits yield and quality of 'Tomato UC-83-B' treated with NaCl was poor and relative to the degree of saline inducements, with 10 g NaCl treatment producing the least fruits. Chlorophyll contents were also significantly reduced by increasing saline concentrations. Ca and K were the predominant elements found in the digested fruit samples observed under Atomic Absorption Spectrometry (AAS) at different NaCl concentrations, while Mg, Na and P were significantly less. Salinity is a major abiotic factor that hampered the overall performance of tomato crop in salient ways and must therefore be curbed in order to meet its increasing global demand.

Keywords: chlorophyll, germination, growth, NaCl (Sodium Chloride Salt) salinity, tomato

Introduction

All the factors that inhibit plant growth are defined as stresses. Drought, saltiness, excess irrigation, high or low temperature, pH and heavy metals are common sources of stress, and these might create social and economic problems, especially in developing countries. A survey report revealed that only 10% of the land that can be used for agriculture worldwide is not under the effect of environmental stress elements, whereas for the remaining 90%, the most common stress element is drought, with 26%, followed by salt stress with 20% (Ashraf, 2009).

Plant salt stress is a condition where excessive salts in soil solution cause inhibition of plant growth or even plant death (Zhu *et al*., 2005). On a world scale, no other toxic substance restricts plant growth more than salt. Salt stress presents an increasing threat to plant agriculture (Zhu *et al*., 2005).

Among the various sources of soil salinity, irrigation from brackish water and sea, combined with poor drainage and fertilizer application, are the most serious influences, as they represent losses in terms of performance of vegetable crops (Katja, *et al*., 2009).

Worldwide, more than 45 million hectares of irrigated land have been reported damaged by salt, and 1.5 million hectares are taken out of production each year as a result of high salinity levels in the soil. Together, these effects reduced plant growth, development and survival, with global food production having to meet the demands of a growing world population. Improving salt tolerance of crops is an important global priority, and has become the focus for ongoing breeding efforts (Zhu *et al*., 2005).

This research was carried out to investigate the effect of salinity on the overall performance of *Solanum lycopersicum* (L.), using growth parameters, chlorophyll concentration and nutritional analysis of the fruits.

Materials and Methods

The study was carried out in a greenhouse at the Botanical Garden within University of Ilorin. The Botanical Garden lies between latitude 8°30′N and longitude 4°33′E/ latitude 8.500° N and 4.550° E.

The tomato variety used for this study was 'Tomato UC-82-B' gotten from Nigeria Stored Product Research Institute in Ilorin, Kwara state (NSPRI); the industrial

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salt (NaCl) used for the experiment was procured from the laboratory of the Department of Plant Biology, University of Ilorin.. Viable seeds were sown in plastic pots containing loamy soil with punctured holes to avoid water logging. Twenty five (25) plastic pots of five replicates were prepared and labelled.

The pots were irrigated with different concentrations of saline water (NaCl). Five different concentrations of salinity were prepared: 0, 4, 6, 8 and 10 g NaCl were diluted in 10 litres of tap water, respectively applied to 10 kg of garden soil; the control pots contained no salinity.

The pots containing soil were irrigated every two days with NaCl salt dissolved in 10 litre of water in a bucket for each concentration and allowed to stay for a week, so as the solution to penetrate well into the soil particles before the seeds were sown.

The experiment was arranged in a completely randomized design; ten viable seeds of tomato were sown separately in each of the pots and were thinned down to three per pot after total germination percentage was recorded.

Average seed germination in the five replicates was determined and the percentage of germination was calculated as follows:

Percentage of seed germination = number of seeds that germinated / total number of seed planted ×100

Average number of seeds that germinated/ total number of seeds planted in each pot ×100

The following parameters were taken and recorded:

Plant height: Three tagged plants of each treatment were used in determining the plant height using a measuring rule. The height (cm) was determined every two weeks by measuring the length of shoot from the soil surface to the apex of the plant.

Leaf number: The leaves of each plant were counted visually and recorded. Leaves from the tagged plant from each treatment were counted every two weeks.

Leaf length and breadth (Leaf area): Three leaves were selected for measurements every two weeks. The length and breadth of the selected leaves were taken with the aid of a 30 cm plastic metre rule. The leaf area (LA) of each plant was determined using the formula: LA = L × B × Franco's constant (0.75) and the average were recorded.

Stem girth: The stem girth was determined using a thread rolled over the middle of the plant stem once and then stretched over a 30 cm meter rule.

Fruit number: The numbers of fruits were counted visually and recorded.

Fruit fresh weight: The fresh weight of the fruits was determined using a weighing balance (g).

Fruit dry weight: The fruits of 'Tomato-UC-82-B' were dried at room temperature (20-26 °C) for 4-5 weeks and the weights were determined using a weighing balance (g).

Fruit diameter: The fruit diameter was measured using a veneer caliper.

Fruit circumference: The fruit circumference was determined by placing the centre of the fruit in a venire caliper to the nearest centimetre and readings were recorded.

Estimation of chlorophyll content by acetone incubation method

Leaf tissue of tomato (50 mg) was placed in a sample bottle containing 5 mL of 80% buffered acetone (80 mL of acetone made up to 100 mL with 20 mL of 2.5 mM sodium phosphate buffer, pH 7.8) and the sample bottles were placed under refrigeration for three days. The extract liquid was filtered through glass wool to remove leaf pieces and transferred to another graduated tube (Makeen *et al*., 2007).

Determination of chlorophyll concentration

Arnon's equation (below) was used to convert absorbance measurements to mg Chl g-1 leaf tissue:

Chl *a* (mg g-1) = $[(12.7 \times A_{663}) - (2.6 \times A_{645})] \times$ ml acetone / mg leaf tissue

Chl *b* (mg g-1) = $[(22.9 \times A_{645}) - (4.68 \times A_{663})] \times$ ml acetone / mg leaf tissue

Total Chl = Chl *a* + Chl *b*.

Digestion of fruit samples: Aqua Regia method

Each sample was measured up as 1 g of *S. lycopersicum* fruit, into a clean digestion flask. Nine mills (9 ml) of concentrated HNO_3 and 3 ml of concentrated HCl were added to the samples into the digestion flasks. The obtained samples were then heated in a hot plate until all brownish fumes were expelled out (Nitrogenous compound), which confirmed that the samples were digested. The samples were then allowed to cool at room temperature and few millilitres of distilled water were added and the mixture was filtered into 25 ml standard flasks, from where the content was transferred into plastic reagent bottle for AAS (Atomic Absorption Spectrometry) determination.

Determination of nutrient content of the tomato fruit

The nutrient contents after digestion was determined by placing each sample in an Atomic Absorbance Spectrophotometer (AAS).

The data recorded were analyzed statistically using SPSS (Statistical Package for Social Sciences) with significant difference separated by DMRT (Duncan Multiple Range Test) and origin.

Results

The results of the experiment are presented in figures and tables below. The results of the hereby study revealed that salinity had inhibitory effect on germination duration and significantly reduced germination percentage with increased NaCl concentration, although with no significant effect at low NaCl concentration (4 g NaCl treatment). The maximum impact of salinity on germination was recorded at 10 g NaCl treatment with 34% germination compared to the control (100% germination) (Fig. 1).

Significant reduction in leaf number became apparent as NaCl concentration increased (Table 1). Leaf area for control (no salinity) and 4 g NaCl concentration at early stage was not significant affected, but as the plant attained maturity (10WAP-16WAP), there were

Table 1. Effect of NaCl treatments on the number of leaves in *S. lycopersicum* ('Tomato UC-82-B')

NaCl treatments	2WAP	4WAP	6WAP	8WAP	10WAP	12WAP	14WAP	16WAP
Control	2.20±0.45^{a}	7.800±1.09^{a}	12.40±0.55^{a}	17.800±0.84^{a}	23.60±1.34^{a}	31.60±2.61^{a}	33.60±1.14^{a}	36.00±1.00^{a}
4 g	2.00±0.00^{a}	5.80±0.45^{b}	8.60±0.55^{b}	14.40±0.55^{b}	19.80±0.84^{b}	29.60±0.89^{b}	31.40±0.89^{b}	32.40±1.14^{b}
6 g	2.00±0.00^{a}	3.80±0.45^{c}	4.40±0.89^{c}	6.40±0.89^{c}	9.40±1.52^{c}	13.60±1.14^{c}	21.40±0.89^{c}	24.00±0.71^{c}
8 g	2.00±0.00^{a}	3.00±0.00^{d}	3.40±0.55^{d}	5.40±0.55^{d}	6.80±0.84^{d}	11.40±1.14^{d}	16.00±0.71^{d}	19.20±0.84^{d}
10 g	0.80±1.09^{b}	2.00±0.00^{e}	2.80±0.45^{d}	3.60±0.55^{e}	4.60±0.55^{e}	8.20±0.83^{e}	12.80±1.30^{e}	16.00±0.71^{e}

Means followed by the same letter (s) within the same column are not significantly different at P<0.05; WAP=Weeks after planting

Table 2. Effect of NaCl treatments on the leaf area of *S. lycopersicum* ('Tomato UC-82-B') (cm^{2})

NaCl treatments	2WAP	4WAP	6WAP	8WAP	10WAP	12WAP	14WAP	16WAP
Control	8.42±0.02^{a}	10.33±0.50^{a}	11.43±0.04^{a}	11.68±0.18^{a}	13.13±0.42^{a}	13.55±0.40^{a}	15.64±0.09^{a}	16.66±0.22^{a}
4 g	8.12±0.02^{a}	9.71±0.36^{b}	10.35±0.01^{a}	11.15±0.05^{b}	11.96±0.25^{b}	12.74±0.10^{b}	14.45±0.02^{b}	15.94±0.52^{b}
6 g	6.09±0.04^{b}	7.83±0.09^{c}	8.15±0.10^{a}	8.23±0.05^{c}	10.10±0.03^{c}	10.69±0.05^{c}	12.74±0.23^{c}	14.35±0.39^{c}
8 g	5.36±0.15^{b}	6.72±0.30^{d}	14.76±1.63^{a}	7.95±0.09^{d}	9.47±0.29^{d}	9.87±0.21^{d}	11.200±0.07^{d}	12.82±0.43^{d}
10 g	1.89±2.59^{c}	4.59±0.02^{e}	6.07±0.06^{a}	6.700±0.02^{e}	9.36±0.01^{d}	9.67±0.15^{d}	10.09±0.09^{e}	12.10±0.13^{e}

Means followed by the same letter (s) within the same column are not significantly different at P<0.05; WAP=Weeks after planting

Table 3. Effect of NaCl treatments on the stem girth of *S. lycopersicum* ('Tomato UC-82-B') (cm)

NaCl treatment	2WAP	4WAP	6WAP	8WAP	10WAP	12WAP	14WAP	16WAP
Control	0.56±0.55^{a}	0.66±0.55^{a}	0.80±0.00^{a}	1.14±0.09^{a}	1.36±0.05^{a}	1.52±0.04^{a}	1.64±0.05^{a}	1.64±0.05^{a}
4 g	0.48±0.04^{ab}	0.54±0.05^{b}	0.60±0.00^{b}	0.84±0.05^{b}	1.12±0.04^{b}	1.40±0.00^{ab}	1.58±0.08^{a}	1.58±0.05^{a}
6 g	0.40±0.00^{bc}	0.42±0.04^{c}	0.58±0.04^{b}	0.74±0.05^{c}	0.88±0.04^{c}	1.20±0.00^{b}	1.24±0.05^{b}	1.38±0.04^{c}
8 g	0.32±0.04^{c}	0.34±0.05^{d}	0.48±0.04^{c}	0.64±0.05^{d}	0.78±0.04^{d}	0.76±0.39^{c}	0.84±0.05^{c}	1.16±0.05^{d}
10 g	0.10±0.14^{d}	0.24±0.05^{e}	0.38±0.04^{d}	0.54±0.05^{e}	0.70±0.00^{e}	0.82±0.04^{c}	0.74±0.05^{d}	1.08±0.04^{e}

Means followed by the same letter (s) within the same column are not significantly different at P<0.05; WAP=Weeks after planting

Table 4. Effect of NaCl treatments on the stem height of *S. lycopersicum* ('Tomato UC-82-B') (cm^{2})

NaCl treatments	2WAP	4WAP	6WAP	8WAP	10WAP	12WAP	14WAP	16WAP
Control	3.28±0.22^{a}	4.54±0.05^{a}	6.92±0.27^{a}	10.48±0.18^{a}	16.16±0.62^{a}	26.84±1.54^{a}	16.92±0.53^{a}	18.40±0.48^{a}
4 g	2.96±0.05^{a}	3.56±0.38^{b}	3.86±0.09^{b}	6.92±0.14^{b}	10.08±0.69^{b}	13.88±0.26^{b}	13.14±0.75^{b}	15.60±0.68^{b}
6 g	2.74±0.38^{a}	3.48±0.29^{b}	3.18±0.19^{c}	3.52±0.08^{c}	8.56±0.89^{c}	11.00±0.69^{c}	10.10±0.31^{c}	12.34±0.45^{c}
8 g	2.74±0.15^{a}	3.02±0.04^{c}	3.02±0.04^{c}	3.02±0.04^{d}	7.80±0.21^{c}	9.60±0.34^{d}	9.54±0.37^{cd}	11.50±0.64^{d}
10 g	1.02±1.39^{b}	2.44±0.05^{d}	2.04±0.05^{d}	2.44±0.05^{e}	7.74±0.26^{c}	9.18±0.19^{d}	9.10±0.10^{d}	10.66±0.05^{e}

Means followed by the same letter (s) within the same column are not significantly different at P<0.05; WAP=Weeks after planting

Table 5. Effect of NaCl treatments on the fruit parameters of *S. lycopersicum* ('Tomato UC-82-B')

NaCl treatments	Fruit number	Fruit length (cm)	Fruit diameter (cm)	Fruit circumference (cm)	Fruit fresh weight (g)	Fruit dry weight (g)
Control	8.80±0.84^{a}	3.22±0.23^{a}	2.08±0.08^{a}	8.14±0.17^{a}	15.11±0.58^{a}	2.35±0.03^{a}
4 g	5.40±0.89^{b}	3.06±0.05^{a}	1.90±0.07^{b}	7.88±0.27^{a}	13.37±0.56^{b}	1.42±0.02^{b}
6 g	3.60±0.55^{c}	2.78±0.11^{b}	1.68±0.08^{c}	7.26±0.34^{b}	10.92±0.35^{c}	1.02±0.01^{c}
8 g	2.20±0.45^{d}	2.60±0.17^{bc}	1.52±0.08^{d}	6.88±0.13^{c}	8.91±0.41^{d}	0.88±0.02^{d}
10 g	1.40±0.55^{d}	2.48±0.08^{c}	1.36±0.05^{e}	7.04±0.13^{bc}	7.14±0.23^{e}	0.34±0.02^{e}

Means followed by the same letter (s) within the same column are not significantly different at P<0.05

differences in leaf area in all the NaCl treatments and severe reduction was recorded at 8 g and 10 g NaCl treatments (Table 2).

The stem girth at 4 g NaCl from control was the same, although a slight difference existed in 6, 8 and 10 g at 16WAP (Table 3). During the early stage of development (2WAP), the stem height of *S. lycopersicum* var. 'Tomato-UC-82-B' was not affected by NaCl concentrations, but as the plants developed and NaCl concentration increased, the stem height was significantly reduced in comparison with the control (Table 4).

The fruits number declined significantly as NaCl concentrations increased, with 10 g NaCl concentration giving the lowest yield (Table 5). Fruit length (Table 5) for control was not different from 4 g salt concentration, but was significantly reduced at 6, 8 and 10 g concentrations.

The fruits' diameter (Table 5) for control was significantly different from all NaCl treatments, whereas fruits circumference for control was not different from 4 g salt concentration, but was significantly different from 6, 8 and 10 g NaCl concentrations.

The fruits fresh weight and dry weight was significantly reduced as NaCl concentrations increased (Table 5). The results indicated that *S. lycopersicum* var.

'Tomato UC-82-B' was significantly affected by salinity.

Chlorophyll concentration was significantly reduced with increased NaCl concentrations at 6, 8 and 10 g NaCl treatments (Fig. 2).

Regarding nutrients' concentration (Fig. 3), Ca, K, Na and P were significantly different in all the treatments ($P<0.05$). The control experiment for Mg had no significant difference from 6 g NaCl treatment, but was significantly different from 4, 8, and 10 g NaCl treatments at ($P<0.05$).

Discussion

The following shall be discussed from the results obtained:

Germination

Results obtained from study of salinity effect on 'Tomato UC-83-B' revealed that seed germination rates for the control experiment was high (100% germination) compared to seeds under NaCl treatments; 'Tomato UC-83-B' seeds at 4 g salt concentration exhibited delayed germination, which is in agreement with Lauchli and Grattan (2007) who reported the same trend in their research work on plant growth and development under salt stress, stating that during germination, most plants are tolerant although salinity stress delays the germination process. The difference in germination between the control (no salinity) and NaCl treatments is attributed to osmotic or ionic effect of salinity as reported by Foolad (1996) with similar observation.

Germination of 'Tomato UC-83-B' at 6, 8 and 10 g NaCl treatments was adversely affected in numbers and duration. Therefore, 'Tomato UC-83-B' seeds can be said to be salt tolerant at low saline concentration (4 g NaCl) during germination, but are affected by increased salinity (6, 8 and 10 g NaCl concentrations).

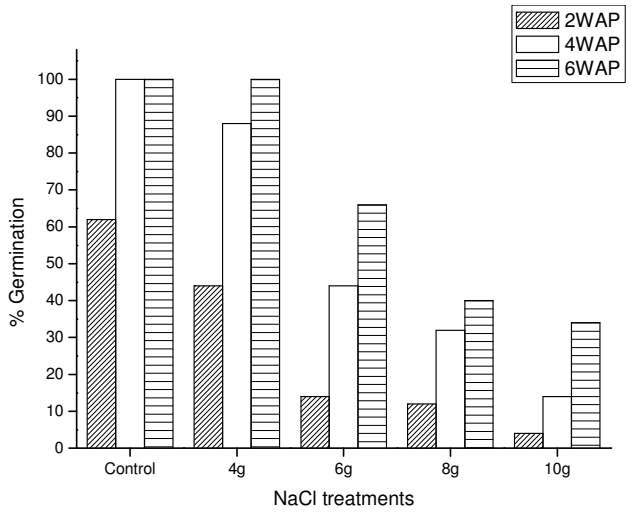

Fig. 1. Effect of NaCl treatment on germination percentage (%) of *S. lycopersicum* ('Tomato UC-82-B')

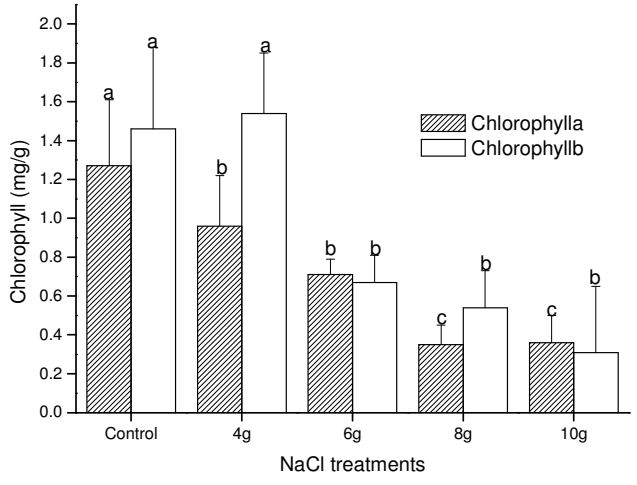

Fig. 2. Effect of NaCl treatments on chlorophyll concentrations of *S. lycopersicum* ('Tomato UC-82-B')

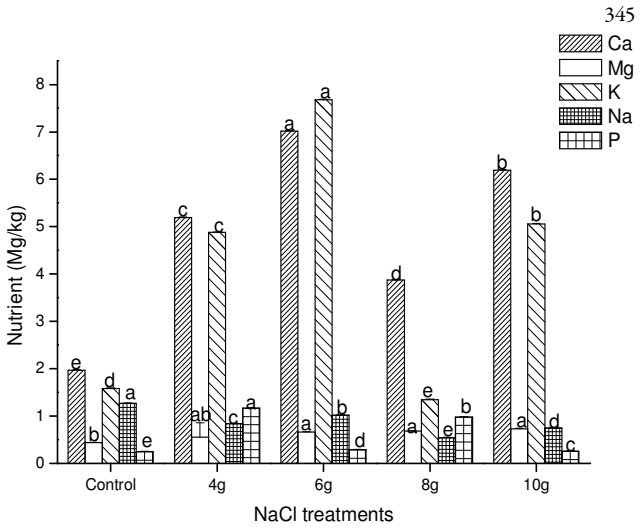

Fig. 3. Effect of NaCl treatments on the nutrients' contents of *S. lycopersicum* fruits ('Tomato UC-82-B')

Plant growth

The leaves number of 'Tomato UC-83-B' was not significantly affected at early stage of development by salinity, but as the plants matured and attained reproductive stage, the leaves number for each of the tested samples was observed to be less than the control which had significantly higher number of leaves; these adverse effect in leaf number reduction in turns affected the leaf area (Table 1), inhibiting photosynthetic activities, the plant ability to sustain growth and limited fruit yield as report by Ali *et al*. (2013). Salt stress symptoms were observed on the leaves such as chlorosis, shedding of mature leaves and burning leaves, as also reported by Ali *et al*. (2013).

Stem girth was not affected at early stage of the plant development, but was slightly reduced at later stages of development and as NaCl concentration increased; at 12WAP -16WAP the stem girth for 'Tomato UC-83-B' at 4 g NaCl treatment was the same with control. It was only reduced at 6 g, 8 g and 10 g, NaCl concentrations. Stem height of 'Tomato UC-83-B' was reduced by increasing NaCl concentrations at early stage of development as well as at maturity (Table 4).

The obtained results revealed that over all morphological traits (leaf number, leaf area, stem girth and stem height) were hampered by NaCl treatments (salinity) with more severe effects observed at 8 g and 10 g NaCl treatments.

Fruit yield

The fruits yield of 'Tomato UC-83-B' was affected by the presence of saline stress, whereas the control experiment yielded a higher quantity of fruits. Fruits' number declined with increasing NaCl concentration at 8 g and 10 g NaCl treatments, which produced the poorest fruit yield and quality. This finding is in conformity with data reported by Flowers *et al.* (1977) saying that the period of salt-stress imposition varied from one developmental stage to the next and the adverse effect of salinity is most notable on fruits. Salinity hampered the overall performance of the crop in terms of yield and quality at increased NaCl concentration (6, 8 and 10 g).

Chlorophyll

The results obtained revealed that salinity had effect on the chlorophyll content of 'Tomato UC-83-B' compared with the control (no salinity).

Nutritional analysis

The amount of calcium (Ca^{2+}), potassium (K^{+}), magnesium (Mg^{2+}) and phosphorus (P) ions was found to be high in fruits under NaCl treatments and lesser in fruits under control. Although sodium ion (Na^{+}) was found to be high in control in comparison with fruits under NaCl concentrations (Fig. 3), this is in conformity with Grattan and Grieve (1999b), who reported that depending upon plants selected, developmental stage and salinity composition, different results can be obtained.

The nutritional results obtained had no uniform order, as the various nutrients ions varied in concentration from among fruits under the different NaCl treatments; this may be due to biochemical interactions between salinity and nutrient uptake, as observed by Grieve and Grattan (1999a) who reported that nutrient imbalances can result in salt-stressed plants in various ways.

Conclusions

Salinity caused chlorophyll and nutrition imbalances, significant yield losses, with apparent toxicity symptoms on tomato, although many peasant farmers are not aware of these effects, and which can appear especially for those who have fields located close to water bodies. Salinity problem must therefore be given rapt attention in other to overcome its obstructive impact, by improving salt tolerance cultivars. Valuable data and analysis from the current study might therefore represent a way forward that can enhance the understanding of the mechanisms by which salinity affects photosynthesis and other physiological processes, in other to improve conditions for growing tomato with high yield and quality, and would provide a useful tool for future genetic engineering.

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