Research Article

Effects of ascorbic acid against salt stress on the morphological and physiological parameters of *Solanum melongena* (L.)

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Abstract

The recent research was done to find out the role of ascorbic acid on morphological and physiological parameters of *Solanum melongena* during salt stress. The experiment was carried out in pots in which the effect of salt and ascorbic acid was measured on a range of morphological and physiological parameters. In this study, ascorbic acid was applied in two ways viz. as a foliar spray on leaves or through roots in the soil at two levels 100 ppm and 200 ppm to the plants grown under control, 60mM and 100mM NaCl. After sixty days of treatments it was determined that fresh and dry biomass was decreased considerably under salinity stress. Overall, it was observed that salt stress significantly down effect the morphological and physiological parameters. Decrease in the vegetative and reproductive parameters was improved with the application of ascorbic acid. The best result was obtained with the 200 ppm ascorbic acid which significantly improved the morphological and physiological parameters of plants in both control and salt stress treatments suggesting that ascorbic acid mitigate the negative effects of salt stress.

Keywords: Ascorbic acid; Foliar spray; Morphological; Physiological; Salt stress

Introduction

Salinity refers to the presence of different kinds of salts in soil which inhibits the normal growth of plants. Salinity becomes a concern when more than normal amount of soluble salts occurs in the soil [1]. Worldwide, more than sixty million hectares of irrigated lands have been affected by salinity [2]. About 50% of the irrigated area of the world is affected by salinity and their problems are more severe in arid areas [3]. Salt stress is one of the

major constraints responsible for less agricultural yield in Pakistan and all over the world. A loss of about twenty million rupees per year decrease has been reported in agriculture sector due to salinity.

Solanum melongena is the member of family *Solanaceae* and is an annual herb. The fruits are fleshy and have a meaty texture having less than 3cm diameter. The fruits are technically called as berry which having numerous smaller seeds and are edible having bitter in taste and are 35 to

156 cm in height with large coarsely lobed leaves that are eight to 18cm long and 4 to 12cm broad. Their flower is whitish to purple having five-lobed corolla and yellowish stamens [4].

Ascorbic acid is growth regulator known to provide protection against a number of abiotic stresses [5] because it can influence a range of processes in plants, including seed germination [6] stomatal closure [7] ion uptake and transport [8] membrane permeability [9] photosynthetic and growth rate [10]. It also accumulates in plants under saline conditions and are known to have a vital role in salt tolerance. For example, salt-tolerant tomato cultivars had higher levels of ascorbic acid than salt-sensitive cultivars [11]. Similarly, pre-treatment with ascorbic acid counteracted the inhibitory effects of salt stress on growth and photosynthesis of *Pisum sativum* [12]. Ascorbic acid showed improvement in growth, cell division and cell enlargement of various crops [13]. However ascorbic acid is also known to induce salt tolerance through signal transduction pathways, but the factors involved in the ascorbic acid signal-transduction pathways remain to be elucidated yet [14]. Thus ascorbic acid potentially involved in counteracting salt stress. The current study was designed to analyze the effect of ascorbic acid in mitigating the effect of salinity in *solanum melongena*.

Materials and methods

Soil preparation & salinity treatments

Seeds of *solanum melongena* were grown in pots containing 4 kilogram of soil in each. Sixty pots divided into 5 sets were used in the experiment. Each set consisted of three treatments of NaCl (1) control (without salt) (2) 60mM (3) 100mM. Each treatment was replicated 4 times forming a total of 12 pots for overall set.

Ascorbic acid treatment

In the first set of pots no Ascorbic acid was applied while in the 2nd and 3rd sets of pots 100 ppm and 200 ppm ascorbic acid was applied respectively by mixing it in soil.

However, in the 4th and 5th sets of pots again 100 and 200 ppm ascorbic acid was applied using foliar spray methods. Doses of the ascorbic acid were refreshed in each month for all sets. Electrical conductivity for each treatment in each set was calculated.

Seedling's analysis

Three seedlings were grown in each pot which was irrigated with tap water. After establishment of seedlings, all pots were irrigated with 1.5 L of tap water after every three days. Different morphological and physiological parameters were noted at the time of harvest. Electrolytic Leakage was determined as described by [15] with few modifications.

$$EL (\%) = L_1/L_2 * 100$$

Relative water content was measured using the method described by [16].

$$RWC = (FW-DW) / (TW-DW) * 100$$

Leaf water loss was determined as described by [17].

$$LWL (\%) = W_1 - W_2 / W_1$$

Root weight ratio, shoot weight ratio, leaf weight ratio, shoot root ratio, Leaf area ratio and Specific leaf ratio was determined as described by [18].

Results and discussion

Plant height

Plants of the set-I showed non-significant decrease in 100mM salt stress as compared to control. Similarly, set-II and -III, showed non-significant increase at 60mM salt stress as compared to control. Set-IV resulted non-significant decrease in saline media as compared to control however it was more prominent in 60mM salt stress. Set-V, 60mM salt stress resulted reduction as compared to control. Juxtaposition of set-II and set-III, set-II resulted slight increase in control while a prominent increase in 60mM salt stress as juxtaposition with set-III. Juxtaposition of set-I, set-II resulted increase and set-III resulted decrease in control and 60mM salt stress as juxtaposition with set-I. Juxtaposition between set-IV and set-V resulted that set-IV resulted slight increase in control while a prominent increase at 60mM salt stress as juxtaposition with set-V. When both sets

were juxtaposition with set-I, set-IV resulted increase and set-V results decrease in control and 60mM salt stress as

juxtaposition with set-I (Table 1; Figure 1) which agrees with the earlier work of [19].

Table 1. Anova for different growth parameters in *Solanum melongena* grown in different NaCl levels and ascorbic acid doses

Source	Plant height	Root length	Number of leaves	Leaf area	Fresh Biomass	Dry Biomass
Application	Ns	Ns	Ns	Ns	Ns	Ns
Ascorbic acid	Ns	Ns	Ns	Ns	Ns	Ns
Salinity	Ns	P<0.001	P<0.05	P<0.01	Ns	P<0.05
Application x Ascorbic acid	Ns	Ns	Ns	Ns	Ns	Ns
Application x salinity	Ns	P<0.01	Ns	Ns	Ns	Ns
Ascorbic acid x salinity	Ns	Ns	P<0.05	Ns	Ns	Ns
Application x Ascorbic acid x salinity	Ns	Ns	P<0.05	Ns	Ns	Ns

Figure 1. Effects of Ascorbic acid and different NaCl concentrations on plant height (cms) of *Solanum melongena*. Set-I: Without ascorbic acid, Set-II: 0.25 ppm ascorbic acid applied through roots in soil, Set-III: 0.50 ppm ascorbic acid applied through roots in soil, Set-IV: 0.25 ppm ascorbic acid applied as a foliar spray, Set-V: 0.50 ppm ascorbic acid applied as a foliar spray

Root length

Plants in set-I resulted significant (P<0.001) increase in saline media viz. 60mM salt stress as juxtaposition with control. In set-II salt stress resulted significant (P<0.001) increase as juxtaposition with control. Plants in set-III resulted significant (P<0.001) decrease in 60mM salt stress as juxtaposition with control. Set-IV and set-V resulted

significant (P<0.001) decrease in both salt stress as juxtaposition with control. Juxtaposition of set-II and set-III, set-II resulted decrease in control and 60mM salt stress as juxtaposition with set-III. Juxtaposition of set-II and set-III with set-I both sets resulted increase in 100mM salt stress as juxtaposition with set-I. Juxtaposition of set-IV and set-V resulted that Set-IV resulted increase in all

treatments as juxtaposition with set-V. Juxtaposition of set-IV and set-V with set-I, Set-IV resulted increase in control and set-V resulted significant decrease in saline

media as juxtaposition with set-I (Table 1; Figure 2) which agrees with the earlier work of [20].

Figure 2. Effects of Ascorbic acid and different NaCl concentrations on root length (cms) of *Solanum melongena*. Set-I: Without ascorbic acid, Set-II: 0.25 ppm ascorbic acid applied through roots in soil, Set-II: 0.50 ppm ascorbic acid applied through roots in soil, Set-IV; 0.25 ppm ascorbic acid applied as a foliar spray, Set-V: 0.50 ppm ascorbic acid applied as a foliar spray

Number of leaves

Plants of set-I resulted significant ($P < 0.05$) decrease in 60mM and 100mM salt stress as juxtaposition with control. Set-II grown under 60mM salt stress resulted significant ($P < 0.05$) increase as juxtaposition with control. Set – III resulted significant ($P < 0.05$) increase in 100mM salt stress treatment as juxtaposition with control. Set-IV resulted significant ($P < 0.05$) reduction in saline media as juxtaposition with control. Set-V, 60mM salt stress resulted increase while 100mM salt stress exhibited decrease as juxtaposition with control. This result was statistically significant ($P < 0.05$). Juxtaposition of set-II and set-III, set-II

resulted increase in control and 60mM salt stress as juxtaposition with set-III. Juxtaposition of set-II and set-III with set-I, Set-II resulted increase in 60mM salt stress and set-III resulted increase in both salinity levels 60mM and 100mM salt stress treatments as juxtaposition with set-I. Juxtaposition of set-IV and set-V results that Set-IV resulted increase in control and in high salinity treatment viz. 100 mM salt stresses as juxtaposition with set-V. Juxtaposition of set-IV and set-V with set-I, Set-IV resulted increase in control and 60mM salt stress and set-V resulted increase only at 60mM salt stress as Juxtaposition with set-I (Table 1; Figure 3).

Figure 3. Effects of Ascorbic acid and different NaCl concentrations on number of leaves (cms) of *Solanum melongena*. Set-I: Without ascorbic acid, Set-II: 0.25 ppm ascorbic acid applied through roots in soil, Set-III: 0.50 ppm ascorbic acid applied through roots in soil, Set-IV: 0.25 ppm ascorbic acid applied as a foliar spray, Set-V: 0.50 ppm ascorbic acid applied as a foliar spray

Leaf area

Plants grown in set-I and set-II resulted a prominent significant ($P < 0.01$) increase in 60mM salt stress and a prominent significant ($P < 0.01$) decrease in 100mM salt stress as juxtaposition with control. Set-III grown under 60mM salt stress resulted significant ($P < 0.05$) increase as juxtaposition with control. Set-IV resulted significant ($P < 0.05$) reduction in saline media as juxtaposition with control. Set-V, 60mM salt stress resulted non-significant increase as juxtaposition with control. Juxtaposition of set-II and set-III, set-II resulted increase only in control and 60mM salt stress as juxtaposition with set-III. Juxtaposition of set-II and set-III with set-I, Set-II resulted increase in all treatments and set-III in 100mM salt stress as juxtaposition with set-I. Juxtaposition between set-IV and set-V resulted that Set-IV resulted increase in control as juxtaposition with set-V. Juxtaposition of set-IV and set-V with set-I, Set-IV resulted increase in control and 100mM salt stress and set-V in 100mM salt stress as juxtaposition with set-I (Table 1;

Figure 4) which agrees with the earlier work of [21].

Fresh and dry biomass

Plants of set-I resulted significant ($P < 0.05$) decrease in saline media as juxtaposition with control. Set-II and III resulted significant ($P < 0.05$) increase in 60mM salt stress as juxtaposition with control. Set-IV and V resulted significant ($P < 0.05$) decrease in 60mM salt stress as juxtaposition with control. Juxtaposition of set-II and set-III, set-III resulted slight increase in all treatments as juxtaposition with set-II. Juxtaposition of set-II and set-III with set-I, Set-II resulted decrease in all treatments and set-III in control and 60mM salt stress as juxtaposition with set-I. Juxtaposition of set-IV and set-V resulted that Set-IV showed increase in control and 60mM salt stress as juxtaposition with set-V. Juxtaposition of set-IV and set-V with set-I, Set-IV resulted increase in control and set-V in control and 100mM salt stress as juxtaposition with set-I (Table 1; Figure 5 & 6).

Figure 4. Effects of Ascorbic acid and different NaCl concentrations on leaf area (cms) of *Solanum melongena*. Set-I: Without ascorbic acid, set-II: 0.25 ppm ascorbic acid applied through roots in soil, Set-II: 0.50 ppm ascorbic acid applied through roots in soil, Set-IV: 0.25 ppm ascorbic acid applied as a foliar spray, Set-V: 0.50 ppm ascorbic acid applied as a foliar spray

Figure 5. Effects of Ascorbic acid and different NaCl concentrations on plant fresh biomass (cms) of *Solanum melongena*. Set-I: Without ascorbic acid, Set-II: 0.25 ppm ascorbic acid applied through roots in soil, Set-II: 0.50 ppm ascorbic acid applied through roots in soil, Set-IV: 0.25 ppm ascorbic acid applied as a foliar spray, Set-V: 0.50 ppm ascorbic acid applied as a foliar spray

Figure 6. Effects of Ascorbic acid and different NaCl concentrations on plant dry biomass (gms) of *Solanum melongena*. Set-I: Without ascorbic acid, Set-II: 0.25 ppm ascorbic acid applied through roots in soil, Set-III: 0.50 ppm ascorbic acid applied through roots in soil, Set-IV: 0.25 ppm ascorbic acid applied as a foliar spray, Set-V: 0.50 ppm ascorbic acid applied as a foliar spray

Electrolyte leakage

In set-I 100mM salt stress resulted non-significant increase as juxtaposition with control. Set-II resulted non-significant increase in saline media as juxtaposition with control. Set-III viz. 60mM salt stress resulted non-significant increase as juxtaposition with control. Set-IV and set-V resulted significant ($P < 0.05$) decrease in saline media as juxtaposition with control. Juxtaposition of set-II and set-III, set-III resulted increase in control and 60mM salt stress as juxtaposition with set-II. Juxtaposition of set-II and set-III with set-I both sets resulted increase at 60mM salt stress as juxtaposition with set-I. Juxtaposition between set-IV and set-V resulted that Set-V resulted increase in all treatments as juxtaposition with set-IV. Juxtaposition of set-IV and set-V with set-I, Set-IV resulted decrease in control and 100mM salt stress and set-V resulted increase in 100mM salt stress as juxtaposition with set-II (Table 2).

Leaf water loss

Plants grown in set-I results a prominent increase in saline media as juxtaposition with control. Set-II resulted significant ($P < 0.05$) increase at 100mM salt stress as juxtaposition with control. Set-III resulted significant ($P < 0.05$) decrease in 60mM salt stress as juxtaposition with control. Set-IV resulted increase in saline media as juxtaposition with control. Set-V resulted significant ($P < 0.05$) decrease in saline media as juxtaposition with control. Juxtaposition of set-II and set-III, set-II resulted increase in all treatments as juxtaposition with set-III. Juxtaposition of set-II and set-III with set-I, Set-II resulted increase in all treatments and set-III resulted increase in control and 60mM salt stress as juxtaposition with set-I. Juxtaposition between set-IV and set-V resulted that Set-IV resulted increase in saline media as juxtaposition with set-V. Juxtaposition of set-IV and set-V with set-I, Set-IV resulted increase in control and 100mM salt stress and set-V resulted decrease in saline media as juxtaposition with set-I (Table 2).

Relative water content

Plants of set-I exhibited non-significant increase in 100mM salt stress as juxtaposition with control. Set-II resulted non-significant increase at 60mM salt stress as juxtaposition with control. Set-III resulted non-significant decrease at 100mM salt stress as juxtaposition with control. Set-IV resulted non-significant increase in 60mM salt stress as juxtaposition with control. Set-V resulted non-significant increase in 60mM salt stress as juxtaposition with control. Juxtaposition of set-II and set-III, set-II resulted prominent

increase in saline media as juxtaposition with set-III. Juxtaposition of set-II and set-III with set-I, Set- II resulted prominent increased at 60mM salt stress and set-III resulted increase in control and 60mM salt stress as juxtaposition with set-I. Juxtaposition between set-IV and set-V resulted that Set-IV resulted increase in 60mM salt stress as juxtaposition with set-V. Juxtaposition of set-IV and set-V with set-I, Set-IV resulted increase in control and 60mM salt stress and set-V resulted increase in 60mM salt stress as juxtaposition with set-I (Table 2).

Table 2. Anova for effects of ascorbic acid and different NaCl concentrations on relative water content, Electrolyte leakage and leaf water loss of *Solanum melongena*

Set-I= Without Ascorbic acid

Treatment	Relative water content	Electrolyte leakage	Leaf water loss
Control, Mean, SE	52.226a $\pm$ 23.726	27.062a $\pm$ 14.918	29.414a $\pm$ 1.711
60mM NaCl, Mean, SE	51.376a $\pm$ 13.502	46.076a $\pm$ 1.458	23.156a $\pm$ 2.923
% (+/-)	(-1.627)	(+70.262)	(-21.274)
100mM NaCl, Mean, SE	79.483a $\pm$ 18.348	35.707a $\pm$ 6.83	33.237a $\pm$ 16.618
% (+/-)	(+52.189)	(+31.945)	(+12.997)
LSD _{0.05}	65.716	32.91	3.884

Table 2..... (Contd)

Set- II= 0.25ppm Ascorbic acid applied through roots in soil

Treatment	Relative Water Content	Electrolyte leakage	Leaf Water Loss
Control, Mean, SE	41.006a $\pm$ 4.620	59.183a $\pm$ 17.711	29.212a $\pm$ 1.888
60mM NaCl, Mean, SE	52.333a $\pm$ 6.633	47.243a $\pm$ 1.102	1377.439b $\pm$ 140.612
% (+/-)	(+27.621)	(-20.174)	(+4615.18)
100mM NaCl, Mean, SE	56.29a $\pm$ 9.336	101.873a $\pm$ 46.849	27.042b $\pm$ 3.124
% (+/-)	(+37.27)	(+72.131)	(-7.429)
LSD _{0.05}	24.674	100.09	281.554

Table 2..... (Contd)

Set-III 0.50 ppm Ascorbic acid applied through roots in soil

Treatment	Relative water content	Electrolyte leakage	Leaf water loss
Control, Mean, SE	51.14a $\pm$ 11.14	41.775a $\pm$ 1.065	43.839a $\pm$ 6.756
60mM NaCl, Mean, SE	68.16a $\pm$ 13.517	22.53a $\pm$ 1.506	33.191ab $\pm$ 0.275
% (+/-)	(+33.281)	(+46.069)	(-24.287)
100mM NaCl, Mean, SE	53.55a $\pm$ 17.372	44.323b $\pm$ 5.958	1.628b $\pm$ 1.631
% (+/-)	(+4.712)	(-6.098)	(-38.178)
LSD _{0.05}	49.29	12.462	13.897

Table 2..... (Contd)

Set-IV 0.25 ppm Ascorbic acid applied as a foliar spray

Treatment	Relative Water Content	Electrolyte leakage	Leaf Water Loss
Control, Mean, SE	42.583a ±10.993	39.412a ±11.031	30.945a ±1.937
60mM NaCl, Mean, SE	61.086a ±16.775	44.653a ±5.184	36.162a ±7.481
% (+/-)	(+43.452)	(+13.296)	(+16.857)
100mM NaCl, Mean, SE	74.726a ±12.229	45.026a ±0.973	27.979a ±1.631
% (+/-)	(+75.483)	(+14.244)	(-9.583)
LSD _{0.05}	46.933	24.429	15.780

Table 2..... (Contd)

Set-V 0.50 ppm Ascorbic acid applied as a foliar spray

Treatment	Relative water content	Electrolyte leakage	Leaf water loss
Control, Mean, SE	65.146a ±4.264	41.107a ±4.807	26.522a ±0.927
60mM NaCl, Mean, SE	78.723a ±17.773	26.863b ±2.957	313.118b ±14.985
% (+/-)	(+20.84)	(-34.651)	(+1080.593)
100mM NaCl, Mean, SE	78.576a ±17.091	29.126b ±1.803	99.251b ±70.537
% (+/-)	(+20.615)	(-29.145)	(+274.219)
LSD _{0.05}	49.996	11.839	144.083

Means followed by different letters in the same column differ significantly at 95% probability level according to New Duncan's Multiple Range Test. Figures in parentheses indicate % promotion (+) and reduction (-) over control

Shoot root ratio

Plants of set-I results decrease in 60mM salt stress as juxtaposition with control. Set-II and set-III resulted decrease in saline media as juxtaposition with control. Set-IV resulted increase in 60mM salt stress as juxtaposition with control. Set-V exhibited increase in 100mM salt stress as juxtaposition with control. Juxtaposition of set-II and set-III, set-II resulted reduction in control as well as in saline media as juxtaposition with set-III. Juxtaposition of

set-II and set-III with set-I, both sets resulted increase in control and 100mM salt stress juxtaposition with set-I. Juxtaposition between set-IV and set-V resulted that Set-IV showed increase in control and a prominent increased in 60mM salt stress as juxtaposition with set-V. Juxtaposition of set-IV and set-V with set-I, Set-IV resulted increased in control and a prominent increase in 60mM salt stress and set-V resulted reduction in 60mM salt stress juxtaposition with set-I (Table 3).

Table 3. Effect of Ascorbic acid and different NaCl concentrations on shoot/root ratio of *Solanum melongena*.

Set-I= Without Ascorbic acid

Treatment	Shoot Dry Wt (gms)	Root Dry Wt (gms)	Shoot/Root Ratio
Control, Mean, SE	2.64a ±.359	3.021a ±0.42	7.254a ±0.962
60mM NaCl, Mean, SE	1.314a ±0.574	2.142a ±0.518	15.71a ±10.271
% (+/-)	(-50.227)	(-29.096)	(-116.57)
100mM NaCl, Mean, SE	0.134b ±0.11	0.319b ±0.173	8.172a ±2.927
% (+/-)	(-94.924)	(-89.44)	(-12.655)
LSD _{0.05}	1.371	1.38	21.425

Table 3..... (Contd)

Set-II= 0.25ppm Ascorbic acid applied through roots in soil

Treatment	Shoot Dry Wt (gms)	Root Dry Wt (gms)	Shoot/Root Ratio
Control, Mean, SE	1.074a ±0.435	1.276a ±0.327	50.579a ±47.272
60mM NaCl, Mean, SE	0.910a ±0.230	1.137a ±0.231	4.020 ±0.996
% (+/-)	(-15.27)	(-10.893)	(-92.052)
100mM NaCl, Mean, SE	0.285a ±0.245	0.298a ±0.245	22.820 ±19.67
% (+/-)	(-73.463)	(-76.645)	(-54.882)
LSD _{0.05}	1.099	0.964	102.314

Table 3..... (Contd)

Set-III= 0.50ppm Ascorbic acid applied through roots in soil

Treatment	Shoot Dry Wt (gms)	Root Dry Wt (gms)	Shoot/Root Ratio
Control, Mean, SE	1.241a ±0.532	1.376a ±0.472	61.103 ±57.407
60mM NaCl, Mean, SE	1.142a ±0.071	1.398a ±0.062	6.265 ±2.979
% (+/-)	(-7.977)	(-1.598)	(-89.746)
100mM NaCl, Mean, SE	1.891a ±0.523	2.05a ±0.597	29.826 ±19.404
% (+/-)	(-52.377)	(-48.982)	(-51.187)
LSD _{0.05}	1.499	1.527	121.214

Table 3..... (Contd)

Set-IV= 0.25ppm Ascorbic acid applied as a foliar spray

Treatment	Shoot Dry Wt (gms)	Root Dry Wt (gms)	Shoot/Root Ratio
Control, Mean, SE	2.435a ±0.527	3.278a ±0.759	15.549a ±6.696
60mM NaCl, Mean, SE	0.717b ±0.213	0.915b ±0.262	309.149a ±193.971
% (+/-)	(-70.554)	(-72.086)	(+1888.224)
100mM NaCl, Mean, SE	0.12b ±0.07	0.158b ±0.106	0.661a ±0.381
% (+/-)	(-95.071)	(-95.179)	(-95.748)
LSD _{0.05}	1.186	1.619	387.766

Table 3..... (Contd)

Set-V= 0.50ppm Ascorbic acid applied as a foliar spray

Treatment	Shoot Dry Wt (gms)	Root Dry Wt (gms)	Shoot/Root Ratio
Control, Mean, SE	1.722a ±0.608	2.029a ±0.747	8.19a ±4.125
60mM NaCl, Mean, SE	0.342b ±0.042	0.395b ±0.029	7.427b ±2.09
% (+/-)	(-80.139)	(-80.532)	(-9.316)
100mM NaCl, Mean, SE	0.265b ±0.006	0.276b ±0.007	23b ±0.059
% (+/-)	(-84.61)	(-86.397)	(+180.83)
LSD _{0.05}	1.219	1.493	9.241

Means followed by different letters in the same column differ significantly at 95% probability level according to New Duncan's Multiple Range Test. Figures in parentheses indicate % promotion (+) and reduction (-) over control

Root weight ratio

Plants of set-I exhibited a slight increase in 100mM salt stress as juxtaposition with control. Set-II resulted reduction in salt

stress concentrations as juxtaposition with control. Set-III resulted increase at 60mM salt stress as juxtaposition with control. Set-IV resulted increase at 100mM salt

stress as juxtaposition with control. Set-V resulted decrease in saline media as juxtaposition with control. Juxtaposition of set-II and set-III, set-II resulted increase as juxtaposition with set-III. Juxtaposition of set-II and set-III with set-I, set-II resulted increase in both saline media and control and set-III exhibited reduction at 100mM salt stress as juxtaposition with set-I.

Juxtaposition between set-IV and set-V resulted that Set-IV resulted prominent increased in 100mM salt stress as juxtaposition with set-V. Juxtaposition of set-IV and set-V with set-I, Set-IV resulted a prominent increase at 100mM salt stress and set-V reduction in saline media as juxtaposition with set-I (Table 4).

Table 4. Effect of Ascorbic acid and different NaCl concentrations on root weight ratio of *Solanum melongena*.

Set-I= Without Ascorbic acid

Treatment	Total Root Dry Wt (gms)	Total Plant Dry Wt (gms)	Root Weight Ratio
Control, Mean, SE	0.381a ±0.075	3.021a ±0.42	0.124a ±0.014
60mM NaCl, Mean, SE	0.196ab ±0.055	2.142a ±0.518	0.112a ±0.043
% (+/-)	(-48.556)	(-29.096)	(-9.677)
100mM NaCl, Mean, SE	0.075b ±0.72	0.319b ±0.173	0.155a ±0.072
% (+/-)	(-80.314)	(-89.44)	(+25)
LSD _{0.05}	0.225	1.38	0.171

Table 4..... (Contd)

Set-II= 0.25ppm Ascorbic acid applied through roots in soil

Treatment	Total Root Dry Wt (gms)	Total Plant Dry Wt (gms)	Root Weight Ratio
Control, Mean, SE	0.201a ±0.109	1.276a ±0.327	0.248a ±0.178
60mM NaCl, Mean, SE	0.226a ±0.006	1.137a ±0.231	0.214a ±0.04
% (+/-)	(+12.437)	(-10.893)	(-13.709)
100mM NaCl, Mean, SE	0.0127a ±0.0002	0.298a ±0.245	0.213a ±0.132
% (+/-)	(-93.681)	(-76.645)	(-14.112)
LSD _{0.05}	0.219	0.964	0.451

Table 4..... (Contd)

Set-III= 0.50ppm Ascorbic acid applied through roots in soil

Treatment	Total Root Dry Wt (gms)	Total Plant Dry Wt (gms)	Root Weight Ratio
Control, Mean, SE	0.135a ±0.064	1.376a ±0.472	0.145a ±0.07
60mM NaCl, Mean, SE	0.255a ±0.077	1.398a ±0.062	0.181a ±0.053
% (+/-)	(+88.888)	(+1.598)	(+24.827)
100mM NaCl, Mean, SE	0.158a ±0.073	2.05a ±0.597	0.063a ±0.024
% (+/-)	(+17.037)	(+48.982)	(-56.551)
LSD _{0.05}	0.248	1.527	0.183

Table 4..... (Contd)

Set-IV= 0.25ppm Ascorbic acid applied as a foliar spray

Treatment	Total Root Dry Wt (gms)	Total Plant Dry Wt (gms)	Root Weight Ratio
Control, Mean, SE	0.197a ±0.049	3.278a ±0.759	0.074a ±0.034
60mM NaCl, Mean, SE	0.037a ±0.036	0.915b ±0.262	0.031a ±0.029
% (+/-)	(-81.218)	(-72.086)	(-58.108)
100mM NaCl, Mean, SE	0.307a ±0.163	0.158b ±0.106	5.263a ±4.115
% (+/-)	(+55.837)	(-95.179)	(+70.162)
LSD _{0.05}	0.350	1.619	0.451

Table 4..... (Contd)

Set-V= 0.50ppm Ascorbic acid applied as a foliar spray

Treatment	Total Root Dry Wt (gms)	Total Plant Dry Wt (gms)	Root Weight Ratio
Control, Mean, SE	0.307a ±0.012	2.029a ±0.029	0.151a ±0.046
60mM NaCl, Mean, SE	0.053a ±0	0.395b ±0.007	0.141a ±0
% (+/-)	(-82.736)	(-80.532)	(-6.622)
100mM NaCl, Mean, SE	0.011a	0.276b	0.041a
% (+/-)	(-96.416)	(-86.397)	(-72.847)
LSD _{0.05}	0.328	1.493	0.328

Means followed by different letters in the same column differ significantly at 95% probability level according to New Duncan's Multiple Range Test. Figures in parentheses indicate % promotion (+) and reduction (-) over control

Stem weight ratio

Plants of set-I and set-II results increase in saline media as juxtaposition with control. Set-III and set-V resulted decreased in saline media as juxtaposition with control. Set-IV resulted decrease in 60mM salt stress as juxtaposition with control. Juxtaposition of set-II and set-III, set-II results a slight increase in saline media as juxtaposition with set-III. Juxtaposition of set-II and set-III with set-I, Set-II resulted

increase in 60mM salt stress and set-III in control as juxtaposition with set-I. Juxtaposition between set-IV and set-V resulted that Set-IV showed a slight reduction in 60mM salt stress as juxtaposition with set-V. Juxtaposition of set-IV and set-V with set-I, both of these sets resulted increase in 60mM salt stress and control as juxtaposition with set-I (Table 5).

Table 5. Effect of Ascorbic acid and different NaCl concentrations on Stem weight ratio of *Solanum melongena*.**Set-I= Without Ascorbic acid**

Treatment	Total stem dry Wt (gms)	Total plant dry Wt (gms)	Stem Weight Ratio
Control, Mean, SE	1.073a ±0.131	3.021a ±0.42	0.358a ±0.024
60mM NaCl, Mean, SE	1.044a ±0.258	2.142a ±0.518	0.486a ±0.008
% (+/-)	(-2.702)	(-29.096)	(-35.754)
100mM NaCl, Mean, SE	0.232b ±0.11	0.319b ±0.173	0.781c ±0.051
% (+/-)	(-78.378)	(-89.44)	(-118.156)
LSD _{0.05}	0.2	1.38	0.115

Table 5..... (Contd)

Set-II= 0.25ppm Ascorbic acid applied through roots in soil

Treatment	Total stem dryWt (gms)	Total plant dry Wt (gms)	Stem Weight Ratio
Control, Mean, SE	0.259a ±0.156	1.276a ±0.327	0.178a ±0.11
60mM NaCl, Mean, SE	0.656a ±0.227	1.137a ±0.231	0.55ab ±0.078
% (+/-)	(-153.281)	(-10.893)	(-208.988)
100mM NaCl, Mean, SE	0.279a ±0.242	0.298a ±0.245	0.732b ±0.159
% (+/-)	(-7.722)	(-76.645)	(-311.235)
LSD _{0.05}	0.734	0.964	0.418

Table 5..... (Contd)

Set-III= 0.50ppm Ascorbic acid applied through roots in soil

Treatment	Total stem dryWt (gms)	Total plant dry Wt (gms)	Stem Weight Ratio
Control, Mean, SE	0.516a ±0.148	1.376a ±0.472	0.409a ±0.118
60mM NaCl, Mean, SE	0.537a ±0.052	1.398a ±0.062	0.386a ±0.044
% (+/-)	(+4.069)	(+1.598)	(-5.623)
100mM NaCl, Mean, SE	0.841a ±0.314	2.05a ±0.597	0.374a ±0.0626
% (+/-)	(+62.984)	(+48.982)	(-8.557)
LSD _{0.05}	0.702	1.527	0.282

Table 5..... (Contd)

Set-IV= 0.25ppm Ascorbic acid applied as a foliar spray

Treatment	Total stem dryWt (gms)	Total plant dry Wt (gms)	Stem Weight Ratio
Control, Mean, SE	1.6 ±0.452	3.278a ±0.759	0.484a ±0.047
60mM NaCl, Mean, SE	0.465b ±0.155	0.915b ±0.262	0.546ab ±0.122
% (+/-)	(-70.9375)	(-72.086)	(+12.809)
100mM NaCl, Mean, SE	0.049b ±0.038	0.158b ±0.106	0.258b ±0.04
% (+/-)	(-96.9375)	(-95.179)	(-46.694)
LSD _{0.05}	0.958	1.619	0.274

Table 5..... (Contd)

Set-V= 0.50 ppm Ascorbic acid applied as a foliar spray

Treatment	Total stem dry Wt (gms)	Total plant dry Wt (gms)	Stem Weight Ratio
Control, Mean, SE	1.391a ±0.67	2.029a ±0.747	0.601a ±0.147
60mM NaCl, Mean, SE	0.197a ±0.021	0.395b ±0.029	0.514a ±0.101
% (+/-)	(-85.837)	(-80.532)	(-14.475)
100mM NaCl, Mean, SE	0.131a ±0.003	0.276b ±0.007	0.476a ±0
% (+/-)	(-90.582)	(-86.397)	(-20.798)
LSD _{0.05}	1.341	1.493	0.357

Means followed by different letters in the same column differ significantly at 95% probability level according to New Duncan's Multiple Range Test. Figures in parentheses indicate % promotion (+) and reduction (-) over control

Leaf weight ratio

Plants of set-I and set-II results decrease in saline media as juxtaposition with control. Set-III and set-IV exhibited increase in 100mM salt stress as juxtaposition with control. Set-V resulted increase in saline media as juxtaposition with control. Juxtaposition of set-II and set-III, set-II resulted increase in control as juxtaposition with set-III. Comparison of set-II and set-

III with set-I, Set-II resulted increase in control and set-III exhibited increase in saline media as juxtaposition with set-I. Juxtaposition between set-IV and set-V resulted that Set-V showed increase in 60mM salt stress as juxtaposition with set-IV. Juxtaposition of set-IV and set-V with set-I, both of these sets resulted increase in 100mM salt stress and control juxtaposition with set-I (Table 6).

Table 6. Effects of Ascorbic acid and different NaCl concentrations on leaf weight ratio of *Solanum melongena*.

Set-I= Without Ascorbic acid

Treatment	Total leaves dry Wt (gms)	Total plant dry Wt (gms)	Leaf Weight Ratio
Control, Mean, SE	1.566a $\pm$ 0.268	3.021a $\pm$ 0.42	0.517a $\pm$ 0.035
60mM NaCl, Mean, SE	0.901a $\pm$ 0.316	2.142a $\pm$ 0.518	0.4a $\pm$ 0.042
% (+/-)	-42.464	-29.096	-22.630
100mM NaCl, Mean, SE	0.012b $\pm$ 0	0.319b $\pm$ 0.173	0.062b $\pm$ 0.021
% (+/-)	-99.233	-89.440	-88.007
LSD _{0.05}	0.829	1.38	0.119

Table 6..... (Contd)

Set-II= 0.25ppm Ascorbic acid applied through roots in soil

Treatment	Total leaves dry Wt (gms)	Total plant dry Wt (gms)	Leaf Weight Ratio
Control, Mean, SE	0.8147a $\pm$ 0.38	1.276a $\pm$ 0.327	1.277a $\pm$ 0.150
60mM NaCl, Mean, SE	0.253ab $\pm$ 0.054	1.137a $\pm$ 0.231	0.235b $\pm$ 0.060
% (+/-)	-68.945	-10.893	-81.597
100mM NaCl, Mean, SE	0.006b $\pm$ 0.003	0.298a $\pm$ 0.245	0.053b $\pm$ 0.027
% (+/-)	-99.263	-76.645	-95.849
LSD _{0.05}	0.769	0.964	0.329

Table 6..... (Contd)

Set-III= 0.50ppm Ascorbic acid applied through roots in soil

Treatment	Total leaves dry Wt (gms)	Total plant dry Wt (gms)	Leaf Weight Ratio
Control, Mean, SE	0.725a $\pm$ 0.42	1.376a $\pm$ 0.472	0.445a $\pm$ 0.148
60mM NaCl, Mean, SE	0.604a $\pm$ 0.034	1.398a $\pm$ 0.062	0.432a $\pm$ 0.011
% (+/-)	(-16.689)	(+1.598)	(-2.921)
100mM NaCl, Mean, SE	1.05a $\pm$ 0.209	2.05a $\pm$ 0.597	0.562a $\pm$ 0.087
% (+/-)	(+44.827)	(-48.982)	(+26.292)
LSD _{0.05}	0.941	1.527	0.297

Table 6..... (Contd)

Set-IV= 0.25 ppm Ascorbic acid applied as a foliar spray

Treatment	Total leaves dry Wt (gms)	Total plant dry Wt (gms)	Leaf Weight Ratio
Control, Mean, SE	0.831a ±0.217	3.278a ±0.759	0.266a ±0.051
60mM NaCl, Mean, SE	0.252b ±0.149	0.915b ±0.262	0.229ab ±0.128
% (+/-)	(-69.675)	(-72.086)	(-13.909)
100mM NaCl, Mean, SE	0.071b ±0.032	0.158b ±0.106	0.625b ±0.131
% (+/-)	(-91.456)	(-95.179)	(+134.962)
LSD _{0.05}	0.533	1.619	0.381

Table 6..... (Contd)

Set-V= 0.50 ppm Ascorbic acid applied as a foliar spray

Treatment	Total leaves dry Wt (gms)	Total plant dry Wt (gms)	Leaf Weight Ratio
Control, Mean, SE	0.33a ±0.062	2.029a ±0.747	0.247a ±0.123
60mM NaCl, Mean, SE	0.144b ±0.064	0.395b ±0.029	0.343a ±0.147
% (+/-)	(-56.363)	(-80.532)	(+38.866)
100mM NaCl, Mean, SE	0.133b ±0.003	0.276b ±0.007	0.481±0
% (+/-)	-59.696	-86.397	-94.736
LSD _{0.05}	1.799	1.493	0.385

Means followed by different letters in the same column differ significantly at 95% probability level according to New Duncan's Multiple Range Test. Figures in parentheses indicate % promotion (+) and reduction (-) over control

Specific leaf area ratio

Plants of set-I and set-II results increase in 100mM salt stress as juxtaposition with control. Set-III resulted increase in control as juxtaposition with saline media. Set-IV resulted prominent reduction in control as juxtaposition with saline media. Set-V resulted increase in 60mM salt stress as juxtaposition with control. Juxtaposition of set-II and set-III, set-II resulted increase in saline media as juxtaposition with set-III.

Comparison of set-II and set-III with set-I, Set-II resulted increase in both salinity treatments and control while set-III exhibited decrease in 100mM salt stress as juxtaposition with set-I. Juxtaposition between set-IV and set-V resulted that Set-IV resulted increase in 100mM salt stress as juxtaposition with set-V. Juxtaposition of set-IV and set-V with set-I, both sets resulted increase in control and 60mM salt stress juxtaposition with set-I (Table 7).

Table 7. Effect of Ascorbic acid and different NaCl concentrations on leaf area ratio of *Solanum melongena*.

Set-I= Without Ascorbic acid

Treatment	Leaf Area (mm ²)	Total plant dry Wt (gms)	Leaf Area Ratio
Control, Mean, SE	76.84a ±40.535	1.566a ±0.268	46.216a ±22.694
60mM NaCl, Mean, SE	76.442a ±14.062	0.901a ±0.316	134.204b ±29.299
% (+/-)	(-0.517)	(-42.464)	(-190.384)
100mM NaCl, Mean, SE	23.881a ±11.134	0.012b ±0	276.561b ±819.04
% (+/-)	(-68.921)	(-99.233)	(-589.481)
LSD _{0.05}	88.56	0.829	163.03

Table 7.....(contd)

Set-II= 0.25 ppm Ascorbic acid applied through roots in soil

Treatment	Leaf Area (mm ²)	Total plant dry Wt (gms)	Leaf Area Ratio
Control, Mean, SE	85.669a ±12.234	0.8147a ±0.38	173.546a ±91.862
60mM NaCl, Mean, SE	149.675ab ±37.748	0.253ab ±0.054	700.95b ±261.396
% (+/-)	(+74.713)	(-68.945)	(+303.898)
100mM NaCl, Mean, SE	38.44b ±17.229	0.006b ±0.003	6586.717b ±572.763
% (+/-)	(-55.129)	(-99.263)	(+369.372)
LSD _{0.05}	86.43	0.769	127.18

Table 7.....(contd)

Set-III= 0.50 ppm Ascorbic acid applied through roots in soil

Treatment	Leaf Area (mm ²)	Total plant dry Wt (gms)	Leaf Area Ratio
Control, Mean, SE	68.981a ±22.263	0.725a ±0.42	187.787a ±112.687
60mM NaCl, Mean, SE	82.238a ±10.212	0.604a ±0.034	137.260a ±20.543
% (+/-)	(+19.218)	(-16.689)	(-26.906)
100mM NaCl, Mean, SE	60.344a ±30.22	1.05a ±0.21	47.98a ±23.965
% (+/-)	(-12.52)	(+44.827)	(-74.45)
LSD _{0.05}	77.717	0.941	233.805

Table 7.....(contd)

Set-IV= 0.25 ppm Ascorbic acid applied as a foliar spray

Treatment	Leaf Area (mm ²)	Total plant dry Wt (gms)	Leaf Area Ratio
Control, Mean, SE	122.999a ±37.023	0.831a ±0.217	144.693a ±9.406
60mM NaCl, Mean, SE	57.197a ±28.65	0.252b ±0.149	1487.466a ±139.11
% (+/-)	(-53.497)	(-69.675)	(+928.015)
100mM NaCl, Mean, SE	48.298a ±5.193	0.071b ±0.032	1016.960a ±371.27
% (+/-)	(-60.733)	(-91.456)	(+602.839)
LSD _{0.05}	94.098	0.533	2878.557

Table 7.....(contd)

Set-V= 0.50 ppm Ascorbic acid applied as a foliar spray

Treatment	Leaf Area (mm ²)	Total plant dry Wt (gms)	Leaf Area Ratio
Control, Mean, SE	76.441a ±15.902	0.33a ±0.062	228.998a ±13.44
60mM NaCl, Mean, SE	79.088a ±2.349	0.144b ±0.064	1792.209a ±1402.785
% (+/-)	(+3.462)	(-56.363)	(+682.63)
100mM NaCl, Mean, SE	50.717a ±5.772	0.133b ±0.003	378.318a ±34.351
% (+/-)	(-33.652)	(-59.696)	(-65.205)
LSD _{0.05}	34.124	1.799	280.474

Means followed by different letters in the same column differ significantly at 95% probability level according to New Duncan's Multiple Range Test. Figures in parentheses indicate % promotion (+) and reduction (-) over control

Leaf area ratio

Plants of set-I and set-V resulted prominent increase in 100mM salt stress as juxtaposition with control. Set-II resulted

decrease in control as juxtaposition with salt stress. Set-III resulted prominent increase in control as juxtaposition with salt stress. Set-IV resulted prominent increase

in 60mM salt stress as juxtaposition with control. Juxtaposition of set-II and set-III, set-II resulted increase in control as well as in saline media as juxtaposition with set-III. Juxtaposition of set-II and set-III with set-I, Set-II resulted reduction in 60mM salt stress, while set-III resulted increase in control as juxtaposition with set-I. Juxtaposition between set-IV and set-V

resulted that Set-IV resulted increase in control and in 60mM salt stress as juxtaposition with set-V. Juxtaposition of set-IV and set-V with set-I, Set-IV resulted increase in control and in 60mM salt stress and set-V showed increase both in control and salinity treated plants as juxtaposition with set-I (Table 8).

Table 8. Effect of Ascorbic acid and different NaCl concentrations on specific leaf area of *Solanum melongena*.

Set-I= Without Ascorbic acid

Treatment	Leaf Area (mm ²)	Total leaf dry Wt (gms)	Specific Leaf Area
Control, Mean, SE	76.84a ±40.535	3.021a ±0.42	231.947a ±116.921
60mM NaCl, Mean, SE	76.442a ±14.062	2.142a ±0.518	728.255a ±351.33
% (+/-)	-0.518	-29.096	213.975
100mM NaCl, Mean, SE	23.881a ±11.134	0.319b ±0.173	1416.216a ±565.7
% (+/-)	-68.921	-89.441	510.577
LSD _{0.05}	88.56	1.38	135.79

Table 8.....(contd)

Set-II= 0.25 ppm Ascorbic acid applied through roots in soil

Treatment	Leaf Area (mm ²)	Total leaf dry Wt (gms)	Specific Leaf Area
Control, Mean, SE	85.669a ±12.234	1.276a ±0.327	3064.291a ±279.801
60mM NaCl, Mean, SE	149.675ab ±37.748	1.137a ±0.231	652.927b ±152.998
% (+/-)	74.713	-10.893	-78.692
100mM NaCl, Mean, SE	38.44b ±17.229	0.298a ±0.245	3047.449b ±139.215
% (+/-)	-55.130	-76.646	-0.550
LSD _{0.05}	86.43	0.964	127.18

Table 8.....(contd)

Set-III=0.50 ppm Ascorbic acid applied through roots in soil

Treatment	Leaf Area (mm ²)	Total leaf dry Wt (gms)	Specific Leaf Area
Control, Mean, SE	68.981a ±22.263	1.376a ±0.472	3031.187a ±277.658
60mM NaCl, Mean, SE	82.238a ±10.212	1.398a ±0.062	389.377a ±112.151
% (+/-)	(+19.218)	(+1.598)	(-87.154)
100mM NaCl, Mean, SE	60.344a ±30.219	2.05a ±0.597	265.765a ±124.87
% (+/-)	(-12.520)	(+48.982)	(-91.232)
LSD _{0.05}	77.717	1.527	233.805

Table 8.....(contd)

Set-IV=0.25 ppm Ascorbic acid applied as a foliar spray

Treatment	Leaf Area (mm ²)	Total leaf dry Wt (gms)	Specific Leaf Area
Control, Mean, SE	122.999a ±37.023	3.278a ±0.759	889.056a ±534.48
60mM NaCl, Mean, SE	57.197a ±28.644	0.915b ±0.262	45081.317a ±229.78
% (+/-)	(-53.497)	(-72.086)	(+4970.694)
100mM NaCl, Mean, SE	48.298a ±5.193	0.158b ±0.106	277.699a ±140.81
% (+/-)	(-60.733)	(-95.179)	(-68.764)
LSD _{0.05}	94.098	1.619	287.56

Table 8.....(contd)

Set-V=0.50 ppm Ascorbic acid applied as a foliar spray

Treatment	Leaf Area (mm ²)	Total leaf dry Wt (gms)	Specific Leaf Area
Control, Mean, SE	76.441a ±15.902	2.029a ±0.747	485.92a ±235.38
60mM NaCl, Mean, SE	79.088a ±2.349	0.395b ±0.029	1656.158a ±358.634
% (+/-)	(+3.462)	(-80.532)	(+240.829)
100mM NaCl, Mean, SE	50.717a ±5.772	0.276b ±0.007	4378.633a ±408.992
% (+/-)	(-33.652)	(-86.397)	-801.101
LSD _{0.05}	34.124	1.493	280.48

Means followed by different letters in the same column differ significantly at 95% probability level according to New Duncan's Multiple Range Test. Figures in parentheses indicate % promotion (+) and reduction (-) over control

Conclusion

Salinity has negative effects on plant growth and development which were significantly improved by exogenous and foliar spray applications of ascorbic acid. Ascorbic acid overcomes the destructive effects of salinity and its applications by either way viz. foliar spray and applied through roots in soil mostly led to increase the plant morphological, physiological and biochemical parameters and plants yield. However, the application of ascorbic acid applied in soil was more effective than application through as a foliar spray. This study justifies further work on *Solanum melongena* plant under a broader range of field conditions to evaluate the possibility of using ascorbic acid for improving their growth.

Authors' contributions

Conceived, designed and performed the experiments: M Irfan, Analysed the data: Nabeela, Contributed materials, analysis, tools: M Ilyas, Wrote the manuscript: KU Rahman.

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