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Full Length Article

Alleviation of Salt Stress in Cucumber (*Cucumis sativus*) through Seed Priming with Triacontanol

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Abstract

The present study elucidated the role of triacontanol in regulating seed germination and seedling vigour of four cucumber cultivars under salt stress (50 mM NaCl). Seeds were soaked in aerated solution of triacontanol @ 25 μM, 50 μM for 12 h prior to sowing and untreated seeds were used as control. Priming enhanced the emergence rate, uniformity and early growth of cucumber seedlings under normal and saline conditions. Though, plants exposed to salt stress and seeds not treated with triacontanol showed poor performance in growth, physiology and biochemical attributes. However, priming with 25 and 50 μM triacontanol was very effective in decreasing time to start emergence, improved final emergence, shoot/root lengths, seedling dry weight, gas exchange attributes, chlorophyll and proline contents under saline conditions. Nonetheless, maximum relief from salt stress in all attributes was observed at 50 μM triacontanol. In conclusion, triacontanol can be successfully employed to improve the germination capacity and stand establishment of cucumber under saline conditions by reducing the deleterious effects of salinity. © 2017 Friends Science Publishers

Keywords: Priming; Germination; Salt stress; Cucumber; Gas exchange attributes

Abbreviations: Triacontanol = Tria, Photosynthesis rate = pn, Stomatal conductance = gs, Transpiration = E, Water use Efficiency = WUE, Mean emergence time = MET, Final emergence percentage = FEP, Emergence index = EI

Introduction

Plants reveal many adaptive strategies against abiotic stresses which finally mislead the plant growth (McCue and Hanson, 1990). It is recognized that beside other stresses, salt stress drastically restricts the plant growth and production (Abbas *et al.*, 2010). In order to manage these stresses, plants adapt many variations in their physiology (Vinocur and Altman, 2005). It is reported that world 900 million hectare areas are affected by saline stress (Munns and Tester, 2008). Salinization disrupts the plant life cycle because of osmotic disturbance and specific ions toxicity (Vinocur and Altman, 2005) and osmotic stress produced water deficient environment that lead to physiological drought (Munns, 2005). Such hyper-osmotic disturbance and hyper ionic toxic lead to hang-up seed germination and growth of seedlings (Hasegawa *et al.*, 2000). Salt stress causes cell dehydration due to accumulation of Na^+ and Cl^- ions in soil (Gupta *et al.*, 1993) which decreases the availability of K^+ ions, such conditions restricted the seeds to absorb water for embryo expansion; consequently inactivation of enzymes, nutrient starvation, ionic toxicity and oxidative stress in tissues (Gao *et al.*, 2014). Moreover, excessive salt ions disintegrate radicle and plumule tissues and inhibited radicle growth, which delayed emergence of seedlings (Shahid *et al.*, 2011; El Harfi *et al.*, 2016).

Seed germination significantly contributes to the establishment of vigorous crop stand (Ashraf *et al.*, 2007). Seed priming is very effective strategy to improve seed germination and seedling establishment in several horticultural and agronomic crops under saline and non-saline environments (Ashraf and Foolad, 2005; Afzal *et al.*, 2015). Seed priming in aerated solutions trigger metabolic activities which are essential for germination and improves uniformity, germination rate, final germination and stand establishment (Bradford, 1976; Afzal *et al.*, 2016). Usually seed treatment is conducted in low water potential solution and incorporation of plant growth hormones for priming significantly improved the seed performance of several crops (Afzal *et al.*, 2011) rice (Basra *et al.*, 2006) and rice (Farooq *et al.*, 2007).

Triacontanol is a plant hormone (Singh *et al.*, 2012) that stimulates plant growth at very low concentration when exogenously applied to various plant species like groundnut (Verma *et al.*, 2011), pigeonpea (Pujari *et al.*, 1998), maize, rice and wheat (Perveen *et al.*, 2011; 2012 2013). It has described that triacontanol enhanced the photosynthetic activity (Eriksen *et al.*, 1981) mineral nutrients and water uptake (Ivanov and Angelov, 1997; Chen *et al.*, 2003) and improved the quantity of many organic solutes in leaf

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tissues (Chen *et al.*, 2003). Triacontanol enhanced growth, biomass, photosynthetic pigments, proline accumulation and uptake of K^+ and Ca^+ essential under salt stress (Krishnan and Kumari, 2008). Cavusoglu *et al.* (2008) also reported that seed treatments @ 0.0, 25 µM with triacontanol induced salt tolerance in radish.

Vegetables are rich source of phyto-chemicals and nutrients, which are essential for various metabolic activities in the human body (Noreen and Ashraf, 2009) and production is threatened by rising salinity, mainly in irrigated crop lands which produce 40% of the world's food (FAO, 2011). Cucumber (*Cucumis sativus* L.) is an important vegetable crop for human nutrition worldwide (Stepien and Klobus, 2006) and is native to Asia and Africa, where it has been used for 3,000 years. Fresh cucumber is a source of vitamin C, niacin, thiamine, phosphorus, calcium iron and dietary fiber. Salinity stress had a significant effect on growth rate of cucumber, at salinity level higher than 2.5 dS m^{-1}, which caused decline in yield 13% (Dorota, 1997). Therefore, cucumber has been classified as salt sensitive crop (Wang, 1998; Stepien and Klobus, 2006; Zhu *et al.*, 2008). Between several strategies to tackle the adverse effects of salts on agricultural crops, many shot-gun approaches are used these days. Keeping in view the role of triacontanol, the objectives of our study were to assess whether or not pre-sowing seed treatment with triacontanol could be effective in decreasing the adverse effects of salt stress on growth of cucumber; whether triacontanol could modulate many physiological and biochemical attributes in the seed.

Materials and Methods

Cucumber seeds were collected from Ayub Agricultural Research Institute, Faisalabad, Pakistan. Seeds were containing 9.29% moisture content on dry weight basis. Screened cucumber genotypes against salinity stress such as tolerant genotypes Green long, Marketmore and sensitive genotypes Summer green and 20252 were used to evaluate the role of triacontanol seed treatments in alleviation of salt stress.

Priming

Cucumber seeds were soaked in aerated distilled water, 25 and 50 µM solutions of 95% pure (sigma Aldrich) tria for 12 h, ratio of seed weight to volume of solution was 1:5 gm/L. Un-treated seeds were considered as a control. Hydroprimed and triacontanol treated seeds were rinsed with distilled water and air-dried before experiment (Basra *et al.*, 2002).

Emergence and Seedling Vigour Evaluation

Treated or un-treated 25 cucumber seeds were sown in plastic pots with size 30×30 (cm), containing moist sand and desired salinity level at 50 mM was developed before sowing by using NaCl following USDA laboratory manual (1954). Each treatment was replicated four times; Hoagland solution was used as a nutrient source. Duration of 24 h set by 15 h for day and 9 h for night and 26°C and 20°C temperatures selected day/night, respectively. Numbers of emerged seedling was counted daily. Final emergence and emergence index were determined according to method prescribed in the handbook of Association of Official Seed Analysts (1990). Mean emergence time was calculated according to the described equation of Ellis and Roberts (1981). On the 30th day, physiological attributes were measured after that seedling was carefully removed from the sand and shoot, root lengths were recorded from ten randomly selected seedlings from each replication. Seedling fresh weight was calculated instantly after harvest and dry weight of seedling was calculated after drying at 70ºC for one week.

Measurements

Stomatal conductance, Photosynthetic activity and transpiration rate: On 30th day of emergence four young leaves were selected and placed one by one in the chamber of Infrared Gas Analyzer (IRGA). Readings were taken during 11.00 to 12.00 a.m. with molar flow of 403.3 mmol m^{-2} S^{-1} air per unit leaf area, atmospheric pressure 99.90 kPa; water vapor pressure into chamber ranged from 6.0 to 8.90 mbar, PAR at leaf surface was maximum up to 1711 µmol m^{-2} S^{-1}, temperature of leaf ranged from 28.40 to 32.40°C, ambient temperature ranged from 22.40 to 27.90°C, ambient CO_2 concentration was 352 µmol mol^{-1} (Zekri, 1991; Moya *et al.*, 2003).

Water Use Efficiency (WUE)

WUE is the ratio between photosynthesis (Pn) and the amount of water transpired (E) and it was measured by the following equation:

$$Water\ use\ efficiency\ (WUE) = Photosynthetic\ rate\ (A) / Transpiration\ Rate\ (E)$$

Leaf Chlorophyll Contents (SPAD Value)

Portable chlorophyll meter (Model, SPAD-502: Konica Minolta Sensing: Inc, Japan) was used to record chlorophyll contents of cucumber leaves. Fully expanded third to fourth youngest leaves from apex was taken for this purpose (Khan *et al.*, 2003).

Estimation of Proline Contents (µmol g^{-1} f.wt)

Proline contents were measured by the method of Bates *et al.* (1973). Fresh leaves (0.5 g) were taken and absorbance was noted at 520 nm with double beam spectro-photometer (Hitachi—120; Japan) for blank reading toluene was used. Proline contents were determined from a standard curve and

Table 1: Effect of pre sowing seed treatments with triacontanol on emergence attributes of cucumber genotypes under saline conditions

Treatments	Non-saline				Saline (50 mM NaCl)			
	Mean Emergence Time (days)							
	Green long	Marketmore	Summer green	20252	Green long	Marketmore	Summer green	20252
Untreated	8.00±0.03bc	8.81±0.45abc	9.51±0.34abc	10.18±0.60ab	9.51±0.39def	8.64±0.31cde	11.24±0.68a	10.41±1.78ab
Hydropriming	7.85±0.04bcd	8.00±0.07bcd	9.09±0.47abc	9.64±0.30bcd	9.10±0.29efg	8.37±0.62bcd	10.35±0.99abc	9.74±0.51abc
25 µM Tria	6.79±0.23ghi	6.62±0.49ghi	7.73±0.22def	7.95±0.09efg	7.78±0.08ghi	7.02±0.68ghi	8.29±0.24bcd	8.52±0.87bcd
50 µM Tria	5.41±0.52i	6.21±0.23hi	6.72±0.61ghi	7.22±0.45fgh	6.77±0.30ghi	6.09±0.49hi	7.40±0.30ef	8.04±0.65def
	Emergence Index							
Untreated	10.86±0.23fgh	9.08±0.26ijk	7.23±0.41lm	7.86±0.18kl	5.70±0.11mn	8.73±0.23jkl	4.08±0.14n	3.95±0.16n
Hydropriming	12.14±0.52cd	9.86±0.47ijk	9.21±0.28ijk	8.61±0.32jkl	7.03±0.18lm	9.28±0.38ijk	4.39±0.14n	4.62±0.25n
25 µM Tria	23.94±0.20b	10.92±0.48cde	10.62±0.32def	9.59±0.44fgh	10.73±0.71cde	10.57±0.43def	8.69±0.10ijk	8.71±0.17ijk
50 µM Triac	26.48±0.42a	12.50±0.38c	10.42±0.19def	10.33±0.34efg	11.18±0.30cde	11.98±0.35cde	10.04±0.31fgh	9.45±0.25fgh
	Final emergence (%)							
Untreated	75.03±1.0fgh	68.76±1.63ghi	61.01±1.92kl	65.78±1.0ijk	63.78±1.91jk	68.12±1.63ghi	35.01±1.19n	50.65±3.83m
Hydropriming	75.88±1.91fgh	70.23±1.15ijk	68.10±1.31ijk	70.55±1.15ijk	66.03±2.58ghi	70.33±1.15ijk	36.43±0.98n	52.09±1.63lm
25 µM Tria	93.75±0.85ab	82.22±2.58cd	76.24±1.98cde	74.11±1.15def	68.44±1.63ghi	78.85±2.58cde	63.38±0.78jk	65.34±1.91ijk
50 µM Tria	94.24±2.0a	84.64±2.83bc	76.83±0.72cde	76.54±1.63cde	72.65±1.11efg	79.87±2.52cde	70.58±1.43efg	71.76±1.63efg

Table 2: Effect of pre sowing seed treatments with triacontanol on seedling growth of cucumber genotypes under saline conditions

Treatments	Non-saline				Saline (50 mM NaCl)			
	Shoot length (cm)							
	Green long	Marketmore	Summer green	20252	Green long	Marketmore	Summer green	20252
Untreated	7.28±0.63cde	6.90±0.77cde	5.85±0.46hij	5.03±0.40klm	5.02±0.57klm	5.23±0.73klm	3.75±0.56klm	3.28±0.41m
Hydropriming	7.92±0.45cde	7.38±0.19def	6.00±0.53hi	5.50±0.64ijk	5.33±0.80klm	5.28±0.57klm	3.25±0.19klm	3.50±0.57lm
25 µM Tria	8.75±0.60ab	8.05±0.50abc	7.28±0.43bcd	6.58±0.35def	5.43±0.38ijk	5.48±0.56ghi	5.00±0.54hij	4.48±0.38ijk
50 µM Tria	9.10±0.60a	8.58±0.35abc	7.55±0.48abc	7.15±0.47bcd	5.68±0.51ghi	6.08±0.36efg	5.40±0.77hij	4.48±0.57klm
	Root length (cm)							
Untreated	4.85±0.13jkl	4.43±0.21hij	4.03±0.36jkl	4.58±0.14efg	3.40±0.20jkl	3.35±0.06jkl	2.18±0.14l	2.28±0.22jkl
Hydropriming	5.05±0.53fgh	4.58±0.49ghi	4.03±0.82jkl	5.18±0.11def	3.58±0.27jkl	3.45±0.13jkl	1.88±0.15kl	2.60±0.15jkl
25 µM Tria	5.38±0.60abc	5.38±0.13abc	6.15±0.85abc	6.13±0.24abc	4.20±0.48efg	3.92±0.08cde	2.48±0.14jkl	3.30±0.23fgh
50 µM Tria	6.73±0.77abc	6.01±0.26abcd	6.45±0.82ab	6.88±0.56a	4.52±0.34efg	4.03±0.18bcd	2.93±0.17ghi	3.58±0.16fgh
	Dry weight of seedling (g)							
Untreated	0.32±0.02fgh	0.27±0.03jkl	0.21±0.02jkl	0.24±0.01efg	0.26±0.02jkl	0.22±0.03jkl	0.15±0.01L	0.17±0.01kL
Hydropriming	0.31±0.02efg	0.26±0.03ijk	0.19±0.01jkl	0.25±0.02jkl	0.25±0.02jkl	0.24±0.01jkl	0.16±0.01L	0.19±0.01kL
25 µM Tria	0.46±0.03a	0.36±0.01bcd	0.30±0.03fgh	0.33±0.01def	0.28±0.03def	0.27±0.02def	0.22±0.01hi	0.24±0.02fgh
50 µM Tria	0.60±0.02a	0.41±0.01b	0.34±0.02bcd	0.37±0.02bc	0.29±0.01bcd	0.28±0.01cde	0.25±0.02ef	0.29±0.01cde

Data represent the means ± SE of four repeats. Means having different letters are significantly different at P ≤ 0.05 according to HSD Tukey Test
Tria = Triacontanol

Table 3: Correlation matrix among different attributes of cucumber genotypes

Attributes	SL	RL	DWS	CC	PRO	SC	PR	TR	WUE
SL	1								
RL	0.690***	1							
DWS	0.687***	0.567***	1						
CC	0.777***	0.663***	0.738***	1					
PRO	-0.243**	-0.241***	0.052***	-0.084^{NS}	1				
SC	0.705***	0.641***	0.596***	0.818***	0.027^{NS}	1			
PR	0.809***	0.765***	0.690***	0.823***	-0.160^{NS}	0.762***	1		
TR	0.420***	0.309***	0.242***	0.562***	-0.330***	0.431***	0.505***	1	
WUE	0.666***	0.690***	0.632***	0.615***	0.044^{NS}	0.648***	0.839***	-0.026^{NS}	1

***, * show significant at $P \leq 0.001$ and 0.05 levels; while, NS = non-significant; SL: shoot length, RL: root length, , DWS: dry weight of seedlings, CC: chlorophyll contents, PRO: proline, SC: stomatal conductance, PR: photosynthetic rate, TR: transpiration rate, WUE: water use efficiency

considered on the basis of fresh weight.

Statistical Analysis

The experiment included eight treatments with four replicates, so the experiment contained 32 plastic pots and the design was a factorial randomized complete design. Analysis of variance (ANOVA) and multiple comparison tests (Tukey test) were computed using Statistix 8.1 computer packages. Differences among treatments were considered significant only when a value was lower than P≤0.05 after statistical analysis. Pearson correlation analysis was subjected to a correlation (CORR) between morphological and physiological attributes of cucumber

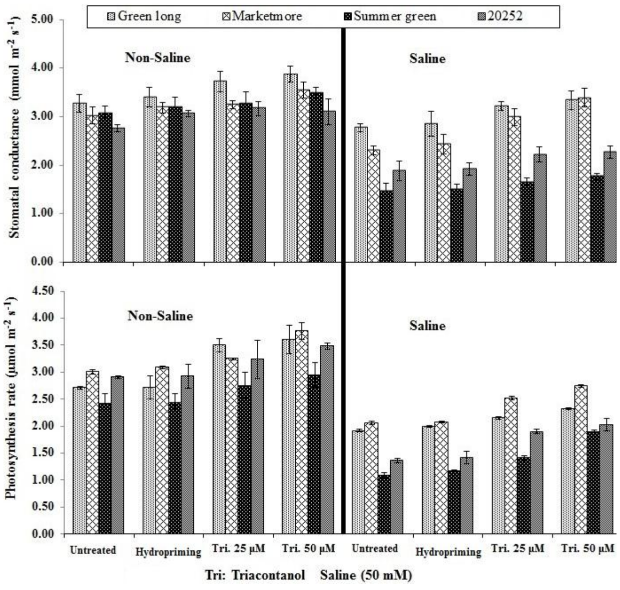

Fig. 1: Effect of pre sowing seed treatment with triacontanol on gaseous exchange attributes of cucumber genotypes

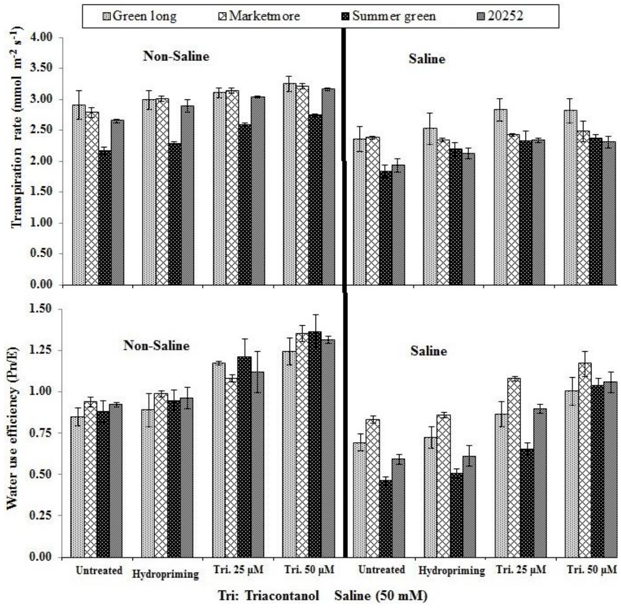

Fig. 2: Effect of pre sowing seed treatment with triacontanol on gaseous exchange attributes of cucumber genotypes

plants using software Statistix 8.1.

Results

It was evident from present study that the deleterious effect of salinity on emergence was surmounted through priming with triacontanol, gave the excellent performance in terms of improvement in emergence percentage, mean emergence time and emergence index (Table 1). Under both conditions, priming with 50 μM Tria maximally reduced mean emergence time of all cucumber genotypes. Similarly, Tria priming significantly improved emergence index followed by hydroprimed and untreated seeds under all experimental conditions (Table 1). However, maximum emergence index was revealed by priming with 50 and 25 μM Tria respectively, under salt stress Marketmore exhibited highest emergence index (11.98) statistically at par with Green long (11.18) exposed to 50 μM Tria. Salt-sensitive genotypes 20252 and Summer green were unable to encounter salinity and resulted in least emergence index (3.95 and 4.08). Overall, seed priming with Tria improved emergence percentage in all tested genotypes under saline and non-saline conditions (Table 1). Emergence percentage was significantly enhanced with 50 μM Tria under non-saline conditions and also maintained it when exposed to salt stress. Un-treated and hydro-primed seeds failed to emerge potentially and resulted in minimum final emergence under both conditions (Table 1).

Salinity stress had adversely affected shoot and root lengths by inhibiting their growth (Table 2). Under normal conditions, maximum shoot/root length was observed in Green long with 50 μM Trai treatment, while minimum value for shoot length was revealed by 20252 but lowest root length was observed for Summer green in un-treated seeds. Under saline stress seed treatment with 50 μM Tria showed maximum shoot/root length followed hydroprimed and un-treated seeds. Green long and Marketmore were superior among the tested genotypes that produced maximum seedling dry biomass under both growing conditions. However, seed priming with 50 μM Tria illustrated maximum improvement in seedling dry weight of Green long under normal and saline regimes which was statistically at par with Tria priming (25 μM). On other hand, hydroprimed seeds failed to maintain better seedling growth under normal and stress conditions.

A significant variation in gas exchange attributes (gs, Pn, E and WUE) occurred due to salinity and seed priming treatments in evaluated genotypes but varied significantly (Figs. 1, 2). All cucumber genotypes gave good response to priming techniques under saline environment. However, Marketmore and Green long showed better gas exchange properties due to seed priming with 50 μM Tria as compared to Summer green and 20252 followed by 25 μM Tria at 50 mM NaCl stress. On exposure to salinity, a marked reduction in chlorophyll content (expressed by SPAD values) was illustrated in all the cucumber genotypes but at variable rate. Seed priming with 50 μM Tria demonstrated maximum stability of chlorophyll and illustrated highest SPAD value in Green long under control and saline environment which was statistically at par with 25 μM Tria in same genotypes (Fig. 3). Another important

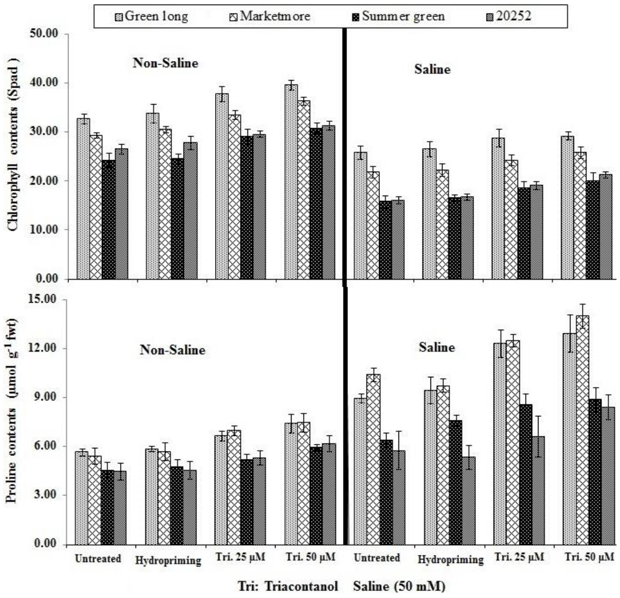

Fig. 3: Effect of pre sowing seed treatments with triacontanol on chlorophyll and proline contents of cucumber genotypes

finding of present study was a significant increase in proline content at varying degree in all genotypes. Marketmore had accumulated highest proline content in response to seed priming with 50 µM Tria under non-saline control and salt stress which is statistically at par with Green long (Fig. 3). Minimum proline contents were produced by 20252 subjected to hydropriming in control and at 50 mM NaCl.

Correlation Studies

The correlation between several variables indicated that shoot length exhibited significant positive correlation with root length, dry weight of seedling, chlorophyll content, gs, Pn, E and WUE, while it was negatively correlated with proline content (Table 3). Dry weight of seedling showed highly significant positive correlation with chlorophyll content and water use efficiency. Proline contents revealed a non-significant positive correlation with stomatal conductance and water use efficiency but it was negatively non-significantly correlated with photosynthesis rate and highly significant negative correlation with transpiration rate.

Discussion

Germination is the first stage of plant phenology, which is affected by root zone salinization due to excessive salts in growing medium (Farooq *et al*., 2015; Almutairi, 2016). Salinity causes an increase in root zone osmotic pressure, which ultimately results in cell dehydration and accumulation of higher amount of Na^+ and Cl^- ions in soil solution that disturbs the availability of the nutrient especially K^+ (Hasanuzzaman *et al*., 2013; Farooq *et al*., 2015). Progressive built up of Na^+ and Cl^- leads to nutrient starvation in seeds through ionic imbalance that restricts the embryo to absorb water and inhibits radicle growth and delays emergence (Gupta *et al*., 1993; Gao *et al*., 2014). It is obvious from current study that salt stress adversely affected emergence potential of cucumber genotypes but seed priming considerably mitigated the drastic effects of salinity (Table 1). Tria priming reduced the time taken to emergence and improved emergence index and final emergence of cucumber seeds, which are important indicators of crop uniformity, synchronization of emergence and seedling vigor (Bewley and Black, 1994; Lara *et al*., 2014). Significant results of Tria were proved in increasing the rate of germination of cotton (*Gossypium hirsutum*) (Zerong *et al*., 1981) and leguminous crops (Janardhan, 1992). Better stand establishment induced through seed priming might be due to the stimulation of an array of biochemical changes in seeds such as hydrolysis, activation of enzymes and dormancy breaking, which are prerequisite to initiate the germination process (Aziza *et al*., 2004).

Salt stress inhibits the plant growth by suppressing the development of plant organs, which results in reduced root and shoot lengths and biomass (Shoresh *et al*., 2011). Likewise, reduction in root-shoot length and plant biomass were also found in all cucumber genotypes in this study (Table 2). Among priming strategies, Tria priming had significantly improved the seedling growth attributes in cucumber genotypes. These results are supported by previous findings that pre-imbibed seed treatment with Tria triggered plant growth under saline conditions in radish (Cavusoglu *et al.,* 2008). Correlative analysis proposed that plant dry biomass was positively significantly correlated with all physiological attributes (Table 3) and indicated that better plant growth under stressed conditions lead to production of biomass and facilitating the plants to withstand under stressed conditions.

Our results showed that imposition of salt stress adversely affects gas exchange properties in all cucumber genotypes (Figs. 1, 2). Similar findings have also been reported by many researchers in different crops (Zheng *et al*., 2009; Perveen *et al*., 2010; Kanwal *et al*., 2011). Photosynthesis rate significantly reduced under salts, which could be a result of oxidative damage to important photosynthetic cells (Kanwal *et al.*, 2011; Shahbaz and Zia, 2011; Shahbaz *et al*., 2011). Reduced photosynthesis and transpiration activities are associated with lower stomatal conductance that ultimately restricts the availability of carbon dioxide to leaf tissue. The lower stomatal conductance might be due to antagonistic of Na^+ ion on K^+ which is required for stomatal activity (Ahmad and Jabeeen, 2005). Tria priming has significantly induced salt tolerance in cucumber genotypes through better gas exchange properties (Figs. 1, 2). This improvement in gas exchange attributes might be due to its well-established role in stomata regulation by up-regulating photosynthetic genes (Chen *et al*., 2002) and increased CO_2 exchange rate under optimal and saline conditions (Srivastava and Sharma, 1990; Perveen *et al*., 2010). Tria treatment causes fast elicitation of a specific second messenger like 9-b-L(-) adenosine, which could be induced extremely quick physiological responses (Ries *et al.*, 1990). Salt tolerant cucumber genotypes are known to possess higher photosynthetic capacity than sensitive ones under salt stress (Zheng *et al*., 2009); similar findings were also found in present study, where triacontanol priming demonstrated more stomatal conductance in salt-tolerant Green long and Marketmore as compared to Summer Green and 20252 under same conditions.

Chlorophyll played a vital role in photosynthesis being a photosynthetic pigment. Salinity stress induced activity of chlorophyllase (Reddy and Vora, 1986), enhanced H_2O_2 production and photo-damaged to chlorophyll (Hossain *et al*., 2011) accelerate the degradation of original chlorophyll. It could be salinity induced accumulation of toxic ions and physiological water deficit in leaves delayed the chlorophyll biosynthesis and also accelerated the degradation of original chlorophyll (Zheng *et al.,* 2009). Similar results were also found in present study, where a significant degradation of chlorophyll was noted in all the cucumber genotypes at 50 mM NaCl stress (Fig. 3). While many investigators have reported that triacontanol significantly improved chlorophyll contents under stress conditions (Krishnan and Kumari, 2008; Borowski and Blamowski, 2009; Naeem *et al*., 2010; 2011; Perveen *et al*., 2010; 2011). Tria to enhance the diterpenoid production may be attributed to biosynthesis of the compounds that is probably confined in the chloroplasts (Munne-Bosch and Alegre, 2001), tria mediated increment in chlorophyll content in many plants being one of the strong evidences in this regard (Ries, 1985).

Proline plays a significant role as an endogenous osmotic regulator and its accumulation in plant tissues enhance their stress tolerance (Munns *et al.*, 2006; Dos-Reis *et al.,* 2012; Shahbaz *et al.,* 2012). Similar increase in endogenous proline was also observed in all cucumber genotypes in response to salinity. However, genotypes exposed to Tria priming exhibited higher proline accumulation under control and salinity as well. Similarly, increase in proline accumulation as a result of Tria treatment has been reported by Perveen *et al.* (2011) in wheat and Krishnan and Kumari (2008) in soybean.

Conclusion

The imposition of salt stress significantly affected the emergence, seedling growth, dry biomass and physiological attributes, but priming with Tria ameliorated the adverse effects of salinity on cucumber plants. Among priming strategies, 50 μM Tria was more effective to promote early seedling stand as well as later growth along with better chlorophyll, free proline and gas exchange properties which explores its potential to alleviate the effects of salinity. Moreover, Green long and Marketmore were comparatively better in their performance and more respondent to Tria priming under salinity as compared to Summer green and 20252.

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