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IMPACT OF PLANT GROWTH REGULATORS AND NUTRIENTS ON MITIGATION OF SALINITY STRESS EFFECT IN TOMATO

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KEYWORDS

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ABSTRACT

An experiment was conducted to mitigate the salinity stress effect in tomato genotypes (PKM 1 and TNAU THCO 3) by using PGRs and nutrients. Salinity was imposed by using NaCl at 100 mMconcentration. Foliar application of plant growth regulators like brassinolide (0.5 ppm), salicylic acid (100 ppm), benzyl amino purine (50 ppm), ascorbic acid (100 ppm), glutathione (50 ppm), KNO_3 (0.5%) + $FeSO_4$ (0.3%) + Borax (0.2%) and nutrient PGR concoction (K_2SO_4 (0.5%) + $CaSO_4$ (0.5%) + Borax (0.2%) + NAA (20 ppm) were carried out at 20 and 40 DAT. The study revealed that, brassinolide (0.5 ppm) recorded highest leaf water potential (-1.51 MPa), maximum relative water content (69.60%), highest soluble protein content (13.53 mg g^{-1}), higher catalase activity (5.48 ìg H_2O_2 g^{-1} min^{-1}), minimum Na/K ratio (0.37) and superior fruit yield (574.55 g $plant^{-1}$) followed by salicylic acid and ascorbic acid compared to control in tomato genotypes. However, brassinolide performed better in yield, salicylic acid recorded highest benefit cost ratio of 3.2 and 2.5 in TNAU THCO 3 and PKM 1 respectively followed by brassinolide (3.1 and 2.3). Among the two genotypes used in this study, TNAU THCO 3 responded better for plant growth regulators and nutrients than PKM 1 under salinity.

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INTRODUCTION

In nature, there exists a great variety of stressful environments; some of limited scale and consequences, and some are vast expanse and causing unprecedented decline in plant growth and yield. Salinization of soil or water is one of the world's most serious environmental problems in agriculture. The problem of salinity is characterized by an excess of inorganic salts and is common in the arid and semi-arid lands, where it has been naturally formed under the prevailing climatic conditions and due to higher rates of evapotranspiration and lack of leaching by rain water. Although more frequent in arid lands, salt-affected soils are also present in areas where salinity is caused by poor quality of irrigation water. Saline soil induces physiological and metabolic disturbances in plants, affecting growth, development, yield, and quality of plants. Salinity stress is becoming a major limitation to crop productivity (Munns, 2011). Biswas and Biswas (2014) reported that in India salt affected area is 6.74 million hectare lands. Up to 20 per cent of the irrigated arable land in arid and semiarid regions is already salt affected and still expanding (Koryo, 2006). Salinity stress is causing poor response of crops to fertilizer application as a result to decrease in photosynthesis in the presence of high osmotic pressure in root medium. The use of low quality water causes an increase of soil salinity, which may have negative effects on growth and yield of crops. In many areas the availability of good quality water is limited. Hence, the increasing demands for irrigation water forces the growers to utilize semi-saline underground water, which causes a gradual build-up of Na and Cl in the root zone (Sonneveld, 2000). High osmotic pressure due to high salts affects the plant growth by restricting the water uptake and interferes with balanced absorption of essential nutritional ions by plants (Tester and Devenport, 2003). Accumulation of salts in the growth medium induces the formation of toxic reactive oxygen species (ROS) including singlet oxygen, superoxide and hydroxyl radical.

Tomato (*Solanum lycopersicum*L.), is one of the most popular and widely grown vegetable crops in the world. It plays a vital role in providing vitamins in human diet and an important cash crop for small holders and medium-scale commercial farmers. As tomato is moderately sensitive to salinity, its fruit production was adversely affected by high salt concentrations. Salt stress increased the uptake of sodium and chloride ions in tomato plants. The effects of salinity on the tomato are harmful, reducing the yield, increasing the incidence of blossom-end rot, and beneficial by increasing the concentration of soluble solids in fruits (Mizrahi and Pasternak, 1985).

Plant growth regulators (PGRs) are used extensively in horticultural crops to enhance plant growth, stress alleviation and improve yield (Batlang, 2008). Hence, the present investigation was carried out to mitigate the salinity effect by using various plant growth regulators and nutrients.

MATERIALS AND METHODS

The experiment was carried out with two tomato genotypes (PKM 1 and TNAUTHCO 3) with the salinity concentration of 100 mM in pot culture at glass house,Department of Crop Physiology, TNAU, Coimbatore. Red sandy soil was used for pot culture experiment by using red soil, sand and vermicompost in the ratio of 3:1:1. Uniform size pots 23(cm) X 25(cm)were filled with 10 kg of soil. Twenty five days aged seedlings were transplanted and one plant was maintained in each pot. Salinity was imposed from transplanting onwards till the end of the harvest. Crop was applied with recommended dose of fertilizers (75:100:50 Kg NPK/ha, Borax (10 Kg/ha) and $ZnSO_4$(50 Kg/ha) as basal, 75 kg N/ha at 30 DAT. were carried out as per recommended practice of Tamil Nadu Agricultural University, Coimbatore.

The experiment was laid out in completely randomized block design with three replications. The salinity was imposed with 100 mMNaCl water for irrigation from transplanting onwards. Nine treatments *viz.*, T_1 - Absolute control (Without salinity), T_2- Control (Water spray), T_3 - Brassinolide (0.5 ppm), T_4- Salicylic acid (100 ppm), T_5- Benzyl amino purine (5 ppm), T_6 - Ascorbic acid (100 ppm), T_7 - Glutathione (50 ppm), T_8- KNO_3 (0.5%) + $FeSO_4$ (0.3%) + Borax (0.2%),T_9- Nutrient PGR Concoction K_2SO_4 (0.5%) + $CaSO_4$ (0.5%) + Borax (0.2%) + NAA (20 ppm)were given as foliar spray at 20 and 40 DAT.

Leaf water potential was measured by using an instrument Leaf Water Potential Meter (ARIMAD 3000) and expressed as MPa. The relative water content (RWC) was estimated according to Barrs and Weatherly (1962).

Soluble protein content of the leaf was estimated by using FolinCiocalteau reagent as per the procedure described by Lowry *et al.* (1950) and expressed as mg g^{-1} of fresh weight. Catalase activity was determined by titration method using potassium permanganate (Gopalachari, 1963) and expressed as $\mu g\ H_2O_2\ g^{-1}\ min^{-1}$.

Leaf was digested with 1percent of HNO_3andsodium, potassium and magnesium content were estimated by using atomic absorption spectrometer and expressed in per cent.

Yield was calculated by the total weights of fruits harvested from each plants of all picking were added and average yield per plant was worked out and expressed in gram per plant. Later the expected yield per hectare was calculated and expressed as tonnes per hectare withBenefit cost ratio. The data collected were subjected to statistical analysis in completely randomized block design following the method of Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Leaf water potential (LWP)

can be considered as a good indicator of leaf water status. In the present study, the salt imposed plants showed reduced LWP due to reduction of soil water potential created by salt.Leaf water potential in the abiotic stress was lower than in the control plants in oil palm (Suresh *et al.*, 2012). Benzyl amino purine @ 50 ppm (-1.51 MPa) and Ascorbic acid @ 100 ppm (-1.49 MPa) performed with low leaf water potential and Salicylic acid (100 ppm), KNO_3 (0.5%) + $FeSO_4$ (0.3%) + Borax (0.2%) and Glutathione (50 ppm) (-1.42 MPa, -1.43 MPa and -1.44 MPa) are on par to each other, while, the highest leaf water potential was observed in Brassinolide (0.5 ppm) (-1.35 MPa) and nutrient PGR concoction (K_2SO_4 (0.5%) + $CaSO_4$ (0.5%) + Borax (0.2%) + NAA (20 ppm) (-1.38 MPa). Among the PGRs used for mitigation, brassinolide showed its supremacy with 25 per cent increased water potential over control followed by salicylic acid (21%) (Fig. 1). Li *et al.* (2012) reported that the leaf wilting, reduction in growth, and complete drying of some seedlings are frequently observed in untreated, but are considerably reduced in epibrassinolide treated seedlings. Salicylic acid increased the water potential of stressed plants expected that it reduces the damaging action of abiotic stress like water deficit on growth. This was confirmed with the earlier findings of Senaratna*et al.* (2000) in tomato.

Relative Water Content

(RWC) is the appropriate parameter to measure the plant water status. It was used instead of plant water potential as RWC referring to its relation with cell volume, which could accurately indicate the balance between absorbed water by plant and lost through transpiration (Rosales-Serna *et al.*, 2004). Brassinolide treatment gave statistically superior relative water

Table 1: Effect of plant growth regulators and nutrients on Relative water content, Catalase activity and Soluble protein of tomato genotypes under salinity

Treatments	Relative water content(%)		Soluble protein(mg g^{-1})		Catalase activity(ìg H_2O_2 g^{-1} min^{-1})	
	Pkm 1	TnauThco 3	Pkm 1	TnauThco 3	Pkm 1	TnauThco 3
Absolute control	76.98	81.99	14.16	14.51	7.63	8.52
Control (Water spray)	57.42	53.00	8.81	10.51	6.94	7.17
Brassinolide (0.5 ppm)	69.97	69.21	12.79	14.27	5.24	5.73
Salicylic acid (100 ppm)	69.48	68.98	11.71	13.42	5.48	5.57
Benzyl amino purine (50 ppm)	62.00	66.73	10.21	12.54	5.96	6.26
Ascorbic acid (100 ppm)	61.32	67.82	10.98	12.39	5.85	5.92
Glutathione (50 ppm)	59.52	58.00	10.76	12.27	6.16	6.35
KNO_3 (0.5%) + $FeSO_4$ (0.3%) + Borax (0.2%)	64.23	61.99	11.63	12.81	6.67	6.69
Nutrient PGR Concoction [K_2SO_4 (0.5 %)+ $CaSO_4$ (0.5 %) + Borax (0.2 %) + NAA (20 ppm)]	65.28	62.78	11.64	12.59	6.43	6.59
Mean	65.13	65.61	11.41	12.81	6.26	6.53
	V	T	V	T	V	T
SE (d)	0.33	0.71	0.05	0.12	0.03	0.07
CD (P=0.05)	0.68	1.45	0.11	0.24	0.06	0.14

Table 2: Effect of PGRs and nutrients on Na/K$^+$ ratio, Magnesium content of tomato genotypes under salinity.

Treatments	Na^+/K^+		Mg (%)	
	PKM 1	TNAUTHCO 3	PKM 1	TNAUTHCO 3
Absolute control	0.10	0.11	0.96	0.97
Control (Water spray)	0.77	0.75	0.43	0.51
Brassinolide (0.5 ppm)	0.37	0.38	0.76	0.76
Salicylic acid (100 ppm)	0.38	0.39	0.72	0.75
Benzyl amino purine (50 ppm)	0.41	0.43	0.50	0.60
Ascorbic acid (100 ppm)	0.39	0.41	0.58	0.73
Glutathione (50 ppm)	0.40	0.42	0.46	0.56
KNO_3 (0.5%) + $FeSO_4$ (0.3%) + Borax (0.2%)	0.39	0.38	0.55	0.63
Nutrient PGR Concoction [K_2SO_4 (0.5 %)+ $CaSO_4$ (0.5 %) + Borax (0.2 %) + NAA (20 ppm)]	0.38	0.40	0.58	0.71
Mean	0.39	0.40	0.61	0.69
	V	T	V	T
SE (d)	0.002	0.005	0.003	0.007
CD (P=0.05)	0.005	0.119	0.007	0.015

Table 3: Effect of PGRs and nutrients on benefit cost ratio of tomato genotypes under salinity

Treatments	Benefit Cost Ratio	
	PKM 1	TNAU THCO 3
Absolute control	-	-
Control (Water spray)	-	-
Brassinolide (0.5 ppm)	2.3	3.1
Salicylic acid (100 ppm)	2.5	3.2
Benzyl amino purine (50 ppm)	1.5	2.0
Ascorbic acid (100 ppm)	2.1	2.5
Glutathione (50 ppm)	1.3	1.5
KNO_3 (0.5%) + $FeSO_4$ (0.3%) + Borax (0.2%)	2.2	2.4
Nutrient PGR Concoction [K_2SO_4 (0.5 %)+ $CaSO_4$ (0.5 %) + Borax (0.2 %) + NAA (20 ppm)]	2.0	2.0
Mean	1.9	2.3

content of 69.59 per cent followed by salicylic acid (69.23%) and ascorbic acid (67.28%). This result was agreement with the result of Tuna *et al.* (2007) in maize plant. Similar results were obtained with strawberry, a salt-sensitive plant, when exposed to35 mMNaCl in the nutrient solution and sprayed with salicylic acid solutions at concentrations ranging from 0.25 to 1.00 mM, increase leaf relative water content (Karlidag *et al.,* 2009). The deleterious effects induced by salinity were reduced when bean seeds were treated with brassinolide (Shahid *et al.,* 2011) (Table. 1).

Soluble protein

content of the leaf, being a measure of RuBP carboxylase activity was considered as an index for photosynthetic efficiency. Brassinolide recorded the highest soluble protein(13.53 mg g^{-1}) followed by salicylic acid (12.56 mg g^{-1}). Lowest soluble protein content was noticed in Benzyl amino purine (11.37 mg g^{-1}) followed by Glutathione (11.51 mg g^{-1}).

The positive effect of brassinolide onsoluble protein content might be due to its involvement in the expression and activation of genes responsible for synthesis of rubisco and rubisco activase (Xia *et al.*, 2009), thereby increasing the capacity of CO_2 assimilation in the Calvin cycle. Enhancing effect of salicylic acid on photosynthetic capacity can be attributed to its stimulatory effects on rubisco activity and pigment contents (Table 1).

Catalase activity

Any abiotic stress invariably showed an increased production of reactive oxygen species and salt stress is no more an exception.The plants in absolute control registered minimum enzyme activity of 8.07 ìg H_2O_2 g^{-1} min^{-1} than control (7.05 μg H_2O_2 g^{-1} min^{-1}) (Table 1). Hence, it was showed that the catalase activity increased under stress condition. Among the PGRs and nutrients used, maximum catalase activity was observed in brassinolide (5.48 ìg H_2O_2 g^{-1} min^{-1}) followed by salicylic acid (5.53 ìg H_2O_2 g^{-1} min^{-1}) and ascorbic acid (5.88 ìg H_2O_2 g^{-1} min^{-1}), the minimum catalase activity was observed in KNO_3 (0.5%) + $FeSO_4$ (0.3%) + Borax (0.2%) (6.68 ìg H_2O_2 g^{-1} min^{-1}) and nutrient PGR concoction K_2SO_4 (0.5%) + $CaSO_4$ (0.5%) + Borax (0.2%) + NAA (20 ppm (6.51 ìg H_2O_2 g^{-1} min^{-1}).

The involvement of brassinosteroid in the regulation of reactive oxygen species (ROS) metabolism is evident as they can induce and regulate the expression of certain antioxidant genes and increase the activities of key antioxidant enzymes, including superoxide dismutase (SOD), peroxidase (POD) and catalase (CAT) (Ogweno *et al.,* 2008). Singh and Usha (2003) reported that salicylic acid regulates physiological and biochemical processes in plants and can be used as a potential growth regulator to improve plant growth under saline conditions.The increase in the activity of antioxidant enzyme by application of Salicylic acid is the key indicator to buildup protective mechanism to reduce oxidative damage induced by salt stress (Akankshajaiswal *et al.*, 2014). Ascorbic acid act beneficially, damage reduction caused by salt stress. This may be due to

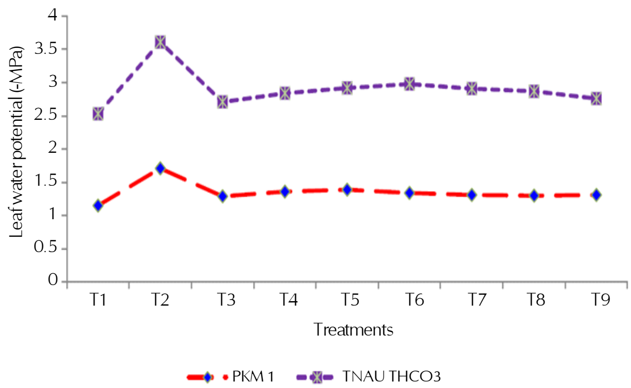

Figure 1: Effect of plant growth regulators and nutrients on leaf water potential (-MPa) of tomato genotypes under salinity

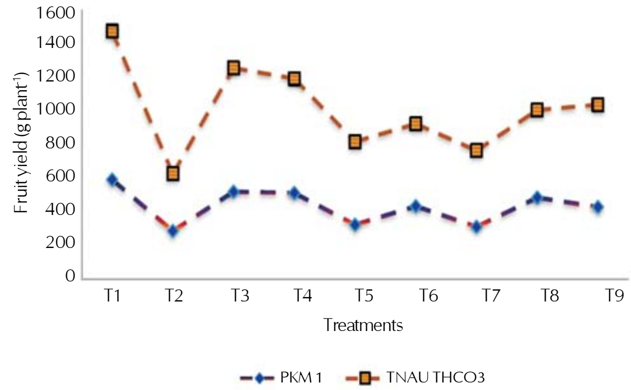

Figure 2: Effect of plant growth regulators and nutrients on fruit yield (g plant^{-1}) of tomato genotypes under salinity

salinity resulting in increased activity of ROS which may cause severe cellular damage. One proposed biochemical mode of ascorbate is to act as an antioxidant scavenging hydrogen peroxide (Beltagi, 2008).

Sodium/potassium ratio

was high in plants when subjected to salt stress. But application of ameliorants reduces the sodium potassium ratio in salt stress condition. The lowest Na^+/K^+ ratio was recorded by brassinolide (0.37 and 0.38) followed by salicylic acid (0.38 and 0.39) in PKM 1 and TNAU THCO 3 respectively. The highest value of 0.77 was recorded by untreated control in PKM 1. This result is supported with Garcia *et al.* (2007) the increasing of soil salinity by irrigation with saline water resulted in increased Na^+/K^+ the content. Glutathione integrated into primary metabolism and influence the functioning of signal transduction pathways by modulating cellular redox state, reduces the sodium and potassium ratio (Hemmat, 2007). The magnesium content was high in brassinolide (0.76%) followed by salicylic acid (0.72 in PKM 1 and 0.75 in TNAU THCO 3) and the least value of magnesium content was recorded in unsprayed control. Under saline conditions, salicylic acid inhibits Na and Cl accumulation, but stimulates N, Mg, Fe, Mn, and Cu contents in the shoots (Gunes *et al.*, 2007) (Table 2).

The reduction in fruit yield and related parameters under salt stress probably due to reduction of water potential in soil which reduce the water content in plant. This situation, disturb the leaf gas exchange properties which limited the photosynthesis activity and partitioning of photo assimilates to fruits sink size and activity (Farooq *et al.*, 2009). Among the PGRs, brassinolide documented significantly superior fruit yield of 574.55 g which is closely followed by salicylic acid (570.27 g) and lowest fruit yield was registered in glutathione (513.30 g) (Fig. 2). The potential application of brassinolide in agriculture to improve crop growth and seed yield under various stress conditions is well documented (Khripachet *al.*, 2000). Applied SA induced changes in endogenous phytohormones of tomato and other plants (Waffaaet *al.*, 1996). Similar results of yield increment were obtained by salicylic acid in tomato (Mady, 2009), soybean and broad bean (Sanaa *et al.*, 2001).Foliar application of salicylic acid 100 ppm resulted in the highest increase in yield and nutritional value of the grain (Jayalakshmi *et al.*, 2010).

Benefit-cost ratio (BC) worked out for all the treatments indicated that, a higher ratio of 2.8 for salicylic acid, which was closely followed by brassinolide (2.7). The least was registered in glutathione (1.4). Among the genotypes, TNAU THCO 3 recorded the BC ratio of 2.3 and PKM 1 recorded the benefit cost ratio of 1.9.Comparing the BC ratio of different treatments, salicylic acid 100 ppm andbrassinolide 0.5 ppm treatments on TNAU THCO 3 recorded the highest BC ratio of3.2 and 3.1 respectively. The same treatments on PKM 1 resulted in the BC ratio of2.5 and 2.3 among the treatments imposed on this variety (Table 3).

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