Pak. J. Bot., 41(6): 3093-3105, 2009.

VEGETATIVE GROWTH AND YIELD OF TOMATO AS AFFECTED BY THE APPLICATION OF ORGANIC MULCH AND GYPSUM UNDER SALINE RHIZOSPHERE

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Abstract

The present study was carried out to observe the effects of organic mulch with and without gypsum on vegetative growth and reproductive yield of tomato plant (*Lycopersicon esculentum* Mill. cv. F_1 Avinash) under control (non-saline) and saline rhizosphere. Significant decrease was noticed in vegetative growth and reproductive yield proportionate to increasing salinity levels, while application of mulch treatments revealed significant increase under both the conditions. The salinity hazard reduced upto considerable extent. Data with reference to plant height, fresh and dry vegetative biomass, number and weight of fruit/plant and circumference of fruit showed comparatively higher growth at all the parameters in T_4 (mixture of mulch and gypsum) followed by T_3 (gypsum alone), T_2 (mulch alone) and T_1 (control without mulch or gypsum) under saline as well as non-saline conditions. Among the biochemical effects, total soluble carbohydrate was increased, total proteins and chlorophyll were proportionally decreased in all treatments with increasing salinity levels. Water potential significantly increased with increasing salt stress while treatment of above mentioned mulches lowered down this value. Solute potential also shows increase with increasing salinity while mulch and gypsum treatments show significant decline both alone and in combination. Our results suggest that application of organic mulches with or without gypsum to soil being irrigated with saline water increases the yield by reducing salinity hazards which could be quantified on growth of tomato plant.

Introduction

The progressive salinization of land is considered a major environmental factor limiting plant growth and productivity of the arid and semi arid regions. Scarcity of good quality water is another problem of the world. Quantity and quality of available irrigation water in many arid and semi arid regions of the world are considered the limiting factors for undertaking agriculture (Munns, 2002). Role of gypsum to reduce salinity hazards is well understood and practiced in certain arid and semiarid regions (Bajwa *et al*., 1986; Grattan, 2002; Ebtisam & El Dardiry, 2007). Calcium is also reported to increase nitrogen, potassium and phosphorous absorption in roots, stimulates photosynthesis, increases the plant size and improves fruit quality in various vegetables like tomato and sugar beat etc., (Fenn & Taylor, 1990; Fenn *et al.*, 1991). Application of $CaSO_4$ in saline conditions has shown increase in fruit yield and improves quality of strawberry (Khayyat *et al.*, 2007).

Surface mulching either by synthetic plastic sheets (or films) or natural organic waste material is now a days being used to protect plants from root borne diseases and for water conservation. Organic mulches containing sawdust, dry grass (lawn clippings), maize cobs, rice and wheat straw, water hyacinth etc., have been very effective for vegetable growth and yield through improving water content of soil, heat energy and add some of the organic nitrogen and other mineral to improve nutrient status of the soil. Surface mulching has shown to reduce evaporation and decrease salinity hazards to improve wheat production in China (Yang *et al*., 2006). Mulch keeps the surface layer wetter and helps to increase root growth in maize (Gajri *et al*., 1994). Ground nut mulch has been found to reduce day time temperature and conserve moisture, increase growth and yield attributes of lettuce (Adetunji, 1990). Mulching has been used to obtain good vegetable growth and yield in crops like sweet potato, potato, tomato and pepper (Aiyelaagbe & Fawusi 1986; Rahman *et al*., 2006). Rahaman *et al*., (2004) have also shown that mulching can minimize salinity hazards.

Tomato (*Lycopersicon esculentum,* Mill.) is the most popular vegetable with great nutritive value and good source of Potassium and Vitamin A & C. It is moderately sensitive to salinity and few cultivars are salt tolerant up to some extent. The threshold value of saline rooting medium is given as EC 2.5 dS/m (Mass, 1986). In order to see the effect of above mentioned mulches, lower levels of sea salt in irrigating water under present investigation was kept at 0.2% (EC_{iw} 2.8 dS/m) which is close to threshold value, and in higher level of irrigation water as 0.4% (EC_{iw} 5.4 dS/m), which is almost twice of the above mentioned critical salt concentration.

Materials and Methods

The experiment was conducted at the nursery of Biosaline Research Field, Department of Botany, University of Karachi. Five seeds of tomato cv. Avinash (F1 Tomato) were sown in large earthen pots of 0.3 m diameter having a basal hole containing about 20 Kg of sandy loam soil. Thinning was done at two leaf stage by leaving a single well developed seedling in each pot. There were 60 pots divided in three sets comprising of 20 pots in each, undergoing following treatments.

C. Control (non-saline), irrigated with tap water EC_{iw} 0.5 dS/m.
S_1. Soil salinity irrigated with 0.2% sea salt solution EC_{iw} 2.8 dS/m.
S_2. Soil salinity irrigated with 0.4% sea salt solution EC_{iw} 5.4 dS/m.

A number of 20 pots of each above mentioned set was subjected to four treatments with respect to mulch comprising of five pots in each. Mulch was prepared by mixing grass clippings, sawdust and cow dung (2:4:1) and kept wet to decompose for about 6 months before use in experiment.

Treatments:
T_1. Without mulch or gypsum
T_2. Mulch only
T_3. Gypsum only
T_4. Mulch and Gypsum both

One third amount of initial fertilization was given in a ratio of NPK at 5:3:3.5 vide urea, DAP (Diammonium Phosphate) and SOP (Sulphate of Potash) (Singh *et al*., 2006). Micronutrient was provided as described by Hoagland & Arnon (1950). Second and third dozes of one third amount of fertilizer were given on onset of flowering and at fruit formation. Insecticides and fungicides were sprayed whenever needed. Leaf samples were randomly taken from the third node of three months old plants for determining water relations, biochemical and mineral analysis. Fruit yield per plant was determined by picking ripe fruits during whole growth period and adding them up at harvest. Three replicates were taken for each parameter.

Observations were taken on following parameters:

Vegetative growth: Plant height, fresh and dry vegetative biomass.

Reproductive growth (fruit yield): Number of fruits/plant, circumference of fruit and total weight of fruit per plant.

Water relations: Leaf water potential and osmotic potential was measured by Pressure Bomb (ARIMAD-2 Israel) and microOsmometer (Model 5004) respectively. Turgor potential was calculated as the difference between water potential and osmotic potential.

Biochemical estimation: Quantitative estimation of total chlorophyll (MacLachlan & Zalik, 1963), total protein (Hartree, 1972), total soluble carbohydrate (Yem & Willis, 1954) was done on the above mentioned harvested leaf samples.

Mineral analysis: Analysis of Na^+ and K^+ by Flame Photometer (JENWAY PFP7) was done in ashed and digested leaves in 2 N HCl and diluted with distilled water (Chapman & Pratt, 1982).

Statistical analysis: The experiment was in completely randomized design with three replicates maintained for each treatment. Data were analyzed by two-way ANOVA. Least significant difference (LSD; at P level of 0.05) values were calculated for comparisons of treatment means.

Results and Discussion

Salinity profile in rooting medium: Saline rhizosphere was made through successive irrigation of water containing various concentrations of sea salt. Leaching fraction was of about 40%. The resultant salinity build up in the layer of mulch and in soil below the mulch under various treatments determined at the end of experiment is given in Table 1. There appears a general increase in salinity level of mulch in comparison with the soil present below except that of 0.2% sea salt irrigation water (S_1 Salinity treatment). The mulch seems to have adsorbed cations at its active surfaces reducing the concentration of salts in leachate passing through soil. Increase of salts in rooting medium is proportionate to increase of salt in irrigation.

Vegetative growth: Data presented in Fig. 1 shows the effect of mulch and gypsum application on different parameters of vegetative growth of tomato under root zone salinities created with different concentrations of sea salt irrigation. Significant decrease in plant growth as expressed in terms of plant height and vegetative biomass of tomato with increase in salinity levels in irrigating water is evident. Hajer *et al*., (2006) have also reported reduction in plant height, fresh and dry vegetative biomass in three tomato cultivars grown under sea water salinity. Amini & Ehsanpour (2006) have reported reduction in vegetative growth of tomato with increasing salinity.

Table 1. Salinity profile of rooting medium under mulch treatment.

Salinity treatment	Mulch treatment	ECe dS/m	
		Soil	Mulch
Control	$\mathbf{T_1}$ (Without mulch or Gypsum)	1.5	-
(0% Sea Salt)	$\mathbf{T_2}$ (Mulch only)	1.1	1.7
EC iw = 0.5 dS/m	$\mathbf{T_3}$ (Gypsum only)	1.9	-
	$\mathbf{T_4}$ (Mulch & Gypsum)	1.6	2.0
$\mathbf{S_1}$	$\mathbf{T_1}$ (Without mulch or Gypsum)	5.7	-
(0.2% Sea Salt)	$\mathbf{T_2}$ (Mulch only)	4.9	4.0
EC iw = 2.8 dS/m	$\mathbf{T_3}$ (Gypsum only)	6.6	-
	$\mathbf{T_4}$ (Mulch & Gypsum)	5.6	4.2
$\mathbf{S_2}$	$\mathbf{T_1}$ (Without mulch or Gypsum)	7.1	-
(0.4% Sea Salt)	$\mathbf{T_2}$ (Mulch only)	5.7	5.9
EC iw = 5.4 dS/m	$\mathbf{T_3}$ (Gypsum only)	7.6	-
	$\mathbf{T_4}$ (Mulch & Gypsum)	5.9	6.1

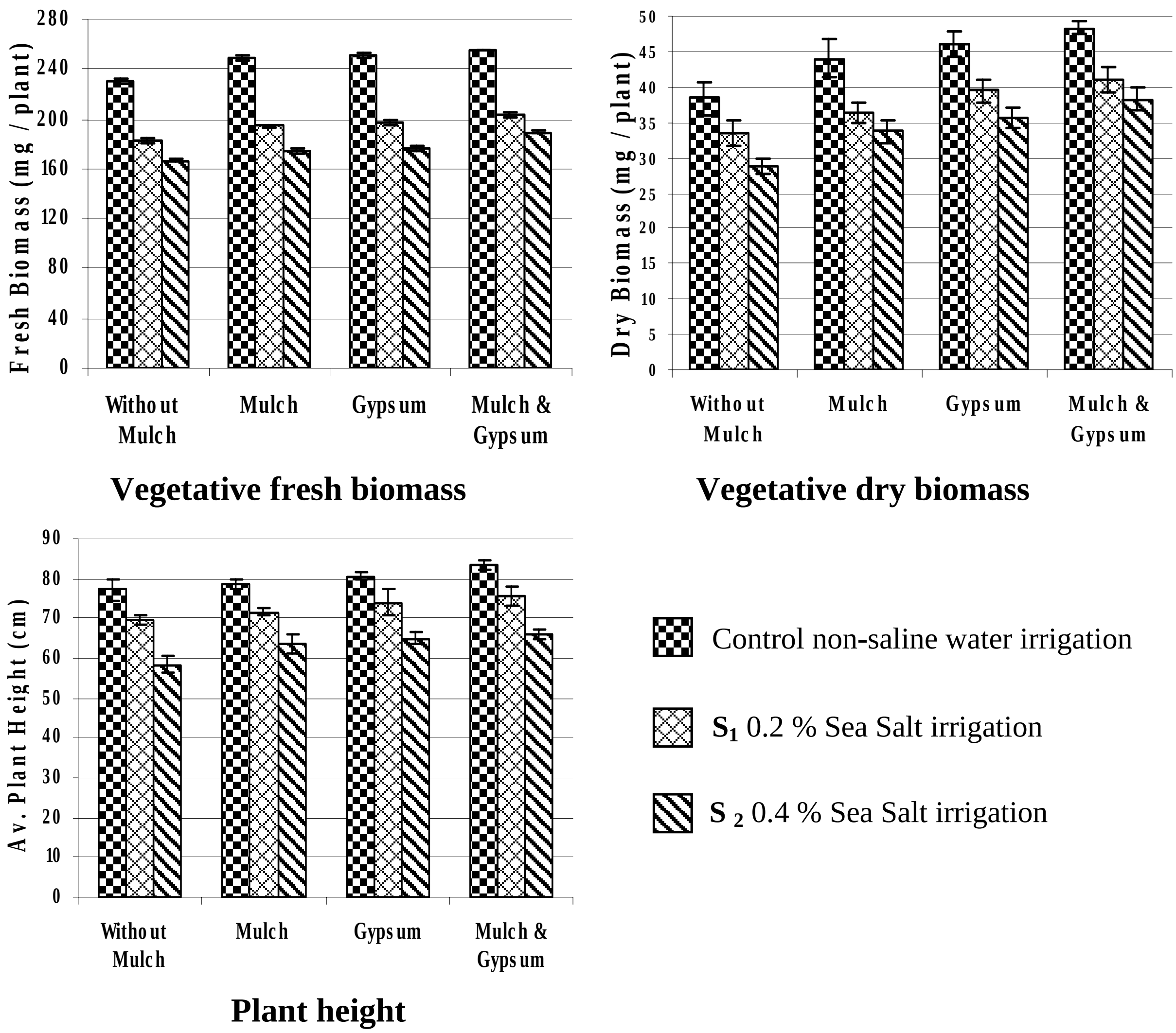

Fig. 1. Vegetative parameters as affected by mulch and gypsum under irrigation of saline water. T_1 – Without mulch, T_2 – Mulch, T_3 – Gypsum, T_4 – Mulch with gypsum.

Application of mulch, gypsum and their mixture has minimized these inhibitory effects up to different extent. Plant height, fresh and dry biomass was increased with application of mulches. Haque *et al*., (2003) have found increased growth of garlic under non-saline irrigation with various types of organic and synthetic mulches. The present study showed significant increase with mulch and gypsum application in all vegetative parameters in non-saline control as well as under saline treatments. Highest growth is evident in T_4 (mixture of mulch and gypsum), followed by T_3 (only gypsum without mulch), T_2 (mulch without gypsum) and T_1 (control, without mulch and gypsum). Rahman *et al*., (2006) reported increase in plant height of tomato mulched with rice straw while lowest height was observed in control (un-mulched) under saline soil. Furthermore, they have observed lower salinity (approx. 4 dS/m) in mulched plots using mulch of water hyacinth, rice straw and wastage of rice rather than that of non-mulched plots (approx. 6 to 7 dS/m), which was due to hindering or prevention of upward movement of ground water through capillary rise in the root zone.

Reproductive growth: Fig. 2 shows significant decrease in fruit yield per plant under saline water irrigated in terms of number of fruits produced by plants, circumference of the fruit and weight of total fruits produced by plant. Similar results were observed by Mitchel *et al*., (1991) and Rahman *et al*., (2006) in tomato under saline soil, Awang *et al*., (1995) and Saied *et al*., (2005) in strawberry. The threshold value of saline rhizosphere of tomato is given as 2.5 dS/m in non gypsiferrous soil and the reduction in fruit yield by increase of one dS/m of salinity is 9.9%. While the same reduction in the threshold value was noted by increase of about 2 dS/m under gypsiferrous soil (Mass, 1986). Application of gypsum alone or in mixture with mulch has increased fruit yield in non-saline control as well as under saline water irrigation. Furthermore, the reduction in yield due to salinity has been offset by above mentioned upto greater extent at 0.2% and lesser extent at 0.4% sea salt dilutions. Many secondary roots arise from upper part of primary root and their tertiary roots penetrate in the layer of mulch which has better retention of water and aeration instead of a little increase in EC of mulch than that of soil beneath it. Application of gypsum has its own advantages due to operating antagonistic effects of calcium against sodium and sulphate ions help in lowering down pH of rhizosphere which improves growth conditions.

The increase of fruit yield per plant in comparison with their respective non-saline or saline control under various treatments is given below:-

Treatments	Control	Mulch	Gypsum	Gypsum& Mulch
Non-saline	100 %	+26.9 %	+50.0 %	+66.5 %
0.2 % Sea salt irrigation	- 26.9 %	+17.3 %	+34.7 %	+55.7 %
0.4 % Sea salt irrigation	- 51.5 %	+23.8 %	+45.2 %	+66.6 %

Increase in yield has been reported by Khayyat *et al*., (2007) in strawberry, Aiyellagbe *et al*., (1986) in pepper, Rahman *et al*., (2004) in potato while using mulches of different composition at soil of various salinity regimes. Muller (1993) noted significant increase in tomato yield in only gypsum application. Liasu & Achakzai (2007) noticed that leaf mulch of wild sunflower alone and with fertilizer (NPK 5:5:5) enhances the growth and development of tomato plant with reference to number of leaf, height and fruit yield.

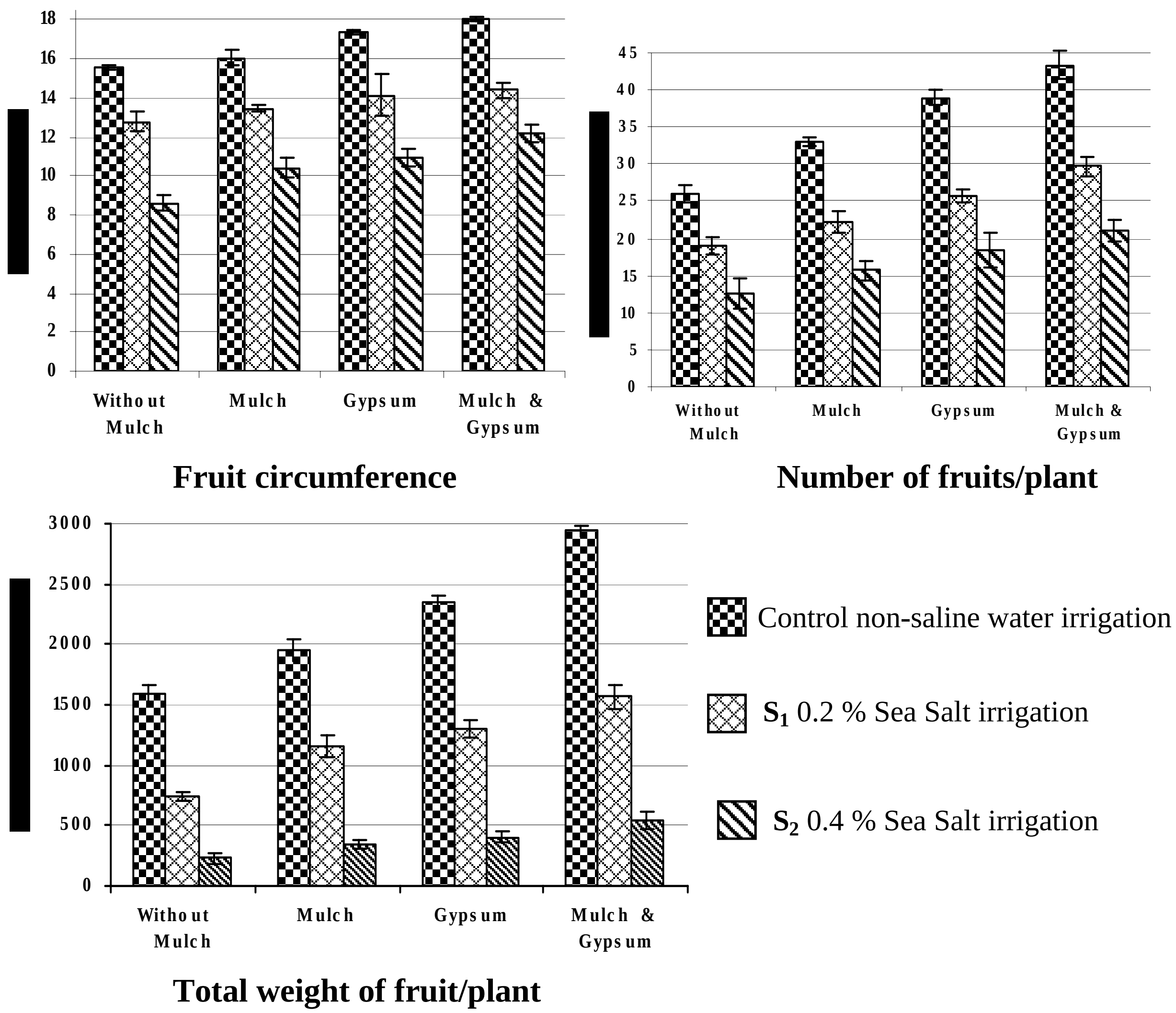

Fig. 2. Reproductive parameters as affected by mulch and gypsum under irrigation of saline water. T_1 – Without mulch, T_2 – Mulch, T_3 – Gypsum, T_4 – Mulch with gypsum

Mulching the soil has been reported to prevent water loss from soil and facilitate mineral uptake to the plant. Tejedor *et al*., (2003) has reported that mulches help to prevent soil salinity from capillary rise to soil surface through reducing evaporation. Rahman *et al*., (2006) found lower salinity level under various organic mulched (rice straw, water hyacinth and wastage of rice straw) plot than unmulched plots while studying tomato growth under various types of mulch treatments. Fan *et al*., (1993) observed that decrease in soil salinity in the plots mulched with wheat straw persisted for two years. Yang *et al*., (2006) found decreased salt content in about 0-40 cm deep soil layer under various kinds of mulches (Concrete > Straw > Plastic film) under saline water irrigation.

Organic mulches helped to maintain moisture content longer than bare soil. Ghosh *et al*., (2006) found more moisture content in wheat straw mulch than without mulch under field condition while observing growth and yield response of ground nuts.

Biochemical estimation: Data of total soluble carbohydrate (TSC), protein and chlorophyll contents in leaves of tomato grown under salinity, mulch and gypsum is presented in Fig. 3.

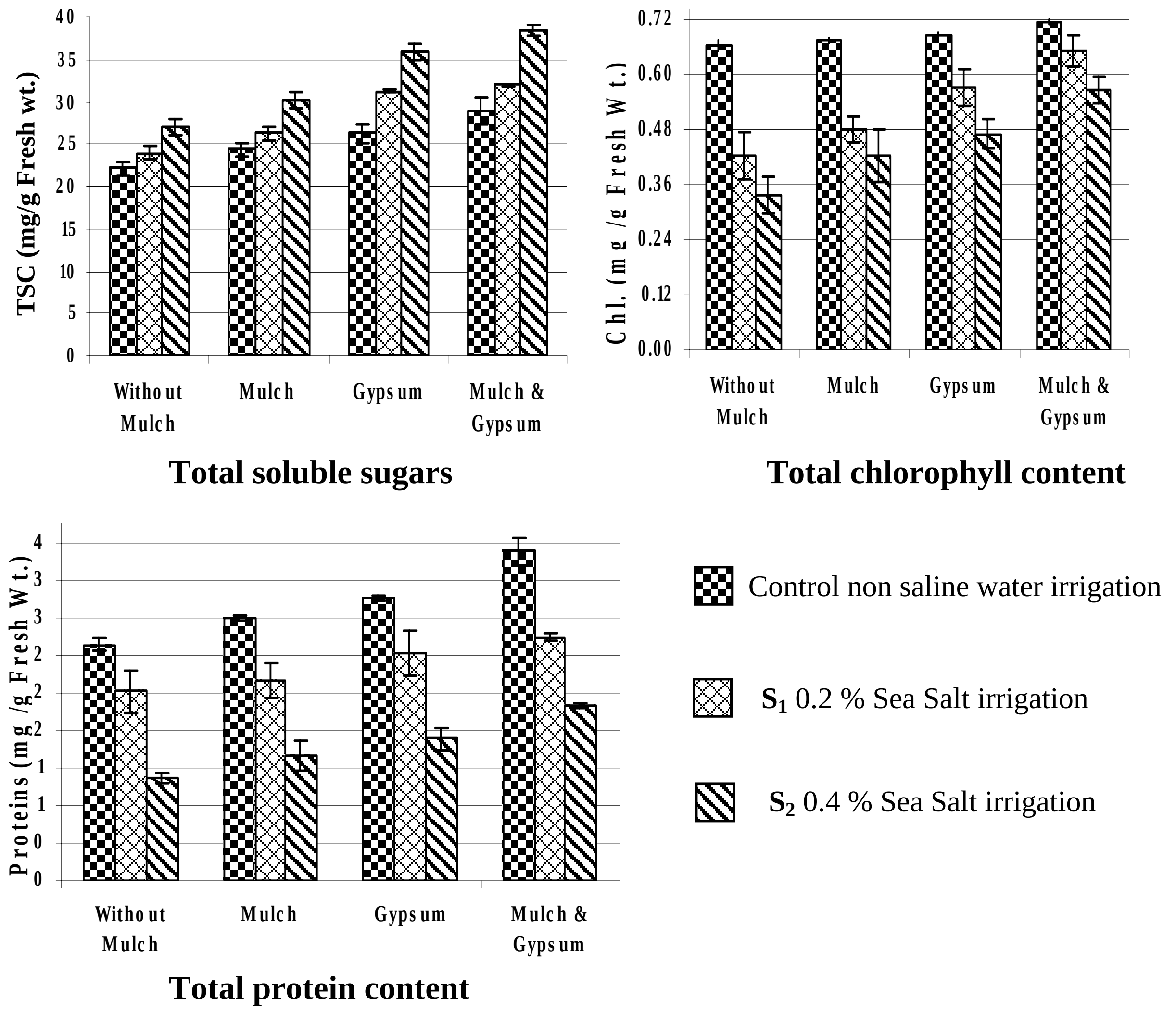

Fig. 3. Biochemical parameters of tomato leaf as affected by mulch and gypsum under irrigation of saline water. T_1 – Without mulch, T_2 – Mulch, T_3 – Gypsum, T_4 – Mulch with gypsum.

Total Chlorophyll content proportionally decreased with increase in salinity levels up to 0.4 % sea salt solution (EC_{iw} 5.4 dS/m) whereas application of mulch and gypsum helped to increase amount of chlorophyll and carbohydrate biosynthesis. The highest amount was noted from T_4, followed by T_3, T_2 and the lowest in T_1. Reduction in chlorophyll amount under salinity is in general observation. Amini & Ehsanpour (2006) reported decrease in chlorophyll content in tomato cultivar due to salt stress. Khavari & Mostofi (1998) found reduction in photosynthetic pigments with increasing salinity level in tomato cultivars.

Thakur *et al.*, (2000) reported increased photosynthesis in chillies with application of mulch, and Bhadauria & Kumar (2006) in okra leaves under control and saline irrigation due to higher retention of soil moisture for longer period that increased rate of transpiration also. Yang *et al.*, (2006) have reported increased chlorophyll content and dry matter accumulation with application of mulch in wheat under salinity.

Total soluble carbohydrate (TSC) was significantly increased with increasing salinity level. Mulch treatments showed highest TSC in T_4 (mulch with gypsum) followed by T_3, T_2 and T_1. The lowest amount was observed in T_1 irrigated with (control) non-saline water without gypsum and mulch application. Lopez-Berenguer *et al.*, (2004) observed increase in soluble carbohydrate in pepper under saline irrigation. Adams (1991) and Mirzrahi *et al.*, (1988) found similar results in tomato.

Yang *et al*., (2006) reported increase in grain due to increase photosynthesis in wheat with straw mulching under salinity. Mulch is reported to retain soil moisture for longer duration provide additional amount of nutrition which help to enhance the fruit quality and rate of photosynthesis as a result the total carbohydrate is increased improving plant health (Pongsa-Anutin *et al*., 2007)

Total protein content showed significant decrease with increasing salinity level up to 0.4 % sea salt solution (EC_{iw} = 5.4 dS/m). This reduction was suppressed by mulch with or without gypsum. Reduction in amount of protein due to salinity is the general observation of many scientists (Al-Khateeb, 2005 in tomato; Amini & Ehsanpour *et al*., 2006 in tomato; Ashraf & Waheed 2008 in lentil).

The present study showed that the application of mulch helps to increase the protein content. The trend of increasing amount of protein in T_4 (Mulch & Gypsum) was evident irrespective of salinity. Kotoky & Bhattacharyya (1992) found highest protein content in leaves of banana associated with application of organic mulch. Aregheore & Tofinga (2004) obtained higher amount of crude proteins in sweet potato under the various types of organic mulches.

Leaf water relations: Water potential, Osmotic potential and Turgor pressure in leaf of tomato have been summarized in Fig. 4.

Leaf water potential (WP) in tomato was significantly increased with increasing salinity. Gad (2005) has also reported that $CaCl_2$ amendment in irrigating saline water increase the water potential in tomato. Mulch application is reported to lower the water potential in leaves under salinity, reduced the salinity hazard and water stress and provides more water to the soil (Yang *et al.*, 2006). Leaf water potential and osmotic potential decrease with increasing salinity level has been reported by other scientists in various plants, such as sunflower (Ahmad & Jabeen, 2009), safflower (Siddiqui & Ashraf, 2008), wheat (Khan *et al.*, 1999). Leaf water potential in tomato cultivar has been reported as more negative with increasing salinity while Cobalt application decreased both water and osmotic potential (Gad, 2005). She has further reported that higher leaf water potential has been considered to enhance the photosynthetic process directly or indirectly by reducing the diffusion of CO_2 in the leaf. Calcium plays a great role to ameliorate the salinity hazards by reducing the water potential in leaves which promotes the biosynthesis of carbohydrates.

Osmotic potential of tomato leaves was significantly lowered (more negative) with increasing salinity level up to 0.4% sea salt solution. Torrecillas *et al*., (1994) has also reported more reduction in leaf osmotic potential of tomato cultivar under salinity stress conditions. The highest osmotic potential was shown in T_4, which were probably the result of increased carbohydrate, protein and other inorganic content of leaves.

Turgor potential of tomato leaves revealed significant increase in turgor with increasing salinity levels upto 0.4 % sea salt solution of EC_{iw} 5.4 dS/m. The highest turgor achieved in T_4 (Mulch plus Gypsum) by accumulation of organic and inorganic salts compared to other treatments and the osmotic adjustment occurs to maintain the turgor. Applying a large amount of K^+ might increase the plant's capacity for osmotic adjustment in saline habitats (Cerda *et al*., 1995). Mulch and gypsum played great role in maintaining turgor under salinity stress than non-saline control. Ji & Unger (2001) reported the beneficial aspects of wheat straw in controlling evaporation and conserving water by decreasing the initial evaporation rate and increasing the depth of water movement into the soil. This mechanism of mulching helps to maintain leaf turgor at certain level to cope with salt stress.

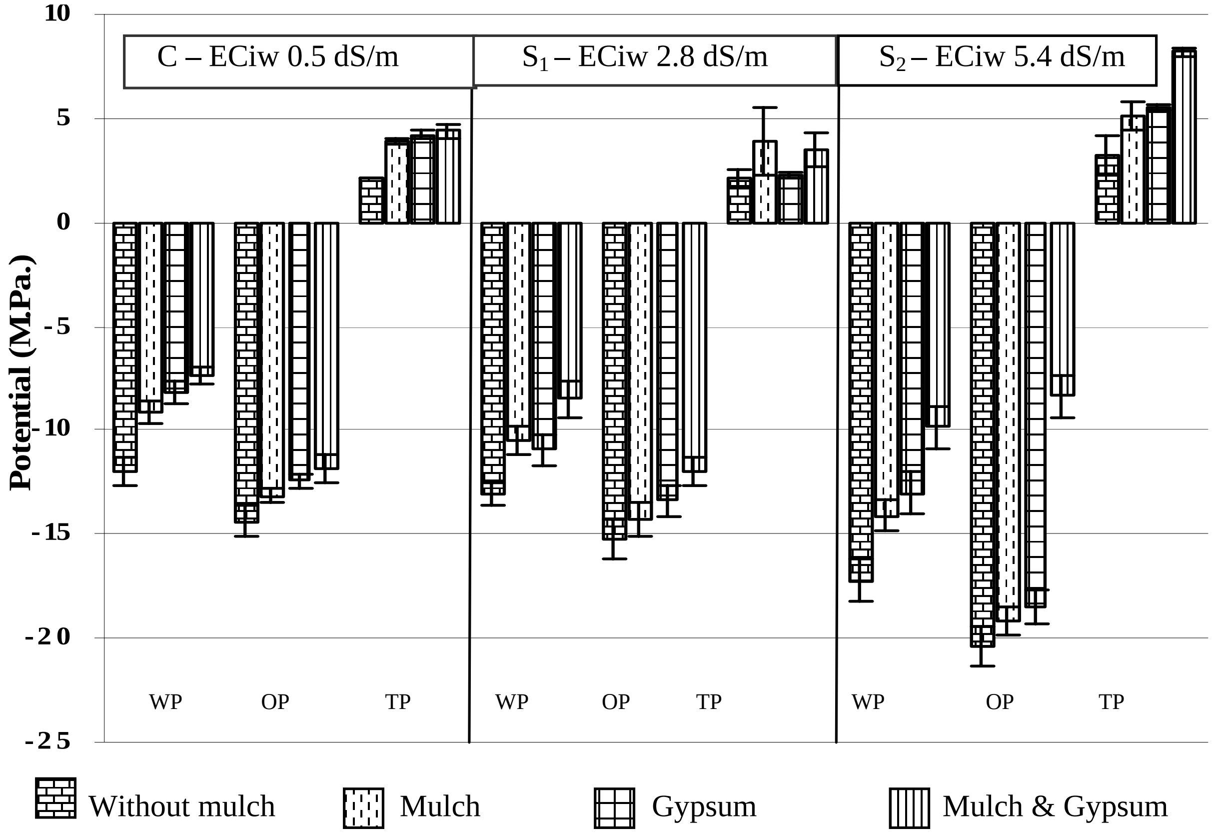

Fig. 4. Water relations of tomato leaf as affected by mulch and gypsum under irrigation of saline water. WP = Water potential, OP = Osmotic potential and, TP = Turgor pressure, T_1 – Without mulch, T_2 – Mulch, T_3 – Gypsum, T_4 – Mulch with gypsum

Mineral analysis: Mineral analysis has revealed significant effects on Na^+ and K^+ content of tomato leaves under going saline water irrigation. The accumulation of Na^+ increased significantly with increasing salinity levels from 0.2% to 0.4% sea salt irrigating solutions as compared to control (table 2). Our result is supported by many other scientists (Inal, 2002 in tomato; Ashour *et al.*, 1986 in wheat). Whereas in present investigations the amount of Na^+ in mg/g Dry wt. is reduced significantly with application of mulch, while K^+ uptake was increased. More reduction is found in T_4 (Mulch with Gypsum) followed in descending order by T_3, T_2 and T_1. K^+ content in leaves of tomato significantly declined with increasing salinity levels. The amount of K^+ is more than Na^+ in control but kept on decreasing with increase of Na^+ in leaves under salinity. Mulch application helped to increase accumulation of K^+ in leaves and was inhibited in non-mulch with increasing salinity levels in irrigation water. Potassium to sodium ratio is another aspect to recognize the salt tolerance in plants. The ratio decline with increasing salinity levels in salt sensitive plants while salt tolerant plants keep this ratio maintained to some extent to cope up with higher salinity stress (Mansour *et al.*, 2000). Our results represented significant decline in K^+ to Na^+ ratio with increasing salinity levels while mulch application revealed an increased in this ratio for betterment of growth.

Conclusion

From the present study it appears that organic mulch (mixture of partially composted grass clippings, saw dust, and cow dung in ratio of 1:2:0.5) increase the yield of tomato even under saline rhizosphere above the threshold level of salinity. The amendment of gypsum in mulch could further improve the situation.

Table 2. Effect of organic mulch and gypsum application on the amount of K^+ and Na^+ and their ratio in Tomato leaves under saline water irrigation.

Treatment	Control (0% Sea Salt) EC iw = 0.5 dS/m			S_1 (0.2% Sea Salt) EC iw = 2.8 dS/m			S_2 (0.4% Sea Salt) EC iw = 5.4 dS/m		
	K^+ mg/g. Dry wt.	Na^+ mg/g. Dry wt.	$K^+ : Na^+$	K^+ mg/g. Dry wt.	Na^+ mg/g. Dry wt.	$K^+ : Na^+$	K^+ mg/g. Dry wt.	Na^+ mg/g. Dry wt.	$K^+ : Na^+$
T_1 (Without mulch or gypsum)	0.240 ± 0.017	0.070 ± 0.012	3.719 ± 0.898	0.150 ± 0.023	0.940 ± 0.012	0.158 ± 2.25	0.087 ± 0.012	1.190 ± 0.040	0.072 ± 0.0076
T_2 (Mulch only)	0.250 ± 0.023	0.060 ± 0.012	4.681 ± 1.359	0.160 ± 0.032	0.810 ± 0.017	0.198 ± 0.042	0.100 ± 0.012	1.020 ± 0.017	0.097 ± 0.0095
T_3 (Gypsum only)	0.270 ± 0.012	0.050 ± 0.017	7.175 ± 2.711	0.210 ± 0.017	0.740 ± 0.111	0.301 ± 0.06	0.100 ± 0.020	0.850 ± 0.020	0.117 ± 0.0153
T_4 (Mulch & Gypsum)	0.290 ± 0.017	0.030 ± 0.012	9.95 ± 2.81	0.220 ± 0.012	0.600 ± 0.017	0.366 ± 0.0086	0.130 ± 0.017	0.790 ± 0.040	0.176 ± 0.0057

Acknowledgement

The financial support given by the Pakistan Academy of Sciences/Higher Education Commission for undertaking this research work is highly acknowledged.

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(Received for publication 7 September 2009)