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Response of Different Tomato Cultivars to Diluted Seawater Salinity

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Abstract: Pot experiments were carried out to evaluate the effects of saline irrigations on five varieties of tomato (4, 22, 38, 46 and 54). Plants were irrigated with diluted seawater adjusted to three levels of electrical conductivity; freshwater (control), 3 and 6 dS m^{-1}. The results of the experiment showed that saline water remarkably affected the evapo-transpiration rate, soil moisture, salts accumulation and plant biomass production. Saline irrigation had the ability to keep much water in the soil with higher value of salt content. Low salinity treatment exhibited highest plant growth and lowest soil moisture and salts deposition. Varieties number 38 and 46 gave the highest values for fruits number and weight. Whereas, variety number 22 got the lowest values. However, variety No. 4 was the tallest and had the highest value for green matter even under high salinity treatment. Overall, under saline condition it was observed that all plant parameters of different varieties were reduced compared to the control except for the number of fruits of some varieties such as 38, 46 and 54. However, fruit fresh weight for variety number 38 was enhanced by saline irrigation which could be a good sign for salt tolerance in saline conditions.

Key words: Saline irrigation, evapotranspiration, plant growth, stress coefficient

INTRODUCTION

Conventional water resources of good quality are scarce especially in arid and semiarid regions. The salinization of soil and water at these places is a substantial constraint of crop productivity. It is well documented that the amount and quality of irrigation water available in many of the arid and semiarid regions of the world are the main limiting factors to the extension of agriculture (Munns, 2002). Saline-sodic irrigation water, coupled with the low annual rainfall and high evaporation and transpiration in the arid and semi-arid regions, have resulted in accumulation of soluble salts in the soil solution, which can alter the structure and consequently, affect the soil hydraulic conductivity (Sameni and Morshedi, 2000). The build up of salts in irrigated regions is of particular concern since 14% of cultivated land that is irrigated supplies approximately half of the world's food (Ben-Hur *et al*., 2001). This has prompted researchers to study the impact of salinity on plant. Several studies showed external signs of salt toxicity due to irrigation with saline water such as sclerosis, leaf burning and poor vegetative growth (Munns, 2002).

Tomato (*Lycopersicon esculentum*) is a major food plant and it is moderately sensitive to salinity (Peralta *et al*., 2005). Extensive research is necessary to develop growing conditions in moderate salinity to produce good vegetative growth. The effect of salinity concentration on plant growth has been studied in different tomato cultivars. Adler and Wilcor (1987) found that salinity adversely affected the vegetative growth of tomato and it reduced plant length and dry weight. Salinity also reduced the fresh and dry shoot and root weight of tomato (Shannon *et al*., 1987). Increased salinity over 4000 ppm led to reduction in dry weight, leaf area, plant stem and roots of tomatoes

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(Li *et al*., 2001). The reduction of dry weights due to increased salinity may be a result of a combination of osmotic and specific ion effects of Cl and Na (Al-Rwahy, 1989). The leaf and stem dry weights of tomato were also reduced significantly in plants irrigated with saline nutrient solution in contrast with control plants (Satti and Al-Yahyai, 1995). Byari and Al-Maghrabi (1991) found that tomato cultivars varied greatly in their response to different salinity levels. Increasing NaCl concentration in nutrient solution adversely affected tomato shoot and roots, plant height, K concentration and K/Na ratio (Al-Karaki, 2000).

Tomato is a major vegetable crop that has achieved tremendous popularity over the last century. It is grown in practically every country in the world, in outdoor fields, greenhouses and net houses (Peralta *et al*., 2005). The main purpose of this study was to evaluate the ability of five different varieties of tomato for growing under different saline condition and screen them for salt tolerance. Moreover, this study will help Omani farmers in selecting the right variety for growing in salt affected soil.

MATERIALS AND METHODS

The pots experiments were carried out in Agricultural Experiment Station at the College of Agricultural and Marine Sciences, Sultan Qaboos University, Oman. The study was conducted in glasshouse. Air temperature (°C) and relative humidity (%) were measured continuously by relative humidity and temperature meter (HOBO, Pro Series, onset, Japan) and Pyranometer (EKO, MS-601F) for solar radiation (mV/kw/m^2). In all treatments, seeds of five varieties of tomato (4, 22, 38, 46 and 54) were sown in plastic trays and later transferred to plastic pots (depth = 30 cm, diameter = 25 cm) filled with a low salinity sandy soil. Irrigation with diluted seawater in different concentrations was started after 21 days from sowing. Treatments were made of three levels of water salinities (control, 3 and 6 dS m^{-1}). The three saline water treatments were factorially combined with the five varieties of tomato and arranged into a completely randomized design with four replications. Irrigation frequency was every two days and in amount depending on crop evapotranspiration (ETc). The ETc was measured gravimetrically in the pots by weighing some treatments before and after irrigation and the required quantity of water was added plus extra water for leaching. Saline water for each treatment was prepared by mixing tap water with seawater at appropriate ratios to obtain the desired Electrical Conductivity (EC). In addition, solid fertilizer was added to the irrigation water as recommended. Plant growth (height and leaf area) was monitored and at the end of the experiment, plant height, leaf area (using a portable area meter LI-3000A), number and weight of fruits and plant fresh weight were recorded. Soil samples at a depth of 15 cm were taken from each treatment.

Stress factor was calculated by using the formula:

$$\text{Stress factor } (K_s) = 1 - [(b/100\ K_y)\ (EC_e - EC_{threshold})]$$

where, b is the percentage reduction in crop yield per 1 dS m^{-1} which is equal to 9, K_y is the yield response factor equal to 1, EC_e is the soil salinity. The threshold EC value for tomato is considered as 2.5 dS m^{-1} (FAO, 1998).

Statistical analysis of the data (ANOVA) was performed and the means compared at 5% probability level.

RESULTS AND DISCUSSION

Irrigation Water Quality

Irrigation water is the most important parameter controlling plant life. Water shortage problem could stress plant and reduce its productivity. All over the world, different irrigation water are used

Table 1: Chemical properties of different water

Water type	pH	EC (dS m^{-1})	Na^+	Cl^-	K^+	Ca^{2+}	Mg^{2+}	NO^{3-}	p-value
			(mg L^{-1})						
Fresh water	8.1	0.7	39.9	540.0	3.5	95.6	11.2	-	-
Saline water	7.7	6.0	828.0	1366.8	15.6	114.0	108.0	-	-
Sea water	7.5	38.5	11211.0	18834.0	377.0	266.0	1976.0	0.2	2.1

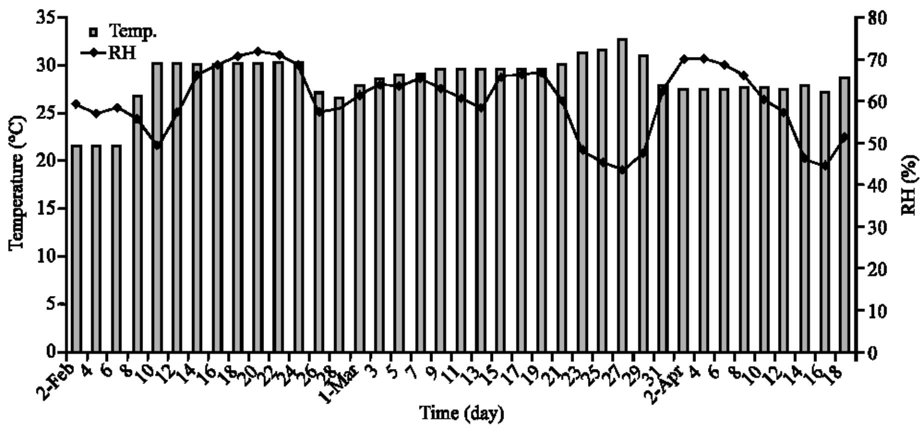

Fig. 1: Mean value of the meteorological data during study

for agriculture purposes but applications depend on soil, plant and quality of the irrigation water. Analysis of some irrigation water similar to the treatments of this experiment have been presented in Table 1 that were used by Daoud *et al*. (2001), Yamamoto *et al*. (1988) and FAO (1998). Freshwater is the best option for optimum plant growth but the shortage of fresh water is compelling researchers to investigate the use of saline irrigation. Using saline or diluted seawater for agriculture could add soil salinity. Under sodic conditions, saline water may improve soil physical conditions. Saline water, especially seawater could also contain some beneficial plant nutrients (Table 1). The inability of sandy soil to hold much salt as compared to clayey soil supports the idea of saline irrigation. The plant response to salt stress is complex, since it varies with the salt concentration, the type of ions, other environmental factors and the stage of plant development depending on the growth conditions. Nutrient availability and uptake by plants in saline environments is related to (1) the activity of nutrient ion in the solution, which depends upon pH, pE, concentration and composition, (2) the concentration and ratios of accompanying elements that influence the uptake and transport of this nutrient by roots and (3) numerous environmental factors (Pessarakli, 1999).

Growth Conditions

Soil Parameters

Tomato plants are widely grown in sub-tropical regions where they often experience high temperatures during fruit setting. It has been reported that heat stress can occur at temperatures just a few degrees above the optimal mean daily temperatures of 27 and 29°C (Peet *et al*., 1998). Climatic conditions in the glasshouse were varied during the study with average temperature of 29°C and relative humidity of 60%. In Fig. 1, air temperature remained within the suitable conditions (21-32°C) for tomato growth for the most of the days. Moreover, the relative humidity was also good indicating that plant was growing without any environmental stress conditions. Berry and Uddin (1988) demonstrated that the periods of high temperature during the reproductive stage cause interruption in fruit set and spilt of fruit, resulting in losses of yield in the temperate growing areas of

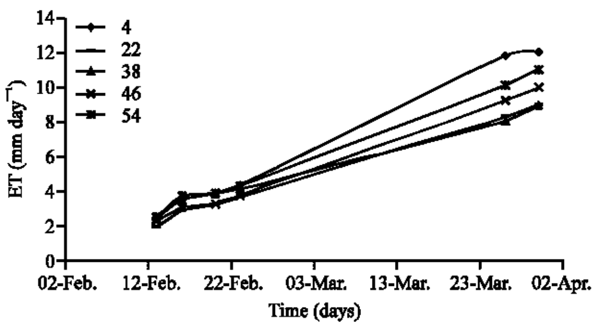

Fig. 2: Evapotranspiration of different varieties under saline irrigation

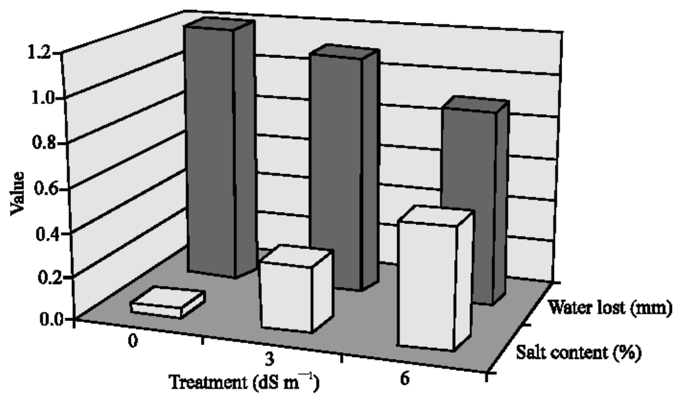

Fig. 3: Salts concentration and water loss as affected by saline water treatments

the world. They also indicated a highly significant negative correlation between the number of flowers pollinated and the percentage of flowers that had set fruit when plants were exposed to 35/26°C day/night temperature.

Evapo-Transpiration (ET) remained as the function of growing conditions and salinity treatments. Water lost by evapotranspiration was directly related to the prevailing environmental conditions in the glasshouse. Figure 2 shows evapotranspiration variation with time (2-12 mm day^{-1}) with an average value of 6 mm day^{-1}. At the beginning of the study when the plant was small, the value of ET between different varieties was almost same but due to salt tolerance of some varieties and other physical properties of the plants such as leaf area and plant height the variation started to increase. It could be seen that variety number 4 gave the highest ET value whereas 22 was assessed as the lowest. Air temperature and salt stress led to several changes in the plant growth parameters. Plant substantially enhanced the evapo-transpiration at the peak growth stage. Environmental condition along with the growing stage of plants tremendously affected the evapo-transpiration and salt accumulation in the soil irrespective of the salt treatments (Al-Busaidi *et al*., 2007).

The evapotranspiration values were generally higher under low salt treatment regardless of the weather conditions (Fig. 3). In other words evapotranspiration was negatively related to the quality of irrigation water. A reduced water loss under high saline treatment was measured as compared to low saline water. Reduced bioavailability of water and retarded plant growth under saline irrigation produced poor evapotranspiration in the system. The depressing effects of salinity on plant growth have been reported by various researchers (Heakal *et al*., 1990; Abdul *et al*., 1988). Saline soil inhibit plant growth through reduced water absorption, reduced metabolic activities due to salt toxicity and

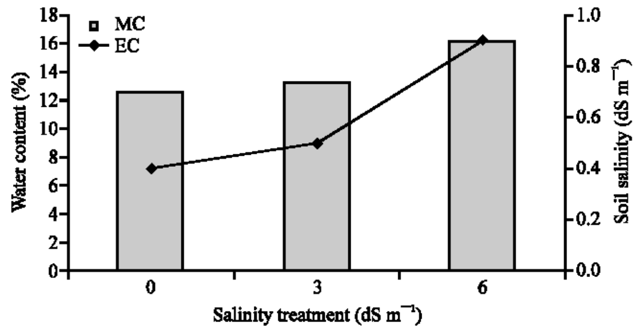

Fig. 4: Soil water content and salt accumulation as affected by saline irrigation

nutrient deficiency caused by ionic interferences (Yeo, 1983). Salt concentrations in irrigation water inhibited evaporation from the soil surface (Fig. 3). This phenomenon could be related to the enhanced water density, viscosity and chemical bonds in the soil-salt system. High concentrations of salts also form salt crusts, which could reduce soil evaporation. Richards *et al.* (1998) reported that density, temperature and salinity affected several water characteristics e.g., evaporation etc. Al-Busaidi and Cookson (2005) reported salt crust formation on the soil surface due to saline irrigation, which inhibited evaporation and reduced leaching efficiency.

Salts accumulation in soil was highly affected by the saline irrigation water. Moreover, the data showed that soil water was apparently affected by the quality of irrigation water and salt accumulation (Fig. 4). The amount of water in each treatment was following same sequence as indicated in Fig. 3. When salinity of soil and water increase, the ability of plant to absorb more water will decrease and the rate of evapotranspiration will decrease. This phenomenon can be seen clearly in Fig. 4 with the positive relationship between soil water content and salinity. The trend shown between lowest (0 dS m^{-1}) and highest (6 dS m^{-1}) salinity treatments is the best example for that.

Water uptake by plants and evaporation from the soil surface were reported the main factors for salts accumulation in the root zone (Ben-Hur *et al.*, 2001; Bresler *et al.*, 1982). This phenomenon can be seen clearly even with fresh water. Moreover, Blanco and Folegatti (2002) found linear values of soil salinity through application of saline water down the soil profile with higher salts contents near the surface and this is why treatment of highest salinity (6 dS m^{-1}) got the highest value for salt accumulation. However, leaching soil is one of the ways to reduce salt accumulation and salinity stress problem. Petersen (1996) reported low soil salinity with increased volume of irrigation water due to salt transportation below the root zone.

Plant Growth

Plant Parameters

Soil salinity is one of the principal abiotic factors affecting crop yields in the arid and semi-arid irrigated areas. Plant growth was significantly affected by different varieties as well as saline irrigation (Table 2). Treatment with lower salinity gave the higher values of most plant parameters as compared to the high salinity (Table 3). Among different varieties and with higher salinity treatment, varieties number 38 and 46 got the highest values for fruits number and weight (33, 17, 555.23 and 344.34 g, respectively). Whereas, variety number 22 got the lowest values. The biomass yield was reduced typically due to higher amount of salt depositions in the rhizosphere. However, variety number 4 was the tallest and got the highest value for green matter even under high salinity treatment and this is why the fruits production in this variety was low. Generally, the incorporation of salinity stress and weakness to tolerate salinity could lead to higher loss of plant production (Daoud *et al.*, 2001).

Table 2: Analysis of variance (ANOVA) for plant parameters

Parameters	Sum of squares	df	Mean square	F-value	Sig.*
Height	44712.98	14	3193.78	7.83	0.00
Leaf area	3769.91	14	269.28	4.22	0.00
Fruit	3866.53	14	276.18	7.96	0.00
Fruit fresh weight	774626.68	14	55330.48	50752.35	0.00
Plant fresh weight	3680804.75	14	262914.63	8.57	0.00

*Level of significance at p<0.05

Table 3: Plant growth parameters as affected by saline irrigation

		Plant parameters				
Saline water treatments	Variety	Height (cm)	Leaf area (cm^2)	Fruit No.	Fruit fresh weight (g)	Plant fresh weight (g)
Control	4	161.33b*	67.48a	7f	323.28j	1377.20a
	22	108.67d	65.77a	15f	687.62a	635.63c
	38	101.67d	47.26d	29c	525.47d	638.07c
	46	144.67b	53.29ead	13f	453.79h	686.30c
	54	110.33d	47.33de	9f	485.95f	511.53c
3 dS m^{-1}	4	169.33a	48.39c	6d	234.33o	967.37b
	22	88.67f	50.38c	10d	513.25e	456.90e
	38	87.33f	38.57c	36a	566.58b	532.47e
	46	169.33a	43.16c	12d	274.63m	1007.87b
	54	105.00f	50.44c	19d	469.47g	590.43e
6 dS m^{-1}	4	151.00c	41.88f	7e	315.91k	610.10d
	22	84.67fe	42.71f	9e	309.65l	228.37f
	38	74.33f	36.68g	33b	555.26c	318.63f
	46	107.00e	54.90b	17e	344.34i	555.10d
	54	97.00ef	35.04g	12e	260.56n	330.97f

*Mean values in the column with same letter(s) indicate no difference at Duncan's multiple range test at p<0.05

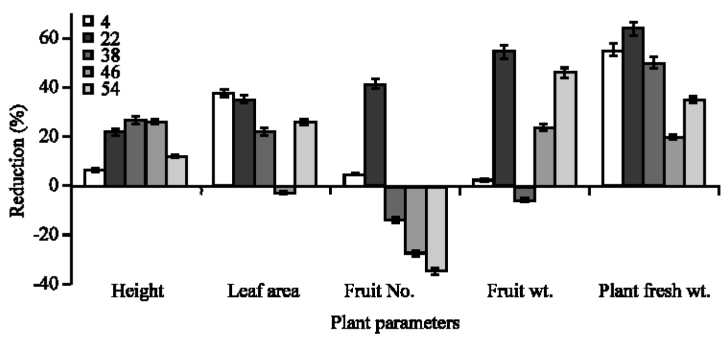

Fig. 5: Reduction in plant growth parameters due to salinity treatments

Comparing the response of different varieties to saline irrigation, it could be seen that all plant parameters of different varieties were reduced compared to control except number of fruits of some varieties such as 38, 46 and 54 (Fig. 5). Moreover, the fruit fresh weight for variety number 38 was enhanced by saline irrigation. This evidence could be a good sign for positive response of plants to saline irrigation.

Generally soil salinity affects the plant growth by producing an ionic imbalance or water deficit state in the expanded leaves. Shani and Dudley (2001) related the yield loss to reduced photosynthesis, high energy and carbohydrate expenses in osmoregulation and interference with cell functions under saline conditions. Heakal *et al*. (1990) reported that dry matter yield of plant shoots decreased with increasing salinity of water. The incorporation of some salts with high temperature could lead to higher loss of plant production (Daoud *et al*., 2001).

The effect of NaCl stress on the growth of tomato plants is reflected in lower dry weights. The reduction of the dry weights due to increased salinity may be a result of a combination of osmotic and specific ion effects of Cl and Na (Al-Rwahy, 1989). The results indicated that the stem, leaves and root dry weights decreased in saline condition, due to the exposure to seawater stress. Similar outcome were obtained earlier by Mohammad *et al*. (1998) in other tomato cultivars. Saline stress leads to changes in growth, morphology and physiology of the roots that will in turn change water and ion uptake. The whole plants are then affected when roots are growing in saline medium. The results also indicate that salt tolerance of tomato plants tends to increase with age. The same trend was observed on the leaves and roots as also documented by Al-Rawahy (1989), Pessarakli and Tucker (1988) and Munns (2002). Finally, in this study, salinity stress resulted in a clear stunting of plant growth, which results in a considerable decrease in the fresh weight of leaves and stems. Increasing salinity is accompanied also by significant reductions in shoot weight and plant height.

There are inconsistencies in the literature regarding the contribution of fruit number to EC-induced reductions in tomato fruit yield. Li *et al*. (2001) and Eltez *et al*. (2002) reported that the number of fruits was unaffected by moderate salinity and that reduced yield was entirely due to smaller fruit. Results of this study are consistent with Adams and Ho (1989) and Van -Ieperen (1996) who observed that the number of harvested fruits per plant decreased with salinity and was a contributing factor to reduced fruit yield. The decrease of fruit number in the present study was affected by EC and the duration of the harvesting period. The differences in fruit number were larger with increasing duration of the harvesting period as reported by Adams and Ho (1989) and Van Ieperen (1996). The reduction in fruit number observed in the present study appeared to be related to a reduction in the average number of flowers per truss and per plant observed with increasing salinity (Magán, 2005). This is consistent with the hypothesis of Cuartero and Fernandez-Munoz (1999) that stress restricts the number of flowers per truss.

Stress factor (K_s) is an additional parameter to determine crop evapotranspiration. It is an indicator of unusual plants stress such as salinity, deficit water, disease or nutrient imbalance. It implies when its value decreases by less than 1 and smaller K_s value means higher stress. The stress co-efficient was found in the order of highest saline treatment > medium > control (Fig. 6). The K_s values greatly decreased under high level of salinity and heat conditions. Control plants irrigated with fresh water produced more biomass which did not decline K_s values and as salinity increased the K_s values decreased. It was reported that increased evaporation from the soil surface can counteract the reductions in crop coefficient factor (K_c) and K_s caused by high EC_e of the root zone (FAO, 1998). Letey *et al*. (1985) and Shalhevert (1994) reported that the effects of soil salinity and water stress were interactive to crop evapo-transpiration.

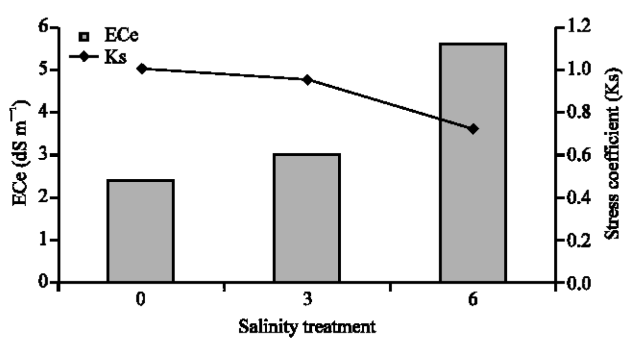

Fig. 6: Stress coefficient as affected by saline treatments

The water deficit conditions under high salinity treatments could be directly attributed to the impaired water flow from soil to plant. Yeo (1999) reported that root selectivity and transpirational water flow provide the net uptake of salts whereas the salt concentration develops with the growth rate. The greater mass flow of solution through the soil-root interface or higher magnitude of evapotranspiration would increase the salt transport in plants. Thus, there is a potential risk of higher salt damages in hot climate. Ghadiri *et al*. (2005) reported restricted water uptake by salinity due to the high osmotic potential in the soil and high concentrations of specific ions that may cause physiological disorders in the plant tissues and reduce yields. Whereas, Hajer *et al*. (2006) and Reina-Sánchez *et al*. (2005) reported that plants irrigated with saline water reached maximum daily water uptake earlier than control plants because salinity enhanced plant senescence.

Management of soil and water salinity in Oman is direly needed if agriculture of the country has to be kept alive and the ever increasing decertification is to be mitigated at all. A comprehensive research project in the management of saline soil is required to generate data under agro-climatic conditions of Oman, preparation of economically useful techniques and formulation of recommendations to the farmers.

CONCLUSION

Soil salinity is a major constraint to economic use of land for agriculture especially in the arid and semiarid regions. The results of the present pot study showed that the fresh fruit yield of tomato grown in glasshouse was reduced by increasing salinity. Saline irrigation added much salts to the soil and inhibited plant growth. Treatment of less salinity gave higher values for most plant parameters and as salinity increased there was a reduction in plant growth and final yield. Some varieties (No. 38) showed an optimistic response to saline agriculture by producing more yield under saline conditions. Hence, there is further need for more study under higher salinity condition to evaluate which variety can survive and produce good yield in arid and semi arid fields.

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