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Ionic concentration and growth response of sunflower (*Helianthus annuus* L.) genotypes under saline and/or sodic water application

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Abstract

To investigate the effect of saline and/or sodic waters on growth and ionic concentration in sunflower, ten genotypes were grown in solution culture. Five treatments of irrigation water viz. T1 (control), T2 (EC 10 dS m^{-1}), T3 (SAR 20 mmol $L^{-1})^{1/2}$, T4 (RSC 5.4 meL^{-1}), T5 (EC 10 dS m^{-1}) + (SAR 20 mmol $L^{-1})^{1/2}$ + (RSC 5.4 meL^{-1}), having different ECiw, SAR and RSC were used. Root/shoot fresh and dry weight and K^+/Na^+ in plant samples were determined. Growth parameters and ionic analysis showed a differential response to varying levels of salinity and/or sodicity. Also variations existed among genotypes for their response to all stress levels. SF-187 was ranked as tolerant because this genotype produced the maximum shoot fresh weight (SFW) and K^+/Na^+ ratio at all stress levels. The genotypes Hysun-33 was ranked as salt sensitive along with Hysun-38 which was at par with Hysun-33.

Key words: Sunflower, saline water, salinity tolerance, growth, ionic concentration

Introduction

Sunflower is a major oil seed crop, with the world harvested area of about 23 mha and seed production about 31 million tons (FAO, 2005). Pakistan has chronic deficiency in edible oilseed production and is the third largest importer of edible oil in the world. At present indigenous oilseed production, estimated at 0.857 million tons, meets only 31% of domestic requirement, while the remaining 69% is met through imports (GOP, 2006). Resultantly a huge amount is spent in this regard and edible oil imports take the second position after petroleum products.

Tremendous yield potential, coupled with high oil contents, sunflower offers great promise to meet the edible oil deficit in the country. Moreover, it is gaining popularity among consumers for its good cooking quality from health stand point. However many adverse factors including soil salinity and low quality irrigation water is a menace for plants, dipping average yield each year.

Water demands for agriculture production are projected to rise, bringing increased competition between agriculture and other users. For this purpose about 0.53 million tube wells are pumping about 49.91 million actor feet underground water in Pakistan (GOP, 2002). Estimates show that about 70–80% of pumped water (67, 842 million m^3) contains soluble salts and/or sodium ions (Na^+) levels above the permissible limits for irrigation water (Latif and Beg, 2004). Hence irrigated agriculture is exposed to increasing pressure to expand the use of saline and/or sodic waters for crop production. Low quality irrigation water is one of the factors leading to decline sunflower productivity in Pakistan over the past many years (GOP, 2006).

Under saline stress, sunflower plants show worsening leaf water status (Rivelli *et al*., 2002) and accumulation of toxic ions, particularly Na^+ mainly in the older leaves. The other adverse effects include, malfunctioning of enzymes, osmotic imbalance, membrane disorganization, reduction in growth, inhibition of cell division, reduction in photosynthesis and production of reactive oxygen species (Niu *et al*., 1995; Zhu, 2001; Munns, 2002).

Combined evidence of many workers has resulted in consideration that sunflower is a species moderately tolerant to salt stress being unaffected by soil salinity up to EC_e 4.8 dS m^{-1} (Mass and Hofman, 1977; Ayers and Westcot, 1985; Francois, 1996). More recently Flagella *et al*. (2004) has found that each unit in ECe above 4.8 dS m^{-1} resulted in yield reduction by 4.5%. Sunflower genotypes exhibit considerable genetic diversity for salinity tolerance, which can be exploited for the selection of salt tolerant material using optimum selection tools (Ashraf and Tufail, 1995). The capability of sunflower to grow on saline soils varies among cultivars and depends on the concentration of salts present in the root zone and on various other environmental and cultural conditions. Keeping in consideration importance of sunflower crop for sustainable production, the present study was conducted to evaluate the effects of saline and/or sodic waters on growth and ionic parameters of different sunflower genotypes.

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Materials and Methods

Seed material of 10 sunflower hybrids namely SF-187, S-278, Hysun-38, Hysun-33, FH-259, FH-333, FH-106, FH-332, FH-260 and FH-37 (obtained from Ayub Agriculture Research Institute, Faisalabad) were sown in trays (60 cm × 45 cm × 5 cm) having five cm layer of river sand. At two leaves stage, the seedlings were transplanted in hydroponics system having thermo pore sheets with holes and floating on half strength Hoagland's nutrient solution (Hoagland and Arnon, 1950) in 200 L capacity iron tubs lined with polyethylene sheet. Five treatments of irrigation water viz. T_1 (control), T_2 (EC, 10 dS m^{-1}), T_3 (SAR, 20 (mmol L^{-1}) $^{1/2}$), T_4 (RSC, 5.4 meL^{-1}), T_5 (EC, 10 dS m^{-1}, SAR (20 mmol L^{-1}) $^{1/2}$, RSC 5.4 meL^{-1}), were developed gradually with Na_2SO_4, $CaCl_2.2H_2O$, $MgSO_4.7H_2O$ and $NaHCO_3$ in distilled water using quadratic equation (Abid, 2002). Concentration of cations and anions in different waters is summarized in table 1. The Quadratic Formula uses the "*a*", "*b*", and "*c*" from "$ax^2 + bx + c$", where "*a*", "*b*", and "*c*" are just numbers; they are the "numerical coefficients". The equation is derived from the process of completing the square, and is formally stated as: For $ax^2 + bx + c = 0$, the value of *x* is given by:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

The solution was changed after 15 days. The pH of the solution was maintained between 6.0 ± 0.5 throughout. Plants were harvested after 30 days of treatment, roots and shoots were separated in each plant and data about shoot/root fresh weights, and shoot/root dry weights were recorded directly. K^+ and Na^+ concentrations were determined by flame photometer (Jenway 480) from the leaf sap and K^+: Na^+ ratios were estimated. A completely randomized design of five saline and/or sodic water levels with four replicates and factorial arrangement was used. The data obtained were analyzed, means were compared and standard errors were calculated (Steel and Torrie, 1980).

Results

Growth parameters

Data pertaining to shoot fresh weight (SFW) is graphically presented in Figure 1. With increasing salinity and/or sodicity of water all genotypes exhibited a trend of declining biomass regarding SFW. A critical observation of data reveals that maximum SFW is produced in case of T_1 (Fit water) while minimum was recorded in T_5 [EC-SAR-RSC water]. The performance of different genotypes under same and various levels of saline and/or sodic waters is also significantly different. Comparison of genotypes indicated that SF-187 performed best in all stress treatments, closely followed by S-278. At T_2 [EC (10.0 dS m^{-1}) Water] SF-187, S-278 and FH-106 produced maximum SFW, whereas Hysun-33 and Hysun-38 produced minimum SFW. A similar trend was observed in T_3, T_4 and T_5 where performance of SF-187 and S-278 was better as compared to other genotypes while Hysun-33 and Hysun-38 were most affected genotypes and produced minimum SFW. Under nonsaline treatment FH-206 and FH-37 produced maximum and minimum SFW, respectively, while under saline and/or sodic treatments, SF-187 and Hysun-33 proved to be the most efficient and least efficient genotypes, respectively.

Root fresh weight (RFW) of all genotypes decreased consistently with increasing salinity and/or sodicity in rooting medium. In $T_{2,}$ only saline treatment [EC (10.0 dS m^{-1}) Water] SF-187 and Hysun-33 produced the maximum and minimum RFW, respectively. Same trend of declining RFW was also observed in T_3 and T_4. In T_5 (mixed stress) the performance of SF-187 was least affected while Hysun-38 was the most affected genotype and produced only 18% of the control (Figure 3). A critical observation of data regarding shoot dry weight (SDW) revealed that SF-187

Table 1. Quality of different waters used for solution culture study

Characteristic	Unit	T_1 (Distilled water)	T_2 (Saline water)	T_3 (Sodic water)	T_4 (Alkaline water)	T_5 (Saline –sodic water)
EC	dS m^{-1}	-	10.00	01.50	01.50	10.00
$Ca^{2+} + Mg^{2+}$	$mmol_c$ L^{-1}	-	57.21	00.98	03.87	26.79
Na^+	$mmol_c$ L^{-1}	-	42.79	14.02	11.13	73.21
HCO_3^{-1}	$mmol_c$ L^{-1}	-	42.79	00.98	09.27	32.19
Cl^{-1}	$mmol_c$ L^{-1}	-	45.76	00.78	03.10	21.43
SO_4^{-2}	$mmol_c$ L^{-1}	-	11.45	13.24	02.63	46.38
SAR	(mmol $L^{-1})^{1/2}$	-	08.00	20.00	08.00	20.00
RSC	me L^{-1}	-	-	-	05.40	05.40

and Hyun-33 produced maximum and minimum SDW respectively, in all stress treatments (Figure 2). Similarly in T_1, FH-260 produced maximum root dry weight (RDW) while FH-106 produced minimum RDW. In all saline and/or sodic treatments, SF-187 produced maximum RDW except T_3 where Hysun-38 produced maximum RDW (Figure 4). The behavior of genotypes (FH-259 and Hysun-33) showed a different response in T_5, where performance of Hysun-33 was better as compared to FH-259 contrary to all other treatments.

Ionic concentration

The Na^+ contents of all genotypes increased with incrementing salinity and/or sodicity in the growing medium. However, the degree of Na^+ increase tended to be more serious in case of T_5 in all genotypes. In T_1, Hysun-38 and FH-259 accumulated the maximum Na^+ in leaves. However, in all stress treatments, Hysun-33 proved to be the least efficient in avoiding Na^+ uptake and showed maximum Na^+ contents. Furthermore, this increase was maximum in case of T_5 where high salinity was coupled with high sodicity and alkalinity (Figure 5).

Data pertaining to K^+ concentration (Figure 6) depicted significant genotypic differences in K^+ leaf contents among different genotypes in all stress treatments. In T_1, maximum K^+ contents were evident in FH-332 while FH-259 accumulated minimum K^+ contents. However in all saline and/or sodic treatments, Hysun-33 accumulated minimum K^+ contents as against performance of SF-187 which tended to accumulate maximum K^+ contents consistently. Data regarding K^+/Na^+ are graphically depicted in Figure 7. The decrease in K^+/Na^+ was observed under all stresses, the highest being in T_1, where highest and lowest K^+/Na^+ was observed in SF-278 and FH-259, respectively. Anyhow, a consistent behavior with maximum K^+/Na^+ was evident by SF-187 under all stresses; however it was at par with S-278. Minimum K^+/Na^+ was observed by Hysun-33 in case of T_5.

Discussion

Among many techniques/criteria for screening of genotypes against salinity, shoot fresh/dry weight and Na^+, K^+ and K^+: Na^+ ratios are mostly considered as selection criteria. Potassium selectivity, exclusion and/or compartmentation of sodium, osmotic adjustment and the accumulation of organic solutes are different physiological traits related to salt tolerance of cultivars of different species (Barrett-Lennard *et al*., 1999). Great variation with respect to saline and/or sodic water tolerance was observed amongst studied sunflower genotypes.

Fresh and dry weights of shoots of sunflower genotypes were reduced significantly at all stress levels (Figure 1). Shoot fresh and dry weights under T_5 were reduced by 77 and 78.2 %, respectively, in Hysun-33, the salt-sensitive genotypes, relative to the control. By contrast, in the salt-tolerant genotype, SF-187, the reduction in both fresh and dry weights was relatively low (60 and 61%, respectively, relative to T_1). These results confirm the greater salt tolerance of SF-187 in relation to the salt-sensitive genotype, Hysun-33, as was already observed in a previous study which involved screening of sunflower genotypes using NaCl stress (Riaz *et al*., 2008). Reduced dry weight of plant tissues under salt stress reflects the increased metabolic energy cost and reduced carbon gain, which are associated with salt adaptation (Netondo *et al*., 2004). The enhanced plant growth in control (low external sodium) might be due to quick response to K^+, resulting in high K^+/Na^+ ratio (Shirazi *et al*., 2005). Protection of metabolic process and maintenance of high growth rate is frequently associated with restricted Na^+ transport into shoot and its low accumulation in shoot, a characteristic of salt tolerance genotypes (Eker *et al*., 2006). So, there is clear consideration that salinity tolerance is associated with low uptake of Na^+ (Guillermo *et al*., 2001).

Sodium in higher amounts in leaf sap significantly reduced growth which was evident from these results where the genotypes Hysun-33 and Hysun-38 had maximum Na^+ concentration in their shoots and produced minimum dry matter, characteristics of salt sensitive genotypes. By contrast, the genotypes SF-187 and S-278 had minimum shoot Na^+ concentration and produced maximum dry matter. These results were in line with Munns *et al*. (2006) who reported that the salt tolerance in wheat was associated with low shoot Na^+ concentration. As Na^+ is the key ion impairing plant growth under salt stress and most of the researchers used shoot dry weight as growth indicator in solution culture experiments along with ionic analysis for salt tolerance assessments. Therefore, salt tolerance (% reduction at salinity with respect to control) was calculated on the basis of shoot dry weight and its correlation was drawn (Figure 8) with leaf Na^+ concentration at T_5 (EC 10 dS m^{-1}, SAR (20 mmol $L^{-1})^{½}$, RSC 5.4 meL^{-1}). A highly significant negative relationship was observed for salt tolerance (%) with shoot dry weight (r^2 = 0.7). This relationship of Na^+ accumulation with salt tolerance was previously described by many researchers (Schachtman and Munns, 1992; Saqib *et al*., 2006).

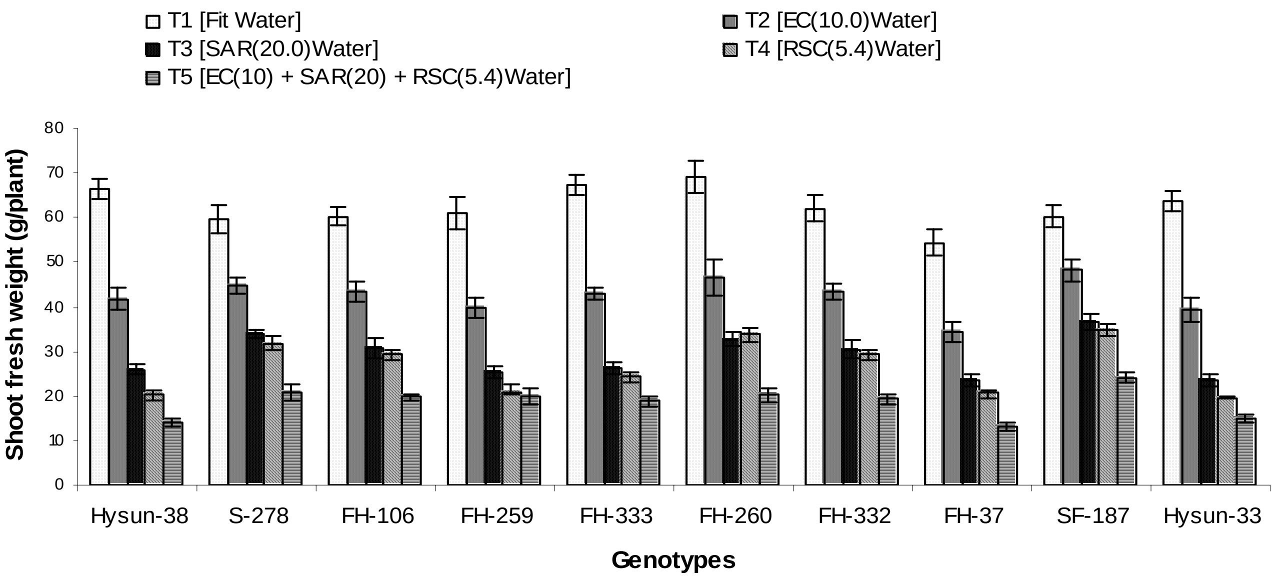

Figure 1. Effect of saline and/or sodic waters on shoot fresh weight (g plant^{-1}) of sunflower genotypes

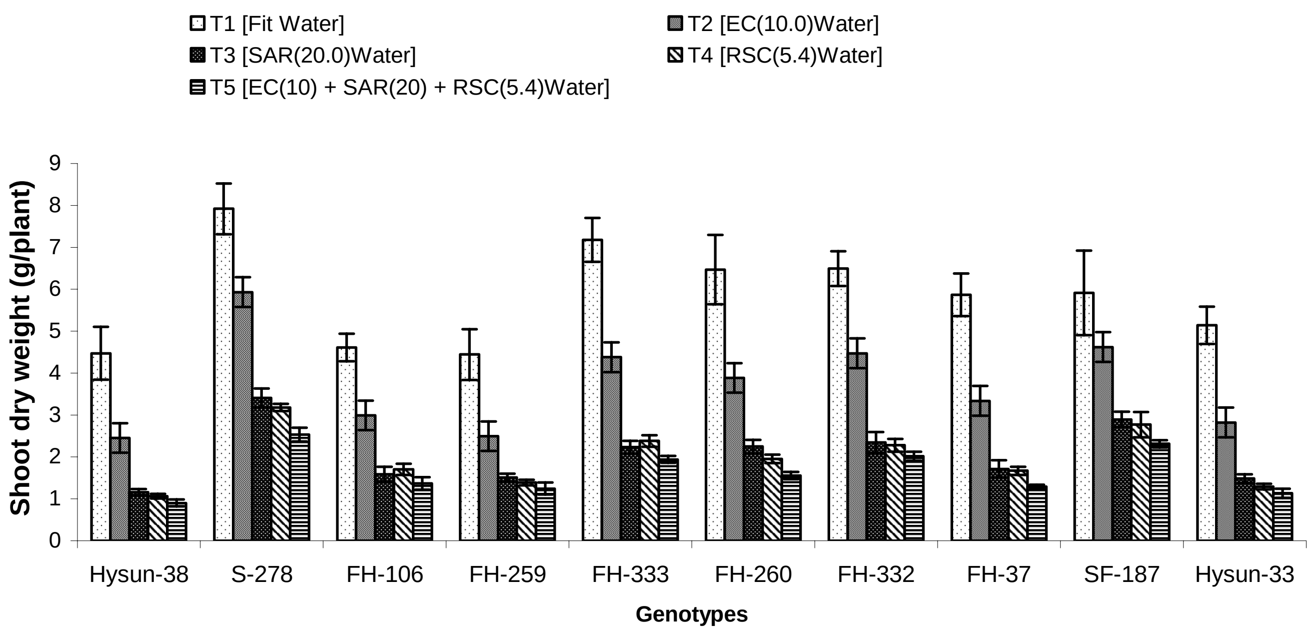

Figure 2. Effect of saline and/or sodic waters on shoot dry weight (g plant^{-1}) of sunflower genotypes

K^+/Na^+ ratio in plants is also considered as a good tool to determine plant resistance to salinity (Santa-Maria and Epstein, 2001). Reduction in K^+/Na^+ ratio of sunflower genotypes in the presence of salinity could be due to the antagonism of Na^+ and K^+ (Suhayda *et al*., 1990). Wide differences among sunflower genotypes for K^+/Na^+ ratio could be attributed to their restriction ability for both the uptake of Na^+ by root cells and also the movement of Na^+ to shoots by controlling their influx into the root xylem from root cells (Hu and Schmidhalter, 1997). In fact, it is possible that a high K^+/ Na^+ ratio is more important for many species than simply maintaining a low concentration of Na^+ (Cuin *et al*., 2003; Mark and Romola, 2003). Many workers have already demonstrated high K^+/Na^+ as reliable

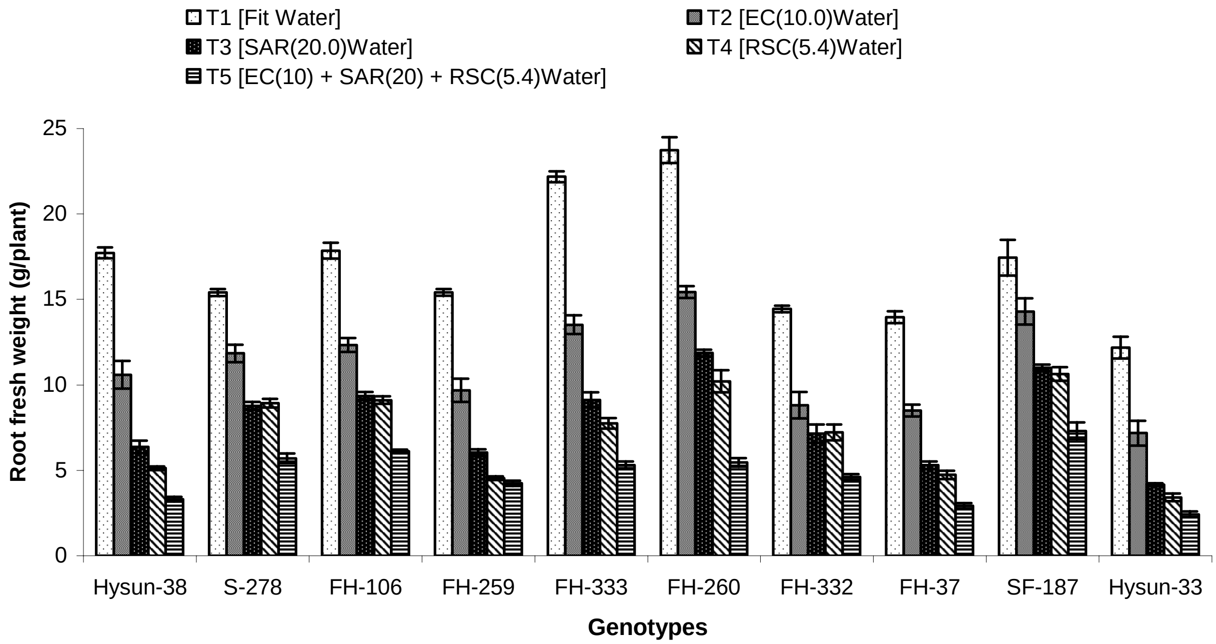

Figure 3. Effect of saline and/or sodic waters on root fresh weight (g plant^{-1}) of sunflower genotypes

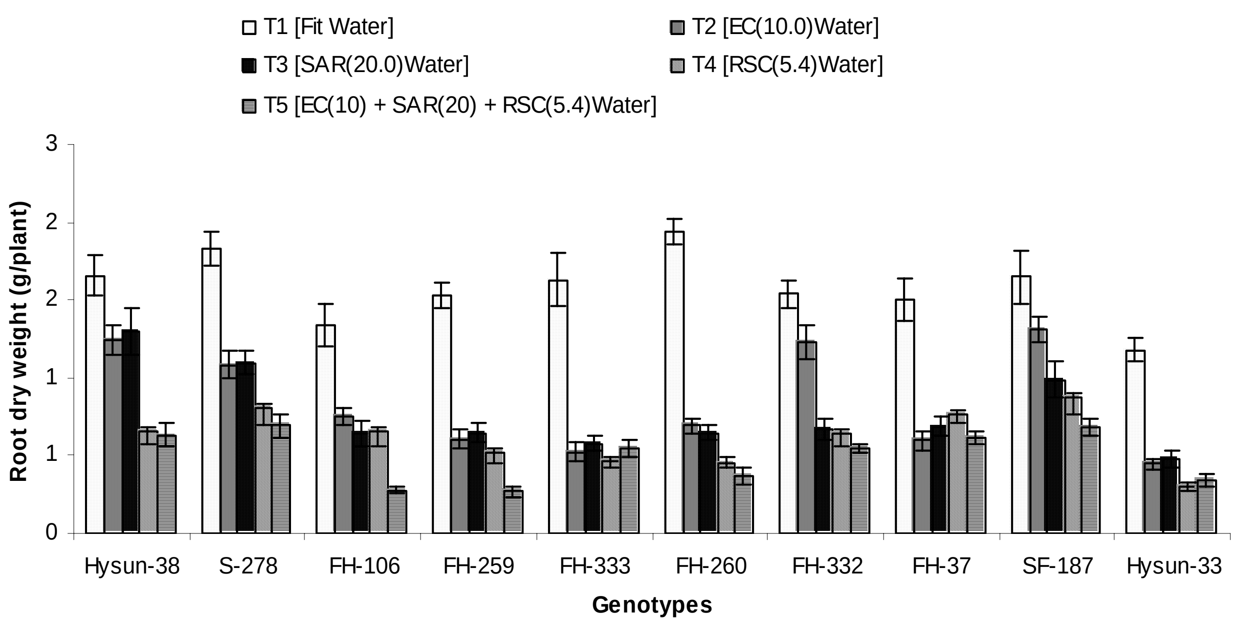

Figure 4. Effect of saline and/or Sodic waters on root dry weight (g plant–1) of sunflower genotypes

parameter for determination of salt tolerance in different crops. (Ashraf, 2002; Aslam *et al*., 2003; Ibrahim *et al*., 2007). Thus the ratio of K^+/ Na^+ is an important factor to be considered as selection criteria.

Conclusion

Solution culture experiments are successful in recognizing salt tolerant genotypes at early growth stage of plants, by using growth parameters and ionic concentration.

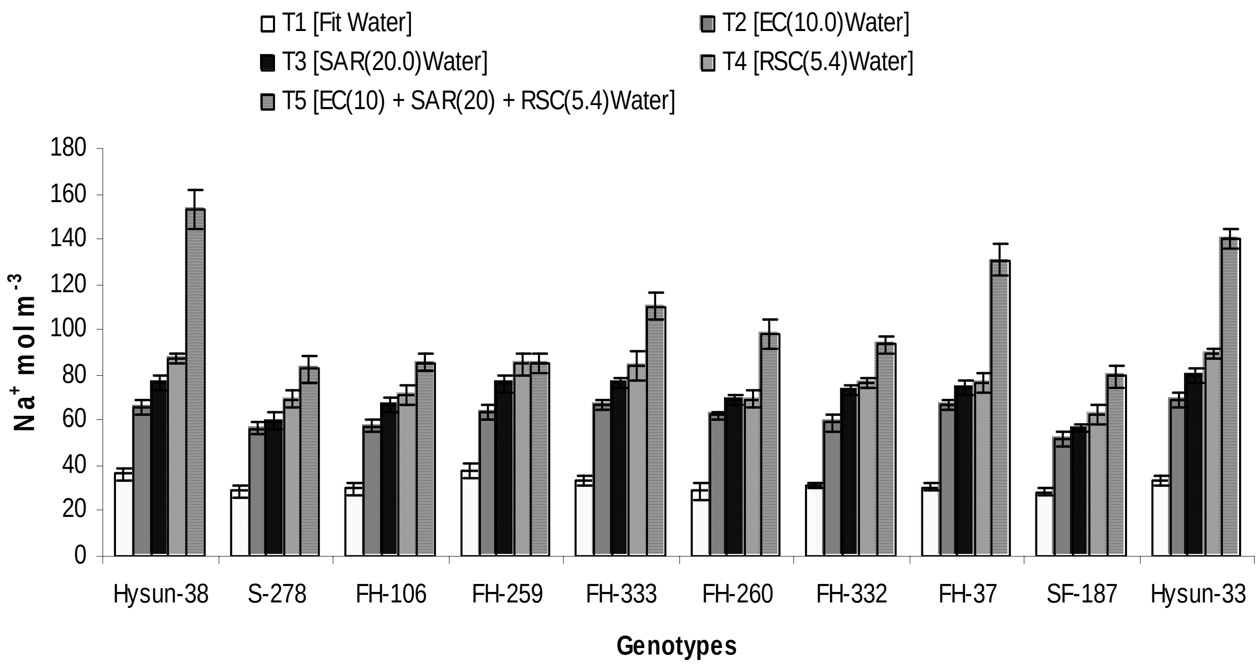

Figure 5. Effect of saline and/or Sodic waters on Na^+ (mol m^{-3}) of sunflower genotypes

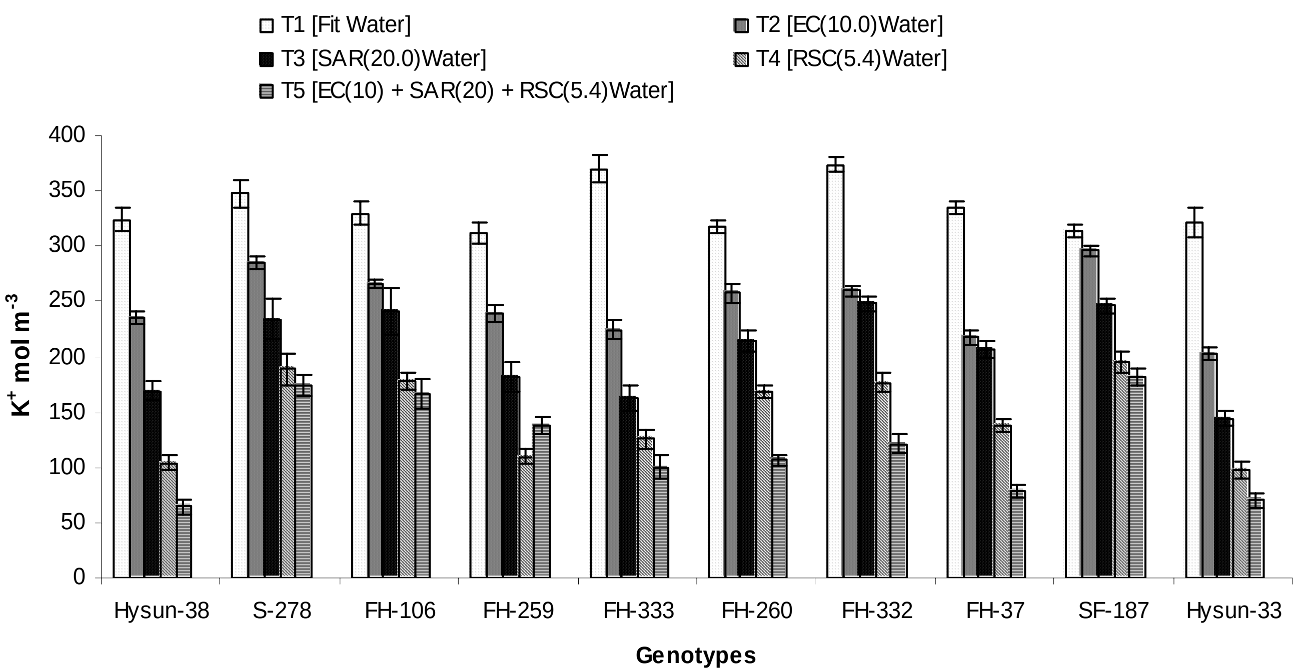

Figure 6. Effect of saline and/or Sodic waters on K^+ (mol m^{-3}) of sunflower genotypes

Clear comprehension of present study revealed that salt tolerant sunflower genotypes showed a consistent higher K^+/Na^+ ratio in cell sap, contrary to salt sensitive genotypes. On the basis of K^+/Na^+ ratio and salt tolerance % SF-187 and S-278 proved to be the salt tolerant genotypes while Hysun-33 and Hysun-38 were ranked as salt sensitive genotypes.

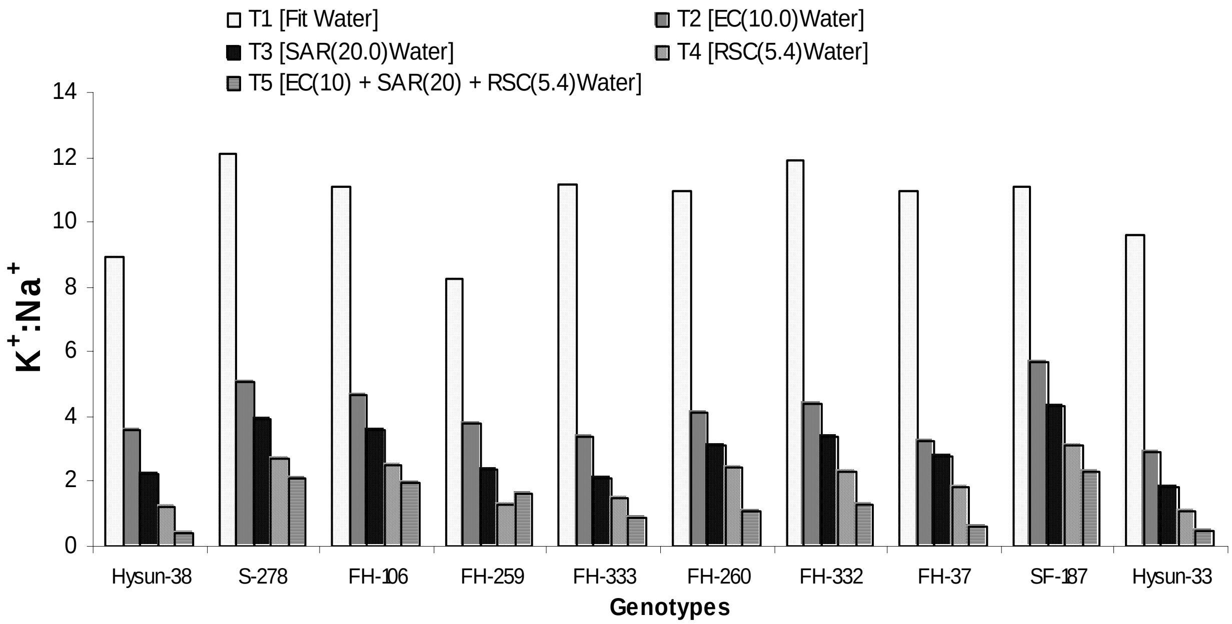

Figure 7. Effect of saline and/or Sodic waters on K^+: Na^+ ratio (mol m^{-3}) of sunflower genotypes

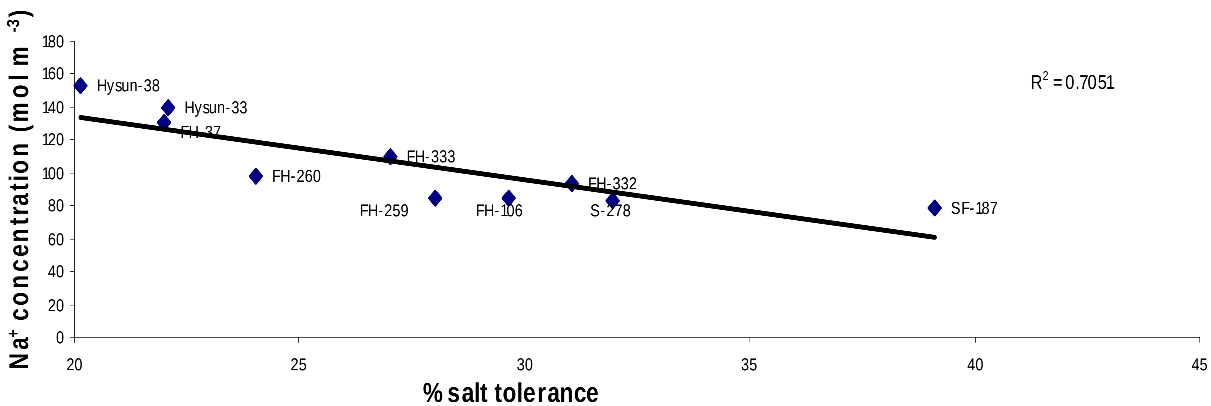

Figure 8. The correlation between Na^+ concentration (mol m^{-3}) in leaf and salt tolerance % with respect to shoot dry weight

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