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Interactive effect of salinity and boron application on growth and physiological traits of sunflower *(Helianthus annuus* L.) genotypes

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Abstract

Soil salinity is a major problem of agriculture in Pakistan. Permanent solution of salinity problem is removal of salts by leaching and drainage whic is expensive. So research efforts should involve profitable utilization of these lands through biological approaches. Considering these observations, this study was designed with the objectives to explore changes in growth and physiological attributes of different sunflower genotypes under interactive effect of salinity and boron. Vigorous seeds of selected genotypes (two tolerant, two sensitive) were sown in gravels. One week old seedlings were transplanted to ½ strength Hoagland's nutrients solution. *Three days after transplantation the requisite salinity (control and 100 mM NaCl) and boron levels (0.05 mM B, 0.5 mM B and 1.0 mM B as H_3BO_3) were established in three installments. The arrangement of the experiment was split plot with three replications. The data regarding shoot and root fresh weights, relative water contents (RWC), membrane stability index (MSI), and leaf area (LA) were recorded. The results revealed that salinity and boron adversely affected the growth and physiology of sunflower genotypes with a higher effect in the case of combined stress. This study also showed that the growth reduction was more in the salt susceptible genotypes (Hysun-33, Hysun-38) than in the salt tolerant genotypes (SF-187, S-278).*

Keywords: Boron, growth, membrane stability index, salinity, sunflower

Introduction

Throughout the world more than 800 m ha land is salt affected (FAO, 2008). Mostly salt affected lands are developed naturally as a result of salt accumulation over extensive periods of time in areas with less precipitation (Rengasamy, 2002). High salt concentrations cause a reduction in plan productivity and may lead to plant death (Parida and Das, 2005). Severe effects of salinity on plant growth are characterized as: (1) less availability of water to plants due to high osmotic potential of soil solution due to salinity, (2) specific ion effects due to high concentration of certain ions (e.g. Na^+, Cl^-, B etc.) and (3) ion imbalance due to decreased availability of certain ions (Munns, 2005; Saqib *et al.* 2006).

In saline lands high amount of boron is often present and during leaching process, leaves the soil system slowly; therefore, it may still be found in high amount in some reclaimed soils (Nable *et al*., 1997). Important role is played by boron in membrane processes and metabolic pathways and is also important for cell wall (Blevins and Lukaszewski, 1998; Lauchli, 2002; Brown *et al*., 2002). Like salinity, high boron is also an important abiotic stress that negatively affects crops. Around the world, in many crop lands, both high salinity and high boron are present together (Tanji, 1990). High concentration of salinity and boron adversely affects the membrane and photosynthesis by increasing stomatal resistance and upsetting the biosynthesis of photosynthetic pigments (Karabal *et al*., 2003; Sairam *et al*., 2005). In spite of the common occurrence of high salinity and high boron in different parts of the world, a little work has been conducted to explore the interaction of the two (Gratten and Grieve, 1999; Ben-Gal and Shani, 2002).

Sunflower (*Helianthus annuus* L.) is a significant source of vegetable oil i.e., unsaturated semidrying type like corn (*Zea mays* L.), sesame (*Sesamum indicum* L.), and cotton seed (*Gossypium spp*.). It is used in food preparation. Sunflower is also cultivated as a food source for direct utilization (i.e. seeds in snacks, candies, and birdfeed) (Xianan and Baird, 2003). In the year 2006-2007 domestic production of edible oil in Pakistan was estimated to be 0.855 Mt, the direct import of edible oil was 2.20 Mt and import of oil seeds was 0.35 Mt (Anonymous, 2006). This shows a great opportunity for raising oil seed crops in Pakistan. Francois (1996) suggested that sunflower is a moderately salt tolerant species being unaffected by salt stress up to 4.8 dS m^{-1}. On the basis of crop water stress index Katerji *et al*. (2000) sorted sunflower as salt tolerant crop. Furthermore, as it requires less number of irrigations,

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it may be successfully cultivated by applying saline sodic water with little harmful effects on physicochemical properties of soil.

Increasing salinity enhances the boron sorption which may be due to increased dissociation of H_3BO_3 in the presence of salts. A decrease in dry mass production, grain yield and root length, and an increase in boron and Na^+ concentrations under high concentration of boron and salinity has been reported (Holloway and Alston, 1992). The objective of the present study is to explore the interactive effect of salinity stress and boron application in sunflower genotypes of differential salt tolerance.

Materials and Methods

The seedlings of the selected sunflower genotypes [two tolerant (SF-187, S-278) and two sensitive genotypes (Hysun-33, Hysun-38)] were raised in gravels. The seedlings were transplanted in thermo pore sheets floating on 25 L capacity tubs, containing Hoagland's nutrient solution (Hoagland and Arnon, 1950). The arrangement of the experiment was split plot with three replications. Three days after transplantation the requisite salinity (control and 100 mM NaCl) and boron levels (0.05 mM B, 0.5 mM B and 1.0 mM B as H_3BO_3) were established in three installments. The treatments are summarized as: T_1= Control (non-saline + 0.05 mM B), T_2= (non-saline + 0.5 mM B), T_3= (non-saline + 1.0 mM B), T_4= (100 mM NaCl + 0.05 mM B), T_5= (100 mM NaCl + 0.5 mM B), T_6= (100 mM NaCl + 1.0 mM B). Thirty days after imposition of stress, harvesting was done and data about shoot and root fresh weights were recorded. Leaf area meter was used to determine leaf area per plant. Relative water contents (RWC) was determined on the basis of the following formula described by Weatherley (1950).

$$RWC = \left[\frac{\text{(Fresh Weight - Dry weight)}}{\text{(Turgid weight-Dry weight)}}\right] \times 100$$

Membrane stability index (MSI) was determined according to the method of Premachandra *et al*. (1990) as modified by (Sairam, 1994) and was calculated using the following formula.

$$MSI = [1-C_1/C_2] \times 100$$

Results

Shoot fresh weight of all the sunflower genotypes decreased with increasing levels of boron both under non-saline and saline conditions with a higer reduction under saline condition. In 0.05 mM B + non-saline treatment the maximum shoot fresh weight (g plant^{-1}) was in SF-187 (82) which was significantly higher as compared to S-278 (73) and Hysun-33 (71), while under 0.5 mM B application under non-saline condition SF-187 (77) showed maximum shoot fresh weight which was significantly higher than Hysun-38 (71), S-278 (69) and Hysun-33 (67) genotypes. In only saline and 0.5 and 1.0 mM B treatments under saline condition, SF-187 and S-278 produced the maximum shoot fresh weight which was significantly higher as compared to shoot fresh weight recorded in Hysun-33 (Figure 1). The reduction pattern in root fresh weight has also been shown by sunflower genotypes with increasing boron application under both saline and non-saline conditions (Figure 2). The maximum root fresh weight (g plant^{-1}) was noted in S-278 (12) and S-187 (8) in saline conditions and in saline + 0.5 mM boron (10, 7) and saline + 1.0 mM boron (9, 6). This was significantly higher than in Hysun-33 and Hysun-38 under the respective treatments. More reduction in membrane stability index was noted under combined application of boron and salinity as compared to salinity or boron alone (Figure 3). A significantly lower membrane stability index was observed in Hysun-33 as compared to SF-187 and S-278 by application of 0.5 and 1.0 mM B in non-saline conditions and similar trend was noted in these genotypes in saline medium with boron levels of 0.5 and 1.0 mM B. SF-187 showed significantly higher membrane stability index as compared to Hysun-38 and Hysun-33 in saline treatment alone. . SF-187 showed significantly high relative water contents in all treatments in both saline as well as non-saline conditions as compared to Hysun-33, which showed significantly lower relative water contents (Figure 4). Non-significant differences were noted among Hysun-38, Hysun-33 and S-278 genotypes by the application 1.0 mM B under saline conditions. In all treatments the maximum and significantly more leaf area was produced by SF-187 as compared to rest of the genotypes and Hysun-33 produced the minimum leaf area (Figure 5). The genotypes SF-187 and S-278 produced significantly higher leaf area than in Hysun-33 and Hysun-38 under saline conditions alone. Similar genotypic trend was shown by these genotypes under 0.5 and 1 mM B in saline conditions.

Discussion

The objective of this experiment was to test the performance of selected sunflower genotypes under combined stress of salinity and boron application. Results of experiment showed that the biomass in terms of shoot fresh weight and root fresh weight of sunflower genotypes reduced significantly in both saline and non-saline conditions with the application of 1 mM boron. However, growth was more adversely affected with the application of high boron concentrations under saline conditions. The toxic effect of boron and salinity was more prominent in the salt sensitive genotype (Hysun-33). In comparison to saline treatment alone, the percent decline in shoot fresh weight of the salt-sensitive genotypes Hysun-33 and Hysun-38 was

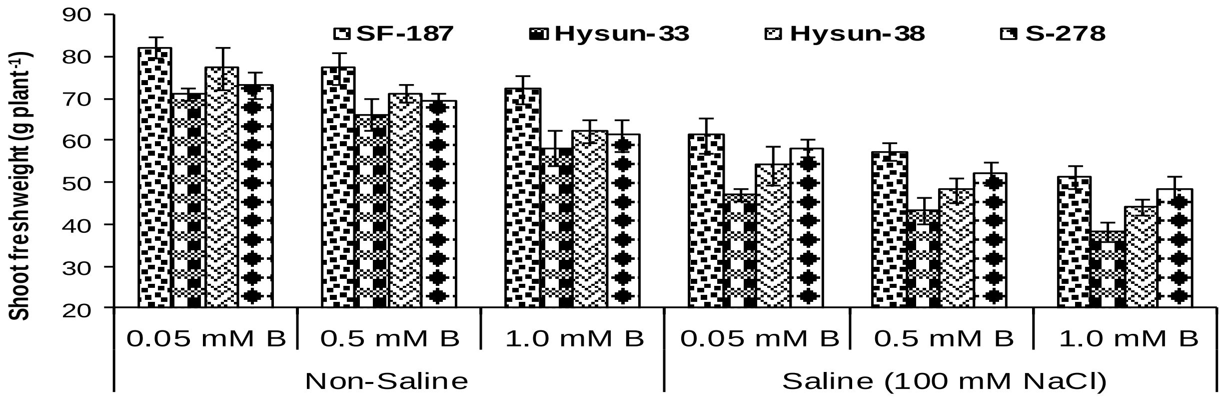

Figure 1: Interactive effect of salinity and boron application on shoot fresh weight (g plant^{-1}) of sunflower genotypes. The values are means of three replications ± SE

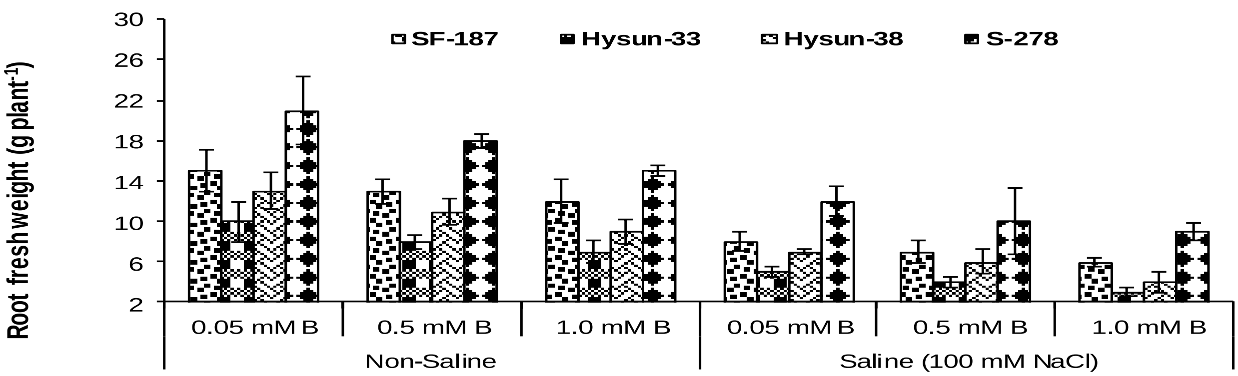

Figure 2: Interactive effect of salinity and boron application on root fresh weight (g plant $^{-1}$) of sunflower genotypes. The values are means of three replications ± SE

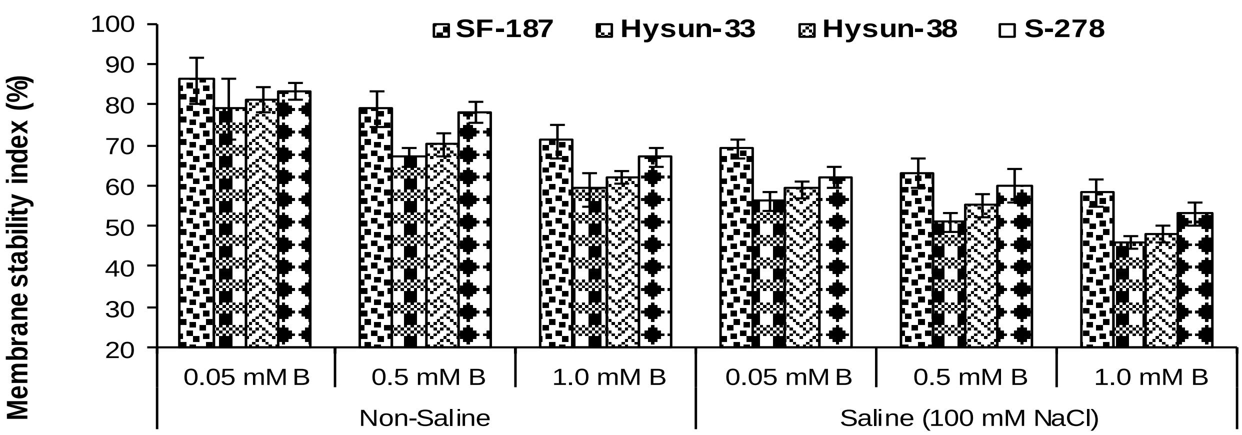

Figure 3: Interactive effect of salinity and boron application on membrane stability index (%) of sunflower genotypes. The values are means of three replications ± SE

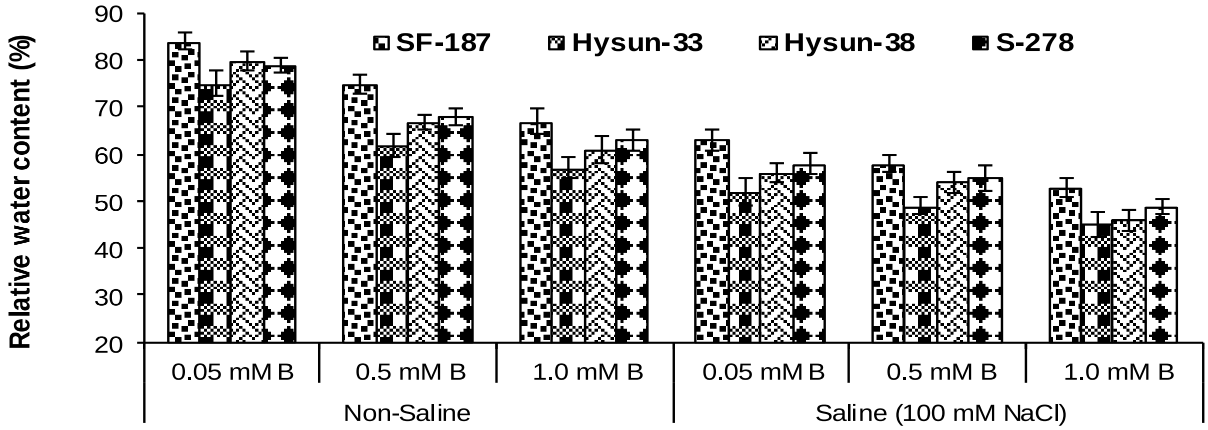

Figure 4: Interactive effect of salinity and boron application on relative water contents (%) of sunflower genotypes. The values are means of three replications ± SE

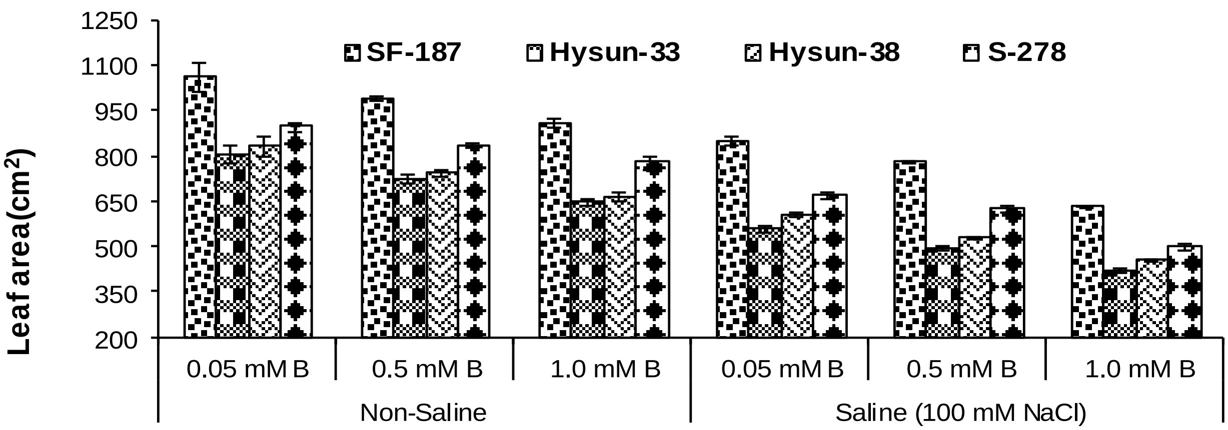

Figure 5: Interactive effect of salinity and boron application on leaf area (cm^2) of sunflower genotypes. The values are means of three replications ± SE

higher than the salt tolerant genotypes SF-187 and S-278 when grown at 1.0 mM boron under saline conditions.

Similarly the extent of reduction in the root fresh weight was more in the salt susceptible genotypes than in the salt tolerant genotypes. Our findings are supported by Alpaslan and Gunes (2001) who reported that adverse effect due to boron application was more in salt sensitive cucumber plants than in the salt tolerant tomato plants. Comparable effects due to interactive effect of salinity and boron application on growth have also been described earlier by Grieve and Poss (2000) and Holloway and Alston (1992). Membrane stability index was markedly decreased under saline conditions by the application of 0.5 and 1 mM boron and the decrease was higher in Hysun-33 and Hysun-38 than SF-187, S-278. Similar results have also been reported by Ismail (2003) that membrane permeability was high in maize (salt sensitive) as compared to sorghum (salt tolerant) while growing under saline conditions with high boron levels. Among genotypes SF-187 showed better performance in relative water contents and leaf area production than Hysun-33 which showed the minimum production of leaf area and poor maintenance of relative water contents. Such findings could be explained by the fact that boron sensitivity apparently induces a number of metabolic processes like decrease in the expansion of meristematic tissues resulting in the loss of leaf area and the production of necrotic regions on mature tissues which decreases the transport of photosynthates to younger parts of the plant (Nable *et al*., 1997). Tripler *et al.* (2007) found that plant growth and water uptake was less affected under boron application of 0.463 mmol L^{-1} while plant size was decreased substantially by application of higher level of boron (1.85 and 3.71 mmol L^{-1}) in irrigation water. Mostly the experiments on wheat (Holloway and Alston, 1992; Grieve and Poss, 2000) tomato (Alpaslan and Gunes, 2001; Ben-Gal and Shani, 2002), chickpea (Yadav *et al*., 1989) and eucalyptus (Gratten *et al.*, 1997; Marcar *et al*., 1999) show higher growth reduction due to a combined stress of salinity and boron toxicity as compared to their individual effects..

Conclusion

It is concluded from the current study that combined effects of salinity and boron application limit the growth of all sunflower genotypes and capabilities of Hysun-33 and Hysun-38 is less to tolerate salinity and boron application than that of SF-187 and S-278.

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