INT. J. BIOL. BIOTECH., 12 (2): 329-336, 2015.

SALICYLIC ACID ENHANCES WHEAT PLANT GROWTH UNDER WATER STRESS CONDITIONS

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ABSTRACT

Salicylic acid (SA) exogenous application could modify the physiological and morphological capacity wheat plants in water stress condition. A greenhouse experiment was conducted with seeds of a drought tolerant (NARC-2009) and a susceptible (PAK-2013) wheat varieties. At tillering stage drought was induced by holding water and salicylic acid (SA) was applied at three levels (0, 5, and 10mM). The parameters investigated were shoot and root length, fresh and dry weight, relative water content (RWC), membrane stability index (MSI) and chlorophyll content. Results showed that water stress reduced the dry, fresh weights, shoot length and chlorophyll content, RWC and MSI. It was clearly observed that SA application via root enhance water stress tolerance of wheat seedlings and alleviated the effect of drought as compared to PAK-2013, NARC-2009 shows better results. The results of this study indicated the role of salicylic acid (SA) in enhancing plant growth under stress condition.

Key words: Salicylic acid, Water stress, Wheat, Physiology

Introduction

Crop plant production is affected by biotic and abiotic factors. Abiotic stress include water shortage, high salts, high and low temperature effect plant growth but water shortage is major limiting factor for crop plant production and it is increasing day by day (Gamze *et al*., 2005; Passioura, 2007). Water stress will be there when there is reduced water availability in the soil or high salinity (Khaje Hosseini *et al*., 2003). Plant are severely affect by this and many factors involved in the response of plants to water stress, which are developmental stages, severity of the stress, duration of stress and cultivar genetics (Beltrano and Marta, 2008). Plants produce proteins as a reaction to biotic and abiotic stresses to reduce them which were induced by some phytohormones such as Salicylic Acid (SA) (Davis, 2005).

Seed germination, stomata adjustment, absorption and transfer of ions are regulated by endogenous growth regulator salicylic acid. SA is a conservative compound of some biotic and abiotic stresses. SA acts as important molecular signal for plants adjustment under abiotic stress (Waseem *et al.*, 2006; Arfan *et al.*, 2007). In plants various physiological processes are regulated by SA such as growth, transpiration rates, photosynthetic processes and stomatal regulation, ion uptake and transport (Gunes *et al*., 2005). Moreover, salicylic acid also reduces negative effects of various abiotic stresses by increasing internal level of other plant growth regulators in plants (Sakhabutdinova *et al.*, 2003). Wheat is consumed as food by about 35% of the human population .Wheat is a staple food so, wheat plant growth and yield under different abiotic stress condition is compulsory (Zhu *et al*., 2000). Thus, present study was conducted to assess the role of SA in alleviating the adverse effects of drought stress on wheat plants.

MATERIALS AND METHODS

This experiment was conducted in PMAS Arid Agriculture University, Rawalpindi, Pakistan and wheat varieties seeds NARC 2009 drought tolerant and PAK 2013 drought susceptible were obtained from Crop Science institute, NARC, Islamabad. The experimental design was completely randomized. Sodium hypochlorite 5% solution was used for seed surface sterilization and washed thoroughly with distilled water. After that surface sterilized seed were planted. Drought was induced by holding water at tillering stage of plant and then the SA was applied regularly for 1 week in solution form.

T_0 = Control; T_1 = Drought; T_2 = 5 mM Salicylic acid + Well water; T_3 = 5 mM Salicylic acid + Drought;
T_4 = 10 mM Salicylic acid + Well water; T_5 = 10 mM Salicylic acid + Drought

Morphological Parameters

Different morphological parameters such as root, shoot length, fresh, dry weight and turgid weight of the plant were measured.

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Physiological Parameters

For relative water content leaves were kept in water for 24 hours and then turgid weight was measured after this plant were oven dried for two days at 75ºC and then their dried weight was measured. The RWC was calculated by the following formula:

$$RWC = [(FW - DW)/ (TW- DW)] \times 100$$

To measure the membrane stability index the leaf disc of the each plant samples were taken into 10ml distilled water and heated in water bath at 40ºC for 30 minutes and measured EC that was C1. Then the same sample was again heated at 100ºC for 10 min and measured EC as C2. The MSI was calculated by the following formula:

$$M.S.I= [1- (C1/C2)] \times 100$$

The pigments were estimated according to Arnon (1949) and expressed in mg per g FW.
Chlorophyll a, b, total chlorophyll and carotenoids were measured according to the following formulas:
Chlorophyll a = 12.7 (A633) - 2.7 (A645), Chlorophyll b = 22.9 (A645) – 4.7 (A633)
Total chlorophyll = Chlorophyll a + Chlorophyll b

RESULT AND DISCUSSIONS

The present results suggest that an exogenous application of SA may help to decrease the hostile effects of water stress in wheat. It was observed that SA in two different wheat varieties shows different result in morphological and physiological parameters against drought stress. Drought stress drastically reduced the seedling fresh and dry weight. Application of different concentrations (5mM, 10mM) of salicylic acid to wheat plants under stress condition change their growth pattern as compared to control plants. Water stress is important abiotic factors that drastically influence the growth and development of crop plant (Ren *et al*., 2007). Crop plants response to stress condition depends upon on plant species, timespan of stress and stage of development of plant (Bray, 1997). In present study, we investigate that drought effect many morphological parameters of plant by reducing the shoot 0 length, increasing root length, decreasing fresh and dry weight, while application of SA was proved to be effective in reducing the drought stress damages. Different concentrations shows different effect in both varieties i.e. (5mM) SA under drought increase the root length in susceptible but decrease root length in tolerant variety (Fig. 01). The increase root system of the plant may facilitate it to adapt under water stress. Jaleel *et al*., (2007) explain that this may help plants in selective ion uptake, transportation as well as maintain the water status of the plant. SA pronounced this effect under stress and enable the plant to overcome the adverse conditions of stress. Similarly (5mM) SA shows more pronounced increase in shoot length under drought as compared to 10mM in both varieties (Fig. 02). These result shows that salicylic acid at low concentration is more effective. These findings are in agreements with other workers shows that application of SA through the rooting medium increased shoot length under drought and salinity (Shah *et al*., 2002; Arfan *et al*., 2007; Baghizadeh *et al*., 2009). Fresh and dry weight are drastically reduced under water stress conditions but improved fresh and dry weight was observed with SA treatment and 5mM SA was proved more effective in drought condition as compared to10mM SA (Fig. 03 and 04) but in both well water and drought condition tolerant variety (NARC 2009) showed better results as compared to the susceptible variety (PAK 2013). These results are in agreement with that of Arfan *et al.*, (2007); Farooq *et al*., (2009); Farooq *et al*., (2010). Singh and Usha, (2003) showed that exogenous application of SA increased total dry and fresh weight of plant under stress condition. Their finding indicates that increase in dry weight of plants under stress in response to SA application due to the induction of antioxidant responses that protect the plant from damage (Shakirova *et al*., 2003; Khodary, 2004; El-Tayeb, 2005).

SA application enhances the physiological processes of the wheat plant under unfavourable conditions. Exogenous application of SA different concentration had major effect on plant water relation in drought condition. Present findings suggest that SA also increased the relative water content of plants in the stress conditions (Fig: 05). In stress plant relative water content was relatively low as compared to well water. In drought relative water content tended to drop as transpiration rate overdo absorption leading to decrease in cell turgor (Tas and Tas, 2007). Similar results were obtained in barley (Kocheva *et al.* 2005), wheat (Lei *et al.* 2007), *Nigella sativa* (Kabiri *et al.*, 2014) and rice (Hsu and Kao 2003) under drought stress. Treatments with different concentration of SA increased the RWC as compared to stress plant (Fig. 05). These results were in agreement with the findings of (Singh and Usha 2003; Kabiri *et al.*, 2014). They also reported that increase of RWC may be related with the role of SA in accumulation of compatible osmolytes in plants subjected to drought stress. A number of scientist suggested that in stress conditions stability of the cell membrane was disturbed due to accumulation of ions consequently the ion leakage started and the wilting of leaf examined. SA applications enhanced membrane integrity and stability and significantly higher MSI was observed with application of SA than those of stress plants (Fig. 09).

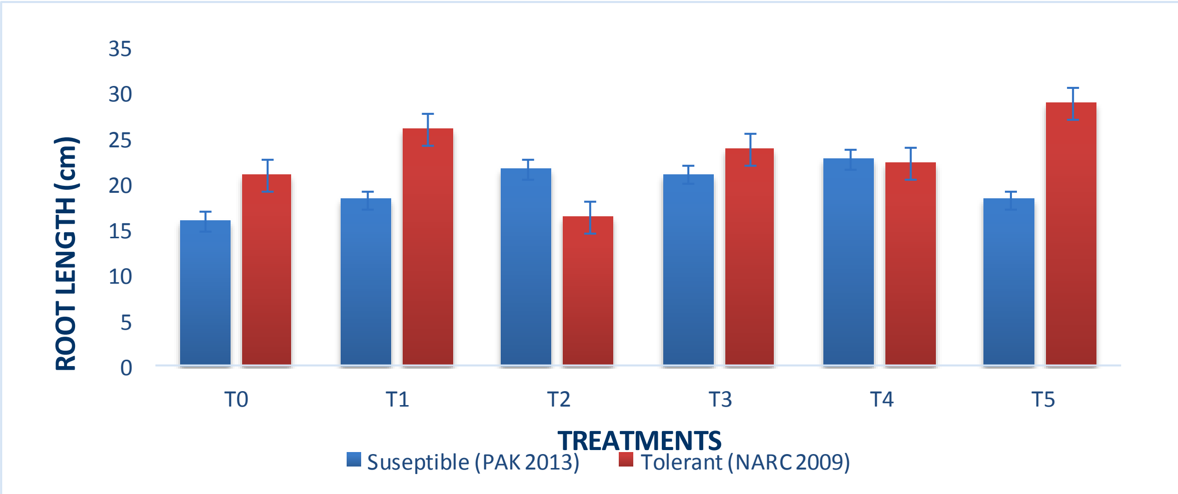


Fig..1. SA effects on root length of two varieties of wheat PAK 2013 (drought susceptible) and NARC 2009 (drought tolerant). T_0 well water, T_1 Drought, T_2 5mM+well water, T_3 5mM+drought, T_4 10mM+well water, $T_5$10mM+drought.

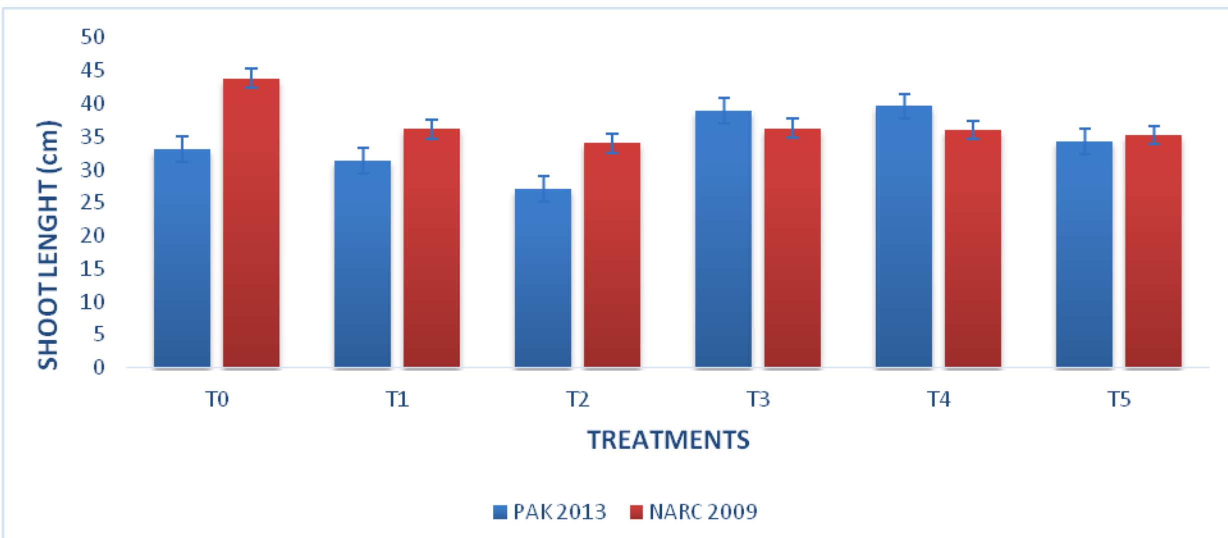


Fig. 2. SA application effects on shoot length of wheat varieties.

Drought stress affects the integrity of cell membrane established by lower value of MSI (Tas and Tas, 2007). Membrane stability is the major component of water stress tolerance (Sairam *et al*., 1997) Exogenous application of SA enhances the accumulation of Ca^{+2} which can keep membrane stability (Khan *et al*., 2010). These finding are similar with that of Kabiri *et al.* (2014). In crop plant photosynthesis is chief physiological processes and that enhance crop growth and productivity. However, photosynthetic rate varies with the alteration in ecological factors thereby affecting plant growth and development (Ashraf and Ashraf, 2012). Several abiotic stresses reduce photosynthesis in which drought is major one. In present study, chlorophyll a, b and total chl. content of water deficit wheat plants was significantly decline as compared to controls (Fig. 06-08). Reduction of chlorophyll content may reduce photosynthesis, reduction of photosynthetic pigments in drought stress could be related to degradation of chloroplast structure and photosynthetic apparatus, chlorophyll photo oxidation, destruction of chlorophyll substrate, inhibition of chlorophyll biosynthesis, and the increase of chlorophyllase activity (Kabiri *et al.*, 2014). But in the present study, in both wheat varieties SA application via roots enhanced chlorophyll content of plant under stress condition (Fig. 06-08). In present study exogenously applied SA increased chlorophyll content and that was in agreement with some earlier studies in which it was found that exogenously applied SA increased the chlorophyll content in different crops, e.g., *Brassica napus* (Ghai *et al.* 2002), soybean (Khan *et al*., 2003), wheat (Waseem *et* *al*., 2006), and maize (Khan *et al*., 2003; Khodary, 2004), barely (El-Tayeb 2005), *Nigella sativa* (Kabiri *et al*., 2014). Enhancement of the level of chlorophyll pigments, photosynthetic rate, carboxylase activity of Rubisco, and modification of the activity of some other important enzymes – have been done to SA (Hayat and Ahmad, 2007).

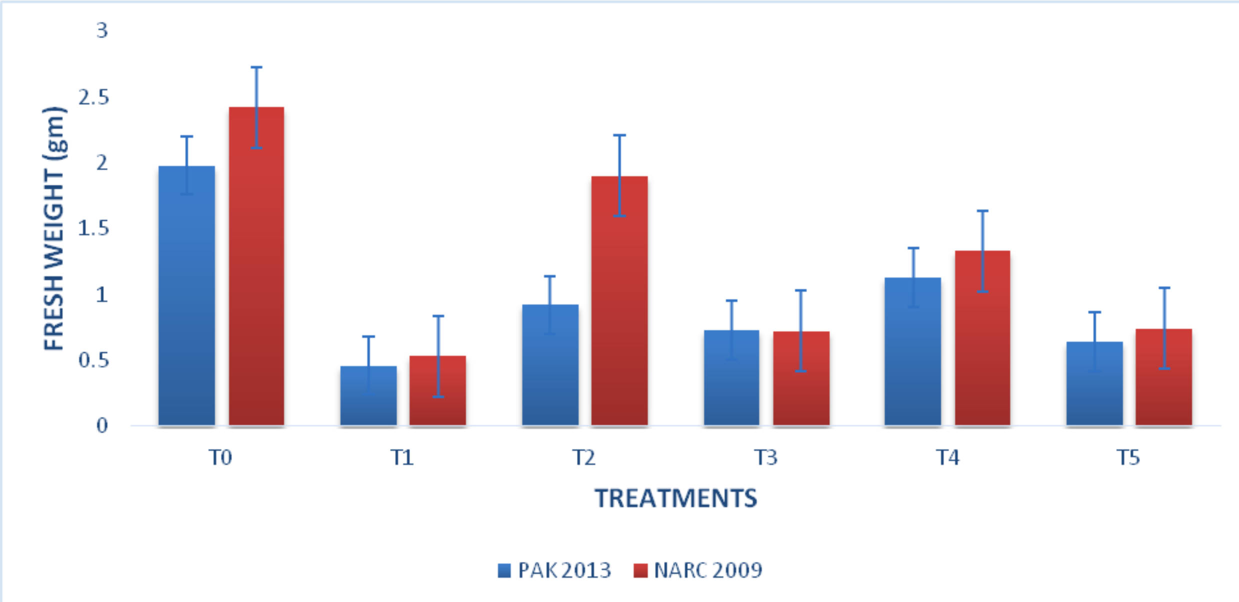


Fig. 3. Effects of SA application on the fresh weight of seedlings of Wheat varieties.

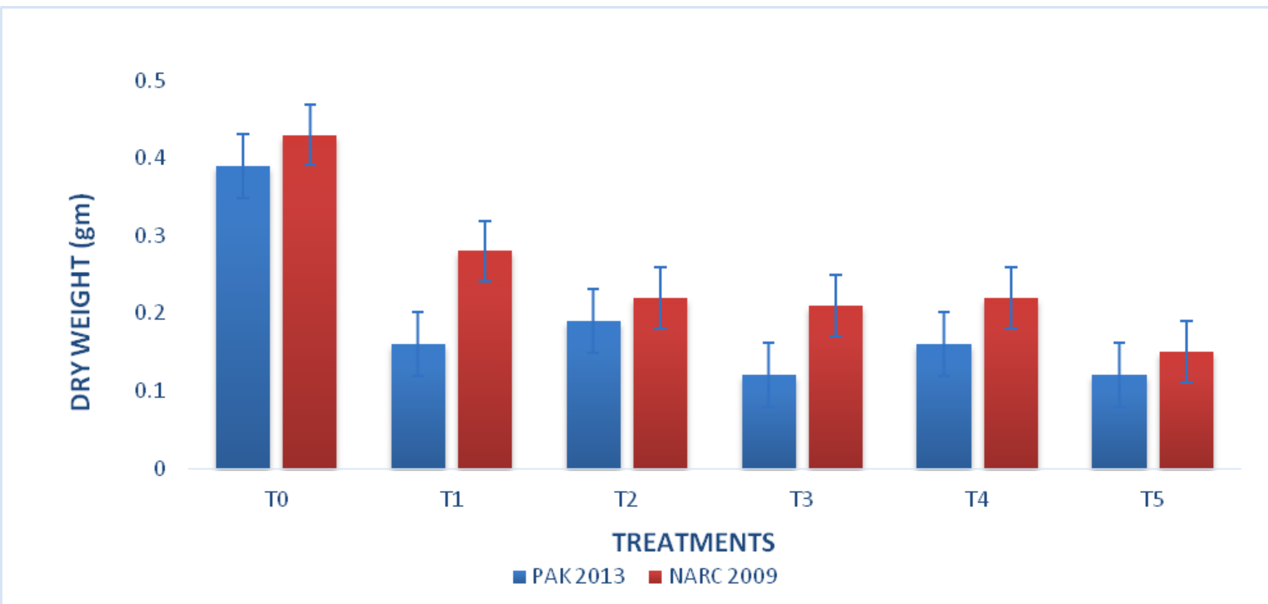


Fig. 4. Effects of SA application on the dry weight of seedling of Wheat varieties.

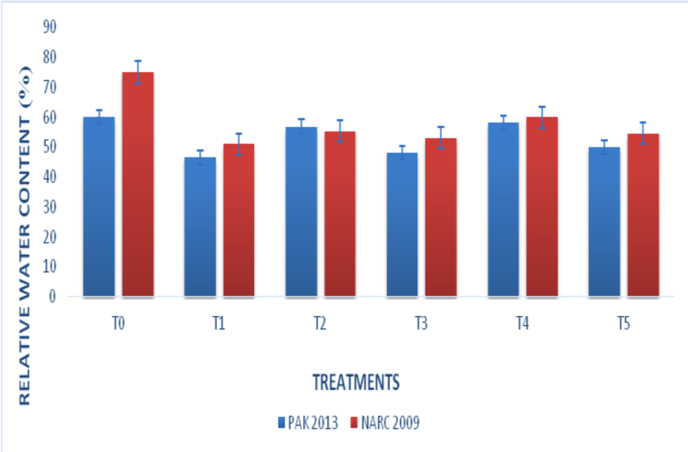
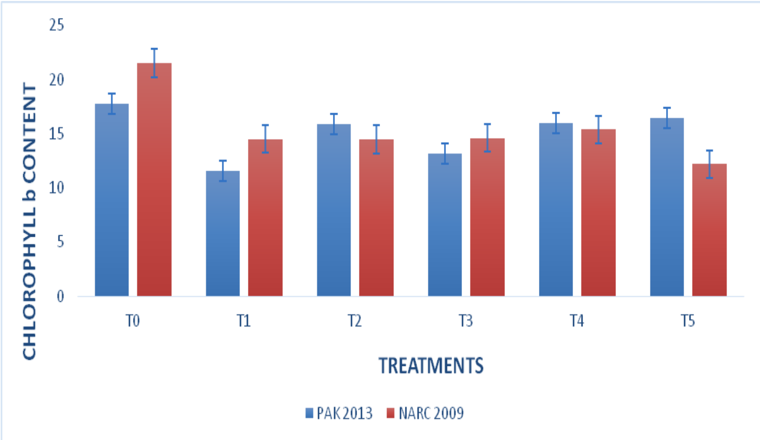


Fig.05. Effects of SA application on relative water content (RWC) of seedling of Wheat varieties.



Fig, 6. Effects of SA treatments on the Chlorophyll b content of Wheat Varieties.

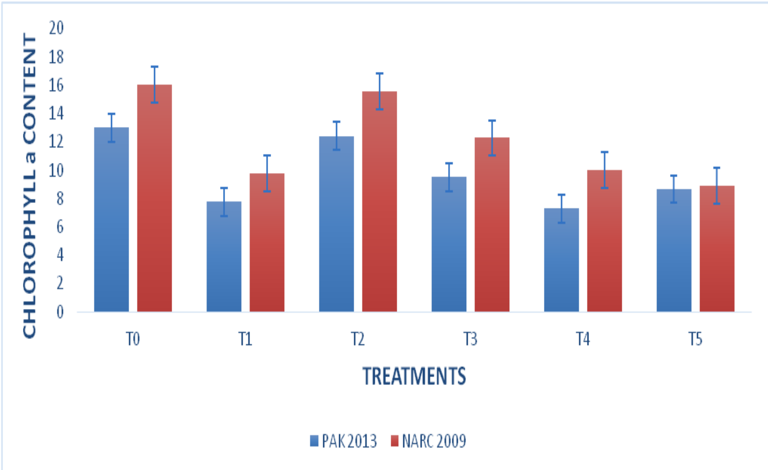


Fig.07. Effects of SA treatments on the Chlorophyll a content of the Wheat Varieties.

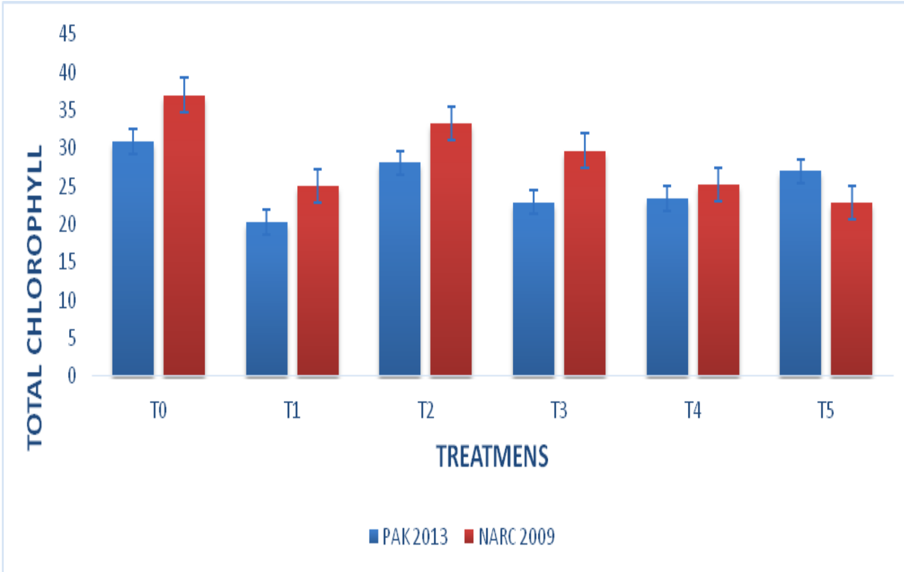


Fig. 8. SA treatments on the total Chlorophyll content of the Wheat Varieties.

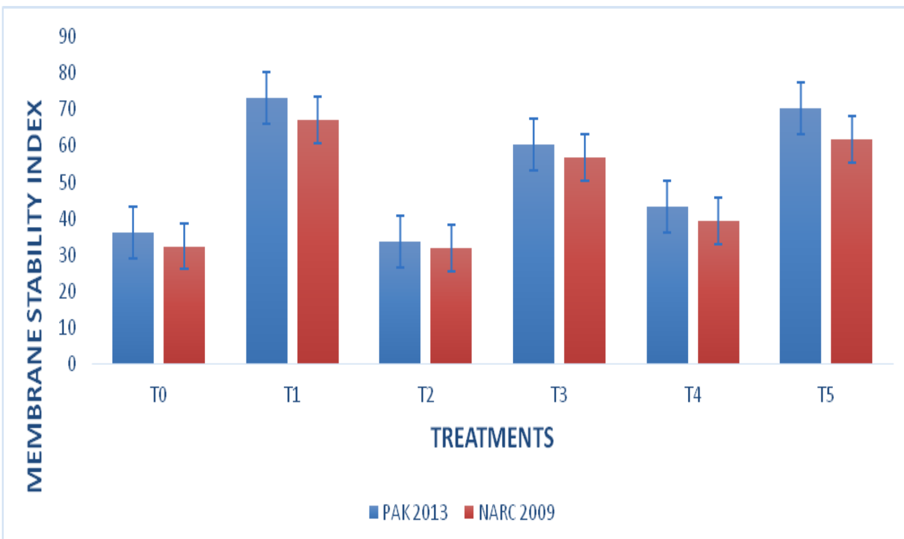


Fig. 9. SA effects on membrane stability index (MSI) of seedling at different concentrations in Wheat varieties.

Conclusion

It may be concluded that salicylic acid increases the drought tolerance in both varieties. However, the same SA treatment shows more pronounced effect in NARC 2009 then PAK 2013. Thus the exogenous application of SA may be considered to be variety specific.

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(*Accepted for publication March 2015*)