Research Article

Salicylic Acid Induced Physiological and Ionic Efficiency in Wheat under Salt Stress

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Abstract | Soil salinity is a menace that is affecting the agricultural soils and turning these soils into low productive ones and interfere the normal crop development. Wheat is an important cereal crop and salinity is also affecting the growth and yield of this crop. While salicylic acid is found to play a helpful role in supporting the plant growth and development under salt stress. Keeping in view these factors a hydroponic experiment was conducted on wheat with two levels of salicylic acid (0.25 mM and 0.50 mM) under two salt levels (75 mM and 150 mM) to assess that whether the salicylic acid is helpful in coping the harmful effects of salinity on crop growth or not and if it has certain positive response then which level is more suitable for wheat crop growth along with the genotypic assessment of salt tolerance in wheat cultivars (Faisalabad-2008 and Punjab-2011). Punjab-2011 performed better under normal and saline conditions than Faisalabad-2008. Shoot length reduction was 13.15 and 27.50% for Faisalabad-2008 and Punjab-2011 respectively under 75 mM salt stress but response at higher level 150 mM was different with 34.21 and 25.0% reduction in shoot length for Faisalabad-2008 and Punjab-2011 respectively. A significant improvement in shoot length was observed with the application of salicylic acid. Same trend was found for root length. Salt stress lowered the chlorophyll contents, number of tillers and K^+/Na^+ ratio in both genotypes but the application of salicylic acid improve all the mentioned parameters significantly. The treatment effect of 0.25 mM salicylic acid was more effective under both levels of salt stress as compared to 50 mM salicylic acid treatment. Genotypic differences were non-significant but cumulatively Punjab-2011 showed better performance as compared to Faisalabad-2008.

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Keywords | Salinity, Wheat, Growth, Number of tillers, Ionic contents

Introduction

Soil salinization is a major growth and development retarding factor for many crops in arid to semi arid zones (Yusuf et al., 2008). The unchecked and excessive use of water unfit for irrigation having high salts content is the main contributor in aggravating this problem (Chinnusamy et al., 2005). Physiological and biochemical processes are severely affected due to salinity resulting in poor growth and yield

(Khan et al., 2009). The physiology of the plants is disturbed because of osmotic stress, ionic imbalances, improper nutrition and oxidative damage under saline environment (Flowers, 2004). Reduction in plant height (Jamil et al., 2007; Ruiet al., 2009), fresh and dry biomass of root and shoot (Ashraf and Ali, 2008; Shahbazet al., 2010) and leaf area (Zhao et al., 2007; Yilmaz and Kina, 2008) is reported under salt stress.

Salicylic acid (SA) plays a vital role in defense machinery of plants as a signaling molecule under stress environments (Kang et al., 2012). Salicylic acid induced tolerance in barley (Metwallyet al., 2003; El-Tayeb, 2005), wheat (Singh and Usha, 2003), maize (Janda et al., 1999) and mustard (Dat et al., 1998) under heavy metal, salinity, drought, chilling and heat stress respectively, represent its importance in crop growth and development under stress conditions. It imposes tolerance to salinity in wheat plants because by signaling the plant to respond against abiotic stresses (Shakirova et al., 2003; Senaratna et al., 2000). Salicylic acid is considered as a endogenous growth simulator as in wheat it improves the plant dry biomass (shoot and root), K^+/Na^+ ratio and chlorophyll contents (Kaydan et al., 2007) and in soybean it is reported to increase the leaf area of the plants (Khan et al., 2003).

Globally, wheat (*Triticumaestivum* L.) is considered as an important cereal crop among others because it is utilized as a staple food in 1/3rd countries of the world as a food grain. While in Pakistan it ranks 1st in the cereals group (FAO, 1998) and is been cultivated on a vast area of 9.20 million hectares, yielding 25.08 million tons of grain per annum out of which 19.28 million tones is produced by the province Punjab from an area of 0.69 million hectares under wheat cultivation (ASP, 2014-15). Now a days its production and yielding potential is declining due to salt stress faced by the crop plants.

Keeping in view the importance of wheat crop in Pakistan and declining yield potential of the crop in salt affected areas this study was planned to assess the beneficial effect of salicylic acid on crop growth under saline environment.

Materials and Methods

This study was conducted in University of Agriculture Faisalabad, in the wire house managed by Institute of Soil and Environmental Sciences. Wheat seeds of two varieties (Faisalabad-2008 and Punjab-2011) were arranged from Institute of Soil and Environmental Sciences. Nursery was established in sand filled iron trays with routine check for sufficient moisture. At two leaf stage healthy seedlings were chosen from both varieties and were transplanted using foam plugs in polystyrene sheets floating over ½ strength Hoagland's solution (Hoagland and Arnon, 1950) with pH maintained daily at 6 ±0.5. Continuous aeration for 8 hrs was provided daily. Salinity (75 mM and 100 mM) was developed in the respective saline treatments within 10 days of transplantation using NaCl in three increments. Salicylic acid treatments (0.25 mM and 0.50 mM) were applied in respective saline and non-saline treatments by dissolving salicylic acid in ethanol. 2 genotypes of wheat (Faisalabad-2008 and Punjab-2011) were used with 5 replicates.

After one month of transplantation chlorophyll contents and number of tillers were recorded and plants were harvested. Growth attributes were recorded using meter rod and data for shoot length and root length was noted. Na^+/K^+ in wheat plants was recorded using flame photometer from the youngest fully expanded centrifuged (6500 rpm) leave sap that was detached at the time of harvest (Gorham et al., 1984). Recorded data was statistically analyzed using completely randomized factorial design with 9 treatments (3 levels of salicylic acid and 3 levels of salinity) and 5 replications (Steel and Torrie, 1987).

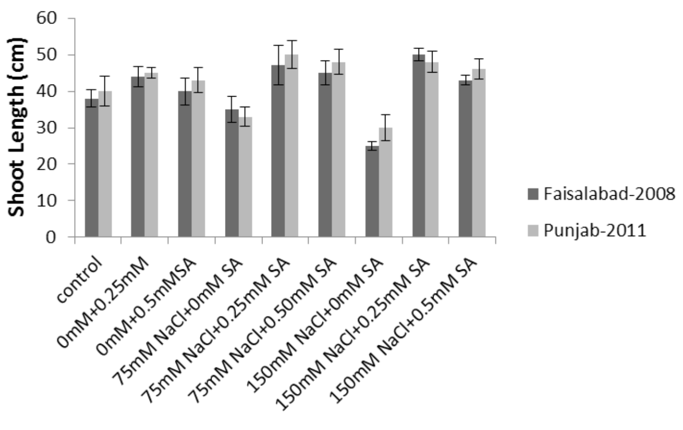

Figure 1: *Influence of SA on shoot length in different wheat varieties under salt stress.*

Results and Discussion

Effect of salicylic acid and on growth attributes (cm)
The treatment effect was found significant. Both levels (75 mM and 150 mM) of NaCl caused reduction in shoot growth (Figure 1). There was a decline in shoot

length in Faisalabad-2008 and Punjab-2011by 13.15 and 27.50% respectively under 75 mM NaCl toxicity as compared to control. The higher level of 150 mM NaCl significantly reduced the shoot length by 34.21 and 25.0% in Faisalabad-2008 and Punjab-2011 respectively with respect to control. Under non saline conditions, salicylic acid application (0.25 mM) increased the shoot length by 15.78 and 12.50% in both varieties i.e Faisalabad-2008 and Punjab-2011. Salicylic acid level of 0.25 mM under 150 mM NaCl toxicity caused the increment of 100 and 60.0% in Faisalabad-2008 and Punjab-2011respectively with respect to the treatment having 150 mM NaCl toxicity alone. Salicylic acid application affected the root length significantly. Treatments effects were found significant regarding root length (Figure 2). Salinity stress caused decrease in root length than the control. The NaCl concentration of 75 mM caused reduction in root length by 50.54 and 22.85% in Faisalabad-2008 and Punjab-2011respectively as compared to control. While the NaCl treatment of 150 mM decreased the root length in Faisalabad-2008 (58.69%) and Punjab-2011 (35.42%) over control.The salicylic acid level of 0.25 mM under normal conditions increased the root length by 49.45 and 42.85% in Faisalabad-2008 and Punjab-2011 respectively with respect to control. The application of 0.50 mM salicylic acid enhanced the root length by 41.30 and 34.28% in Faisalabad-2008 and Punjab-2011 respectively with respect to control. Salicylic acid application of 0.25 overcame the adverse effects of salinity and promoted the root length by 70.0 and 67.27% under 150 mM NaCl treatment.

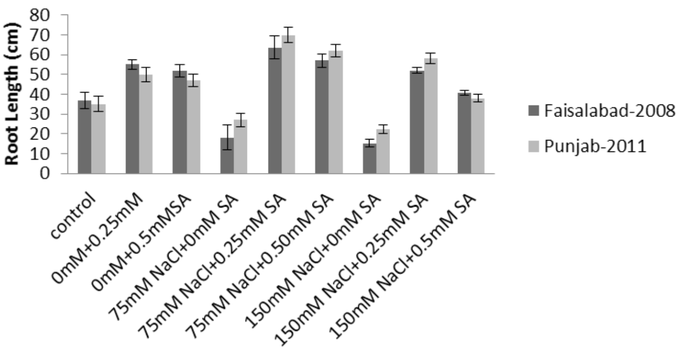

Figure 2: *Influence of SA on root length in different wheat varieties under salt stress.*

Chlorophyll contents (SPAD value)

The effect of the salicylic acid on chlorophyll contents was significant at $p < 0.05$. Both levels of salinity reduced the chlorophyll contents significantly (Figure 3). The NaCl treatments reduced the chlorophyll contents by causing adverse effects on plant physiology. There was found a remarkable increase in chlorophyll contents in the treatments where salicylic acid was applied. The application of 0.25 mM and 0.50 mM salicylic acid increased the chlorophyll contents as compare to the control and NaCl toxicity. The NaCl toxicity of 75 mM reduced the chlorophyll contents as 6.07 and 17.54 in Faisalabad-2008 and Punjab-2011respectively as compared to control. While 150 mM NaCl toxicity decreased the chlorophyll contents by 16.34 and 23.25% in Faisalabad-2008 and Punjab-2011 respectively.

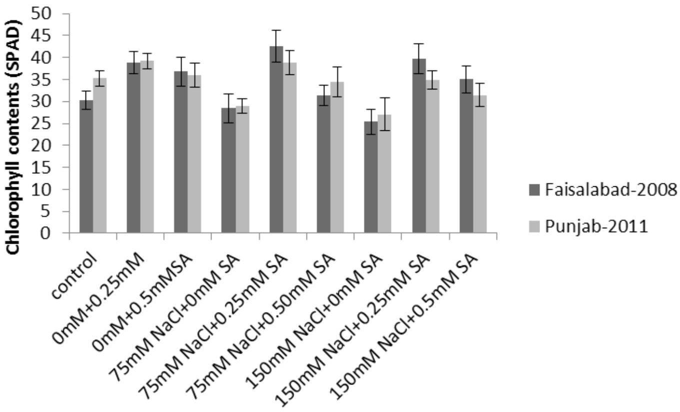

Figure 3: *Influence of SA on chlorophyll contents in different wheat varieties under salt stress.*

The lower level of salicylic acid (0.25 mM) increased the chlorophyll contents as 28.02 and 11.35% in Faisalabad-2008 and Punjab-2011respectively. While 0.50 mM salicylic acid caused an increase by 21.36 and 2.19% in both varieties i.e. Faisalabad-2008 and Punjab-2011 respectively as compare to control. The application of 0.25 mM under 75 mM NaCl toxicity increased the chlorophyll contents in Faisalabad-2008 (49.59) and that for Punjab-2011 was (33.81%)as compare to 75 mM NaCl toxicity alone. The application of 0.5 mM salicylic acid in the presence of 150 mM NaCl enhanced the chlorophyll contents by 38 and 16% inFaisalabad-2008 and Punjab-2011respectively as compare to 150mM NaCl alone.

Number of tillers per plant

Significant results were found for the no. of tillers per plant. The significant differences were recorded among treatment means (Figure 4). In the absence of NaCl toxicity, the application of 0.25 mM salicylic acid enhanced the number of tillers per plant by 41.18 and 27.27% in Faisalabad-2008 and Punjab-2011respectively with respect to control. NaCl treatments noticeably reduced the number of tillers per plant thereby affecting the plant growth. The NaCl treatment of

150 mM reduced the number of tillers by 17.64 and 31.81% in Faisalabad-2008 and Punjab-2011 respectively, as compare to control. The lower level of salicylic acid (0.25 mM) under 75 mM NaCl increased the number of tillers in Faisalabad-2008 (93.33%) and that for Punjab-2011 was (41.17%)as compare to 75 mM NaCl toxicity alone. The salicylic acid application (0.25 mM) under 150 mM salt stress increased the number of tillers by 85.71 and 46.66% in Faisalabad-2008 and Punjab-2011 respectively.

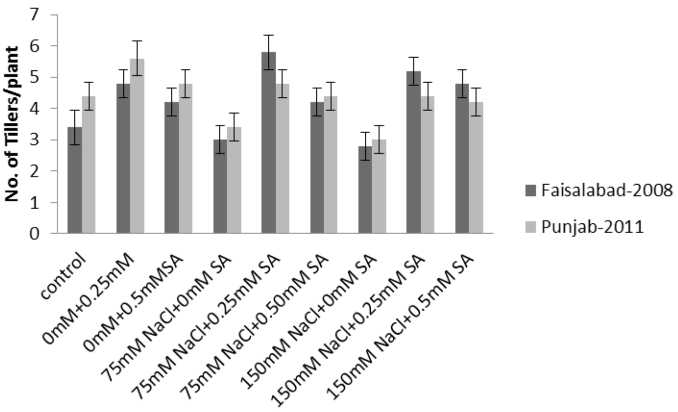

Figure 4: *Influence of SA on No. of tillers in different wheat varieties under salt stress.*

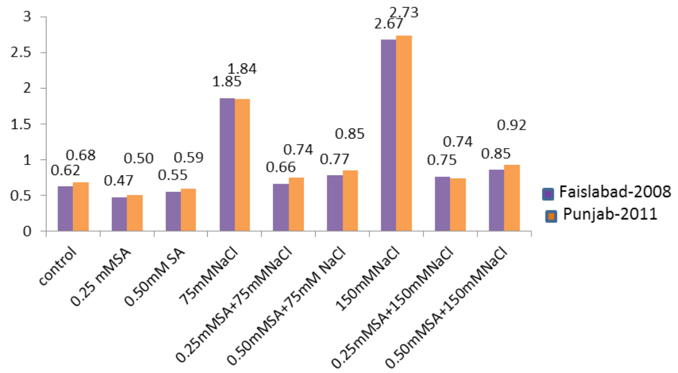

Figure 5: *Influence of SA on Na/K ratio in different wheat varieties under salt stress.*

Effect of salicylic acid on Na^+/K^+ ratio

The salinity treatments significantly increased the Na^+/K^+ ratio in wheat plants. But salicylic acid remarkably reduced the sodium uptake by the plants (Figure 5). The application of 150 mM NaCl treatment increased Na^+/K^+ ratio in the leaf sap in bothvarieties i.e. Faisalabad-2008 and Punjab-2011. While 75 mM NaCl toxicity increased the Na^+/K^+ratio in Faisalabad-2008 (197.71%) and that for Punjab-2011 was (169.08%) respectively, as compared to control.The salicylic acid level (0.25 mM) under 150 mM NaCl toxicity decreased the Na^+: K^+ ratio by 71.63 and 72.92% in Faisalabad-2008 and Punjab-2011respectively as compared to 150 mM NaCl alone.The application of 0.50 mM salicylic acid under 150 mM NaCl toxicity decreased the Na/K ratio by 67.92 and 66.14% in Faisalabad-2008 and Punjab-2011respectively as compared to treatment where 150mM NaCl was applied alone. Both levels of salicylic acid (0.25 mM and 0.50 mM) increased the shoot and root length of wheat genotypes in both saline and non-saline conditions supporting the fact that salicylic acid has a positive role in plant metabolism that ultimately improves the plant development either in stress or non stress conditions. These results are in accordance with those of Jazi et al. (2011), who found increased shoot growth when salicylic acid was applied under heavy metal stress conditions in *Brassica napus*. Turkyilmaz (2012) also recorded an increase in shoot length in wheat plants in those treatments where salicylic acid was applied. Cornelia et al. (2011) reported that salinity treatments reduced the shoot growth but salicylic acid alleviated the effect of salinity in wheat plants. Sadeghipour and Aghaei (2012) recorded enhanced shoot lengths in water stressed common bean when 0.50 mM salicylic acid was applied. Turkiyalmaz (2012) from his experiment concluded that Salinity caused a dramatic decrease especially at 200 mM NaCl in root and shoot lengths in 4 weeks old wheat seedlings. Salicylic acid application increased the root length under both saline and non-saline conditions. Both levels of salicylic acid (0.25 mM and 0.50 mM) increased the root length. Waseem et al. (2006) reported that salicylic acid when applied through the rooting medium enhanced the root length and other physiological parameters of two wheat cultivars (MH-97 and S-24). Szepesi et al. (2009) reported an increase in root length under 100 mMNaCl in potato cultivars. Ghafiyehsanj et al. (2013) quantified the effect of salicylic acid on some biochemical characteristics of wheat under saline conditions and found that salinity significantly decreased the plant growth but salicylic acid application enhanced the growth by enhancing root length.

El-Tayeb (2005) found remarkable decrease in chlorophyll contents in barley under salinity stress. Yildirim et al. (2008) who indicated that chlorophyll content considerably decrease due to the formation of proteolytic enzymes such as chlorophyllase, which is responsible for the chlorophyll degradation under saline conditions. Yildirim et al. (2008) quantified the effect of foliarly applied salicylic acid on chlorophyll contents of cucumber plants grown under salinity stress and found that foliarly applied salicylic acid enhanced the chlorophyll contents by eliminating the deleterious effects of salinity. Karim and Khursheed (2010) reported a significant increase in chlorophyll and carotenoid contents in wheat plants by salicylic acid application. Amin et al. (2008) reported an increase in number of tillers per plant and also other physiological parameters of wheat plant by foliar application of salicylic acid. Mohammed et al. (2011) found that salicylic acid (SA) application affected the number of productive tillers per plant.

Jayakannan et al. (2013) reported that salinity stress enhanced Na^+/K^+. Parizi et al. (2011) found that salinity treatments remarkably increased Na/K ratio in sweet basil. The application of both levels of salicylic acid in the presence of NaCl reduced Na^+/K^+ ratio alleviating the deleterious effect of salinity. The control treatment had minimum Na^+/K^+ ratio. Maximum Na^+/K^+ ratio was found in 150 mM NaCl treatment. This may indicate that pretreatment with salicylic acid induced a reduction of Na^+ absorption and toxicity, high water content and dry matter production. Essa (2002) reported that NaCl salinity may produce extreme ratios of Na/Ca and Na/K in the maize plant, causing them to be susceptible to osmotic and specific-ion injury, as well as to nutritional disorders but when salicylic acid was applied, drastic decrease was found in Na/K ratio. The results for K^+ and Na^+ ratio were similar to those indicated by other researchers (Ahmad et al., 2007; Molassiotis et al., 2006).

Conclusion

Application of salicylic acid had a significant effect on improving the crop growth under saline environment. It improves the root and shoots length (growth parameters), number of tillers and chlorophyll contents in the stressed crop plants. Its ameliorative effect could be assessed from the fact that all applied levels of salicylic acid reduced the Na^+/K^+ in the crop plants as compared to saline treatments alone, showing that it subjected the plant to uptake more K^+ as compared to Na^+ even under salt stress. Along with all the improvement, genotypic differences among the genotypes were non-significant but Punjab-2011 showed better performance as compared to Faisalabad-2008.

Author's Contribution

Muhammad Suhaib planned and conducted research. Ijaz Ahmed and Masooma Munir did the analytical techniques. Khubaib abuzar and Muhammad Bilal Iqbal supported in paper write up and necessary proceedings.

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