Biological and Clinical Sciences Research Journal
ISSN: 2708-2261
www.bcsrj.com
DOI: https://doi.org/10.54112/bcsrj.v2020i1.24
Biol. Clin. Sci. Res. J., Volume, ***2020****: 24*
Original Research

EFFECTS OF SALICYLIC ACID PRIMING FOR SALT STRESS TOLERANCE IN WHEAT

GHAFOOR MF, *ALI Q, MALIK A

Institute of Molecular Biology and Biotechnology, The university of Lahore, Lahore, Pakistan
Corresponding author: saim1692@gamil.com

(Received, 6th April 2020, Revised 12th September 2020, Published 16nd September 2020)

Abstract: *The present research experiment was conducted in the greenhouse of the Institute of Molecular Biology and Biotechnology, The University of Lahore for determining the possible involvement of salicylic acid (SA) in seed priming and affects on the seedling growth and development under NaCl treatments in wheat variety ANAJ-2017, Shafaq-2006 and Galaxy-2013. The data was collected for various seedling traits and statistically analyzed, which revealed the significance of results for treatments, salt applications, genotypes and the interactions between salt treatments and genotypes. The lower coefficient of variation was recorded for all studied traits which revealed that there was consistency among the results for salicylic acid applications and salt or NaCl treatments. It was concluded from our study that the application of salicylic acid (SA) under salt (NaCl) stress conditions helps wheat seedlings to withstand and compete with stressful conditions. The study revealed that the seed priming with salicylic acid helps to improve root length, shoot length, seedling moisture percentage and fresh seedling weights. The application of NaCl caused to increase the root length, number of roots and shoot length of wheat while salicylic acid (SA) was applied in foliar spray. The use of water priming shows medium effects for the seedling growth of wheat under salt stress environmental conditions. The wheat variety Galaxy-2013 has shown good performance for most of the studied traits of seedlings under salt stress conditions. It was suggested from our study that the variety Galaxy-2013 may be used under salt stress conditions or salt affected soils to improve grain yield of wheat.*

Keywords: wheat, salicylic acid, priming, salt stress, NaCl, root length, shoot length

Introduction

The bread wheat (*Triticum aestivum* L.); is as an important cash crop among the food crops throughout the world farming which occupies a significant position among all of the cultivated cereal crops. The cultivation of wheat has been remained the symbolic of the green revolution which has played a pivotal role in making the nations a food spare nation. The bread wheat is one of the member of the poaceae family with chromosomes 2n = 42 and is highly self-pollinated crop among cereals (Dixon et al., 2009; Sears, 1954; Shewry, 2009). Wheat ranks first among the world food and grain crops, in the terms of cultivated area which is about 223.813 m ha or production about 733.144 m tonnes and along with the productivity of about 3280 kg ha^{-1} (Asseng et al., 2015). Wheat may be grown from the below of sea level up to 5000 meter altitude and in the areas where the rainfall ranges between 300-1130 mm per annum. Wheat contributes higher calories up to 20% and higher protein to the growing population of the world's more than any of the other food crops. The demands of wheat has been increased from about 79 g $capita^{-1}day^{-1}$ to higher as much as 185 g $capita^{-1}day^{-1}$ regardless of the doubling of the world population since from 1961 (Bhardwaj et al., 2010; Sarker et al., 2015).In Pakistan, the bread wheat is the second foremost important cereal crops next only to the rice and also a key crop in the green and post green revolution eras. India stands the second among world wheat producing countries while China stands first. The wheat production in Pakistan was 28.9 million tones and was grown over an area of about 31.18 m ha (Govt, 2018). The wheat production in Pakistan is lower as compared with other wheat growing countries in the world due to various factors including the quality seed availability, irrigation water, fertilizers, farm mechanization and biotic and abiotic stress conditions. Among abiotic stress conditions, drought, heat, salt, clod and heavy metal played an important role in decreasing the yield, production and over productivity of wheat in Pakistan (Charles et al., 2006; Fisher and Byerlee, 1990; Kirkegaard et al., 2008; Raza et al., 2006). Under abiotic stress conditions the wheat is highly affected which caused reduction in the yield and productivity. The salt stress caused cell membrane damage, production of toxic chemicals and accumulation of reactive oxygen species in the plant body. We have conducted our research while keeping few research objectives in mind as given below: To evaluate the effects of salicylic acid wheat seedling growth and development. To find out the stress resistant wheat variety from selected varieties for research work and to find out the seed priming effects on wheat seedling growth with water and salicylic acid (SA).

Materials and Methods

The present research experiment was conducted in the greenhouse of the Institute of Molecular Biology and Biotechnology, University of Lahore for determining the possible involvement of salicylic acid **(**SA) in seed priming and affects on the seedling growth and development under NaCl treatments in wheat variety ANAJ-2017, Shafaq-2006 and Galaxy-2013. The seed of selected genotype was sown in 18 pots which were filled with 2kg of sand and soil. 500mg/kg of NaCl was added in the soil filled in the pots along with the control pots. The 120 wheat seeds were primed out through water while 120 wheat seeds were primed out by using 100mg/g of salicylic acid solution for overnight. In the next morning the primed wheat seeds which were washed out by distilled water (H_2O dist.) and 20 primed seeds were sown in each pot. The following sets of SA and NaCl treatments were kept for study: T_0 (Control), T_1 (Water priming), T_2 (SA priming), T_3 (Only NaCl), T_4 (Water priming + NaCl) and T_5 (SA priming + NaCl). The data was collected for various seedling morphological traits, *viz*., leaf area (LA), number of roots/plant (NR), root length (RL), shoot length (SL), shoot/root dry weight ratio (SRDWR) and shoot/root fresh weight ratio (SRFWR). The data was statistically analyzed through analysis of variance techniques by using SPSS23.1 software.

Results and Discussions

Leaf area or LA (cm^2)

The results given in table 1 described significant differences among the genotypes, treatments and interactions between the treatments × genotypes. It was found from results that the average leaf area under all applied treatments was recorded as 6.0043±0.0213cm^2. The lower value of coefficient of variation (0.24%) for leaf area indicated that there was consistency among the results which also cleared that the results were reliable for leaf area of wheat seedling under different treatments of salicylic acid and NaCl or salt. The results form table 2 indicated that the higher leaf area (97.3033cm^2) under T3 (NaCl application) treatment, T4 or water priming + NaCl (6.3967cm^2) was found while lowest was for control (5.190cm^2) and treatment T5 or salicylic acid + NaCl (4.6556cm^2). The mean performance of genotypes under all treatments of NaCl and salicylic acid priming indicated that the genotypes/variety Galaxy-2013 (6.1933cm^2) showed higher leaf area while Shafaq-2006 (5.9933cm^2) and ANAJ-2017 (1.58261cm^2) average leaf area under all treatments (Table 3). The higher leaf area of wheat seedlings under NaCl treatment indicated that the genotypes with higher leaf area showed tolerance against salt stress without any application of growth regulator. The higher leaf area also revealed that the photosynthetic rate under salt stress may be higher which helped the seedlings to withstand under stressful environmental conditions (Agarwal et al., 2005a; Agarwal et al., 2005b; Shakirova et al., 2003). The results from figure 1 indicated that the ANAJ-2017 wheat variety or genotype showed higher leaf area (6.1cm^2) under water priming + NaCl treatment followed by NaCl (6.11 cm^2) and salicylic acid priming + NaCl (6.01 cm^2) while lowest leaf area under control (5.01 cm^2) and salicylic acid priming (5.0 cm^2). The Galaxy-2013 wheat variety or genotype showed higher leaf area (6.27cm^2) under water priming + NaCl treatment followed by NaCl (6.28 cm^2) and salicylic acid priming + NaCl (6.26 cm^2) while lowest leaf area under control (5.18 cm^2) and salicylic acid priming (5.17 cm^2). The Shafaq-2006 wheat variety or genotype showed higher leaf area (6.47 cm^2) under water priming + NaCl treatment followed by NaCl (6.48 cm^2) and salicylic acid priming + NaCl (6.46 cm^2) while lowest leaf area under control (5.38 cm^2) and salicylic acid priming (5.37 cm^2). It was found from results that the seed priming with the application of salicylic acid for better growth and development plays an important role while depending upon the genetic potential of the crop plants. The genotype Galaxy-2013 showed good performance for leaf area under salt stress conditions and also good response for applications of salicylic acid. It was suggested that the genotype or variety Galaxy-2013 may be used for improved plant growth, development and higher grain yield variety under salt stress and salt affected soils (Amin et al., 2008; Catinot et al., 2008; Hayat et al., 2005; Singh and Usha, 2003).

Table 1: Pooled analysis of variance for different traits of wheat genotypes

Source	DF	Shoot length	Root length	Roots per plant	Fresh root/shoot weight ratio	dry root/shoot weight ratio	Leaf Area
Replication	2	0.1666	0.0881	0.03185	0.01494	0.00607	0.00075
Treatment	5	26.3633*	64.0019*	1.61575*	0.28158*	0.08995*	7.9883*

[Citation: Ghafoor, F., Ali, Q., Malik, A. (2020). Effects of salicylic acid priming for salt stress tolerance in wheat. *Biol. Clin. Sci. Res. J.*, **2020***:* 24 https://doi.org/10.54112/bcsrj.v2020i1.24]

Genotypes	2	7.5317*	0.7233*	0.46702*	0.13474*	0.44435*	0.60845*
Treatment × Genotypes	10	0.0017	0.0001	0.00002	0.12578*	0.00630*	0.00005*
Error	34	0.0342	0.0197	0.00897	0.00673	0.01165	0.0002
Grand mean	53	20.306	20.269	7.2217	0.8186	1.0082	6.0043
Standard Error		0.0643	0.0479	0.0432	0.0023	0.0011	0.0213
Coefficient of variation		0.91	0.69	1.31	10.02	10.71	0.24

* = Significant at 5% probability level

Table 2: Tukey HSD for all-pairwise comparisons test for different stress treatments

Treatments	Leaf area	Shoot length	Root length	Roots per plant	Fresh root/shoot weight ratio	dry root/shoot weight ratio
Control	5.1900 E	18.867 D	19.040 D	7.0500 B	0.7466 BC	1.0706 AB
Water priming	6.2800 C	21.740 B	19.740 C	6.9833 C	0.7709 BC	0.8910 C
Salicylic acid priming	6.2000 D	20.697 C	17.460 F	8.0833 A	0.7521 BC	0.9450 BC
NaCl	7.3033 A	22.800 A	22.593 B	7.0833 B	0.6553 C	1.0441 ABC
Water priming + NaCl	6.3967 B	18.900 D	18.393 E	7.0833 B	0.8251 B	0.9404 BC
Salicylic acid + NaCl	4.6556 F	18.833 D	24.387 A	7.0467 B	1.1619 A	1.1581 A

Table 3: Tukey HSD all-pairwise comparisons test of different traits for varieties/genotypes

DF	Leaf area	Shoot length	Root length	Roots per plant	Fresh root/shoot weight ratio	dry root/shoot weight ratio
ANAJ-2017	5.8261 C	19.617 C	20.077 C	7.1056 B	0.8788 A	0.8878 B
Shafaq-2006	5.9933 B	20.401 B	20.253 B	7.1539 B	0.8576 A	0.9508 B
Galaxy-2013	6.1933 A	20.901 A	20.477 A	7.4056 A	0.7195 B	1.1859 A

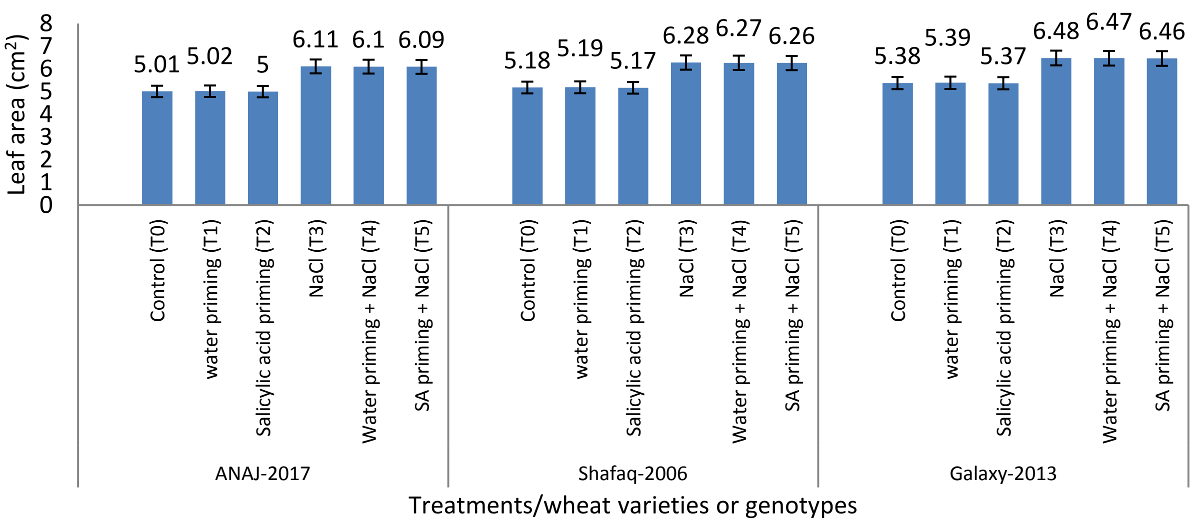

Fig. 1: Leaf area (cm^2) of wheat varieties under different treatments

Shoot length or SL (cm)

The results given in table 1 suggested that significant differences were found among genotypes and treatments while non-significant for interactions between treatments × genotypes. It was found from results that the average shoot length under all applied treatments was recorded as 20.306±0.0643cm. The lower value of coefficient of variation (0.91%) for shoot length indicated that there was consistency among the results which also cleared that the results were reliable for shoot length of wheat seedling under different treatments of salicylic acid (SA) and NaCl. The results form table 2 revealed that there was higher shoot length (20.800cm) under T3 (NaCl application) treatment, T1 or water priming (21.740cm) while lowest was for control (18.867cm) and treatment T5 or salicylic acid + NaCl (18.833cm). The mean performance of genotypes under all treatments of NaCl and salicylic acid priming indicated that the genotypes/variety Galaxy-

2013 (20.904cm) showed higher shoot length while Shafaq-2006 (20.401cm) and ANAJ-2017 (19.617cm) average shoot length under all treatments (Table 3). The higher shoot length of wheat seedlings under NaCl treatment indicated that the genotypes with higher shoot length showed tolerance against salt stress without any application of growth regulator. The higher shoot length also revealed that the accumulation of organic compounds under salt stress may be higher which helped the seedlings to withstand under stressful environmental conditions (Afzal et al., 2006a; ASHRAF, 2006; Kovács et al., 2014; Misra and Saxena, 2009). The results from figure 2 indicated that the ANAJ-2017 wheat variety or genotype showed higher shoot length (21.12 cm) under water priming + NaCl treatment followed by NaCl (21 cm) and salicylic acid priming + NaCl (21 cm) while lowest shoot length under water priming (18 cm) and salicylic acid priming (18 cm). The Galaxy-2013 wheat variety or genotype showed higher shoot length (22.42 cm) under water priming + NaCl treatment followed by NaCl (22.30 cm) and salicylic acid priming + NaCl (22.30 cm) while lowest shoot length under water priming (19.30 cm) and salicylic acid priming (19.3 cm). The Shafaq-2006 wheat variety or genotype showed higher shoot length (21.92 cm) under water priming + NaCl treatment followed by NaCl (21.82 cm) and salicylic acid priming + NaCl (21.80 cm) while lowest shoot length under water priming (18.8 cm) and salicylic acid priming (18.8 cm). It was found from results that the seed priming with application of salicylic acid for better growth and development plays an important role while depending upon the genetic potential of the crop plants. The genotype Galaxy-2013 showed good performance for shoot length under salt stress conditions and also good response for applications of salicylic acid. It was suggested that the genotype or variety Galaxy-2013 may be used for improved plant growth, development and higher grain yield variety under salt stress and salt affected soils (Afzal et al., 2006b; Gautam and Singh, 2009; Rafique et al., 2011; Turkyilmaz, 2012).

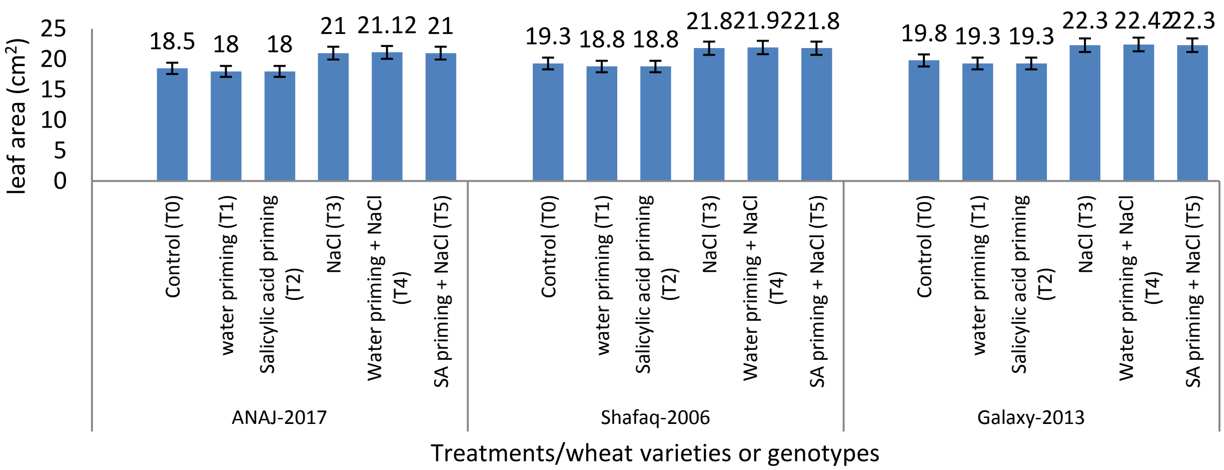

Fig. 2: Shoot length (cm) of wheat varieties under different treatments

Root length or RL (cm)

The results as given in table 1 suggested that significant differences were found among genotypes and the applications of treatments while non-significant for interactions between treatments × genotypes. It was found from results that the average root length under all applied treatments was recorded as 20.269±0.0479cm. The lower value of coefficient of variation (0.69%) for root length indicated that there was consistency among the results which also cleared that the results were reliable for root length of wheat seedling under different treatment applications of salicylic acid (SA) and NaCl. The results form table 2 revealed that there was lower root length (18.393cm) under T4 (water priming+ NaCl application) treatment, T2 or salicylic acid priming (17.406cm) while higher was for NaCl application (22.592cm) and treatment T5 or salicylic acid + NaCl (24.387cm). The mean performance of genotypes under all treatments of NaCl and salicylic acid priming indicated that the genotypes/variety Galaxy-2013 (20.477cm) showed higher root length while Shafaq-2006 (20.253cm) and ANAJ-2017 (20.077cm) average root length under all treatments (Table 3). The higher root length of wheat seedlings under NaCl treatment indicated that the genotypes with higher root length showed tolerance against salt stress without any application of growth regulator which can absorb water mineral salts from deeper soil. The higher root length also revealed that the accumulation of organic compounds under salt stress may be higher which helped the seedlings to withstand under stressful environmental conditions (Agami, 2013; Hussein et al., 2007; Idrees et al., 2010; Kang et al., 2012; Wang and Zhang, 2017). The results from figure 3 indicated that the ANAJ-2017 wheat variety or genotype showed higher root length (19.34cm) under water priming + NaCl treatment followed by NaCl (19.60 cm) and salicylic acid priming + NaCl (19.17 cm) while lowest root length under water priming (18.54 cm) and salicylic acid priming (19 cm). The Galaxy-2013 wheat variety or genotype showed higher root length (19.74cm) under water priming + NaCl treatment followed by NaCl (20 cm) and salicylic acid priming + NaCl (20.10 cm) while lowest root length under water priming (18.94 cm) and salicylic acid priming (19.4 cm). The Shafaq-2006 wheat variety or genotype showed higher root length (19.52cm) under water priming + NaCl treatment followed by NaCl (19.78 cm) and salicylic acid priming + NaCl (19.88 cm) while lowest root length under water priming (18.72 cm) and salicylic acid priming (18.18 cm). It was found from results that the seed priming with application of salicylic acid for better growth and development plays an important role while depending upon the genetic potential of the crop plants. The genotype Galaxy-2013 showed good performance for root length under salt stress conditions and also good response for applications of salicylic acid. It was suggested that the genotype or variety Galaxy-2013 may be used for improved plant growth, development and higher grain yield variety under salt stress and salt affected soils (Amin, 2011; Deef, 2007; Liting et al., 2015).

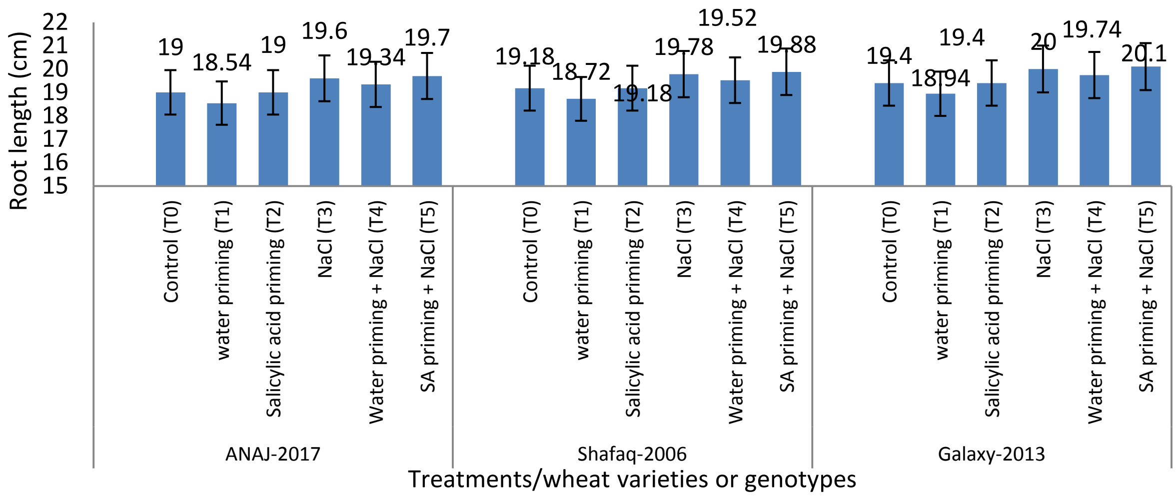

Fig. 3: Root length (cm) of wheat varieties under different treatments

Number of roots per plant or RPP

The results given in table 1 suggested that significant differences were found among genotypes and treatments while non-significant for interactions between treatments × genotypes. It was found from results that the average roots/plant under all applied treatments was recorded as 7.2217±0.0432. The lower value of coefficient of variation (1.31%) for number of roots per plant indicated that there was consistency among the results which also cleared that the results were reliable for number of roots per plant of wheat seedling under different treatments of salicylic acid and NaCl or salt application. The results from table 2 suggested that there was higher number of roots per plant (7.0833) under T4 (water priming+ NaCl application) treatment, T2 or salicylic acid priming (8.0833) while lower was for water priming (6.9833) and treatment T5 or salicylic acid + NaCl (7.0467). The mean performance of genotypes under all treatments of NaCl and salicylic acid priming indicated that the genotypes/variety Galaxy-2013 (7.4056) showed higher number of roots per plant while Shafaq-2006 (7.1539) and ANAJ-2017 (7.1056) average number of roots per plant under all treatments (Table 3). The higher number of roots per plant of wheat seedlings under NaCl treatment persuaded that the genotypes with higher roots/plant showed tolerance against salt stress without any application of growth regulator which can produce large amount of organic compounds through photosynthesis (Iqbal and Ashraf, 2006; Kim et al., 2006; Loutfy et al., 2012; Mohase and van der Westhuizen, 2002). The results from figure 4 indicated that the ANAJ-2017 wheat variety or genotype showed lower number of roots per plant (6.7) under water priming + NaCl treatment followed by water priming (6.8) and salicylic acid priming + NaCl (6.9) while higher number of roots per plant under control (7), NaCl (7) and salicylic acid priming (7). The Galaxy-2013 wheat variety or genotype showed lower number of roots per plant (7) under water priming + NaCl treatment followed by water priming (7.1) and salicylic acid priming + NaCl (7.2) while higher number of roots per plant under control (7.3) and salicylic acid priming (7.3). The Shafaq-2006 wheat variety or genotype showed lower number of roots per plant (6.75) under water priming + NaCl treatment followed by water priming (6.85) and salicylic acid priming + NaCl (6.95) while higher number of roots per plant under control (7.05) and salicylic acid priming (7.05). It was found from results that seed priming with the application of salicylic acid for better growth and development plays an important role while depending upon the genetic potential of the crop plants.The genotype Galaxy-2013 showed good performance for number of roots per plant under salt stress conditions and also good response for applications of salicylic acid. It was suggested that the genotype or variety Galaxy-2013 may be used for improved plant growth, development and higher grain yield variety under salt stress and salt affected soils (Ashraf et al., 2004; Renard-Merlier et al., 2007; Seckin et al., 2009; Yordanova and Popova, 2007).

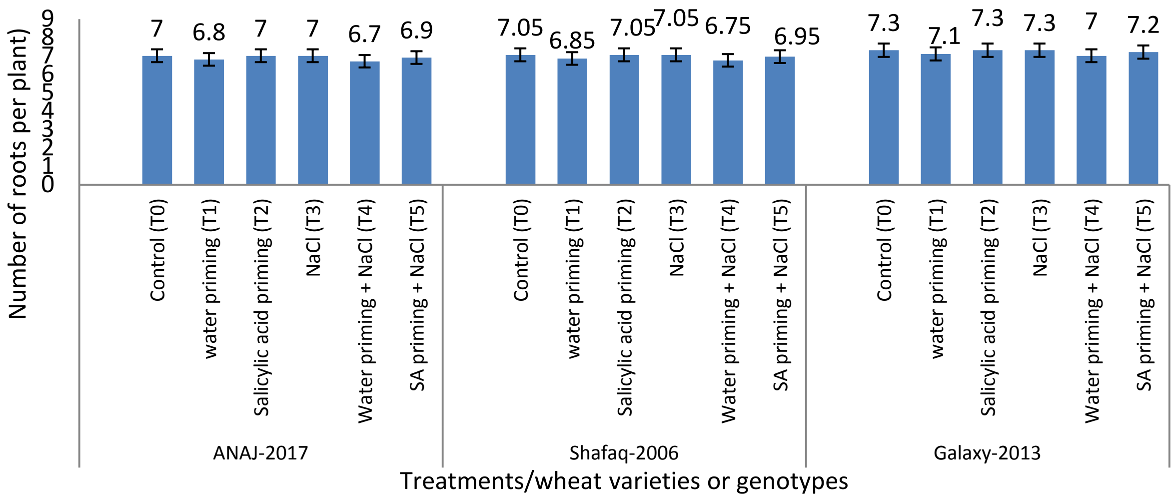

Fig. 4: Number of roots per plant of wheat varieties under different treatments

Fresh root/shoot weight ratio or FRSWR

The results given in table 1 suggested that significant differences were reported among treatments, genotypes and for interactions between treatments × genotypes. It was found from results that the average FRSWR under all applied treatments were recorded as 0.8186±0.0023. The lower value of coefficient of variation (10.02%) for FRSWR indicated that there was consistency among the results which also cleared that the results were reliable for FRSWR of wheat seedling under different applications of salicylic acid (SA) and NaCl. The results form table 2 revealed that there was higher FRSWR (0.7709) under T1 (water priming) treatment, T4 water priming + NaCl (0.8251%) and T5 SA priming + NaCl application showed 1.1619 while lower was for T3 or NaCl (0.6553) and treatment T0 or control (0.7466). The mean performance of genotypes under all treatments of NaCl and salicylic acid priming indicated that the genotypes/variety Shafaq-2006 (0.8576) followed by Galaxy-2013 (0.7195) and ANAJ-2017 (0.8788) average FRSWR under all treatments (Table 3). The results from figure 5 indicated that the ANAJ-2017 wheat variety or genotype showed lower FRSWR (0.750) under water priming + NaCl treatment followed by NaCl (0.76) and salicylic acid priming + NaCl (0.73) while higher FRSWR under water priming (0.82), control (0.79) and salicylic acid priming (0.84). The Galaxy-2013 wheat variety or genotype showed higher FRSWR (0.80) under water priming + NaCl treatment followed by NaCl (0.82) and salicylic acid priming (0.78) while lower FRSWR under water priming (0.58), control (0.58) and salicylic acid priming + NaCl (0.58). The Shafaq-2006 wheat variety or genotype showed lower FRSWR (0.77) under water priming + NaCl treatment followed by NaCl (0.78) and salicylic acid priming + NaCl (0.75) while higher FRSWR under water priming (0.84), control (0.82) and salicylic acid priming (0.86). The higher FRSWR of wheat seedlings under NaCl treatment indicated that the genotypes with higher fresh root-to-shoot weight ratio showed tolerance against salt stress and it may help the seedlings to withstand under stressful environmental conditions. It was found from results that seed priming with the application of salicylic acid for better growth and development plays an important role while depending upon the genetic potential of the crop plants. The genotypes shafaq-2006 and Anaj-2017 showed good performance for FRSWR under salt stress conditions and also good response for applications of salicylic acid (El-Shintinawy, 2000; Hampson and Simpson, 1990; Jafar et al., 2012; Salam et al., 1999; Zheng et al., 2009).

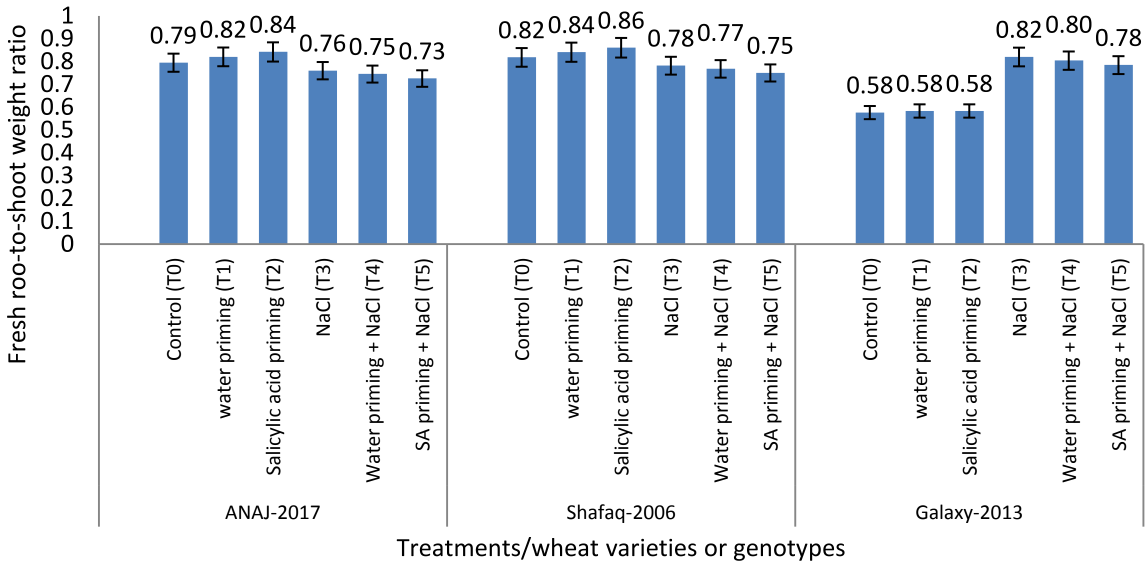

Fig. 5: Fresh root-to-shoot weight ratio of wheat varieties under different treatments

Dry root/shoot weight ratio or DRSWR

The results given in table 1 persuaded that significant differences were reported among treatments, genotypes and for interactions between treatments × genotypes. It was found from results that the average DRSWR under all applied treatments were recorded as 1.0082±0.0011. The lower value of coefficient of variation (10.71%) for DRSWR indicated that there was consistency among the results which also cleared that the results were reliable for DRSWR of wheat seedling under different applications of salicylic acid and NaCl. The results form table 2 revealed that there was lower DRSWR (0.8910) under T1 (water priming) treatment, T4 water priming + NaCl (0.9404) and T2 SA priming application showed 0.9450 while higher was for T5 or SA priming + NaCl (1.1581) and treatment T0 or control (1.0706). The mean performance of genotypes under all treatments of NaCl and salicylic acid priming indicated that the genotypes/variety Shafaq-2006 (0.9508) followed by Galaxy-2013 (1.1859) and ANAJ-2017 (0.8878) average DRSWR under all treatments (Table 3). The results from figure 6 indicated that the ANAJ-2017 wheat variety or genotype showed lower DRSWR (0.80) under water priming + NaCl treatment followed by NaCl (0.67) and salicylic acid priming + NaCl (0.65) while higher DRSWR under water priming (1.02), control (0.90) and salicylic acid priming (1.04). The Galaxy-2013 wheat variety or genotype showed lower DRSWR (1.11) under water priming + NaCl treatment followed by NaCl (1.00) and salicylic acid priming (1.22) while higher DRSWR under water priming (1.33), control (1.20) and salicylic acid priming + NaCl (1.15). The Shafaq-2006 wheat variety or genotype showed lower DRSWR (0.91) under water priming + NaCl treatment followed by NaCl (0.83) and salicylic acid priming + NaCl (0.83) while higher DRSWR under water priming (1.01), control (0.95) and salicylic acid priming (1.02). The higher DRSWR of wheat seedlings under NaCl treatment indicated that the genotypes with higher DRSWR showed tolerance against salt stress and it may help the seedlings to withstand under stressful environment conditions. It was found from results that seed priming with the application of salicylic acid (SA) for better growth and development plays an important role while depending upon the genetic potential of the crop plants. The genotype Glaxy-2013 showed good performance for dry root-to-shoot weight ratio under salt stress conditions and also good response for applications of salicylic acid (Alpaslan et al., 1998; Basra et al., 2005; Li et al., 2011; Ma et al., 2007; Nagy and Galiba, 1995).

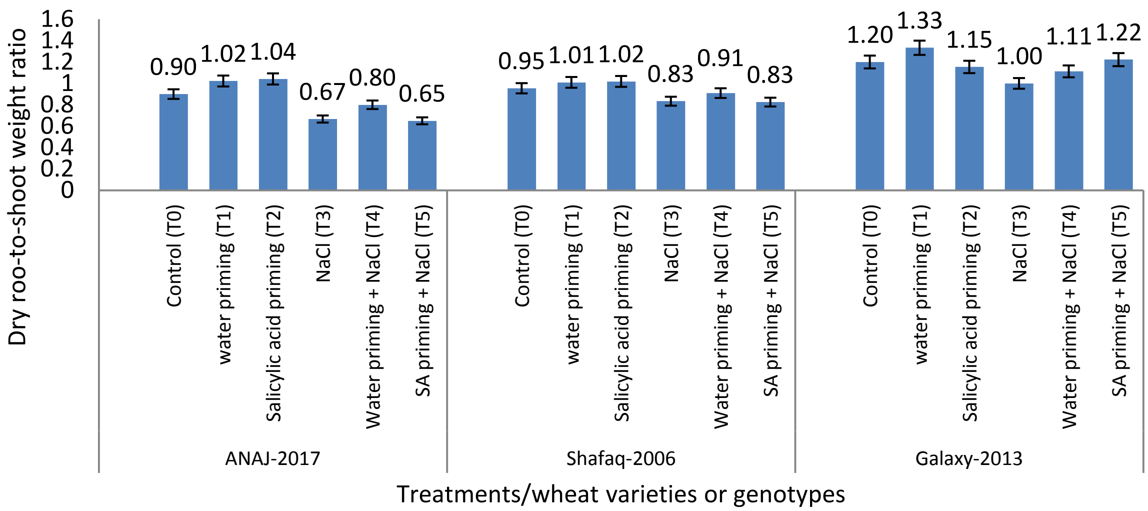

Fig. 6.Dry root-to-shoot weight ratio of wheat varieties under different treatments

It was concluded from our study that the application of salicylic acid under salt stress conditions helps wheat seedlings to withstand and compete with stressful conditions. The study revealed that the seed priming with salicylic acid helps to improve shoot length, root length, seedling moisture percentage and fresh seedling weight. The application of NaCl caused to increase the root length, number of roots and shoot length of wheat while salicylic acid (SA) was applied in foliar spray applications. The use of water priming shows medium effects for the growth of wheat seedlings under salt stressed conditions. The wheat variety Galaxy-2013 revealed good performance for most of the seedlings studied traits of wheat under salt stress conditions.

Conflict of interest

The authors have declared absence of any type of conflict of interest.

References

Afzal, I., Basra, S. M., Farooq, M., and Nawaz, A. (2006a). Alleviation of salinity stress in spring wheat by hormonal priming with ABA, salicylic acid and ascorbic acid. *Int. J. Agric. Biol* **8**, 23-28.

Afzal, I., Basra, S. M. A., Hameed, A., and Farooq, M. (2006b). Physiological enhancements for alleviation of salt stress in wheat. *Pak. J. Bot* **38**, 1649-1659.

Agami, R. A. (2013). Alleviating the adverse effects of NaCl stress in maize seedlings by pretreating seeds with salicylic acid and 24-epibrassinolide. *South African Journal of Botany* **88**, 171-177.

Agarwal, S., Sairam, R., Srivastava, G., and Meena, R. (2005a). Changes in antioxidant enzymes activity and oxidative stress by abscisic acid and salicylic acid in wheat genotypes. *Biologia Plantarum* **49**, 541-550.

Agarwal, S., Sairam, R., Srivastava, G., Tyagi, A., and Meena, R. (2005b). Role of ABA, salicylic acid, calcium and hydrogen peroxide on antioxidant enzymes induction in wheat seedlings. *Plant Science* **169**, 559-570.

Alpaslan, M., Güneş, A., Taban, S., Erdal, İ., and Tarakcioğlu, C. (1998). Variations in calcium, phosphorus, iron, copper, zinc and manganese contents of wheat and rice varieties under salt stress. *Turkish Journal of Agriculture and Forestry* **22**, 227-234.

Amin, A., Rashad, E.-S. M., and Gharib, F. A. (2008). Changes in morphological, physiological and reproductive characters of wheat plants as affected by foliar application with salicylic acid and ascorbic acid. *Australian journal of basic and applied sciences* **2**, 252-261.

Amin, B. M., H (2011). Effect of drought stress and its interaction with ascorbate and salicylic acid on okra (Hibiscus esculents L.) germination and seedling growth. *Journal of Stress Physiology & Biochemistry* **7**.

Ashraf, M. (2006). Effect of salicylic acid applied through rooting medium on drought tolerance of wheat. *Pak. J. Bot* **38**, 1127-1136.

Ashraf, M., Hasnain, S., Berge, O., and Mahmood, T. (2004). Inoculating wheat seedlings with exopolysaccharide-producing bacteria restricts sodium uptake and stimulates plant growth under salt stress. *Biology and Fertility of soils* **40**, 157-162.

Asseng, S., Ewert, F., Martre, P., Rötter, R. P., Lobell, D. B., Cammarano, D., Kimball, B., Ottman, M. J., Wall, G., and White, J. W. (2015). Rising temperatures reduce global wheat production. *Nature climate change* **5**, 143.

Basra, S., Afzal, I., Rashid, R., and Hameed, A. (2005). Inducing salt tolerance in wheat by seed vigor enhancement techniques. *International Journal of Agriculture and Biology* **2**, 173-179.

Bhardwaj, V., Yadav, V., and Chauhan, B. S. (2010). Effect of nitrogen application timings and varieties on growth and yield of wheat grown on raised beds. *Archives of Agronomy and Soil Science* **56**, 211-222.

Catinot, J., Buchala, A., Abou-Mansour, E., and Métraux, J.-P. (2008). Salicylic acid production in response to biotic and abiotic stress depends on isochorismate in Nicotiana benthamiana. *Febs Letters* **582**, 473-478.

Charles, R., Jolliet, O., Gaillard, G., and Pellet, D. (2006). Environmental analysis of intensity level in wheat crop production using life cycle assessment. *Agriculture, ecosystems & environment* **113**, 216-225.

Deef, H. E. (2007). Influence of salicylic acid on stress tolerance during seed germination of Triticum aestivum and Hordeum vulgare. *Advanced in Biological Research* **1**, 40-48.

Dixon, J., Braun, H.-J., Kosina, P., and Crouch, J. H. (2009). "Wheat facts and futures 2009," Cimmyt.

El-Shintinawy, F. (2000). Photosynthesis in two wheat cultivars differing in salt susceptibility. *Photosynthetica* **38**, 615-620.

Fisher, R., and Byerlee, D. (1990). Trends of wheat production in the warmer areas: major issues and economic considerations. *In* "3. International Conference on Wheat for the Nontraditional Warm Areas, Foz do Iguacu (Brazil), 29 Jul-3 Aug 1990". CIMMYT.

Gautam, S., and Singh, P. K. (2009). Salicylic acid-induced salinity tolerance in corn grown under NaCl stress. *Acta physiologiae plantarum* **31**, 1185.

Govt, O. P. (2018). Economic Survey of Pakistan. Govt. of Pakistan, Finance and Economic Affairs Division, Islamabad 2017-2018.

Hampson, C. R., and Simpson, G. (1990). Effects of temperature, salt, and osmotic potential on early growth of wheat (Triticum aestivum). I. Germination. *Canadian Journal of Botany* **68**, 524-528.

Hayat, S., Fariduddin, Q., Ali, B., and Ahmad, A. (2005). Effect of salicylic acid on growth and enzyme activities of wheat seedlings. *Acta Agronomica Hungarica* **53**, 433-437.

Hussein, M., Balbaa, L., and Gaballah, M. (2007). Salicylic acid and salinity effects on growth of maize plants.

Research Journal of Agriculture and Biological Sciences **3**, 321-328.

Idrees, M., Khan, M. M. A., Aftab, T., Naeem, M., and Hashmi, N. (2010). Salicylic acid-induced physiological and biochemical changes in lemongrass varieties under water stress. *Journal of Plant Interactions* **5**, 293-303.

Iqbal, M., and Ashraf, M. (2006). Wheat seed priming in relation to salt tolerance: growth, yield and levels of free salicylic acid and polyamines. *In* "Annales Botanici Fennici", Vol. 43, pp. 250-259. Helsinki: Societas Biologica Fennica Vanamo, 1964-.

Jafar, M., Farooq, M., Cheema, M., Afzal, I., Basra, S., Wahid, M., Aziz, T., and Shahid, M. (2012). Improving the performance of wheat by seed priming under saline conditions. *Journal of Agronomy and Crop Science* **198**, 38-45.

Kang, G., Li, G., Zheng, B., Han, Q., Wang, C., Zhu, Y., and Guo, T. (2012). Proteomic analysis on salicylic acid-induced salt tolerance in common wheat seedlings (Triticum aestivum L.). *Biochimica et Biophysica Acta (BBA)-Proteins and Proteomics* **1824**, 1324-1333.

Kim, K.-H., Tsao, R., Yang, R., and Cui, S. W. (2006). Phenolic acid profiles and antioxidant activities of wheat bran extracts and the effect of hydrolysis conditions. *Food Chemistry* **95**, 466-473.

Kirkegaard, J., Christen, O., Krupinsky, J., and Layzell, D. (2008). Break crop benefits in temperate wheat production. *Field Crops Research* **107**, 185-195.

Kovács, V., Gondor, O. K., Szalai, G., Darkó, É., Majláth, I., Janda, T., and Pál, M. (2014). Synthesis and role of salicylic acid in wheat varieties with different levels of cadmium tolerance. *Journal of hazardous materials* **280**, 12-19.

Li, J.-T., Qiu, Z.-B., Zhang, X.-W., and Wang, L.-S. (2011). Exogenous hydrogen peroxide can enhance tolerance of wheat seedlings to salt stress. *Acta Physiologiae Plantarum* **33**, 835-842.

Liting, W., Lina, W., Yang, Y., Pengfei, W., Tiancai, G., and Guozhang, K. (2015). Abscisic acid enhances tolerance of wheat seedlings to drought and regulates transcript levels of genes encoding ascorbate-glutathione biosynthesis. *Frontiers in plant science* **6**, 458.

Loutfy, N., El-Tayeb, M. A., Hassanen, A. M., Moustafa, M. F., Sakuma, Y., and Inouhe, M. (2012). Changes in the water status and osmotic solute contents in response to drought and salicylic acid treatments in four different cultivars of wheat (Triticum aestivum). *Journal of plant research* **125**, 173-184.

Ma, L., Zhou, E., Huo, N., Zhou, R., Wang, G., and Jia, J. (2007). Genetic analysis of salt tolerance in a recombinant inbred population of wheat (Triticum aestivum L.). *Euphytica* **153**, 109-117.

Misra, N., and Saxena, P. (2009). Effect of salicylic acid on proline metabolism in lentil grown under salinity stress. *Plant Science* **177**, 181-189.

Mohase, L., and van der Westhuizen, A. J. (2002). Salicylic acid is involved in resistance responses in the Russian wheat aphid-wheat interaction. *Journal of Plant Physiology* **159**, 585-590.

Nagy, Z., and Galiba, G. (1995). Drought and salt tolerance are not necessarily linked: a study on wheat varieties differing in drought tolerance under consecutive water and salinity stresses. *Journal of Plant Physiology* **145**, 168-174.

Rafique, N., Raza, S. H., Qasim, M., and Iqbal, N. (2011). Pre-sowing application of ascorbic acid and salicylic acid to seed of pumpkin and seedling response to salt. *Pak. J. Bot* **43**, 2677-2682.
Raza, S. H., Athar, H.-U.-R., and Ashraf, M. (2006). Influence of exogenously applied glycinebetaine on the photosynthetic capacity of two differently adapted wheat cultivars under salt stress. *Pakistan Journal of Botany* **38**, 341-351.
Renard-Merlier, D., Randoux, B., Nowak, E., Farcy, F., Durand, R., and Reignault, P. (2007). Iodus 40, salicylic acid, heptanoyl salicylic acid and trehalose exhibit different efficacies and defence targets during a wheat/powdery mildew interaction. *Phytochemistry* **68**, 1156-1164.
Salam, A., Hollington, P., Gorham, J., Jones, R. W., and Gliddon, C. (1999). Physiological genetics of salt tolerance in wheat (Triticum aestivum L.): performance of wheat varieties, inbred lines and reciprocal F1 hybrids under saline conditions. *Journal of Agronomy and Crop Science* **183**, 145-156.
Sarker, M., Hossain, A., and da Silva, J. A. T. (2015). Timing of first irrigation and split application of nitrogen for improved grain yield of wheat in Old Himalayan Piedmont Plain of Bangladesh. *British Journal of Applied Science & Technology* **6**, 497.
Sears, E. R. (1954). "The aneuploids of common wheat," University of Missouri, College of Agriculture, Agricultural Experiment Station.
Seckin, B., Sekmen, A. H., and Türkan, I. (2009). An enhancing effect of exogenous mannitol on the antioxidant enzyme activities in roots of wheat under salt stress. *Journal of Plant Growth Regulation* **28**, 12.
Shakirova, F. M., Sakhabutdinova, A. R., Bezrukova, M. V., Fatkhutdinova, R. A., and Fatkhutdinova, D. R. (2003). Changes in the hormonal status of wheat seedlings induced by salicylic acid and salinity. *Plant science* **164**, 317-322.
Shewry, P. R. (2009). Wheat. *Journal of experimental botany* **60**, 1537-1553.
Singh, B., and Usha, K. (2003). Salicylic acid induced physiological and biochemical changes in wheat seedlings under water stress. *Plant Growth Regulation* **39**, 137-141.
Turkyilmaz, B. (2012). Effects of salicylic and gibberellic acids on wheat (Triticum aestivum L.) under salinity stress. *Bangladesh Journal of Botany* **41**, 29-34.
Wang, C., and Zhang, Q. (2017). Exogenous salicylic acid alleviates the toxicity of chlorpyrifos in wheat plants (Triticum aestivum). *Ecotoxicology and environmental safety* **137**, 218-224.
Yordanova, R., and Popova, L. (2007). Effect of exogenous treatment with salicylic acid on photosynthetic activity and antioxidant capacity of chilled wheat plants. *Gen. Appl. Plant Physiol* **33**, 155-170.
Zheng, C., Jiang, D., Liu, F., Dai, T., Jing, Q., and Cao, W. (2009). Effects of salt and waterlogging stresses and their combination on leaf photosynthesis, chloroplast ATP synthesis, and antioxidant capacity in wheat. *Plant Science* **176**, 575-582.