World Academy of Science, Engineering and Technology
International Journal of Agricultural and Biosystems Engineering
Vol:8, No:2, 2014

Improvement of Salt Tolerance in Saudi Arabian Wheat by Seed Priming or Foliar Spray with Salicylic Acid

Saad M. Howladar and Mike Dennett

***Abstract*—**The effect of exogenous application; seed priming or foliar spraying of salicylic acid (SA) on Yecora Rojo and Paragon wheat cv. under NaCl-salinity. Gas exchange parameters, growth parameters, yield and yield components were reduced in both cultivars under salinity stress with foliar spray and soaking seeds. Exogenous application of SA through foliar spraying or seed soaking showed a slight increases or decreases with the application method or between cultivars. SA foliar spraying exhibited a slight improvement over SA seed soaking in most parameters, particularly in Paragon. Although, seed soaking was less effective than foliar spraying, it was a slightly better with Yecora Rojo in some parameters. However, the low SA concentration; 0.5mM tended to improve most parameters in both cultivars. From data of the experiment, it has been concluded that the effect of SA depends on cultivar genotype and SA concentration.

***Keywords*—**Salinity, Salicylic acid, Growth parameters, yield components, Wheat cultivars.

I. Introduction

WHEAT is a major world crop in strong increasing demand due to the rapid increase in human population [1], [2], Saudi Arabia was more than self-sufficient in wheat production, producing over 3 million tonnes in the period 1989-1990 [3]. In 1992 wheat production was over 4 million tonnes, but has since it declined to 2.63 million tonnes [4]. Wheat in Saudi Arabia plays a major role in the baking industry [5], thus exported wheat from many countries; such as those in Europe, Indonesia and China [3]. Most recent studies have indicated increasing salinity of groundwater due to the local hydro-geological conditions and intensive irrigation practice [6], [7], which limits agriculture improvement in Saudi Arabia [8]. There are some limiting factors which prevent and inhibit germination and growth of healthy wheat. Salinity is the chief of these factors [9], [10]. Thus, salinity is one of the major obstacles in producing supreme quality of wheat and other crops throughout the world. Wheat (*Triticum aestivum* L.) under salinity conditions increases the concentration of proline and sugar resulting in a significant increase of electrolyte leakage at 10 and 15 dSm^{-1} [11]. It has been asserted that increase in salinity concentration brings about decrease in relative growth rate, net assimilation rate, K^+ and Ca^{2+} concentration, and grain yield of wheat, but causes an increase in Na^+ and Cl^- levels, this might be due to increase in Na^+/K^+ ratio in grain and straw at tillering stage [12]-[14]. Salinity affects wheat seedling growth by changing phytohormone levels [15]. Further, salinity induces a reduction in photosynthetic rate and stomatal conductance in wheat.

Adding more NaCl increases the action of superoxide dismutase and peroxidase in *Triticum aestivum* and reduces transpiration rate [16].

Moreover, increased salinity induces a considerable reduction in height, number of fertile tillers and dry weight of shoots in wheat [17]. Exposing wheat to salt stress leads to decrease in cell growth which causes reduction in leaf area, biomass and yield because many physiological processes are affected by salinity [18]. High salinity concentration (150 mM NaCl) induces leaf senescence or reduction of leaf protein in wheat, consequently accelerating oxygen radicals and hydrogen peroxide production in leaves [19]. Salinity also induces increases in respiration of wheat seedlings due to markedly consuming carbohydrates for maintenance of plant growth [20]. Harris et al. [21] emphasized that, the low salt concentration (15 mM) was able to decrease transpiration rate more than transpiration efficiency in seedlings of wheat and barly. These results are in line with [22] who demonstrated the reduction of net CO_2 assimilation rate, stomatal conductance and transpiration rate in wheat under salt stress (150 mM).

Previous studies investigated the potential role of SA to ameliorate the effects of salinity have applied SA either by seed soaking [23], [24] or by foliar spraying [25]. It has been suggested that the application of SA (1, 2, and 3 mM) especially at 3 mM improved wheat growth under water stress by maintaining photosynthetic rates and stomatal conductance [26]. Pretreatment of wheat seeds with SA (0.05 mM) for 3 hours promotes the development of antistress reaction under salinity and water deficit by preventing reduction of indole acetic acid and cytokinin and maintaining proline accumulation [27] and accumulation of ABA [15]. Moreover, spraying SA (10 mM) encourages salt tolerance in maize due to elevating photosynthesis performance and carbohydrate metabolism [25]. Soaking barley (*Hordeum vulgare*) seeds in SA (1 mM) for 6 hours alleviated adverse impacts of salinity through reduction of the oxidative damage of plant membranes [28]. Hamada and Al-Hakimi [29] found that soaking wheat grains in 0.72 mM SA increased wheat salt and drought tolerance via elevation of net photosynthetic rate and reduced sodium accumulation. Moreover, [30] demonstrated

S. M. Howladar is with Department of Biology, Faculty of Sciences, Al-Baha University, Al-Baha, Saudi Arabia (e-mail: showladar@hotmail.com).
M. Dennett is with School of Biological Sciences, University of Reading, UK.

that adding SA (0, 0.1, 0.5, 1 mM) in soil plays a role as a potential growth regulator to promote plant salt tolerance via an increase in antioxidant activity. Hamayun et al. [31] reported that SA also has ability to mitigate negative effects of salinity stress on soybean (*Glycine max*), perhaps through causing expression of gene coding.

It is possible that the foliar application might be more active at the seedling stage. Therefore, this study was carried out to compare the effect of SA applied by either seed soaking (SOS) or by foliar spray (FOS) treatment on improving wheat salt tolerance. SA was applied through two methods; one was soaking wheat seeds in different concentration of SA; the second was foliar application of SA on wheat leaves at 30 and 40 DAS. The aims of this experiment were to compare seed soaking and foliar spray of SA and to confirm the greater response of Paragon to SA.

II. Materials and Methods

A. Plant Material

Two cultivars were selected for this study; Yecora Rojo is highly recommended in Saudi Arabia by Silos and Flour Mills Organization and it is a semi-dwarf wheat [32] with a high protein content (14.2%) [33] and high yielding in salt-affected fields [34]. The second cultivar is Paragon is highly recommended in the UK by Home Growth Cereal Authority (HGCA) in the UK for baking, due to its high protein content (14%) and high disease resistance and Belvoir is the highest yielding spring cultivar on the NIAB recommended list [35].

B. Salicylic Acid Treatment

Concentrations of 0, 0.5, 1 mM of SA were used for both soaking and foliar spray methods. For seed soaking, Wheat grains (250g) were soaked in 500 ml of SA for 6 h and then dried near to the original weight by forced air under shade [23]. For foliar SA application, each plant was sprayed two times (30 and 40 DAS) with SA solution using a manual sprayer (Hozeloch Spraymist). The spray was applied on plants in the early morning (4 - 6 am). Spray was applied to give complete covering of the plant leaves until run-off occurred. The control plants were sprayed with distilled water [36], [37].

C. Growth Conditions

The experiment was a factorial combination of wheat seeds treated with different levels of Salicylic acid (0, 0.5, and 1 mM), applied by soaking or by foliar spray, with two salt concentrations, tap water (approximately 1 mM NaCl as control) and 100 mM NaCl. Plants were watered with this solution or tap water every three days starting eight days after emergence. The application of SA was either by soaking for 6 hours or by foliar spraying at 30 and 40 DAS. There were four replicates and the soaked and sprayed pots were placed together in each replicate. Pots were removed from their experimental position for spraying to avoid spray drift onto other pots. This study was conducted in the glasshouse (16) at the University of Reading from 10th of October 2009 to 17th of March 2010. Light was provided by high pressure sodium 400W lamps for 16 hour duration, and humidity was between 65 and 75 %. Loam based compost soil (John Innes No.2) was used. Two litres pots were filled with soil; field capacity of these pots was determined by weight. Pots were watered to field capacity and five seeds per pot were sown on 10th of October 2009. The air temperature range was from 10 to 33° C in daytime and 3 to 15° C at night. The weather in December 2009 and January 2010 was exceptionally cold. The germination tests were carried out to confirm the suppliers' information of at least 98% germination in all cultivars.

D. Gas Exchange

Leaf gas exchange measurements, including the net photosynthetic rate (A), stomatal conductance (g_s) and transpiration (E) of the second or third fully expanded leaf from the top of two plants in each of the four replicates was measured at 50 days after sowing (DAS). Measurements were made using a portable infrared gas analyzer (LCI – ADC) connected to a Parkinson leaf chamber (5.8 cm^2) at a light level of PAR > 1000 µmol m^{-2} s^{-1}, with atmospheric CO_2 concentration between 394 to 400 ppm and leaf temperature from 29 to 33 °C [38], [39].

E. Growth Parameters

At first harvest 55 DAS, the four plants from each replicate of each treatment were harvested. Each plant was cut individually at the soil level, and separated into leaves and stems. The leaf area (LA) was determined using an automatic area meter (Delta-T devices Ltd., Burwell, Cambridge, U.K.). Specific leaf area (SLA) was calculated by the following formula:

$$SLA = LA / DGLW$$

where: SLA is specific leaf area, LA is leaf area and DGLW is dry green leaf weight [40].

Green leaf number (GLN), fresh green leaf weight (FGLW), dry green leaf weight (DGLW), Tiller number (TN), fresh stem weight (FSW) and dry stem weight (DSW) were measured (each fraction was weighed (fresh weight) and then dried in an oven at 70° C for 72 hours).

At final harvest 159 DAS, the one remaining plant from each of replicate of each treatment was harvested. Main ear length (MEL), tiller number (TN), ear number (EN), fresh ear weight (FEW), dry ear weight (DEW), grain number (GN) was counted by hand and dry grain weight (DGW) were measured per plant and individual seed weight (ISW) was calculated by the following formula:

$$ISW = DGW / GN$$

where: ISW is individual seed weight, DGW is dry grain weight and GN is grain number.

All data are expressed on a per plant basis. The summary results of the statistical analyses are given in Table I.

F. Statistical Analysis

The data from the four plants per pot were averaged and these values are presented per plant. Data were analysed by ANOVA using the Statistical Analysis Software (SAS) package 9.1 (SAS 2002-2003). The least significant difference (LSD) was used to compare between means at $P < 0.05$ under completely randomized block design. The ANOVA had factors of replicate (4 levels), cultivars (2 levels), salinity (2 levels), SA (3 levels) and application method (2 levels) and all the cultivars by salinity by SA by application interactions. The error then had (69) degrees of freedom.

III. Results and Discussion

The comparison of gas exchange parameters between Paragon and Yecora Rojo under saline (tap water as control and 100 mM NaCl) conditions without SA, indicated that there was a significant reduction in net photosynthetic rate (A), stomatal conductance (g_s) and transpiration rate (E). Compared with control plants, with Paragon the effects of salinity expressed as the reduction in A, g_s and E were 21%, 62% and 35% respectively for foliar spraying, whereas the reduction with seed soaking was slightly greater with reductions of 27%, 69%, and 41% respectively. With Yecora Rojo, there was a slight increase in A with foliar spraying (8.4%) and seed soaking (8.0%) and a slight decrease in g_s by 15% (foliar spraying) and 10% (seed soaking). E showed no effect (Figs. 1 (a), (b), and (c)).

The reduction in gas exchange parameters in this experiment is consistent with Brugnoli and Lauteri (1991) and Sharma et al. (2005) who attributed the decline in A due to restriction of CO_2 via stomatal closure or rise in mesophyll resistance [41], [42]. El-Hendawy et al. [14] and Hassan [43] related the reduction in A to the decreases in chlorophyll content and g_s, where the decline in g_s could be due to hormonal control, sent by signals from the roots on water content in the shoot [44]. The reduction in E may be due to decrease in g_s and stomatal density [45], or due to an increase in abscisic acid under stress which controls stomatal conductance and causes decline in E [46].

However, the rise in A for Yecora Rojo under salinity in this experiment is consistent with Hamada and Al-Hakimi [29] who reported that the increase in A under saline conditions in wheat plants could be due to increase in chlorophyll content per unit leaf area. This is a possible adaptation to saline conditions in Yecora Rojo. However, SA supply had no significant effect on gas exchange parameters with both methods of SA application at different SA levels and different salinity concentrations. Variation in SA impact between cultivars was found in this experiment.

TABLE I
The Summary of P Values at $P < 0.05$ from ANOVA for Final Harvest.
Main Ear Length (MEL), Tiller Number (TN), Ear Number (EN), Fresh Ear Weight (FEW), Dry Ear Weight (DEW), Grain Number (GN) Dry Grain Weight (DGW) and Individual Seed Weight (ISW)

All	MEL	TN	EN	FEW	DEW	GN	DGW	ISW
Rep	0.2006	0.0983	0.1741	0.0219	0.0133	0.0137	0.1457	0.0343
Cul	0.0001	0.0036	0.0010	0.0001	0.0001	0.0001	0.0001	0.0001
Appl	0.1446	0.0186	0.0395	0.0618	0.0307	0.0757	0.1099	0.3837
Cul*Appl	0.9920	0.5487	0.5825	0.3999	0.3002	0.2166	0.1943	0.7360
Sal	0.1929	0.0485	0.0395	0.0004	0.0072	0.0022	0.0120	0.0088
Cul*Sal	0.4305	0.8414	0.5825	0.1031	0.5361	0.0184	0.4335	0.0014
Appl*Sal	0.4190	1.0000	0.5825	0.4323	0.4207	0.7500	0.3209	0.3953
Cul*Appl*Sal	0.2442	0.8414	0.4419	0.3724	0.5486	0.5893	0.3897	0.9507
Salic	0.0354	0.9900	0.6864	0.7234	0.6878	0.5176	0.6684	0.5703
Cul*Salic	0.6906	0.9133	0.7936	0.3519	0.2956	0.3622	0.3763	0.5204
Appl*Salic	0.7537	0.1656	0.2047	0.7180	0.9385	0.9955	0.8557	0.9004
Cul*Appl*Salic	0.3692	0.5327	0.6385	0.9210	0.7093	0.7226	0.7926	0.2354
Sal*Salic	0.5035	0.5434	0.4456	0.7745	0.9045	0.7741	0.8216	0.6563
Cul*Sal*Salic	0.7820	0.9900	0.7936	0.8448	0.4636	0.8679	0.7037	0.2792
Appl*Sal*Salic	0.8120	0.2341	0.1175	0.2973	0.4553	0.1773	0.6155	0.0993
Cul*Appl*Sal*Salic	0.8479	0.9319	0.7380	0.8931	0.8744	0.6874	0.7662	0.6397

Rep= Replicate, Cul= Cultivars, Appl= application, Cul*Appl= Interaction between cultivars and application, Sal= Salinity, Cul*Sal= Interaction between cultivars and salinity, Appl*Sal = Interaction between application and salinity, Cul*Appl*Sal= Interaction between cultivars, application and salinity, Salic= Salicylic acid, Cul*Salic= Interaction between cultivars and salicylic acid, Appl*Salic= Interaction between application and salicylic acid, Cul*Appl*Salic= Interaction between cultivars, application and salicylic acid, Sal*Salic= Interaction between salinity and salicylic acid, Cul*Sal*Salic= Interaction between cultivars, salinity and salicylic acid, Appl*Sal*Salic= Interaction between application, salinity and salicylic acid, Cul*Appl*Sal*Salic= Interaction between cultivars, application, salinity and salicylic acid.

TABLE II
THE SUMMARY OF P VALUES AT P < 0.05 FROM ANOVA FOR NET PHOTOSYNTHETIC RATE (A), STOMATAL CONDUCTANCE (GS) AND TRANSPIRATION RATE (E)

	A	g_s	*E*
Rep	0.0147	0.0173	0.0001
Cul	0.0016	0.0225	0.0199
Appl	0.2356	0.1797	0.1136
Cul*Appl	0.3847	0.9483	0.9967
Sal	0.0009	0.0001	0.0001
Cul*Sal	0.3126	0.6578	0.0289
Appl*Sal	0.5816	0.5126	0.7377
Cul*Appl*Sal	0.6129	0.6392	0.7269
Salic	0.2131	0.8348	0.1531
Cul*Salic	0.3783	0.4081	0.4850
Appl*Salic	0.4475	0.4737	0.4906
Cul*Appl*Salic	0.9265	0.8007	0.9358
Sal*Salic	0.2250	0.5051	0.5652
Cul*Sal*Salic	0.2200	0.0680	0.1030
Appl*Sal*Salic	0.9612	0.7571	0.9967
Cul*Appl*Sal*Salic	0.8331	0.9392	0.9855

Rep= Replicate, Cul= Cultivars, Appl= application, Cul*Appl= Interaction between cultivars and application, Sal= Salinity, Cul*Sal= Interaction between cultivars and salinity, Appl*Sal = Interaction between application and salinity, Cul*Appl*Sal= Interaction between cultivars, application and salinity, Salic= Salicylic acid, Cul*Salic= Interaction between cultivars and salicylic acid, Appl*Salic= Interaction between application and salicylic acid, Cul*Appl*Salic= Interaction between cultivars, application and salicylic acid, Sal*Salic= Interaction between salinity and salicylic acid, Cul*Sal*Salic= Interaction between cultivars, salinity and salicylic acid, Appl*Sal*Salic= Interaction between application, salinity and salicylic acid, Cul*Appl*Sal*Salic= Interaction between cultivars, application, salinity and salicylic acid.

In this context, Borsani et al. [47] explained the variation in response to SA in their work on Arabidopsis to a dual role of SA which can have positive and negative effect under stress whereas Stevens and Senaratna [46] and Najafian et al. [48] attributed the variation to differences in SA concentration and between plant species (Table II).

In addition, this study showed that a significant reduction in green leaf number, leaf area, specific leaf area and tiller number under saline conditions without SA in both cultivars with both applications. With foliar spraying the greatest reduction was in leaf area by 20% for Paragon and 40% for Yecora Rojo. With seed soaking application the decline also was greater and clearer in leaf area than in other growth parameters by17% for Paragon and 19% for Yecora Rojo. However, there was an increase in specific leaf area (11%) in Yecora Rojo (Fig. 2). A similar tendency has been reported in [28], [29], [49], [50]. These reports showed that salinity caused a noticeable reduction in growth parameters of wheat. The decrease in growth parameters could be due to increase in concentration of Na^+ and Cl^- in leaf tissues which induce changes in the osmotic potential [51], or due to decrease in the metabolic processes [15].

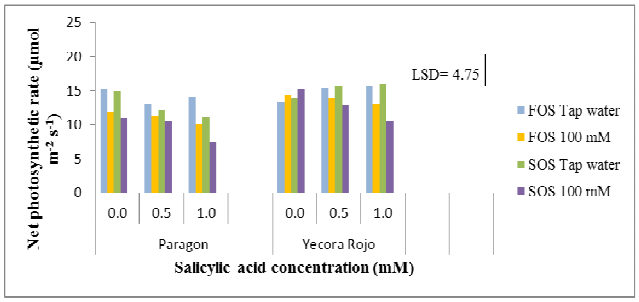

Fig. 1 (a) Net photosynthetic rate at 50 DAS. LSD between individual treatments is shown, LSD between cultivars 1.37, between application 1.37, between salinity 1.37, between salicylic acid 1.68

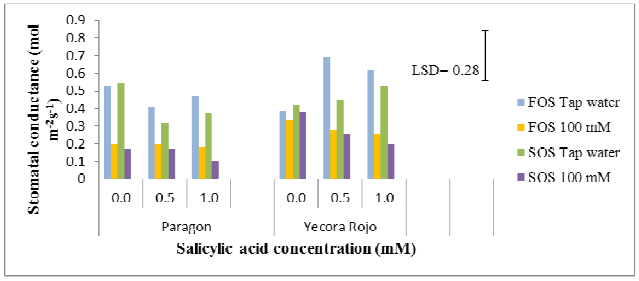

Fig. 1 (b) Stomatal conductance at 50 DAS. LSD between individual treatments is shown, LSD between cultivars 0.08, between application 0.08, between salinity 0.08, between salicylic acid 0.10

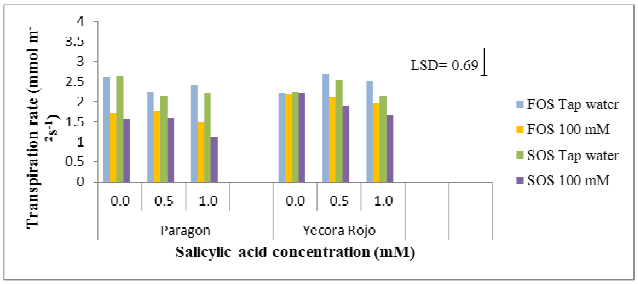

Fig. 1 (c) Transpiration rate at 50 DAS. LSD between individual treatments is shown, LSD between cultivars 0.20, between application 0.20, between salinity 0.20, between salicylic acid 0.25

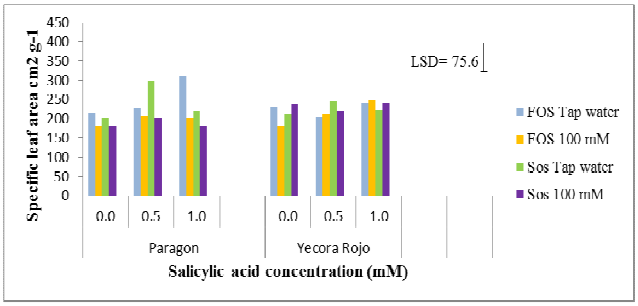

Fig. 2 Specific leaf area at 55 DAS. LSD between individual treatments is shown, LSD between cultivars 21.8, between application 21.8, between salinity 21.8, between salicylic acid 26.7

The reduction in leaf number and leaf area under salinity may be related to the reduction in tiller number [32], [52], and the reduction in leaf growth could be related to water stress [17]. In other words, the decline in leaf area is a means to minimize water loss [51]. Moreover, in this experiment there was a decrease in *A* which might have caused a reduction in growth. This finding is in agreement with the results of [43]. The decline in specific leaf area under salinity was mentioned by [13] who attributed the reduction in SLA to the influence of carbon use in plant changing the ratio of photosynthetic tissues to respiring tissues. This result is consistent with the results of other reports by Jamenez et al. [53] in roses and Bie et al. [54] in lettuce, which attributed the leaf injury to sodium concentration in the plant.

Although SA application showed neither increase nor decrease in green leaf number, leaf area, specific leaf area, and tiller number, there was no significant effect with both methods of SA application under salinity stress or without stress. The results disagree with these of Shakirova et al. [15] who related that the increase in growth parameters is due to the ability of SA to prevent the reduction of IAA and cytokinin concentration under saline conditions. It assists cell division in roots which improve the growth. Similar results were found in [23] in spring wheat. The difference in response to SA between cultivars could be due to a dual function of SA which can have positive and/or negative effect under stress [47].

Total fresh weight and its components (fresh leaf weight and fresh stem weight) were reduced significantly under saline conditions (100 mM NaCl). Compared with control plants, the reduction with foliar application was higher than with soaking seeds. The reduction in fresh and dry matter of wheat could be a toxic effect caused by NaCl concentration [32], [55]. Wheat growth parameters may be affected by osmotic potential [56], or due to changes in plant anatomy, which leads to reduce in water uptake [57]. Sairam et al. [58] demonstrated that the increase in H_2O_2 and lipid peroxidation as a result of salinity influence on membrane stability index led to a reduction in wheat growth.

SA application again induced slight effects but these were not significant with or without salinity stress via both method of SA application. On contrary, Arfan et al. [59] demonstrated that SA induced increases in fresh and dry weight. That could be due to the increase in photosynthesis per unit leaf area. El-Khallal et al. [51] related the increase in growth to increase in concentration of free amino acids and proline by SA, which mitigated salinity stress.

This experiment also indicated that dry green leaf weight, dry stem weight and total dry weight were affected by salinity without SA treatment. Compared with control plants, with foliar spraying with Paragon 100 mM NaCl stimulate slightly dry leaf weight and total dry weight which caused increase by 5% and 6% respectively whereas dry stem weight was not affected. With Yecora Rojo there were reductions of 15%, 25% and 22% respectively. With seed soaking application, the effect of 100 mM NaCl on total dry weight and its components was not constant. With Paragon, dry leaf weight decreased by 7%, dry stem weight increased by 13% whereas total dry weight was not affected. With Yecora Rojo the negative effect of salinity was obvious, dry leaf weight, dry stem weight and total dry weight declined by 23%, 32%, and 27% respectively.

The reduction in dry weight was also found [42], [55]. These reports attributed this reduction in dry weight to toxic effect of NaCl and the reduction in water uptake, and consequently the decrease in nutrient uptake and osmotic potential [30], [51]. El-Hendawy et al. [14] reported that the reduction in growth was due to decrease in photosynthetic capacity. However, the stimulation or unchanged effect by salinity was reported in earlier studies on wheat by Salama et al. [60] who related that to the roots ability to control Na^+ uptake and maintan internal K^+ and Mg^{++} level. Mansour and Salama [61] attributed that to wheat genotype. Wilson et al. [32] refer an increase in or stimulation wheat growth by Na^+ to differences between genotype and to cell expansion.

SA treatment through foliar spraying and seed soaking did not induced significant effects on total dry weight and its components. The results are not in agreement of those in [28], [62], in which found an increase in dry weight and related that to improvement in photosynthetic rate. Afzal et al. [23] associated the rise in dry weight to increase in N and nitrate reductase activity whereas Yildirim et al. [63] related that to increase in mineral uptake.

Final harvest (159 DAS) showed the reduction in yield and yield components under salinity stress (100mM NaCl) without SA. Compared with control plants, in Paragon with foliar spraying tiller number, ear number, fresh ear weight and dry ear weight were reduced significantly by 27%, 22%, 39%, and 33% respectively. For Yecora Rojo the decline was slightly

less in the most parameters, they were reduced by 21%, 43%, 32%, and 20% respectively under 100 mM NaCl. With seed soaking tiller number in Paragon and ear number in both cultivars were not changed under salinity stress whereas other parameters declined. In Paragon, fresh ear weight and dry ear weight reduced by 25% and 21% respectively. With Yecora Rojo tiller number and fresh ear weight reduced by 13% and 6% respectively whereas salinity slightly increased dry ear weight by 13%.

The results are in agreement of those in [52] that reported a reduction in tiller number, ear number and ear weight could be due to influenced leaf extension at early growth and nutrient uptake. Hassan [43] attributed that reduction to decrease in photosynthesis.

However, SA application through foliar spraying and seed soaking did not give any significant effect on yield and yield components whereas previous studies detected a significant effect. The improvement in yield could be due to enhancement in ear number through translocation of photoasimilates from stem to grains during filling stage under SA effect [59], or due to increase in photosynthesis [51].

Grain number and dry grain weight was affected significantly under 100 mM NaCl without SA treatment. Compared with control plants, in Paragon with foliar spraying grain number and dry grain weight declined by 52% and 35% respectively and were reduced by 45% and 40% respectively in Yecora Rojo. With seed soaking in Paragon there were reductions in grain number and dry grain weight by 27% and 19% respectively but they increased by 9% and 8% respectively in Yecora Rojo.

In agreement with our results, in [32], [52] found that the reduction in grain yield under salinity stress could be attributed to decline in leaf and tiller number. Hassan [43] attributed the reduction in grain yield to declined in net photosynthetic by salinity, whereas Poustini and Siosemardehb [64] related that to the reduction in K^+/Na^+ ratio. El-Khallal et al. [51] in their work on maize, suggested the reduction in yield could be attributed to decrease in endosperm cell number as a result in a rise in abscisic acid.

The experiment results did not show any significant effect of SA application on grain yield. On contrary, Singh and Usha [26] found a significant improvement in grain yield by SA and they contributed that to increase in Rubisco activity. Arfan et al. [59] and El-Khallal et al. [51] related that improvement to the general increase in photosynthesis.

Main ear length (MEL) was also affected by salinity without SA. Compared with control plants, in Paragon and Yecora Rojo with foliar spraying MEL showed slight increases by 3.4% and 4.1% respectively. With seed soaking there was also an increase in MEL for both cultivars Paragon (6.1%) and Yecora Rojo (5.0%). These results are not in line with [65] in which it has been reported that the ear length of maize was diminished under salinity stress brought about by decreases in water uptake.

SA supplementation induced a significant impact on MEL (Fig. 3). At tap water, with foliar spraying in Paragon the maximum increase in MEL was 2% at 1 mM SA whereas in Yecora Rojo MEL was decreased by 9% at 0.5 mM SA and 11% at 1 mM SA.

With seed soaking, the effect was adverse; MEL in Paragon was reduced by 10.8% at 0.5 mM SA but only 2% at 1 mM SA. In Yecora Rojo the maximum increases was 1% at 1 mM SA. At 100 mM salinity, SA showed a negative effect on MEL with both applications and in both cultivars. The reduction was more pronounced in Yecora Rojo with foliar spraying.

Increases in ear length with SA were reported in wheat [66] and in maize [67], the latter attributed that to translocation of photosynthesis products from source to sink in yellow maize. Overall, not much work has been done on main ear length. However, the effect of SA on MEL probably depends on plant genotype, plant stage and SA concentration as found for other parameters [67].

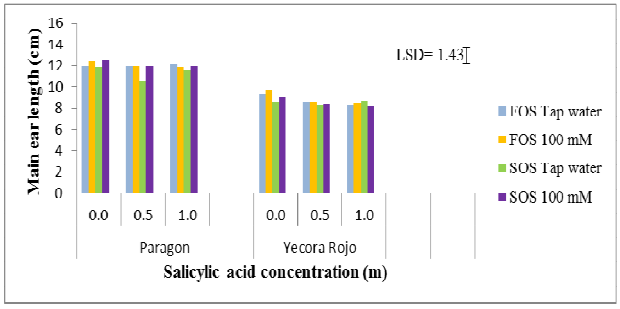

Fig. 3 Main ear length at 159 DAS. LSD between individual treatments is shown, LSD between cultivars 0.41, between application 0.41, between salinity 0.41, between salicylic acid 0.51

IV. Conclusions

The effect of salinity was obvious on gas exchange parameters, growth parameters, yield and yield components. They were reduced in both cultivars with foliar spray and soaking seeds. Using SA through foliar spraying or seed soaking showed a slight increases or decreases but these were not constant and significant with the applications method or between cultivars. Foliar spraying exhibited a slight improvement over seed soaking in most parameters, particularly in Paragon. Although, seed soaking was less effective than foliar spraying, it was a slightly better with Yecora Rojo in some parameters. However, the low concentration (0.5 mM SA) tends to improve most parameters in both cultivars. Overall, this experiment emphasizes that the effect of SA depends on cultivar genotype and SA concentration.

References

[1] Gooding MJ, Davies WP (1997) An introduction to the utilization, development and production of wheat. In MJ Gooding, ed, Wheat production and utilization. CAB International, Oxford, pp 1-59.
[2] Flowers TJ (2004) Improving crop salt tolerance. Journal of Experimental Botany 55: 307-319.
[3] Qarooni J (1995) Wheat usage in the Middle East and North Africa. In H Faridi, J Faubion, eds, Wheat and uses around the world. American Association of cereal Chemists, St. Paul, Minnesota.
[4] FAO (2010) Production crops. http://faostat.fao.org/site. Accessed on 22/06/2010. In FAOSTAT. UN.

[5] Muousa E, Al-Mohizea I (1987) Bread baking in Saudi Arabia. Cereal foods world 32: 614-620.
[6] Alyamani MS (1999) Salinity problem of groundwater in the wadi tharad basin, Saudi Arabia. GeoJournal 48: 291-297.
[7] Subyani A (2005) Hydrochemical identification and salinity problem of ground-water in Wadi Yalamlam basin, western Saudi Arabia. Journal of Arid Environments 60: 53-66.
[8] El-Juhany L, Aref I (2005) Interactive effects of low water supply and high salt concentration on the growth and dry matter partitioning of Conocarpus erectus seedlings. Saudi Journal of Biological Sciences 12: 147-157.
[9] Greenway H, Munns R (1980) Mechanisms of salt tolerance in nonhalophytes. Anuual Review of Plant Physiology 31: 149-190.
[10] Zapata PJ, Serrano M, Pretel MT, Amorós A, Botella MÁ (2003) Changes in ethylene evolution and polyamine profiles of seedlings of nine cultivars of *Lactuca sativa* L. in response to salt stress during germination Plant Science 164: 557-563.
[11] Khatkar D, Kuhad M (2000) Short-term salinity induced changes in two wheat cultivars at different growth stages. Biologia Plantarum 43: 629-632.
[12] Chhipa B, Lal P (1995) Na+/K+ ratios as the basis of salt tolerance in wheat. Australian Journal of Agricultural Research 46: 533-539.
[13] Cramer GR, Alberico GJ, Schmidt C (1994) Salt tolerance is not associated with sodium accumulation of 2 maize hybrids. Australian Journal of Plant Physiology 21: 675-692.
[14] El-Hendawy S, Hu Y, Schmidhalter U (2005) Growth, ion content, gas exchange, and water relation of wheat genotypes differing in salt tolerances. Australian Journal of Agricultural Research 56: 123-134.
[15] Shakirova F, Sakhabutdinova A, Bezrukova M, Fatkhutdinova R, Fatkhutdinova D (2003) Changes in the hormonal status of wheat seedlings induced by salicylic acid and salinity. Plant Science 164: 317-322.
[16] Sharma N, Gupta N, Gupta S, Hasgawa H (2005) Effect of NaCl salinity on photosynthetic rate, transpiration rate, and oxidative stress tolerance in contrasting wheat genotypes. Photosynthetica 43: 609-613.
[17] Iqbal M, Ashraf M (2005) Presowing seed treatment with Cytokinin and its effect on growth, photosynthetic rate, ionic levels and yield of two wheat cultivars differing in salt tolerance. Journal of Integrative Plant Biology (Formerly Acta Botanica Sinica) 47: 1315-1325.
[18] Asadi A, Khiabani B (2007) Valuation of salt tolerance based on morphological and yield traits in wheat cultivars and mutants. International Journal of Agriculture and Biology 9: 693-700.
[19] Hameed A, Naseer S, Iqbal T, Syed H, Ahsanulhaq M (2008) Effects of NaCl salinity on seedling growth, senescence, catalase and protease activities in two wheat genotypes differing in salt tolerance. Pakistan Journal of Botany 40: 1043-1051.
[20] Moud A, Maghsoudi K (2008) Salt stress effects on respiration and growth of germinated seeds of different wheat (*Triticum aestivum* L.) cultivars. World Journal of Agricultural Sciences 4: 351-358.
[21] Harris B, Sadras V, Tester M (2010) A water-centred framework to assess the effects of salinity on the growth and yield of wheat and barley. In Plant and Soil. Springer.
[22] Perveen S, Shahbaz M, Ashraf M (2010) Regulation in gas exchange and quantum yield of photosystem (PSII) in salt-stressed and non-stressed wheat plants raised from seed treated with triacontanol. Pakistan Journal of Botany 42: 3073-3081.
[23] Afzal I, Basra S, Farooq M, Nawaz A (2006) Alleviation of salinity stress in spring wheat by hormonal priming with ABA, salicylic acid and ascorbic acid. International Journal of Agriculture and Biology 8: 23-28.
[24] Dolatabadian A, Sanavy S, Sharifi M (2009) Effect of salicylic acid and salt on wheat seed germination. Acta Agriculturae Scandinavica Section B- Soil and Plant Science 59: 456-464.
[25] Khodary S (2004) Effect of salicylic acid on the growth, photosynthesis and carbohydrate metabolism in salt stressed maize plant. International Journal of Agriculture and Biology 6: 5-8.
[26] Singh B, Usha K (2003) Salicylic acid induced physiological and biochemical changes in wheat seedling under water stress. Plant Growth Regulation 39: 137-141.
[27] Sakhabutdinova AR, Fatkhutdinova DR, Bezrukova MV, Shakirova FM (2003) Salicylic acis prevents the damaging action of stress factors on wheat plants. Bulgarian Journal of Plant Physiology (Special Issue) 314-319.
[28] El-Tayeb M (2005) Response of barley grains to the interactive effect of salinity and salicylic acid. Plant Growth Regulation 45: 215-224.
[29] Hamada A, Al-Hakimi A (2001) Salicylic acid versus salininty-drought-induced stress on wheat seedling. Rostlinna Vyroba 47: 444-450.
[30] Gunes A, Inal A, Alpaslan M, Eraslan F (2007) Salicylic acid induced changes on some physyiological parameters symptomatic for oxidative stress and mineral nutrition in maize (*Zea mays* L.) grown under salinity. Journal of Plant Physiology 164: 728-736.
[31] Hamayun M, Khan S, Khan A, Shinwari Z, Hussain J, Sohn E, Kang S, Kim Y, Khan M, Lee I (2010) Effect of salt stress on growth attributes and endogenous growth hormones of soybean cultivar hwangkeumkong. Pakistan Journal of Botany 42: 3103-3112.
[32] Wilson C, Read J, Abo-Kassem E (2002) Effect of mixed-salt salinity on growth and ion relations of a quinoa and a wheat variety. Journal of Plant Nutrition 25: 2687-2704.
[33] Khatchadourian H, Sawaya W, Bayoumi M (1985) The chemical composition and rheological properties of flours milled from two major wheat varieties growth in Saudi Arabia. Cereal Chemistry 62: 416-418.
[34] Genc Y, Mcdonald G, Tester M (2007) Reassessment of tissue Na+ concentration as a criterion for salinity tolerance in bread wheat. Plant, Cell and Environment 30: 1486-1498.
[35] NIAB (2007) Pocket guide to varieties of cereals, oilseeds & pulses for Spring 2007. NIAB, Cambridge, UK.
[36] Hegazi A, El-Shraiy A (2007) Impact of salicylic acid and paclobutrazol exogenous application on the growth, yield and nodule formation of common bean. Australian Journal of Basic and Applied Sciences 1: 834-840.
[37] Noreen S, Ashraf M, Hussain M, Jamil A (2009) Exogenous application of salicylic acid enhances antioxidative capacity in salt stressed sunflower (*Helianthus annuus* L.) plants. Pakistan Journal of Botany 41: 473-479.
[38] Leidi E, Lips S (1990) Effect of NaCl salinity on photosynthesis, 14C-translocation, and yield in wheat plants irrigated with ammonium or nitrate solutions. Irrigation Science 11: 155-161.
[39] Gravano E, Bussotti F, Strasser R, Schaub M, Novak K, Skelly J, Tani C (2004) Ozone symptoms in leaves of wood plants in open-top chambers : ultrastructural and physiological characteristics. Physiologia Plantarum 121: 620-633.
[40] Ortega L, Taleisnik E (2003) Elongation growth in leaf blades of Chloris gayana under saline conditions. Journal of Plant Physiology 160: 517-522.
[41] Delfine S, Alvino A, Zacchini M (1998) Consequences of salt stress on conductance to CO2 diffusion, rubisco characteristics and anatomy of spinach leaves. Australian Journal of Plant Physiology 25: 395-402.
[42] Ismail A (2003) Effect of salinity on the physiological responses of selected lines/variety of wheat. Acta Agronomica Hungarica 51: 1-9.
[43] Hassan I (2004) Interactive effects of salinity and ozone pollution on photosynthesis, stomatal conductance, growth, and assimilate partitioning of wheat (*Triticum aestivum* L.). Photosynthetica 42: 111-116.
[44] Rivelli A, James R, Munns R, Condon A (2002) Effect of salinity on water relation and growth wheat genotypes with contrasting sodium uptake. Functional Plant Biology 29: 1065-1074.
[45] Romero-Aranda R, Soria T, Cuartero J (2001) Tomato plant-water uptake and plant-water relationships under saline growth conditions. Plant Science 160: 265-272.
[46] Stevens J, Senaratna T (2006) Salicylic acid induces salinity tolerance in tomato (*Lycopersicon esculentum* cv. Roma): associated changes in gas echange, water relation and membrane stabilisation. Plant Growth Regulation 49: 77-83.
[47] Borsani O, Valpuesta V, Botella M (2001) Evidence for a role of salicylic acid in the oxidative damage generated by NaCl and osmotic stress in Arabidopsis seedlings. Plant Physiology 126: 1024-1030.
[48] Najafian S, Khoshkhui M, Tavallali V, Saharkhiz M (2009) Effect of salicylic acid and salinity in thyme (*Thymus vulgaris* L.):investigation on changes in gas exchange, water relations, and membrane stabilization and biomass accumulation. Australian Journal of Basic and Applied Sciences 3: 2620-2626.
[49] Iqbal R (2003) Effect of constant and changing salinity environment on different growth parameters in spring wheat. Asian Journal of Plant Sciences 2: 1112-1117.
[50] Iqbal M, Ashraf M, Jamil A, Shafiq-ur-Rehman (2006) Does seed priming induce changes in the levels of some endogenous plant hormones in Hexaploid wheat plants under salt stress? Journal of Integrative Plant Biology (Formerly Acta Botanica Sinica) 48: 181-189.
[51] El-Khallal S, Hathout T, Ashour A, Kerrit A (2009) Brassinolide and salicylic acid induced growth, biochemical activities and productivity of

maize plants growth under salt stress. Research Journal of Agriculture and Biological Sciences 5: 380-390.
[52] Hu Y, Oertli J, Schmidhalter U (1997) Interaction effects of salinity and macronutrient level on wheat. Journal of Plant Nutrition 20: 1155-1167.
[53] Jamenez M, Gonzalez-Rodriguez A, Morales D, Cid M (1997) Evaluation of chlorophyll fluorescence as a tool for salt stress detection in roses. Photosynthetica 33: 291-301.
[54] Bie Z, Ito T, Shinohara Y (2004) Effects of sodium sulfate and sodium bicarbonate on the growth, gas exchange and mineral composition of lettuce. Scientia Horticulturae 99: 215-224.
[55] Zoppo M, Galleschi L, Onnis A, Pardossi A, Saviozzi F (1999) Effect of salinity on water relation, sodium accumulation, chlorophyll content and proteolytic enzymes in a wild wheat. Biologia Plantarum 42: 97-104.
[56] Saneoka H, Shiota K, Kurban H, Chaudhury M, Premachandra G, Fujita K (1999) Effect of salinity on growth and solute accumulation in two wheat lines differing in salt tolerance. Soil Science and Plant Nutrition 45: 873-880.
[57] Akram M, Akhtar S, Javed I, Wahid A, Rasul E (2002) Anatomical attribtes of different wheat (*Triticum aestivum*) accessions / varieties to NaCl salinity. International Journal of Agriculture and Biology 4: 166-168.
[58] Sairam R, Rao K, Srivastava G (2002) Differential response of wheat genotypes to long term salinity stress in relation to oxidative stress, antioxidatant activity and osmolyte concentration. Plant Science 163: 1037-1046.
[59] Arfan M, Athar H, Ashraf M (2007) Does exogenous application of salicylic acid through the rooting medium modulate growth and photosynthetic capacity in two differently adapted spring wheat cultivars under salt stress? Journal of Plant Physiology 164: 685-694.
[60] Salama S, Trivedi S, Busheva M, Arafa A, Garab G, Erdei L (1994) Effects of NaCl salinity on growth, cation accumulation, chloroplast structure and function in wheat cultivars differing in salt tolerance. Journal of Plant Physiology 144: 241-247.
[61] Mansour M, Salama K (1996) Comparative responses to salinity in wheat genotypes differing in salt tolerance. 1-seedling growth and mineral. Egyptian Journal of Physiology 20: 1-15.
[62] Fariduddin Q, Hayat S, Ahmad A (2003) Salicylic acid influences net photosynthetic rate, caraboxylation efficiency, nitrate reductase activity and seed yield in *Brassica juncea*. Photosynthetica 41: 281-284.
[63] Yildirim E, Turan M, Guvenc I (2008) Effect of foliar salicylic acid application on growth, chlorophyll, and mineral content of cucumber grown under salt stress. Journal of Plant Nutrition 31: 593-612.
[64] Poustini K, Siosemardehb A (2004) Ion distribution in wheat cultivars in response to salinity stress. Field Crops Research 85: 125-133.
[65] Gurbanov E, Molazem D (2009) Effects of saline stress on growth and crop yield of different maize (*Zea mays*) genotypes. Visnyk of of Dnipropetrovsk University, Biologu.Ecology 17: 9-14.
[66] Amin A, El-Sh R, Gharib F (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.
[67] Abd El-Wahed M, Amin A, El-Sh R (2006) Physiological effect of some bioregulators on vegetative growth, yield and chemical constituents of yellow maize plants. World Journal of Agricultral Sciences 2: 149-155.