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Yield enhancement in wheat by soil and foliar fertilization of K and Zn under saline environment

Sara Zafar[1*], Muhammad Yasin Ashraf[2], Sumera Anwar[3], Qasim Ali[1] and Ali Noman[1]
[1]Government College University, Faisalabad, Pakistan
[2] Nuclear Institute of Agriculture and Biology, Faisalabad, Pakistan
[3]Huazhong Agriculture University, Wuhan, China

Abstract

Proper nutrient management is important to reduce yield losses due to salinity. In the present study response of two wheat genotypes was studied when foliar Zn and K were applied (0.2% of Zn, K and Zn+K) along with soil application (25+100 kg ha^{-1} of Zn+K) at the vegetative and reproductive stage. First experiment was conducted in pots and its results were further confirmed in saline field of Biosaline Research Station, Pakka Anna. Salinity significantly reduced all yield attributes. However, application of Zn+K through soil and foliar means significantly improved the plant height, productive tillers $plant^{-1}$, fertile spikelets $spike^{-1}$, spike length, 1000 grain weight, plant biomass and grain yield. Plant height and biomass were significantly increased by foliar application of Zn+K at reproductive stage. Application of Zn+K through soil and foliar was helpful in alleviating the adverse effects of salinity stress at both vegetative and reproductive stages of wheat. Among nutrient combinations, the Zn+K were the most effective treatment for both cultivars under salinity stress. In summary cultivar selection and nutrient application are effective strategies to improve wheat grain yield under salinity stress.

Keywords: Salinity; Zn; K; Wheat; Foliar application

Introduction

World population is envisaged to increase by 34 % till 2050 reaching about 9.1 billion, thus necessitating 70 %more food production (FAO, 2005). Modern agriculture faces several abiotic stresses, such as salinity, drought, chilling and heat as major factors affecting crop yields (Tardieu and Tuberosa, 2010). Among the abiotic stress, salinity is the major constraint limiting growth and productivity of plants affecting their metabolism and ultimately damaging the crop beyond economic repair (Ashraf, 2004). Worldwide, soil salinity adversely affect about 30 % of the irrigated and 6 %of total land area with a resultant monetary loss of 12 billion US $ in agricultural production (Fahad *et al*.,2014). Soil salinization is one of the major stress affecting more than 831 million hectares of the agricultural lands worldwide (FAO, 2005). Inhibition of growth and development, reduction in photosynthesis, respiration and protein synthesis in sensitive species has been reported under salinity. Nutrient deficiencies and excessive generation of reactive oxygen species (ROS) such as superoxide anion, hydrogen peroxide and the hydroxyl radicals, particularly in chloroplasts and mitochondria is an important indication of salinity induced oxidative damage in plants (Masood *et al*., 2006). In Pakistan the soils are characterized as calcareous having high pH and low organic matter, due to which about 70% of the cultivated soils are Zn deficient. Zinc deficiency is the third most serious crop nutritional problem in Pakistan (Abbas *et al*., 2009). Reduction in K concentration was also observed in plants due to Zn deficiency (Zhu, 2001). Saeidnejad and Kafi (2013) reported that Zn plays an important role in decreasing Na^+ and accumulating K^+ in plant under salinity stress conditions.

Wheat (*Triticum aestivum* L.) being a global significant cereal, provides 21% of calories and a source of about 20% protein for the world's increasing population (Braun *et al*., 2010). The demand of wheat will increase more than 60% by 2050 in developing countries (Rosegrant and Agcaoili, 2010), therefore, strategies should be adopted to increase its production to meet challenges of 21st century. A 65% yield loss in wheat grown under moderate saline conditions has been reported in Pakistan (Shafi *et al*., 2010). Application of inorganic nutrients is an efficient, shot gun and economical approach to increase growth and yield of crops under saline conditions (Ashraf *et al*., 2008). The development of salt tolerant wheat genotypes and their management under saline conditions to increase yield is the best option from sustainable agriculture (Asadi *et al*., 2012; Zafar *et al*., 2015).

*Email: saraomer_gcuf@yahoo.com

The aim of the present study was to investigate the effect of foliar and soil applied of Zn and K to increase wheat yield by ameliorating the adverse effects of salinity in pots as well as in saline field studies.

Materials and Methods

Site description

Two separate experiments were conducted at Nuclear Institute of Agriculture and Biology (NIAB) and Biosaline Research Station, Pakka Anna, Faisalabad, Pakistan. From the experimental field, soil samples (0–30 cm) were collected prior to sowing, air-dried, crushed to pass a 2-mm sieve and analyzed (Table 1).

Table 1: Physio-chemical properties of soils of experimental sites

Soil characteristics	(Pot Experiment) NIAB, Faisalabad	(Field Experiment) Pakka Anna
Soil Texture	Sandy Clay loam	Sandy loam
EC_e (dS m^{-1})	0.51	7.07
pH	7.21	8.09
Organic matter (%)	0.3	0.1-0.3
Saturation Percentage	36	27.4-45.3
CO_3^{2-} (meq L^{-1})	Nil	Nil
HCO_3^- (meq L^{-1})	2.96	3.25
Cl^- (meq L^{-1})	2.34	34.43
Ca+Mg (meq L^{-1})	4.5	3.1-8.2
Na^+ (ppm)	2.83	55-65
Soluble K^+ (ppm)	25	100-200
Total N (%)	0.072	0.035
Available phosphorus (ppm)	8.42	2.8
Zn (ppm)	2	0.01

Experimentation and statistical analysis

Two types of experiments were conducted (a) pot and (b) field experiment.

Pot Experiment

Ten seeds of each variety viz. Abadghar and Pari-73 were sown in plastic pots containing 8 kg of soil and were placed in net house. Salinity level of 10 dSm^{-1} was created using NaCl after 14 days of germination in two intervals. Recommended dose of N and P @ 115, 85 kg ha^{-1} were applied in splits. Potassium sulfate (SOP) and zinc ($ZnSO_4.H_2O$) sources were used for K and Zn, respectively. Soil amendment of Zn + K (25+100 kg ha^{-1}) was done to all pots under saline and non-saline conditions after 30 days of sowing. Foliar application of Zn and K (0.2% of Zn and K) was done at the vegetative (30 days old plants) and reproductive stage (90 days old plants) (Table 2). Completely randomized design was used in pot experiment.

Table 2: Treatments used during experiment

Treatment			Description of foliar application of Zn and K (%)
1	Non saline	No spray	-
2		$(K)_f$	0.2 K
3		$(Zn)_f$	0.2 Zn
4		$(Zn+K)_f$	0.2 Zn + 0.2 K
5	Saline (10 dSm^{-1})	No spray	-
6		$(K)_f$	0.2 K
7		$(Zn)_f$	0.2 Zn
8		$(Zn+K)_f$	0.2 Zn + 0.2 K

Field Experiment:

A Field experiment was conducted during Nov. 2012 at Biosaline Research Station (BSRS) Pakka Anna, Faisalabad. The experiment was a randomized complete block design (RCBD) with five replicates. Seeds of wheat genotypes (Abadghar and Pari-73) were planted through dibbler with plant to plant and row to row distance of 15 and 23cm respectively. Zinc and potassium were applied through soil as well as through foliar means at vegetative and reproductive like pot experiment. Recommended doses of N as urea @217kg urea/hectare and P as DAP @ 152kgDAP/hectare were given in splits at the time of sowing, tillering and at anthesis stage. Nine treatments of K, Zn and Zn + K were applied for testing (Table 3).

Table 3: Description of soil and foliar application of Zn and K in saline field

Treatments		Description of soil and foliar application of Zn and K in saline field: Soil (kg ha^{-1})	Foliar (%)
1	$(K)_s$	100 K_2O	-
2	$(Zn)_s$	25 Zn	-
3	$(Zn+K)_s$	25 Zn+100 K_2O	-
4	$(K)_f$	-	0.2 K
5	$(Zn)_f$	-	0.2 Zn
6	$(Zn+K)_f$	-	0.2 Zn + 0.2 K
7	$(Zn+K)_s$ and $(K)_f$	25 Zn+100 K_2O	0.2 K
8	$(Zn+K)_s$ and $(Zn)_f$	25 Zn+100 K_2O	0.2 Zn
9	$(Zn+K)_s$ and $(Zn+K)_f$	25 Zn+100 K_2O	0.2 Zn + 0.2 K

Plants were allowed to grow up to maturity. Data on various growth and yield parameters (plant height, spike length, number of spikelets per spike, number of grains per spike, 1000-grain weight and grain yield per plant) were recorded.

The collected data was analyzed using STATISTIX-8 program. Means (five replicate each) and standard errors were assessed on Microsoft Excel -2007 version.

Results

Pot Experiment

Wheat grain yield and yield attributes like biomass, plant height, productive tiller, ear length, spikelet fertility per spike, and 1000-grain weight were significantly ($p \leq 0.05$) affected by salinity stress (Figure 1 and 2). Effect of nutrients in combinations or alone were also significant ($p \leq 0.05$) for above mentioned attributes (Figure 1 and 2). A reduction in biomass was recorded in plants of wheat genotypes under NaCl stressed environment. Nutrient application of $(Zn+K)_s$ along with $(Zn+K)_f$at reproductive stage was the most effective one in enhancing biomass under saline conditions in pots in Abadghar and Pari-73 followed by $(Zn +K)_s$ in combination with $(K)_f$. The genotype Abadghar exhibited an increase in biomass under both saline and non saline conditions, respectively over Pari-73 (Fig. 1a). Plants exposed to salinity stress exhibited a significant reduction in plant height. The tallest plants were produced under non-saline control conditions (Fig.1b) in both genotypes Abadghar and Pari-73. Foliar and soil application of Zn, K and Zn+K improved the plant height of the wheat plants grown under saline conditions in pot experiment. Maximum height (97, 70 cm) was maintained by plants of Abadghar and Pari-73 which were treated with $(Zn+K)_s$ and supplemented with $(Zn+K)_f$, followed by $(Zn+K)_s$ + $(K)_f$ (93, 69 cm) and $(Zn+K)_s$ + $(Zn)_f$ (90, 68 cm) under saline conditions. Wheat genotype Abadghar maintained more height (26%) than Pari-73, with maximum values (4%) recorded at reproductive stage (Fig.1b).

Productive tillers were also influenced by the adverse affect of salinity. A severe reduction was observed in Pari-743 (33%) followed by Abadghar (23%) under salinity stress conditions over non-saline control plants(Fig.1c). The comparison among treatments indicated that maximum productive tillers plant^{-1}were obtained with nutrient application of $(Zn+K)_s$ and supplemental foliar application of $(Zn+K)_f$ (4.6,3.6) in Abadghar and Pari-743, followed by $(Zn+K)_s$+$(K)_f$, $(Zn+K)_s$+$(Zn)_f$ and $(Zn+K)_s$ (Figure 1c). Exogenous application of Zn, K and their combination improved the ear length in wheat plants. Plants of Abadghar and Pari-73 treated with $(Zn+K)_s$ and $(Zn+K)_f$ (13.1,11.6 cm) exhibited maximum ear length followed by $(Zn+K)_s$ and $(K)_f$ under saline conditions in pot experiment.Comparison between growths stages indicated that plants treated with nutrient application at reproductive stage in pot cultured experiment exhibited a 4% increase in ear length than those treated at vegetative stage (Fig. 1d).

Spikelet fertility was influenced by salinity stress at both vegetative and reproductive stages in both varieties as shown in fig.2a. Nutrient application of $(Zn+K)_s$with $(Zn+K)_f$ was the most effective treatment in reducing the adverse effects of salinity by maintaining higher number of fertile spikelets/spike in plants of Abadghar and Pari-73 (18,14) respectively as compared to other treatments.Analysis of variance indicated a decrease in 1000-grain weight in saline conditions over non-saline control plants; however heavier grains were reported by Abadghar (40.2 g) as compared to Pari-73 (25.3 g) under saline conditions in pot experiment. Plants of Abadgharand Pari-73 treated with $(Zn+K)_f$exhibited a 16 % and 26% increase in grain weight as compared to plants under saline conditions with no spray (Fig.2b). Nutrient application of Zn, K and Zn+K enhanced the yield plant^{-1} of wheat genotypes under stressed environment. Wheat genotype Abadghar and Pari-73 showed an increase in yield of 19% and 14% under saline conditions in pot experiment with nutrient application of $(Zn+K)_f$when applied at reproductive stage (Fig.2c).

Field experiment

Excess saline conditions caused severe reduction in plant height, productive tiller, spikelet fertility and ear length in Pari-73 as compared to Abadghar, however, nutrients application influenced all the growth attributes at reproductive stage. Soil amendment of $(Zn+K)_s$ with $(Zn+K)_f$ maintained the highest plant height followed by plants grown under $(Zn+K)_s$ in combination with $(K)_f$ as compared to control plants (Fig.3a). Between the genotype Abadghar achieved highest plant height (104cm) as compared to Pari-73 plant (81cm) under saline environment with application of Zn+K both in soil and as foliar. Data recorded on productive tillers revealed that nutrient application of $(Zn+K)_s$ along with $(Zn+K)_f$ was the most effective in enhancing productive tillers m^{-2} followed by $(Zn+K)_s$ in combination with $(K)_f$ statistically similar with $(Zn+ K)_s$ along with $(Zn)_f$. Overall, results indicated that maximum productive tillers m^{-2} in plants of Pari-73 (52%) and Abadghar (50%) were obtained with nutrient application of $(Zn+ K)_s$ along with $(Zn+ K)_f$ under saline field conditions (fig. 3b).

An increment in spikelet fertility was observed by the nutrient application under saline conditions (Figure 3c). Nutrient application of $(Zn+K)_s$ along with $(Zn+K)_f$ significantly enhanced the fertile spikelets in wheat plants followed by $(Zn+K)_s$ in combination with $(K)_f$. However minimum value of fertile spikelets spike^{-1}was recorded in

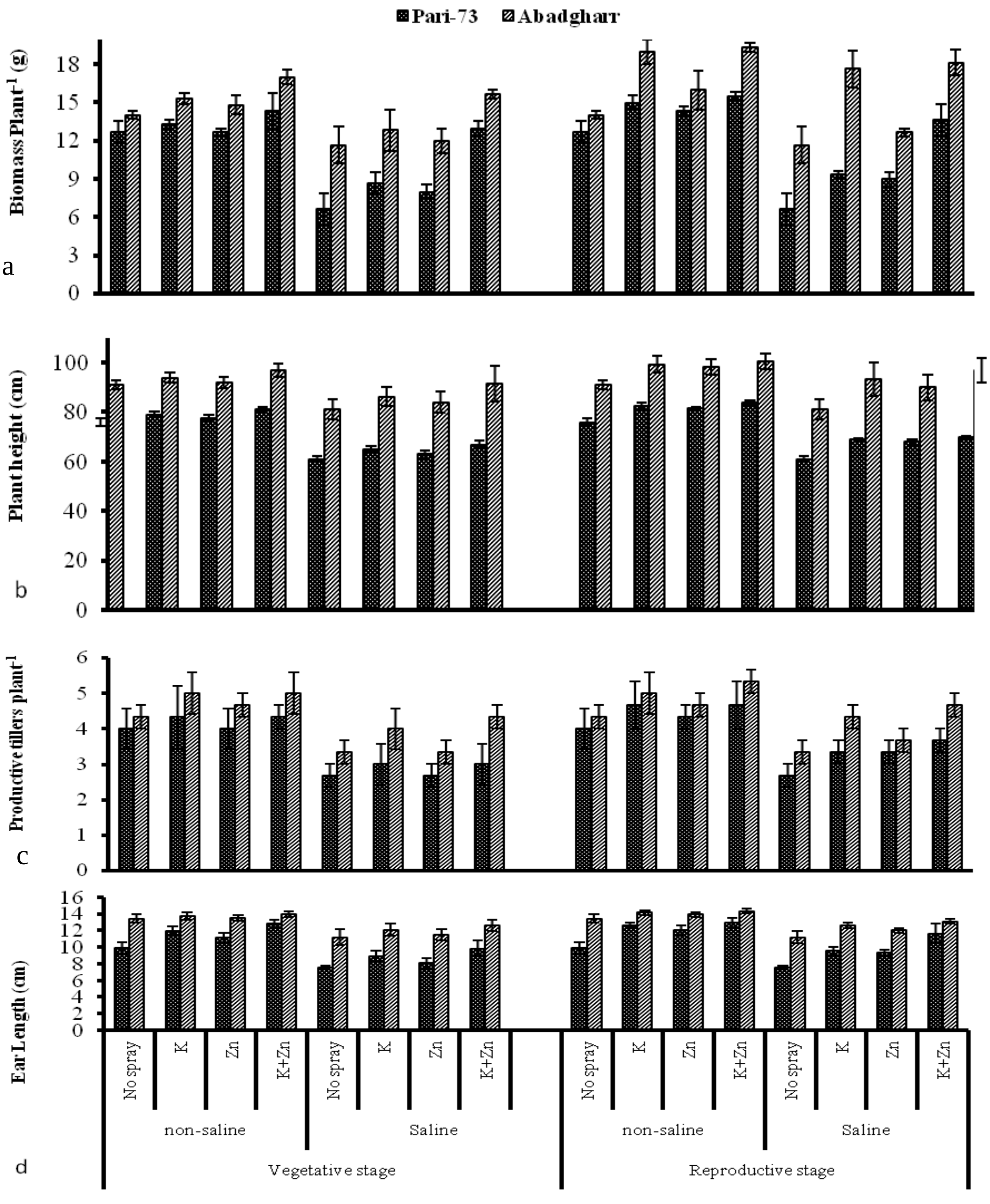

Figure 1: Growth attributes of two wheat cultivars effected by foliar application of K and Zn (0.2%) at vegetative and reproductive stages when grown in non-saline and saline soil.

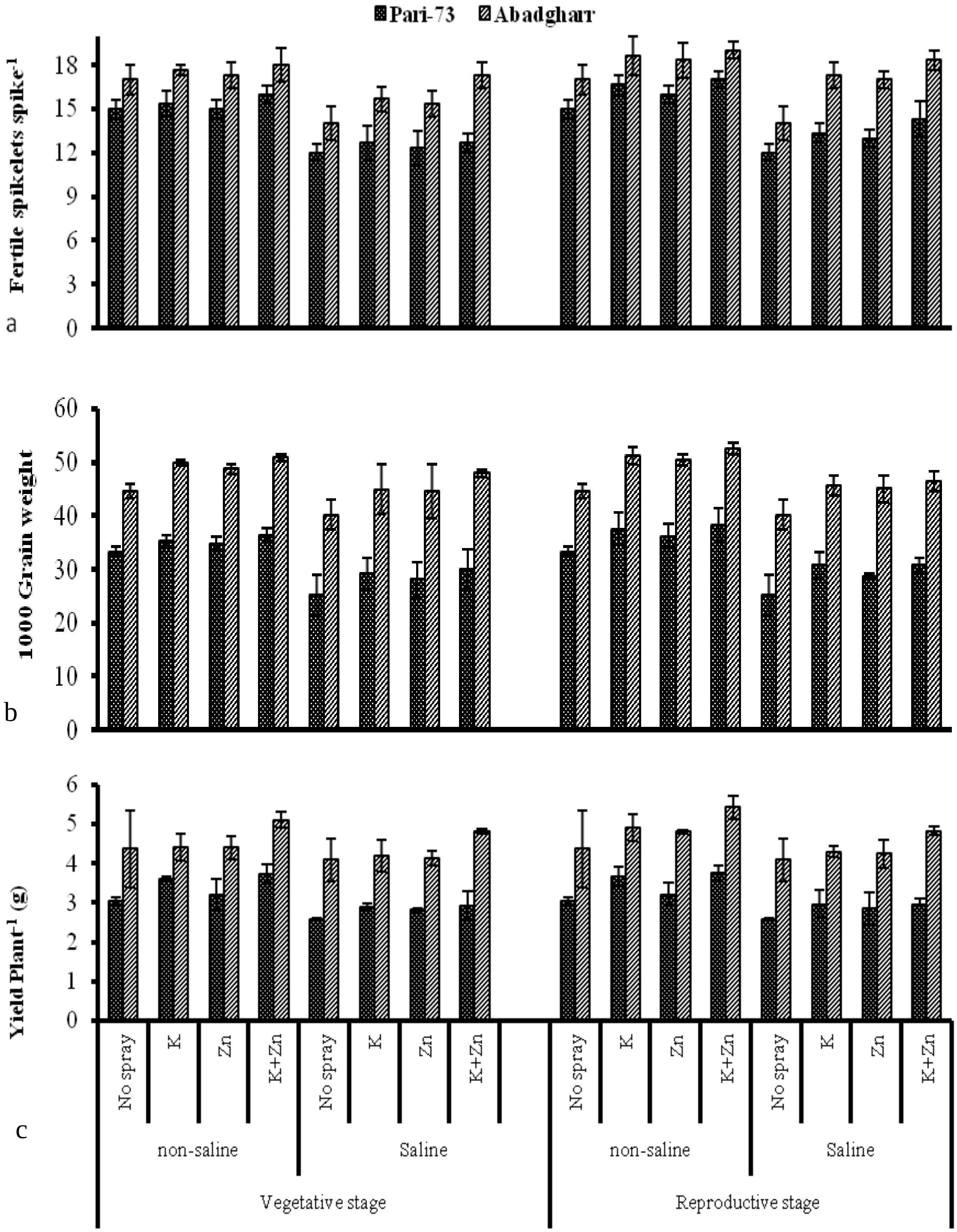

Figure 2: Growth attributes of two wheat cultivars affected by foliar application of Zn and K at different growth stages when grown in non-saline and saline soil

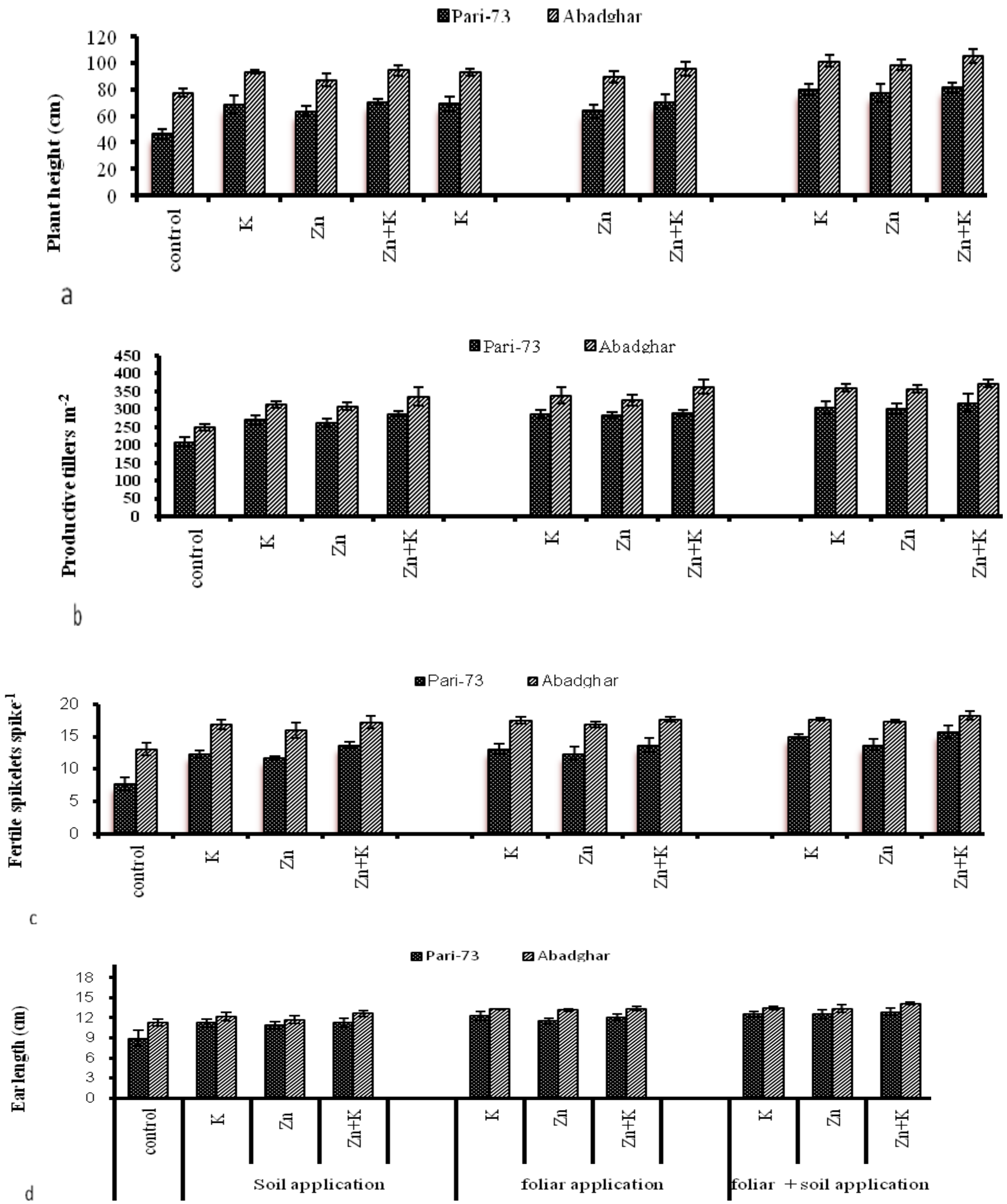

Figure 3: Effect of soil applied and foliar spray of Zn, K alone and in combinations on (a) plant height, (b) productive tillers m^{-2} and (c) fertile spikelets spike^{-1}, (d) ear length, of wheat genotypes under saline field conditions (R=5±S.E) are standard errors)

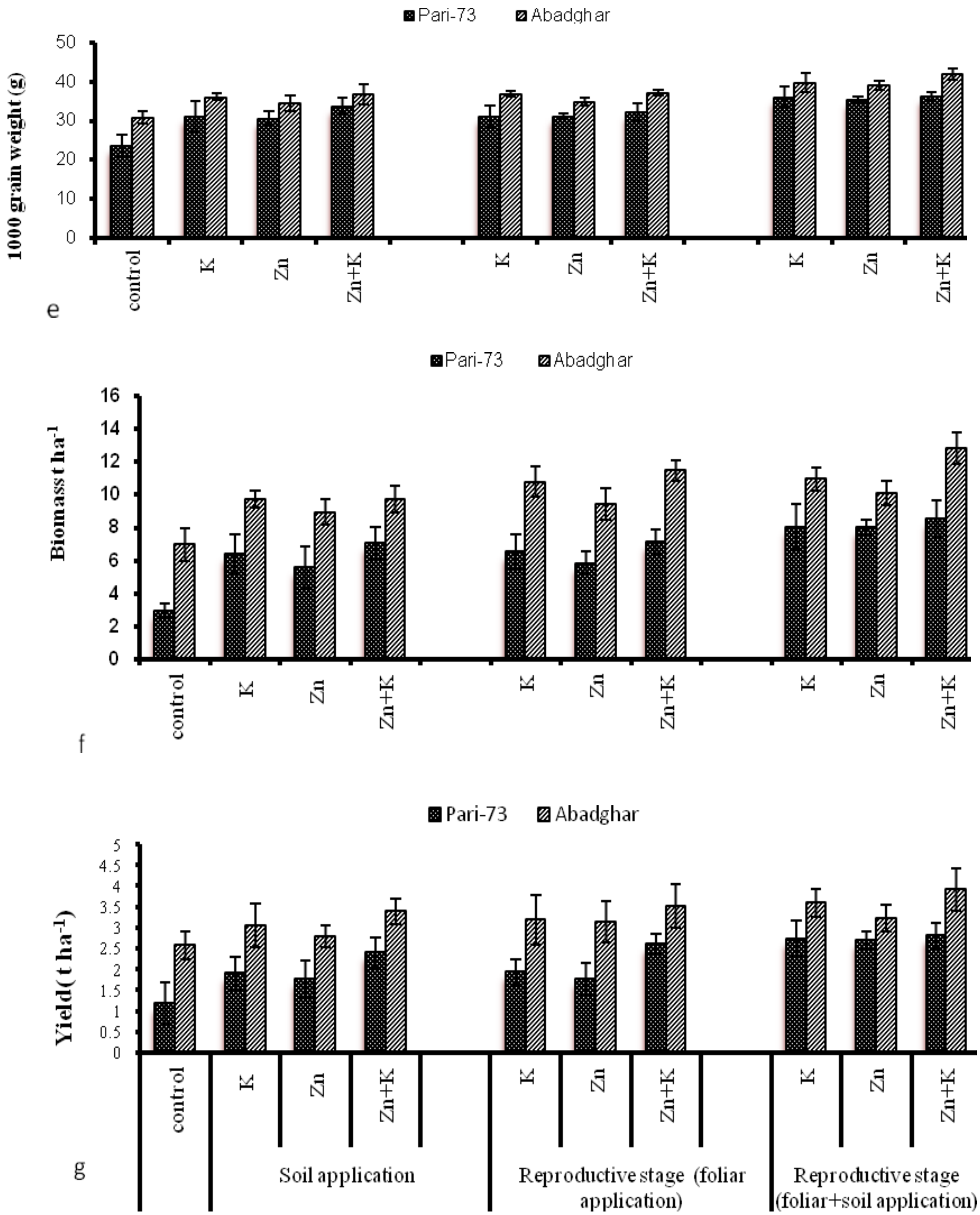

Figure 4: Effect of soil applied and foliar spray of Zn, K alone and in combinations on (a) 1000 grain weight (b) biomass t ha^{-1} and (c) yield t ha^{-1} of wheat genotypes under saline field conditions (R=5±S.E) are standard errors)

both varieties at non treated plants compared to treated varieties in saline conditions. A significant improvement in ear length was observed with nutrient application of $(Zn+K)_s$ along with $(Zn+K)_f$ followed by $(Zn+K)_s$ in combination with $(K)_f$ and minimum ear length was exhibited in plants grown under saline (control) conditions (Fig.3d).Application of $(Zn+K)_s$ along with $(Zn+K)_f$ was more effective in improving ear length in Abadghar (45%) compared to Pari-72 (27%) grown under in salt-affected soil.

Nutrient applications have significantly enhanced grain weight in both wheat varieties grown under saline field. Plants with application of $(Zn+K)_s$ in supplementation of $(Zn+K)_f$ produced grains with higher weight than others treatments. Application of soil + foliar supplementation of Zn+K maintained 56% and 36% enhancement in1000 grain weight in plants of Pari-73 and Abadghar as compared to control saline plants (Fig. 4a). Plant dry biomass was significantly influenced by the exogenous application of Zn, K and Zn+ K in wheat genotypes (Fig. 4b). With the nutrient application of $(Zn+K)_s$ along with $(Zn+K)_f$ Abadghar achieved maximum biomass (11tha^{-1}) followed by Pari-73 (7tha^{-1}) . A significant increase in grain yield was recorded in plants with exogenous application of Zn, K and Zn+ K in both wheat genotypes under saline field conditions (Fig. 4c). The highest grain yield (tha^{-1}) was obtained in Abadghar (51%) and Pari-73 variety (140 %) with foliar and soil application of (Zn+K) followed by K and Zn alone than untreated fertilizer field.

Discussion

The present study demonstrated the positive influence of Zn and K supply either by soil or foliar application on wheat yield and its components to salinity stress. Salinity stress significantly reduced the fertile spikelets, plant height, ear length, 1000-grain weight, biomass and yield $plant^{-1}$ in wheat genotypes Abadghar and Pari-73. Numerous studies have previously reported that salinity stress influenced the wheat genotype performances and its related attributes (Shamsi and Kobraee,2013).

However, K application @ 100 kg ha^{-1} improved the yield and its related attributes as reported by Baque *et al.* (2006). Application of Zn @ 25 kg ha^{-1} was also effective in enhancing grain yield. Similar findings have been reported by Siddiqui *et al.* (2009) in sunflower. Zinc fertilization increased yield, crude protein and Zn concentration by improving plant growth and productivity, maintaining structural integrity of DNA and RNA and regulating enzymes involved in physiological and biochemical functioning in alfalfa plants (Cakmak, 2008). In the present study, yield and 1000 grain weight of wheat genotype Abadghar was higher than Pari-73 under salinity which may be attributed to its lower Na and higher Kuptake (Akram *et al.*, 2010).

Although plant height is an inherited trait, however gene expression is strongly influenced by the environment conditions (Balal *et al.*, 2011). It is evident from present study as wheat genotype Abadghar exhibited significantly more height under normal and stress conditions as compared to Pari-73. Plant height may be reduced due to protoplast dehydration which disturbed plant water relations and decreased cell extensibility (Hussain *et al.*,2008).

Reduction in wheat grain yield was due to reduction in yield contributing traits like spikelets/spike, fertile spike and 1000-grain weight under saline conditions which may be due to reduced photosynthetic activity of plants (Nasri, 2005). Reduction in yield in plant exposed to stress is a common observation (Anjum *et al.*, 2011). However, tolerant varieties successfully maintained higher yield than sensitive ones (Liu and Li, 2005). Results of present study confirmed these findings where tolerant genotype Abadghar maintained higher yield and yield components than sensitive genotype Pari-73.

Number of tillers per plant is also a contributing factor in grain yield of wheat and rice (Kim *et al.*,2010). Nutrient application is effective in improving number of tillers per plant (Hasanuzzaman *et al.*, 2010) as observed in present study where application (Soil or foliar) of K, Zn and K+Zn increased yield and yield relating attributes (spike length, spikelets $spike^{-1}$, productive tillers $plant^{-1}$, 1000 grain weight, biomass $plant^{-1}$) under normal as well as saline conditions. Application of Zn and K increased yield and yield components in wheat plants (Morshedi and Farahbakhsh, 2012). While, Keram *et al*. (2012) recorded maximum yield, nutrient uptake, total carbohydrate in plants treated with 20kg Zn ha^{-1}. Potassium fertilizer application improved the height in wheat plants (Raza *et al*., 2012).

Results of field experiment conducted at Biosaline Research Station (BSRS) at Pakka Anna near Faisalabad, Pakistan confirmed that application of K, Zn and K+Zn (soil or foliar) in improving the yield and yield components. The results are in agreement with Gonzalez *et al*. (2010), who reported that foliar application of nutrients increases yield and meet the crop nutrient demand when salinity limits soil applied nutrients towards photosynthetic mechanism. In our experiment soil + foliar application of fertilizers is more effective to increase biomass and yield in plants (Mousavi, 2011). In our experiment the combined application of K and Zn (25, 100 Zn+K_2O kg ha^{-1}respectively and 0.2% Zn + K each, respectively) was the most effective in increasing yield and yield related attributes as reported by Morshedi and Farahbakhsh (2012). Reports also showed that 33 % $ZnSO_4$ applied @ 22.5 kg

$ZnSO_4$ ha^{-1} with recommended NPK produced yield with higher economic return (Abbas *et al*., 2010). Narwal *et al*. (2010) also reported that highest grain yield was obtained by applying Zn through soil @ 25 kg $ZnSO_4$ ha^{-1} along with foliar spray of 0.5% $ZnSO_4$ in wheat. In respect of the above results soil along with foliar fertilization of Zn+K improved all the yield components of wheat in comparison with the nutrients applied alone in soil or foliar in salt stress condition. So, soil (25, 100 Zn+K_2O kg ha^{-1}respectively) + foliar (0.2% Zn+K each, respectively) application can be considered as the beneficial practice to obtain 51% increase in yield of Abadghar wheat under saline environment. Future work may focus on screening cultivars with higher productivity, higher nutritional value, molecular pathways, recognized by molecular biology and proteomic analyses regarding the perception of plant, may elucidate more details related to the effects of nutrients on plant responses to salinity stress.

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