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Full Length Article

Evaluation of Soil and Foliar Applied Zinc Sources on Rice (*Oryza sativa*) Genotypes in Saline Environments

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Abstract

Zinc (Zn) application to rice crop under saline conditions is an important approach to sustain yield but methods for application with zinc sources are important to improve salinity tolerance in different rice genotypes. This study compared the response of rice (*Oryza sativa L.*) varieties to soil and foliar applied $ZnSO_4$ and Zn-EDTA. Four week old seedlings of four rice genotypes (KSK-133, Bas-198, Bas-2000 and IR-6) were grown in soil with salinity maintained at two levels (control and EC 7 dS m^{-1}). Soil and foliar Zn were applied using 15 mg kg^{-1} $ZnSO_4$ and Zn-EDTA as source. Salinity stress adversely reduced the plant growth while Zn applications increased the plant biomass production. On the basis of dry biomass production, shoot K^+, Na^+ and Zn concentration KSK-133 was regarded as salt tolerant, followed by Bas-2000 and IR-6 while Bas-198 considered as salt sensitive. The soil application of Zn-EDTA increased the plant growth and yield while under saline conditions foliar applied $ZnSO_4$ proved as a good source as its application increased the growth, yield and Zn grain contents. Zn application reduced the adverse effects of salt stress by improving the agronomic attributes and could be used as an effective tool for rice production.

Keywords: Zinc; *Oryza sativa*; Salinity; Foliar application; $ZnSO_4$; Zn-EDTA

Introduction

In arid and semi-arid regions of the world, effects of salinity are more obvious where high evapo-transpiration, limited rainfall and high temperature related with poor quality water and soil management practices are the major contributing factors (AzevedoNeto *et al*., 2006). Salinity is causing a considerable loss of agricultural sector (Wu *et al*., 2007; Shao *et al*., 2008) and more than 800 million hectares of land in the world is salt-affected, either by sodicity (403 million ha) or salinity (397 million ha) (FAO, 2005). Salt stress limits the net photosynthetic and assimilation rate, relative growth rate and reduces the biomass production (Akram *et al*., 2011; Sun *et al*., 2011). Saleh and Maftoun (2008) observed that salinity reduces total dry matter which ultimately causes reduction in crop yield but the application of zinc improved growth and biomass yield of rice under saline conditions. Zinc plays an important role to regulate the nutrient balance in rice by regulating the uptake of Na^+ and K^+ (Jan *et al.*, 2015). Zinc is an important micro nutrient to regulate rice growth in submerged soil conditions and there are several soil, environment and plant factors which can affect its availability (Gill, 1992; Muhling and Lauchli, 2002). There are several evidences that species and cultivars showed a significant variability's to obtain macro and micronutrients including zinc from a given soil like salt affected (Giordano and Mortvedt, 1974; Agarwala *et al*., 1978). Several studies related to determine the genotypic potential to survive against salinity and zinc are conducted by many researches and documented varietal differences in Zn nutritional uptake during salinity stress (Iqbal and Aslam, 1999; Jan *et al*., 2015), but are rather poorly understood (Singh and Singh, 2006). However, studies on soil salinity-Zn interaction in paddy fields are rather scarce for the calcareous soils (Saleh and Maftoun, 2008). There is need to explore the behavior of zinc in submerged soil to quantify the varietal characteristics for the selection of salt tolerant and zinc efficient germplasm (Rehman *et al.,* 2012). The present study was conducted to explore the mechanisms of Zn uptake in different rice cultivars under salinity stress. The Zn source and methods of application were compared. It involved four rice genotypes differing greatly in salt tolerance and Zn response at varying levels of salinity in soil. The objective was to study the Zn availability to rice crop under saline conditions and to find the best application method i.e., soil and foliar and zinc source ($ZnSO_4$ and Zn-EDTA) for rice crop under saline conditions.

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Materials and Methods

Seeds of four rice genotypes (BAS-2000, KSK-133, IR-6, Bas-198 sensitive) were sown in a zinc deficient soil. The plants were properly cared and standing water conditions were maintained. After 30 days of nursery sowing, uniform and healthy plants were selected and transplanted into the pots. Three numbers of seedlings were transplanted into each pot. Experiment was conducted in the wire house, Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad. Soil was collected from university research site and analyzed for physico-chemical properties. Clay textured soil was used having EC_e 1.98 dS m^{-1}, SAR 3.41 (mmol $L^{-1})^{1/2,}$ DTPA extractable Zn 0.46 mg $kg^{-1}$and organic matter 1.18%. This soil was passed through 2 mm sieve and filled using 12 kg per pot. The required salinity levels (control and EC 7 dS m^{-1}) and Zn levels (control and 15 mg kg^{-1}) from both of the sources were developed in the respective treatment pots by adding calculated amount of NaCl, $ZnSO_4$ and Zn-EDTA before filling the soil in the pots. In control no NaCl was added. The recommended doses of nitrogen and phosphorus using 160 and 90 kg ha^{-1} were added in the form of urea and DAP. Potassium was added at the rate of 60 kg ha^{-1} in the form of sulfate of potash (SOP). Full dose of phosphorus, potassium and zinc and half dose of nitrogen were applied after ten days of transplanting while second half nitrogen was divided into two half. First half was applied after one month of 45 days after transplanting and second half of N at panicle initiation stage. Foliar application of 1% Zn solution was applied at three different stages (panicle initiation, flowering and dough stage) to minimize the Zn toxicity. Data on number of tillers per plant, paddy and straw yield were determined before harvesting. The ionic concentration Na^+, K^+ and Zn were determined in straw and grain.

Statistical Analysis

Two-way analysis of variance (ANOVA) was performed using a statistical package, SPSS version 16.0 (SPSS, Chicago, IL). LSD test was done to compare the significance of difference between the treatments.

Results

Salt stress significantly reduced number of tillers, straw and grain yield per plant of all rice genotypes. A significant increase in these yield and growth related traits were observed by soil and foliar applied Zn, under both saline and non-saline conditions (Figs. 1, 2 and 3). Number of tillers, and yield related parameters such as straw and grain yield per plant of all rice genotypes increased by foliar applied Zn of both sources under non-saline conditions, while under saline conditions soil applied Zn-EDTA increased the number of tillers and yield related parameters. Comparing the genotypic performance under saline conditions, KSK-133 genotype performed best while Bas-198 performed poor and there was no significant difference under non-saline conditions.

Concentrations of nutrients in both straw and grain such as Na, K and Zn were significantly lower in all rice genotypes exposed to salinity (Figs. 4 to 9). The only mineral nutrient increased under salinity was Na. The genotype Bas-198 accumulated more Na under salt stress than any other genotype, while genotype KSK-133 showed resistance against Na ion accumulation under salt stress. Effect of soil and foliar applied Zn was opposite to salinity. It increased the concentration of both K and Zn, but decreased the concentration of Na under salt stress and non-stress environment in all rice genotypes. Zinc contents deceased by salinity; however, foliar spray of $ZnSO_4$ greatly increased Zn contents under non saline conditions, while soil applied increased Zn contents under saline conditions.

Discussion

The results of the present study revealed that salt stress severely reduced the growth and yield in all the genotypes of rice. Zinc applied ameliorated adverse effects of salinity have been reported (Tavallali *et al.*, 2010). The reduction in yield and growth under saline conditions can be due to change in many other attributes like nutrient imbalance (Saleh and Maftoun, 2008), insufficient water absorbance under saline conditions (Singh and Singh, 2006), and reduction in photosynthetic rate (Athar and Ashraf, 2005). Zinc application increases the growth of crops due to its effects on photosynthetic rate and nutrient uptake. It increases the photosynthetic rate and speeds up nutrient uptake from soil and stimulates the growth of plants (Dubey, 2005).

In present study, concentrations of nutrients in both straw and grain such as Na, K and Zn altered under stressed environment. Except Na, K and Zn decreased with imposition of salt stress. For soil applied Zn-EDTA, decreased the Na contents and increased K contents. Similar effects of Zn-EDTA are reported by Das *et al.* (2002). In case of soil applied Zn, more Zn contents were in root as compared to straw and grain which might be so it due to its availability at the root zone and rice crop Zn requirement. Rice requires more Zn at the earlier stages as compared to the later stages. Application of $ZnSO_4$ compared to Zn-EDTA releases more Zn at early stages. Zn-EDTA is a slow release nutrient fertilizer and it becomes more available from the vegetative growth up to the maturity (Boonchuay *et al.*, 2013).

By applying Zn, Bas-2000 and KSK-133 produced more number of tillers, straw yield and grain yield under Zn sufficient conditions due to less Zn accumulation in shoots and had higher Zn accumulation in roots or it might be connected with efficient transport of Zn from roots to shoots and thus initiation of the Zn deficiency response results in

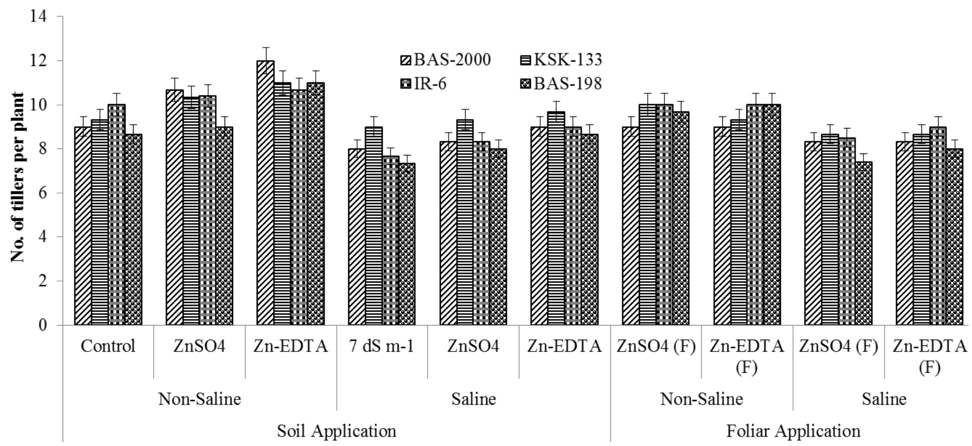

Fig. 1: Effect of NaCl and zinc application on number of tillers per plant of rice genotypes

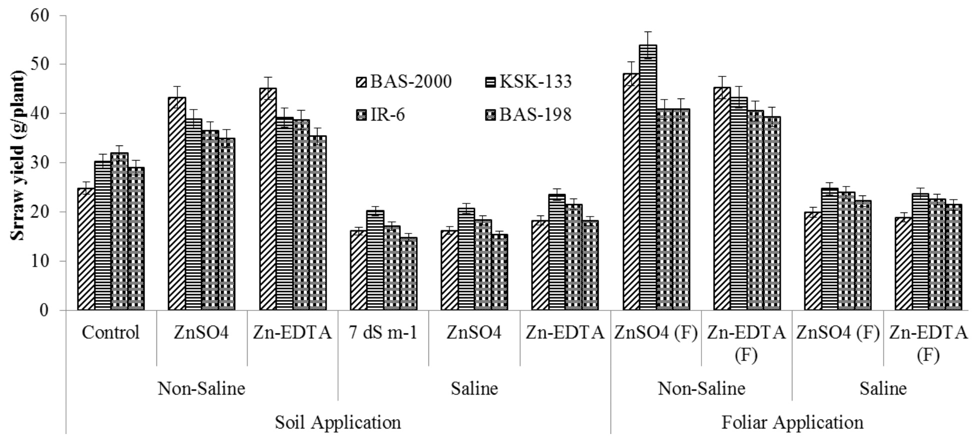

Fig. 2: Effect of NaCl and zinc application on straw yield per plant of rice genotypes

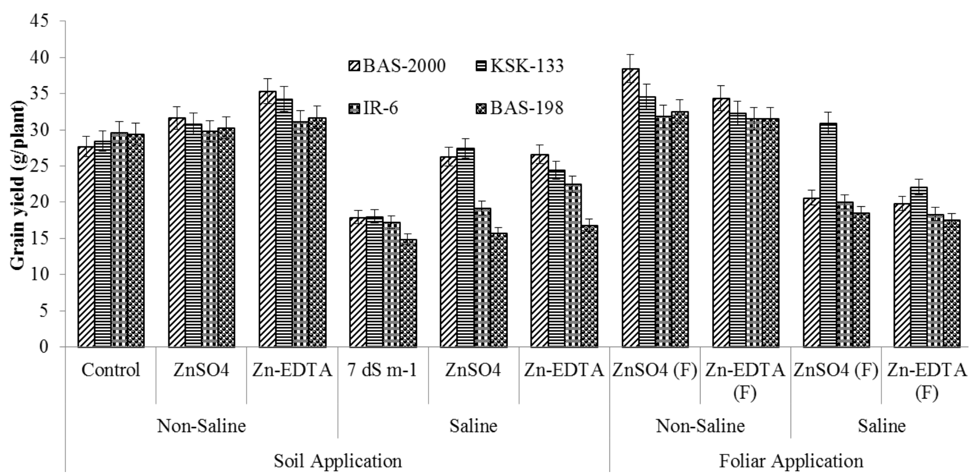

Fig. 3: Effect of NaCl and zinc application on grain yield per plant of rice genotypes

increased release of Zn- and Fe-binding phytosiderophores (Wiren *et al*., 1994).

The mechanisms for improved internal Zn distribution in crop plants are due to increased phloem mobility and root to shoot Zn translocation, subcellular Zn compartmentation, and biochemical Zn use (Hacisalihoglu and Kochian, 2003; White and Broadly, 2011). Plant Zn concentration decreased and of Na and Cl increased significantly in the shoot

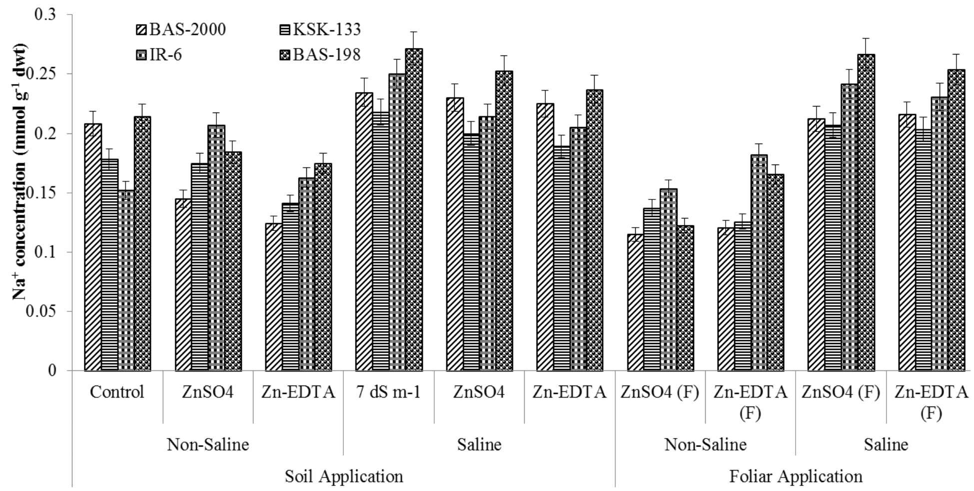

Fig. 4: Effect of NaCl and zinc application on sodium concentration in straw of rice genotypes

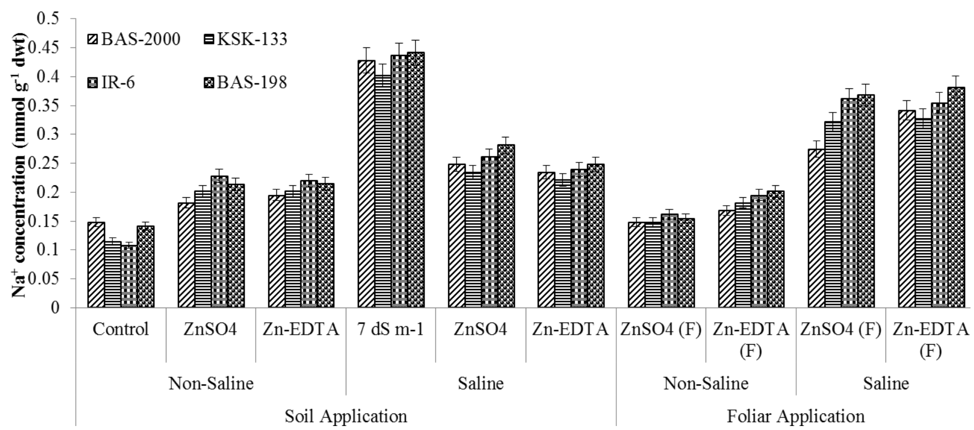

Fig. 5: Effect of NaCl and zinc application on sodium concentration in grain of rice genotypes

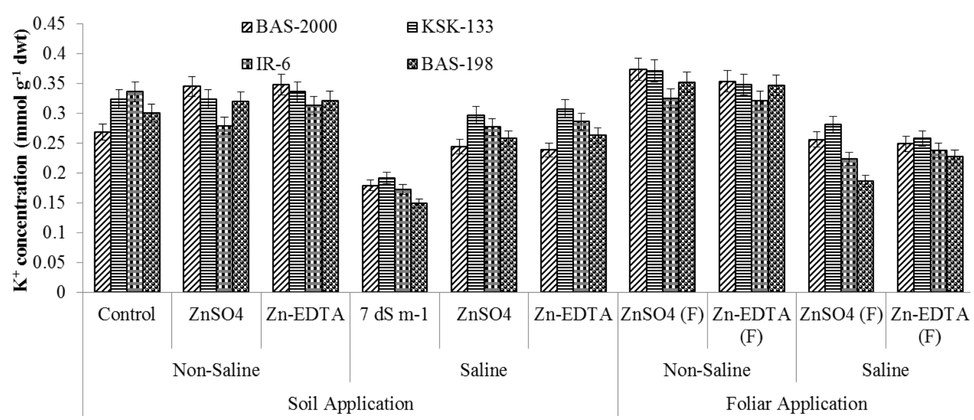

Fig. 6: Effect of NaCl and zinc application on potassium concentration in straw of rice genotypes

under salinity, while Zn application markedly increased it and decreased Na and Cl concentrations in rice.

Potassium concentrations in rice decreased with increasing NaCl levels and an increase was observed by Zn fertilization. Use of 5 and 10 mg Zn kg^{-1} soil, from each of two Zn sources, decreased Na and increased K concentration in rice, respectively. Rice growth decreased with an increase in shoot Na and Cl concentration (Verma and Neue, 1984). Zn addition markedly reduced the depressing effects of NaCl and it is suggested that, in saline soils especially those low in plant available Zn, sufficient Zn should be added for rice crop (Saleh and Maftoun, 2008).

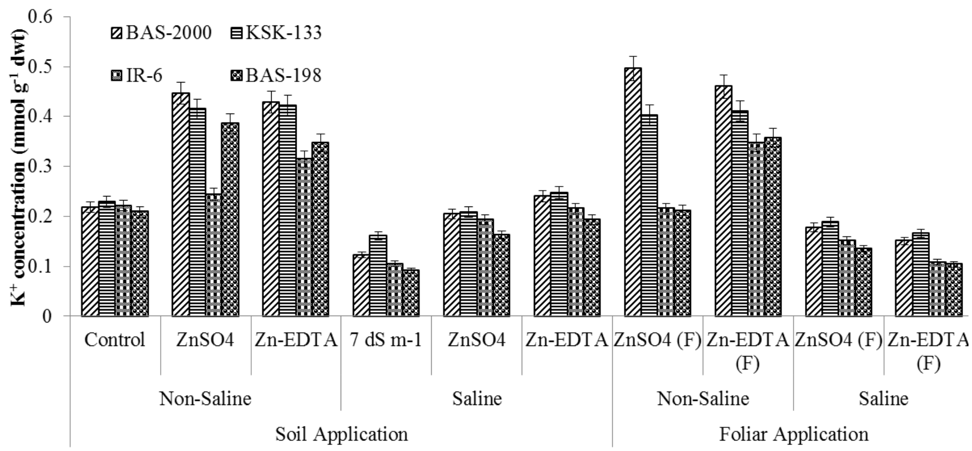

Fig. 7: Effect of NaCl and zinc application on potassium concentration in grain of rice genotypes

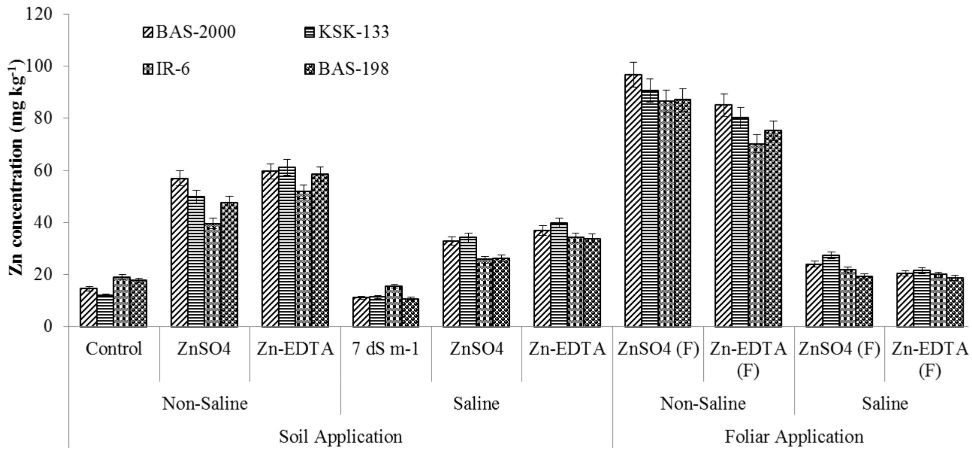

Fig. 8: Effect of NaCl and zinc application on zinc concentration in straw of rice genotypes

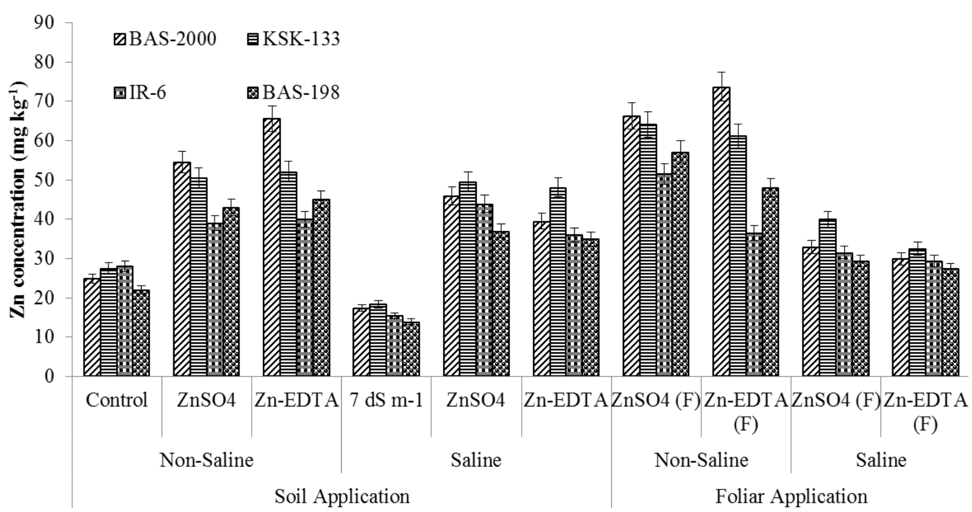

Fig. 9: Effect of NaCl and zinc application on zinc concentration in grain of rice genotypes

Comparing the sources and method of Zn application, the foliar applied $ZnSO_4$ increased the grain yield, while the application of Zn-EDTA increased the straw yield. Modaihsh (1997) showed that foliar application of an individual micronutrient in the form of sulfate compared to chelated form increased in producing higher grain yield more than in the chelated form. Ashraf *et al*. (2014) evaluated the combined effect of salinity and foliar applied chelated zinc in rice they observed that foliar applied Zn improved the plant growth and physiological parameters by increasing the free amino acids and total soluble sugars. Nonetheless foliar applied Zn improved gas exchange parameters as well as the uptake of macro and micronutrient to regulate the growth of rice crop (Eleiwa *et al.*, 2012).

Conclusion

The inhibitory effect of salt stress was more pronounced on rice genotype Bas-198 than KSK-133<Bas-2000<IR-6. Addition of zinc significantly alleviates harmful effect of salinity by improving the plant growth of all rice genotypes. Zinc application rate, 15 mg kg^{-1} was found more effective in alleviating perilous effect of salinity. KSK-133 followed by Bas-2000 showed better response towards zinc application as compared to rice genotype IR-6 and Bas-198 under non saline and saline conditions. The foliar applied $ZnSO_4$compared to Zn-EDTA, increased the grain yield, number of branches per panicle and straw yield while in case of soil applied, Zn-EDTA was appropriate source. The genotype Bas-2000 exhibited more grain yield, number .of branches per panicle and straw yield as compared to KSK-133, IR-6 and Bas-198 under non-saline conditions. KSK-133 showed better performance under salt stressed condition following by Bas-2000, IR-6 and Bas-198.

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