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# AMELIORATION OF SALT STRESS IN WHEAT (*TRITICUM AESTIVUM* L.) BY FOLIAR APPLICATION OF NITROGEN AND POTASSIUM

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## Abstract

An experiment was conducted in the Department of Biological Sciences, University of Sargodha, Pakistan. Different levels, viz. 0, 250, 500 mg/L, of nitrogen (N) and 0, 200, 400 mg/L of potassium (K) were applied exogenously as a foliar spray to determine whether application of N and K could ameliorate the effect of salinity stress on wheat (*Triticum aestivum* L.). It was composed of three replications. Each pot was filled with 8kg of well-mixed soil. Different salinity levels were adjusted in accordance with saturation percentage of soil.

Salinity reduced the growth of wheat plants. When K and N were applied as foliar spray on the wheat plant, it reduced the effect of salinity and increased the plant growth and physiological attributes of wheat plants. Similarly, grains yield is also decreased by salinity but foliar application of K and N mitigated the salinity effect on grains yield.

**Keywords:** Wheat, Salinity, K, Foliar spray.

## Introduction

Salinity is a threat to agriculture all over the world (Flowers and Colmer, 2008). It is observed that over 800Mha of soil is salt-affected in the world (FAO, 2005). Salinity reduces the growth of wheat plant by slowing the plants ability to absorb water from soil. Salinity also disturbs the physiology of plants by changing the metabolism of plants (Garg et al., 2002). Salinity also injures cells in transpiring leaves, thus reducing growth of wheat plant (Munns, 2005). Salinity badly reduces leaf area, accumulation of dry matter content and also reduces net rate of $CO_2$ assimilation (Barnardo et al., 2000). Salinity can be overcome by using NN and KK fertilisers.

KK increases crop yield and K fertiliser increases the production of protein, stimulates early growth and improves efficiency of water use. Salinity inhibits growth of various plants but with the application of K fertiliser, growth of plant increases. Salt accumulation in root zone decreases grain yield but K enhances the yield as well as quality of grain (Thalooth et al., 2006). If K is present in trace amounts growth of plant is stunted and grain yield decreases (Thalooth et al., 2006). Under saline condition, K increases the rate of photosynthesis of crop leaves (Cassman et al., 1990). K mitigates the adverse effect of salt and enhances leaf osmolarity which is reduced by salinity. It improves root length and root number in wheat plant (Shibli and Smith, 1999). K fertiliser is essential for maintenance of cytoplasmic levels and for survival of plants under saline condition (Chow et al., 1992). Salinity decreases dry matter content and also uptake of mineral nutrients. K enhances this uptake of nutrients and improves grain yield of wheat.

N is also one of the best nutrients to control salinity and enhances growth of wheat crop. Sufficient supply of N fertiliser decreases adverse effects of salinity on plant development and grain yield (Raza et al., 2006). During early growing period of plants, sufficient supply of N fertiliser is necessary for initiation of leaves. Ammonium nitrate is an important N fertiliser and gives greater grain yield. All nitrogenous fertilisers enhance plant height, number of leaves, dry and fresh weight of seedling and these fertilisers play a crucial role in cell division (Reddy, 2000; Reddy and Khan, 2000).

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Wheat (*Triticum aestivum* L.) is a crop of global significance, being a staple food of millions of people. It supplies about 20% of the food calories for the world's increasing population. The main constituent of wheat is protein and carbohydrates. Wheat is grown in diversified environments and it contains 11-12% protein. Approximately 1/6 of total land in the world is cultivated with wheat crop.

**Objective**

The objective of this study is to check and control salinity by using N and pK as fertilisers.

**Materials and Methods**

An experiment was conducted in the Department of Biological Sciences, University of Sargodha. Different levels, viz. 0, 250, 500 mg/L of N and 0, 200, 400 mg/L of pK were applied exogenously as a foliar spray to determine whether application of nN and pK could mitigate the effect of salinity stress on wheat (*Triticum aestivum* L.). The experiment was laid down on a completely randomised design with two factors factorial arrangement and three replications. Different salinity levels were adjusted in accordance with saturation percentage of soil.

In each pot, 15 seeds were sown. After complete germination, thinning was practiced to maintain 10 plants in each pot. Three plants were harvested from each pot at the time of sampling.

**Data Collection**

Plant height; root length; shoot fresh and dry weight; root fresh and dry weight; shoot length; number of leaves; leaf area; quantity of chlorophyll a and chlorophyll b, and different types of nutrients, such as, $Na^{+}$, $K^{+}$, $Ca^{2+}$, $Mg^{2+}$, $P^{3+}$ and 100 grains weight, were collected.

**Biochemical Attributes**

The quantity of Chlorophyll a and Chlorophyll b was determined with the method as used by Arnon (1949). Chlorophyll a and Chlorophyll b were calculated by the following formulae:

$$\text{Chl. a} = [12.7\ (OD663) - 2.69\ (OD645)] \times V/1000 \times W$$

$$\text{Chl. b} = [22.9\ (OD645) - 4.68\ (OD663)] \times V/1000 \times W$$

where,

V = Volume of the extract (ml)
W = Weight of the fresh leaf tissue (g)

**Determination of Ions**

Sodium, potassium, calcium, magnesium and phosphorus quantities were determined with help of Flame Spectrophotometer (Jenewa 7).

**Statistical Analysis**

The data for all the traits was analysed by analysis of variance technique (Steel and Torie, 1980). Differences for various characters were compared, using Least Significant Differences test at 0.05 level of significance.

**Results**

Analysis of variance showed that N+K has significant effect on plant height of wheat plants (Table 1). Application of N+K enhanced the height of wheat plant (Fig. 1). Among different concentrations of N and K, 250 + 200 kg/ha of nN, the K concentration has enhanced the plant height more as compared to 500 + 400 kg/ha of N and K under non-saline conditions (Fig. 1) but in case of saline conditions, 500 + 400 kg/ha of N and K were more effective for increasing the plant height of wheat plant (Fig. 1). Overall, it is indicated that the application of N and K reduced the effect of salinity and enhanced the growth of the wheat plants.

Analysis of variance showed that saline growth medium significantly reduced the root length of the wheat plant. Foliar application of N+K alleviates the salinity effect on shoot length of wheat plant (Fig. 2). Under non-saline conditions, foliar applications of 500 + 400 kg/ha alleviated the salinity effect and increased the shoot length of wheat plants (Fig. 2). Same trend of shoot length of wheat plant in case of saline conditions was noted (Fig. 2). Overall, results indicated that the application of N and K reduced the effect of salinity and enhanced the growth of the wheat plants.

Analysis of variance indicated that saline growth medium significantly decreased the root length of the wheat plants. Under non-saline conditions, it has been indicated that 250+200 kg/ha showed a better response in case of root length of the wheat plants (Fig. 3) but in case of saline condition, medium foliar application of 500+400 kg/ha is more effective as compared to the 250+200 kg/ha (Fig. 3). Overall, results indicated that the application of N and K reduced the effect of salinity and enhanced the growth of the wheat plants.

**Table 1. Analysis of variance for data of plant height, shoot, root, leaf length, number of leaves, shoot, root fresh and dry weight and chlorophyll contents under saline and non-saline conditions of wheat when different concentration of nitrogen and potassium were applied as a foliar spray.**

| Source of variation | Plant Height | Shoot length | Root length | Leaf length | Number of leaves | Shoot fresh weight | Shoot dry weight | Root fresh weight | Root dry weight | Chlorophyll a |
|---|---|---|---|---|---|---|---|---|---|---|
| Salinity (S) | 1088.89** | 1250.0* | 200.00** | 4.500* | 4.500* | 0.22445 * | 0.4711*0 | 0.80645* | 0.17326* | 0.12284* |
| N+K | 466.67* | 116.7ns | 112.50** | 4.056ns | 4.056ns | 0.02000ns | 0.08219 ns | 0.03452ns | 0.05253ns | 0.02830ns |
| S x N+K | 22.22ns | 116.7ns | 12.50ns | 0.167ns | 0.167ns | 0.00500ns | 0.06626 | 0.04422ns | 0.02546ns | 0.00218ns |
| Error | 44.44 | 344.4 | 12.50 | 1.278 | 1.278 | 0.03682 | 0.05456ns | 0.06308 | 0.02049 | 0.06005 |

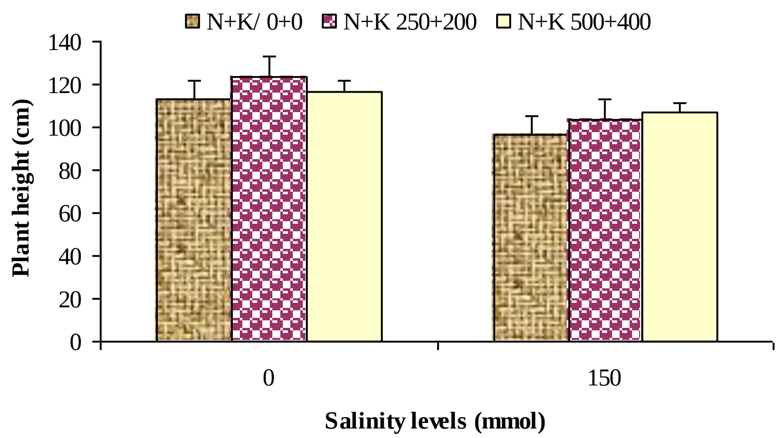


**Fig. 1 Influence of foliar application of (N+K) on plant height on wheat under saline and non-saline conditions**

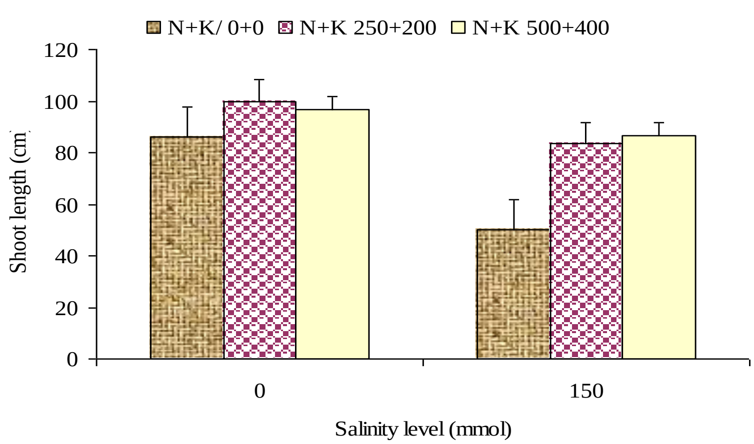


Fig. 2 Influence of foliar application of (N+K)on shoot length of wheat under saline and non-saline conditions

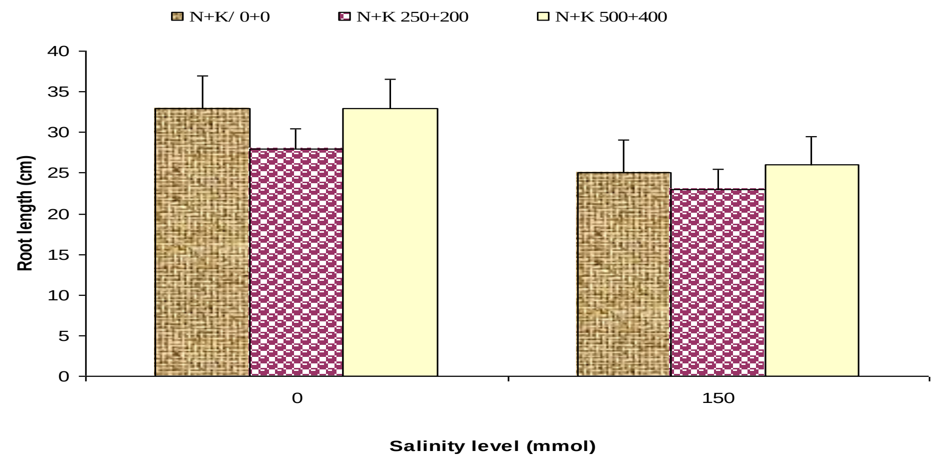


**Fig.3 Influence of foliar application of (N+K) on root length of wheat under saline and non-saline conditions**

Analysis of variance showed that saline growth medium significantly reduced the leaf length of wheat plants. Foliar application of N+K alleviates the effect of salinity of the leaf length of wheat plants (Fig. 4). Under non-saline conditions foliar application of 250+200 kg/ha increased the leaf length of the wheat plants to some extent (Fig. 4). Same trend of leaf length increase was noted under saline conditions by the foliar applications of 250+200 kg/ha (Fig. 4). Overall, results indicated that the application of N and K reduced the effect of salinity and enhanced the growth of the wheat plants.

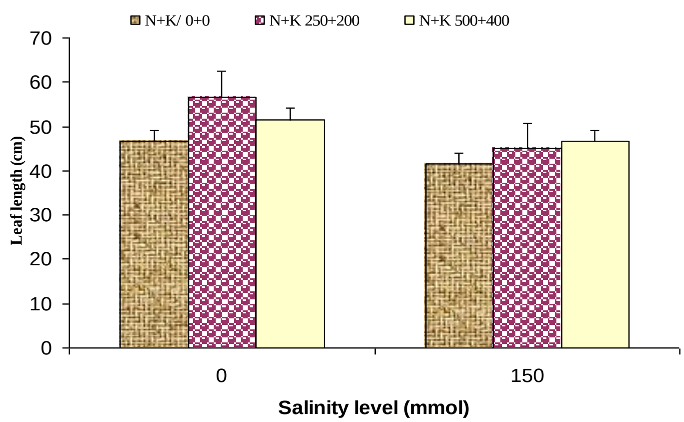


Fig. 4 Influence of foliar application of (N+K) on leaf length of wheat under saline and non-saline conditions

Analysis of variance of data of number of leaves per plant of wheat indicated that saline growth medium decreased the number of leaves per plant of wheat plant. Foliar application of N+K alleviated the salinity effect on number of leaves per plant of wheat plant (Fig. 5). Under non-saline conditions, foliar application of 250+200 kg/ha is more effective in increasing the number of leaves per plant of wheat plant as compared to 500+400 kg/ha (Fig. 5). Same trend of number of leaves per plant of wheat was noted under saline conditions by the foliar application of 250+200 kg/ha (Fig. 5).

Analysis of variance of the data of shoot fresh weight indicated that saline growth medium retarded the shoot fresh weight plant. Foliar application of N+K alleviated the effect of salinity stress and enhanced the shoot fresh weight (Fig. 6). Under non-saline conditions, foliar application of 250+200 kg/ha increased the shoot fresh weight plant to some extent (Fig. 6). Under saline conditions, foliar application of 500+400 kg/ha is more effective in regard to the shoot fresh weight of wheat plants.

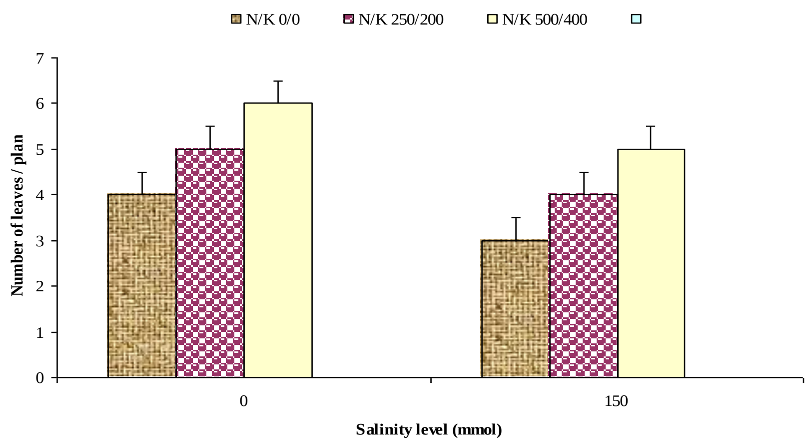


Fig. 5 Influence of foliar application of (N+K) on number of leaves of wheat under saline and non-saline conditions

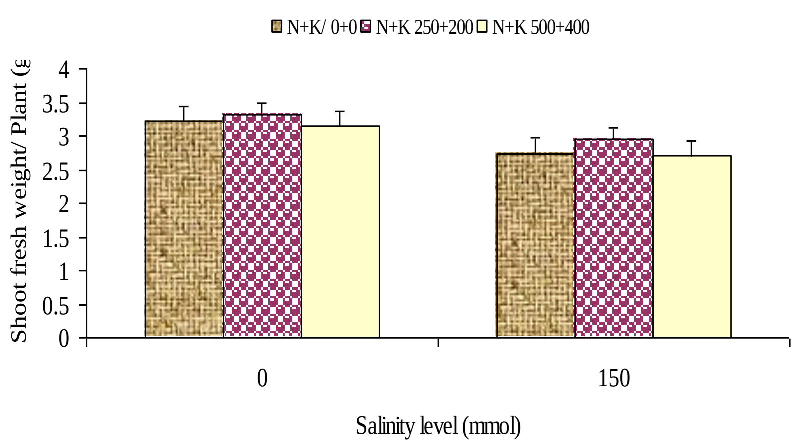


Fig.6 Influence of foliar application of (N+K) on shoot fresh weight of wheat under saline and non-saline conditions

Analysis of variance of the data of shoot dry weight indicated that salinity significantly reduced the shoot dry weight of wheat plants. Foliar application of N+K mitigates the effect of salinity and enhances the root dry weight (Fig. 7). Under non-saline conditions, foliar application of both the treatment 250+200 kg/ha and 500+400 kg/ha reduced the effect of salinity and increased the shoot dry weight (Fig. 7). Under saline conditions, foliar application of 500+400 kg/ha was more effective in enhancing the shoot dry weight to some extent (Fig. 7). Analysis of variance of the data of the root fresh weight indicated that saline growth medium significantly reduced the root fresh weight (Fig. 8). Foliar application of N+K reduced the effect of salinity and increased the root fresh weight (Fig. 8). Under non-saline conditions, foliar application of 250+200 kg/ha is more effective to mitigate the effect of salinity and increase the root fresh weight under saline conditions. Same trend of effectiveness of the foliar application of N+K was observed (Fig. 8).

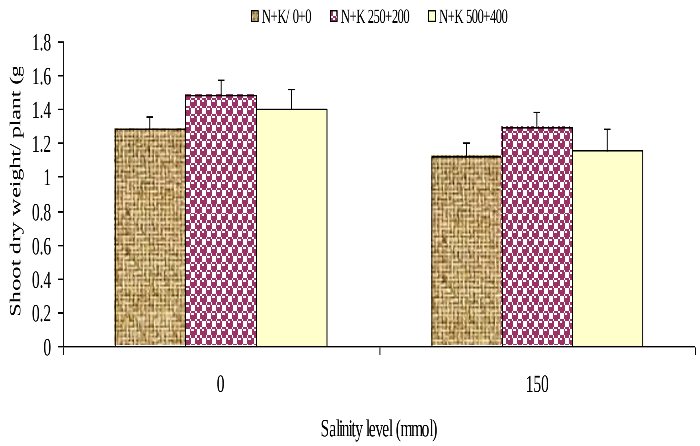


Fig. 7 Influence of foliar application of (N+K) on shoot dry weight of wheat under saline and non-saline conditions

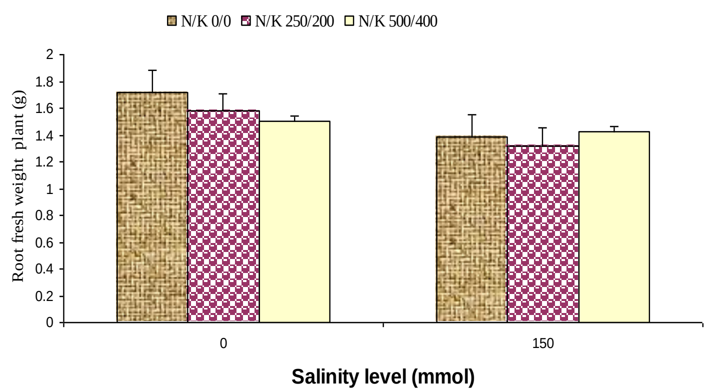


Fig. 8 Influence of foliar application of (N+K) on root fresh weight of wheat under saline and non-saline conditions

Analysis of variance of the data of saline growth medium significantly reduced the root dry weight of wheat plants (Fig. 9). Foliar application of N+K reduced the effect of salinity and increased the root dry weight (Fig. 9). Under non-saline conditions, foliar application of 250+200 kg/ha is more effective and increased the root dry weight (Fig. 11) but in case of saline conditions, both the treatments of foliar application of 250+200 kg/ha and 500+400 kg/ha showed the same effect (Fig. 9). Overall, foliar application of N+K mitigated the effect of salinity and enhanced the root dry weight.

Analysis of variance of the data of the total chlorophyll contents indicated that saline growth medium significantly decreased chlorophyll a of wheat plants (Table 1). Foliar application of N+K reduced the effect of salinity and enhanced the chlorophyll a of the wheat plants contents (Fig.10). Under non-saline conditions, foliar application of 250+200 kg/ha mitigated the effect of salinity and increased the chlorophyll a of the wheat plants (Fig. 10). Under saline conditions, effectiveness of the same treatment was indicated for the enhancement of the chlorophyll a (Fig.10). Overall, foliar application of N+K mitigated the effect of salinity and enhanced the chlorophyll a.

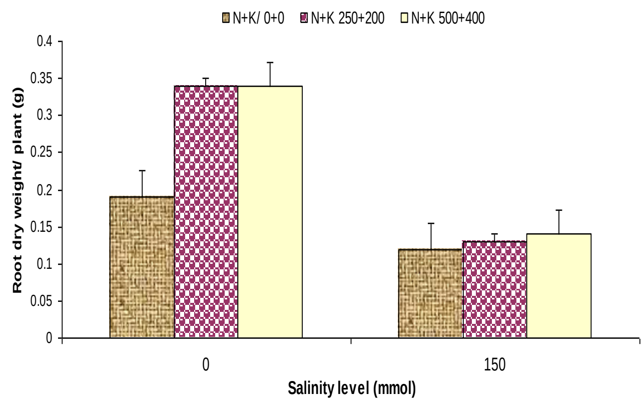


Fig.9 Influence of foliar application of (N+K) on root dry weight of wheat under saline and non-saline conditions

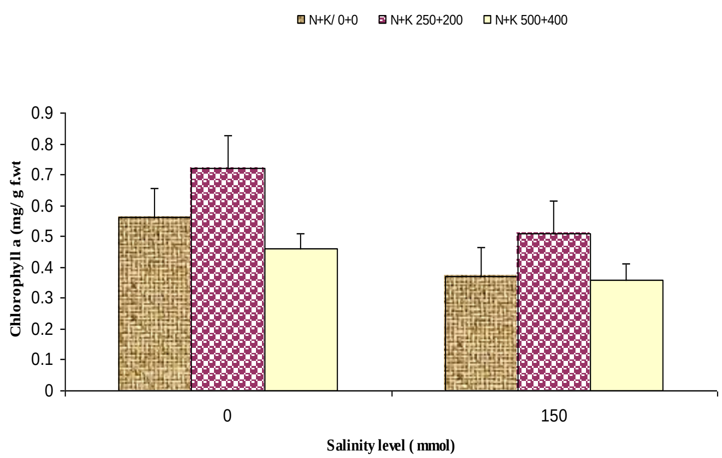


Fig. 10 Influence of foliar application of (N+K) on chlorophyll "a" of wheat under saline and non-saline conditions

Analysis of variance of the data of shoot K showed that saline growth medium significantly reduced the chlorophyll b of wheat plants (Table 2). Foliar application of N+K reduced the effect of salinity and enhanced the chlorophyll b of wheat plants (Fig. 11). Under non-saline conditions, foliar application of 500+400 kg/ha is more effective to reduce the effect of salinity and increase the chlorophyll b in wheat plants and in case of saline conditions, foliar application of 250+200 kg/ha is more effective (Fig. 11).

Analysis of variance of the data of total chlorophyll showed that saline growth medium significantly reduced the total chlorophyll (Table 2). Foliar application of N+K reduced the effect of salinity and increased the total chlorophyll (Fig. 12). Under non-saline conditions, foliar application of 500+400 kg/ha has significant effect on total chlorophyll of wheat plants (Fig. 12). Application of N+K enhanced the root K of wheat plant (Fig. 12). Among different concentrations, 500+400 kg/ha has enhanced total chlorophyll of wheat plants as compared to 250+200 kg/ha under non-saline conditions but in saline condition, both 500+400 kg/ha and 250+200 kg/ha have same effect on total chlorophyll (Fig. 12).

**Table 2. Analysis of variance for data of chlorophyll b, total chlorophyll, potassium, sodium, calcium, magnesium in shoot and root and grains yield/plant of wheat under saline and non saline conditions when different concentration of nitrogen and potassium were applied as a foliar spray.**

| Source of variation | Chlorophyll b | Total Chlorophyll | Shoot K | Root K | Shoot Na | Root Na | Shoot Ca | Root Ca | Shoot Mg | Root Mg | Grain yield |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Salinity (S) | 0.16917* | 0.59405* | 0.06009* | 0.021356* | 1.25876* | 0.05780* | 0.0013520* | 0.0002961* | 0.021356* | 0.026450* | 2.2050* |
| N+K | 0.04284ns | 0.12932ns | 0.02765ns | 0.020172ns | 0.00969ns | 0.01447 ns | 0.0001927ns | 0.0000887ns | 0.020172ns | 0.000372ns | 1.2867ns |
| S x N+K | 0.00838ns | 0.01235ns | 0.00004ns | 0.005372ns | 0.01562ns | 0.00347 ns | 0.0001832ns | 0.0001176ns | 0.005372ns | 0.000050ns | 0.4067ns |
| Error | 0.01859 | 0.09882 | 0.02333 | 0.009706 | 0.08039 | 0.01194 | 0.0003845 | 0.0001052 | 0.009706 | 0.001933 | 0.6711 |

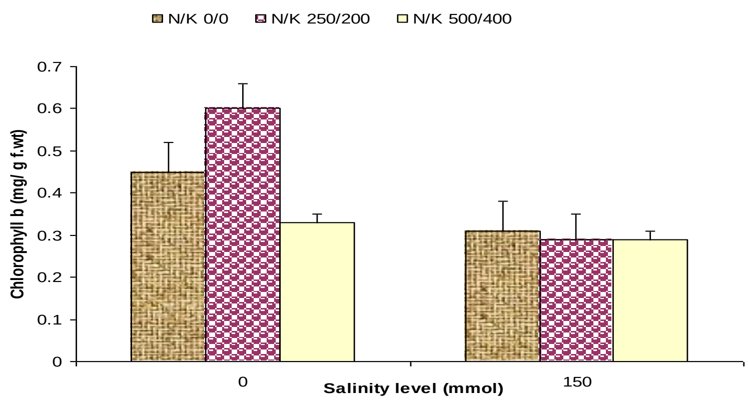


Fig. 11 Influence of foliar application of (N+K) on chlorophyll "b" of wheat under saline and non-saline conditions

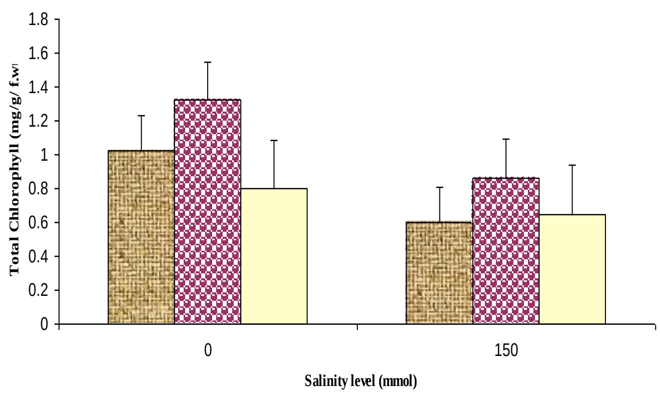


Fig. 12 Influence of foliar application of (N+K) on total chlorophyll of wheat under saline and non-saline conditions

Analysis of variance of the data of shoot K (Table 2) showed that salinity growth medium significantly reduced the shoot K contents of wheat plants (Table 2). Foliar application of N+K reduced the effect of salinity and enhanced the K contents of wheat (Fig. 13). Under non-saline conditions, foliar application of 500+400 kg/ha is more effective in reducing the effect of salinity and increasing the K contents in wheat plants and in case of saline conditions, foliar application of 250+200 kg/ha is more effective (Fig. 13).

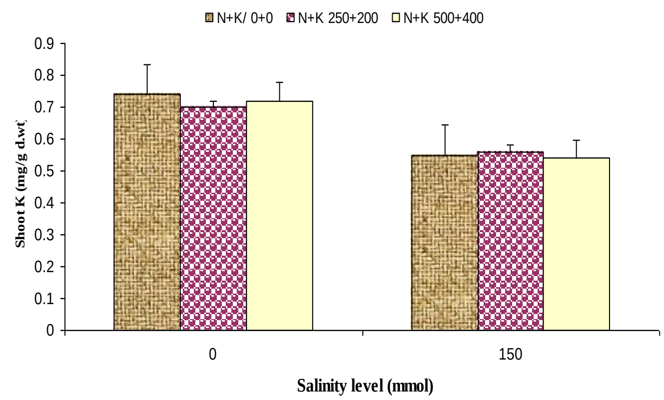


Fig. 13 Influence of foliar application of (N+K) on shoot (K) of wheat under saline and non-saline conditions

Analysis of variance of the data of root K showed that saline growth medium significantly retarded the K root content. Foliar application of N+K reduced the effect of salinity and increased the root K contents (Table 2). Under non-saline conditions, foliar application of 500+400 kg/ha has significant effect on root K content of wheat (Table 2). Application of N+K enhanced the root K content of wheat plant (Fig. 14). A concentration of 500+400 kg/ha enhanced root K of wheat as compared to 250+200 kg/ha under non-saline conditions but in saline conditions, both 500+400 kg/ha and 250+200 kg/ha have same effect on root K (Fig. 14).

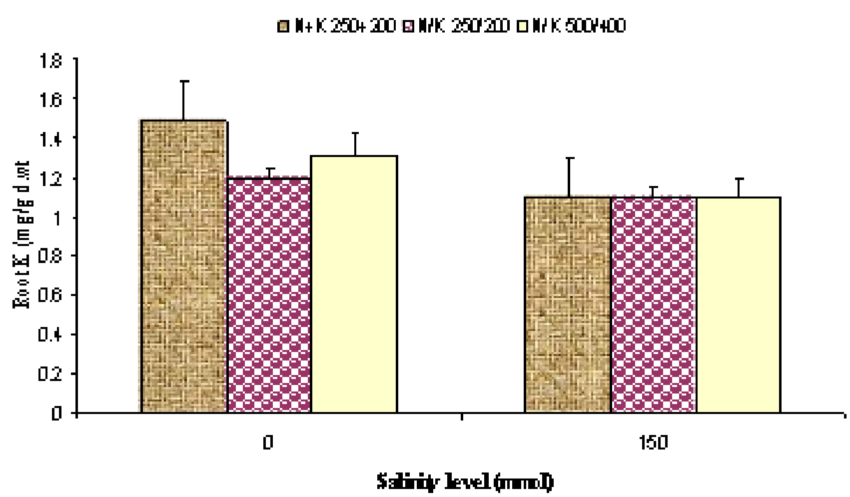


Fig. 14 Influence of foliar application of (N+K) on root (K) of wheat under saline and non-saline conditions

Analysis of variance of the data of shoot sodium content indicated that saline growth medium significantly increased the sodium contents in shoot of wheat (Table 2). Foliar application of N+K alleviated the effect of salinity and reduced the sodium contents in wheat plants (Fig. 15). Foliar application of 250+200 kg/ha is more effective in case of non-saline conditions and reduced the sodium contents in wheat plants (Fig. 15). Under saline conditions, foliar application of 500+400 kg/ha was more effective in reducing the sodium contents (Fig.15). Overall, foliar spray of 250+200 kg/ha and 500+400 kg/ha was effective in reducing the sodium contents from the shoot of wheat plants.

Analysis of variance of the data of root sodium content of wheat plants indicated that saline growth medium increased the sodium content in the root of the wheat plants (Table 2). Foliar application of N+K is effective in alleviating the effect of salinity on root of wheat plants. Under non-saline conditions, foliar application of 250+200 kg/ha was more effective in decreasing the sodium contents in root of wheat plants (Fig. 16). Under saline conditions, same trend of result was found by the application of 250+200 kg/ha (Fig. 16).

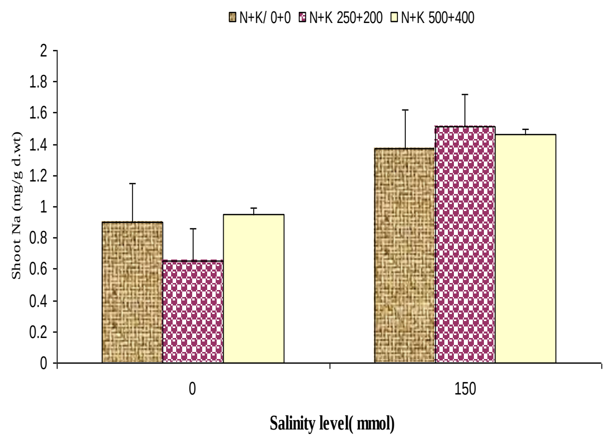


Fig. 15 Influence foliar application of (N+K) on shoot (Na) of wheat under saline and no-saline conditions

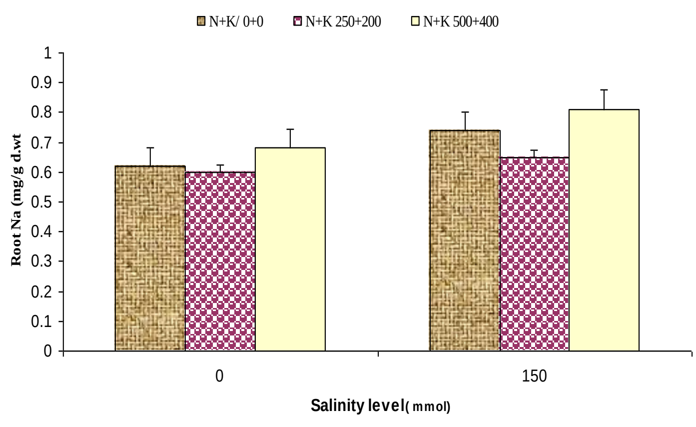


**Fig. 16 Influence of foliar application of (N+K) on root Na of wheat under saline and non-saline conditions**

Analysis of variance of the data of shoot calcium indicated that saline growth medium reduced the Ca contents from the shoot of wheat plants (Table 2). Foliar application of N+K alleviated the effect of salinity and increased the Ca contents in shoot of wheat plants (Fig. 17). Under non-saline conditions, foliar applications of 250+200 kg/ha and 500+400 kg/ha were more effective in reducing the effect of salinity and increased the Ca contents in the shoot of wheat plants (Fig. 17).

Analysis of variance of the data of root calcium indicated that salinity reduced the calcium contents of the root of wheat plants (Table 2). Foliar application of N+K mitigated the effect of salinity and enhanced the calcium contents in root calcium of the wheat plants (Fig.18). Under non-saline conditions, foliar application of 250+200 kg/ha was more effective as compared to 500+400 kg/ha and under saline conditions, foliar applications of both 250+200 kg/ha and 500+400 kg/ha showed the same effect in increasing the root calcium contents of the wheat plants (Fig. 18).

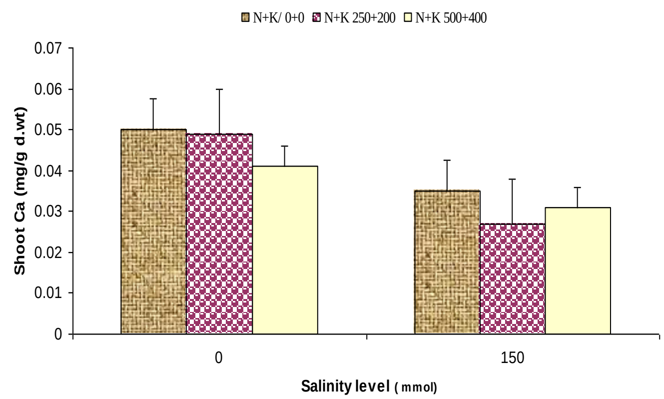


Fig. 17 Influence of foliar application of (N+K) on shoot (Ca) of wheat under saline and non-saline conditions

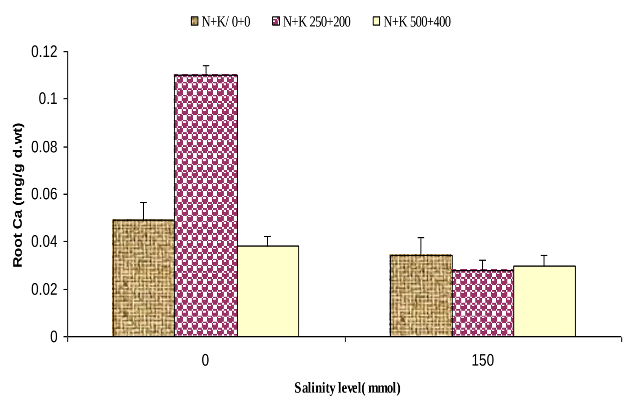


Fig. 18 Influence of foliar application of (N+K) on root Ca of wheat under saline and non-saline conditions

Analysis of variance showed that N+K has significant effect on shoot magnesium of wheat. Application of N+K enhanced the shoot magnesium of wheat plant (Fig. 19). Among different concentration of the application 250+200 kg/ha has enhanced shoot magnesium of wheat as compared to 500+400 kg/ha under saline conditions but in non-saline condition, 500+400 kg/ha was more effective in increasing shoot magnesium content of wheat plant as compared to 250+200 kg/ha (Fig. 19).

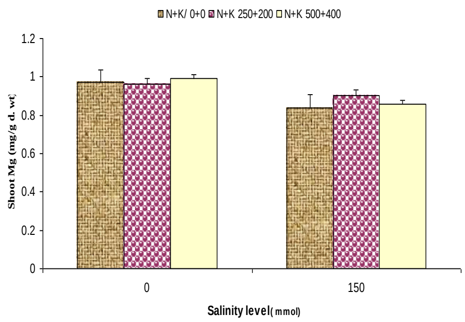


Fig. 19 Influence of foliar application of (N+K) on shoot (Mg) of wheat under saline and non-saline conditions

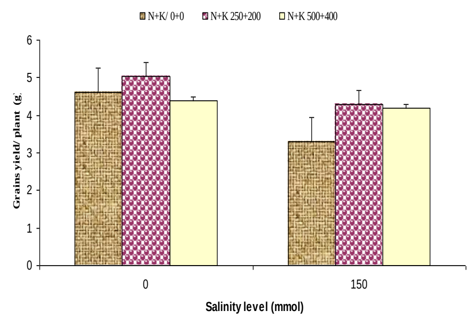


Fig. 21 Influence of foliar application of (N+K) on grains yield / plant of wheat under saline and non-saline conditions

Analysis of variance showed that N+K has significant effect on root magnesium of wheat. Application of N+K enhanced the root magnesium of wheat plant (Fig. 20). Among different concentration of the application 500+400 kg/ha has enhanced root magnesium of wheat as compared to 250+200 kg/ha under non-saline conditions but in saline condition, 250+200 kg/ha was more effective in increasing root magnesium content of wheat plant as compared to 500+400 kg/ha (Fig. 20).

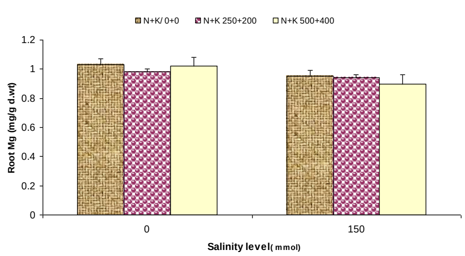


Fig. 20 Influence of foliar application of (N+K) on root (Mg) of wheat under saline and non-saline conditions

Analysis of variance showed that N+K has significant effect on grain yield of wheat. Application of N+K enhanced the grain yield of wheat plant (Fig. 21). Among different concentration of 250+200 kg/ha has enhanced grains yield of wheat as compared to 500+400 kg/ha under non-saline conditions but in saline condition, 250+200 kg/ha has same effect to increase the grains yield of wheat plant as compared with (Fig. 21).

## Discussion

Pretreatment of seeds with different types of hormones and growth regulators are most effective in decreasing stress effects of salinity on plants at different stages especially at early stage and it has been shown to enhance germination under saline conditions (Ashraf and Foolad, 2005; Ashraf and Foolad, 2007). Seedling growth of wheat plant was adversely affected under saline condition; this in agreement with Cicek and Cakirlar (2002), who reported that salinity decreased the shoot length, fresh weight and dry weight of wheat plant. Germination was directly related to the amount of water absorbing capacity and delay in germination to the salt concentration of medium. Our results are related with findings of Cicek and Cakirlar.

Embryo was probably damaged due to presence of sodium or chloride ions and absolute ratio of K or sodium in the tissues is improper because ions ratio are important in determining toxicity of different ions and providing insight into ion antagonism (Wilson et al., 2000). It is indicated that intracellular sodium homeostasis and salt tolerance are modulated by $Ca^+$ and high concentration of $Na^+$ negative affect K acquisition (Munns, 2002).

Recently, it has been observed that decrease in K was due to presence of high $Na^+$ concentration in root medium because high sodium content has an antagonistic effect on K uptake (Sarwar and Ashraf, 2003). Regulation of K uptake in prevention of $Na^+$ entry and efflux of $Na^+$ are strategies commonly used by plants to maintain required K/Na ratio in cytosol.

However, significant decrease in chlorophyll content is due to salinity.

The reduction in chlorophyll content under salinity is reported by Iqbal et al. (2006) and our results are correlated with this work where chlorophyll contents are decreasing. The total N content in wheat plant also decreased under saline condition (Anthraper and Du Bios, 2003). Our results are related with the result of Singla and Garg (2005) who reported that significant decrease in height of wheat plant is due to salt accumulation in root zone of plant. The fresh and dry weight of root and leaves are also affected by salinity. Fresh and dry weight was decreased under saline condition (Singla and Garg, 2005).

Reduction in N percent uptake was attributed to $Cl^-$ antagonism with nitrate uptake which was reported to decrease leaf number and growth under saline condition. High level of salinity reduced uptake of calcium, phosphorus, N, K and magnesium and significantly increased sodium contents. N was reported to decrease with high sodium concentration. High shoot $Na^+$ has been associated with decreased calcium in salt-tolerant plants (Knight et al., 1992).

Foliar spray of N and K fertiliser, when applied to plants in different levels, reduced the deleterious effect of salt stress and enhanced the growth and metabolic activity of plants. From all the above discussion, it can be concluded that reduction in growth and yield of plants can be overcome by application of foliar spray of N and K fertilisers.

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