INTRODUCTION

Maize (Zea mays L.) is largely grown in many parts of the world where soil salinity is one of the major agricultural threats to its productivity. While comparing different crops for their response to salinity stress, this crop is very sensitive to high concentrations of salts in soil solution (Maas and Hoffman, 1977).

Maize (Zea mays L.) is an important crop in Pakistan, which is used as food and corn oil for human consumption, feed for livestock and poultry and raw material for agro-based industries. In Pakistan, maize is the third most important crop after wheat and rice. Being an important crop, maize is grown on about one million hectares with a total yield of about 2 million tones and an average yield of 1882 kg ha\(^{-1}\) (Anonymous, 2005). In view of its increasing importance, improvement in agronomic characteristics of maize has got considerable attention in Pakistan (Mehdi and Ahsan, 2000). More than 800 million hectares of land throughout the world are salt-affected, either by salinity or the associated condition of sodicity by FAO (2005). Soil salinity is one of the major abiotic stresses which badly affect crop growth and productivity. In Pakistan, about 6.30 Mha of land are salt affected (Alam et al., 2000). In the province of Punjab, an estimated 1 hectare of irrigated land is being lost every five minutes to salinity by Rahman (1998).

Marschner, (1986) observed salt stress causes various effects on plant physiology such as increased respiration rate, ion toxicity, changes in plant growth, mineral distribution, and membrane instability resulting from calcium displacement by sodium and salt stress cause membrane permeability which observed by Gupta et al., (2002).

Maize is a highly sensitive to saline irrigation water showing 50 % decrease in yield at EC 3.9 dS m\(^{-1}\), Ayres and Westcot, (1985). Salinity has a two-fold effect on plants, the salt in the soil solution reduces the availability of water to the roots (osmotic stress) and the salt taken up by the plant can accumulate to toxic levels in certain tissues (ionic stress), Munns et al., (1995). Reduction in growth under saline conditions is a reason of several physiological responses, including modification of ionic balance, water status, mineral nutrition, stomatal behavior, photosynthetic efficiency and carbon allocation and utilization, Munns and Termaat, (1986).

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Salt sensitivity of maize plants has been found to be due to high accumulation of Na⁺ in the leaves (Munns, 1993). Wyn Jones, (1981) was observed that soil salinity developed due to high amount of chloride or sulfate salts of sodium. Salt stress reduced the plant growth because plant might suffer different types of stresses (Greenway and Munns, 1980). Osmotic effects are due to salt-induced decrease in the soil water potential. Salinity results in a reduction of K⁺ and Ca²⁺ content and an increased level of Na⁺ and SO₄²⁻, which forms its ionic effects (Mansour et al., 2005). Reduction in biomass, photosynthetic capacity changes in leaf water potential and leaf turgor have been reported to have a cumulative effect attributed to salinity stress (Tourenne and Peltier, 1995; Gama, 2007), it is also clear that several soil and other environmental factors do influence plant growth under salinity conditions. Hussain et al., (2010) was observed that many species of higher plants including most crops was showed to growth inhibition under high salinity conditions. The salinity induced of plant growth was caused not only by osmotic effects on water uptake but also by variable effects on plant cell metabolism under salt stress.

Reduction in growth of plants was mainly due to the adverse effects of salinity on various biochemical and physiological processes by Majeed et al., (2010). It was due to the salt induced osmotic and toxic effects which minimize the uptake of other mineral nutrients such as N, K and Ca²⁺, Ashraf, (2004). The ion concentrations in roots, shoots and leaves are maintained by regulating ion transport to acclimatize salt stress, Tester and Davenport, (2003).

The principal objective of the present study was to determine the effects of Na₂SO₄ on the growth and ion composition of maize (Zea mays L.) plant at growth stage. The hypotheses that Na₂SO₄ effects on plant growth are more severe compared with the Control treatment (Distilled water).

### MATERIALS AND METHODS

Seeds of maize (Zea mays L.) were obtained from Murjan seeds Corporation, Gujranwala, Pakistan. One variety of maize was used in this 4 experiment i.e. 32-B-33 Pioneer. Seeds were surface sterilized by dipping in water for 3 hours and air-dried at an ambient temperature of 32°C in the laboratory. Ten seeds were put in each pot with four replicates. Following treatments of Na₂SO₄ salinity were applied.

- **T₀**: Control (Distilled water)
- **T₁**: Na₂SO₄ 50-mM
- **T₂**: Na₂SO₄ 100-mM
- **T₃**: Na₂SO₄ 150-mM

The experiment was laid out as Completely Randomized Design (CRD) with four replicates. Four levels of Na₂SO₄ salt (0, 50, 100 and 150 mM Na₂SO₄) were applied after 20-days of germination. Plants were treated after 20-days of germinating the seeds and following studies were made. Plants were harvested at maturity. Plants were uprooted carefully and washed in distilled water. After 15-days of treatment, root and shoots lengths (cm) were measured with the help of scale meter. Plant fresh weight (g) was noted by electric balance. Shoot and root length was measured with the help of scale meter in cm at final harvest. Plant samples were placed in oven at 65°C. After 7-days shoot and root dry weight (g/pot) was calculated with the help of electric balance at final harvest (23-days after treatment).

#### 2.1. Leaf area per plant (cm²)

Leaf area per plant was determined following the formula of Carleton and Foote, (1965).

Leaf area (cm²) = maximum leaf length x maximum leaf width x 0.75 (0.75 = Correction factor)

The correction factor (C.F.) of family Gramineae is also 0.75.

### RESULT AND DISCUSSION

Salinity had highly significant effect on growth attributes of maize in pots under different levels of Na₂SO₄ stress.

#### 3.1. Shoot Length (cm)

Shoot lengths significantly decreased with increasing Na₂SO₄ levels in maize (Fig. 1). The maximum reduction was observed at Na₂SO₄ level of 150 mM. Data regarding of shoot length is given in Table (1). In control shoot length was 25.5 cm while it decreased up to 20.8 cm at Na₂SO₄ level of 150 mM.
It is generally accepted that plant growth at all stages of development and sensitivity to salinity varies from one growth stage to another, Ashraf et al., (1994), Hussain et al., (2008). According to many reports maize is sensitive at early stages but could withstand at later growth stages to saline conditions, Shirazi et al., (1971).

| Table 1: Effect of different salinity levels on Maize |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Parameters      | T₀ = Control    | T₁ (50 mM)      | T₂ (100 mM)     | T₃ (150 mM)     |
| Shoot length (cm) | 20.50           | 21.73           | 21.38           | 20.83           |
| Root length (cm)  | 20.50           | 15.45           | 15.25           | 14.33           |
| Leaf area (cm²)   | 18.30           | 15.75           | 14.94           | 12.40           |
| Shoot fresh weight (g) | 1.90         | 1.22            | 1.21            | 1.14            |
| Root fresh weight (g) | 0.79          | 0.60            | 0.58            | 0.50            |
| Shoot dry weight (g) | 0.84          | 0.57            | 0.54            | 0.47            |
| Root dry weight (g)  | 0.39            | 0.31            | 0.30            | 0.28            |

Figure 1: Effect of different concentration of Na₂SO₄ on Root and Shoot length (cm) of maize

Figure 2: Effect of different concentration of Na₂SO₄ on Plant leaf area (cm²) of maize

Figure 3: Effect of different concentration of Na₂SO₄ on Plant fresh and dry weight (g) of maize

3.2. Root Length (cm)

Na₂SO₄ severely affected the root length of maize (Fig. 1). Data regarding of root length of maize is given in Table 1. Na₂SO₄ stress has highly significant effect on root length of maize studied. In case of root length it decreased to 14.3cm at 150 mM Na₂SO₄ than control had 20.5 cm root length (Table 1). Root lengths decreased with increasing Na₂SO₄ concentrations. Maximum reduction in root length was noted 14.3cm in 32-B-33 Pioneer at 150 mM Na₂SO₄. Similarly, Hussain et al., (2009a)
observed the reduction of root length in black seeds under salt stress. This may due to water potential changes caused by salt concentrations in growth medium.

3.3. Leaf Area (cm²)
Leaf area also decreased with increasing Na₂SO₄ levels in maize (Fig. 2). Maximum reduction in leaf area was observed in T₃ (150 mM Na₂SO₄) that was 4.90cm² of maize variety (32-B-33 Pioneer) while in control, plant leaf area was 1.90cm (Table 1). Growth of leaf area is inhibited by salinity (Brugnoli and Lauter, 1991; Alberico and Cramer, 1993). High salt in the soil caused osmotic gradient between root and soil and mild osmotic stress leads rapidly to growth inhibition of leaves and stems, whereas roots may continue to grow and elongate (Frensch and Hsiao, 1994; Hsiao and Xu, 2000).

3.4. Plant Fresh Weight (g)
Reduction in plant fresh weight was also noted in maize (Fig. 3). In control shoot fresh weight was 1.90cm while at T₃ (150 mM Na₂SO₄), it decreased up to 1.14cm (Table 1). Maximum reduction was observed in T₃ (150 mM Na₂SO₄) that was 0.76g in maize (32-B-33 Pioneer). The maximum root fresh weight was calculated in control that was 0.79g and the minimum at 150mM Na₂SO₄ was 0.50g in maize (32-B-33 Pioneer). These results are similar with the earlier findings in maize (Izzo et al., 1996).

3.5. Plant Dry Weight (g)
Similar pattern of reduction in shoot and root dry weight was also noted in maize (Fig. 3). Data regarding to plant dry weight showed that shoot and root dry weights were decreased with increasing Na₂SO₄ level in Table 1. The maximum shoot dry weight was calculated in control (0.79g) and the maximum reduction in shoot dry weight was noted (0.50g) in maize variety at T₃ (150 mM Na₂SO₄). In case of root dry weight, the maximum weight was present in control (0.39g), while it decreased up to 13.31g at 150 mM Na₂SO₄ (Table 1). Similarly, Hussain et al., (2009b) found the reduction of growth in Chaksu (Cassia absus L.) under salt Stress. The results of biomass showed that applied Na₂SO₄ inhibited the growth of maize plant, and led to a decrease in biomass. The results of biomass may be related to the effect of salt stress which resulted in the limitation of water absorption and biochemical processes (Cusido et al., 1987; Parida and Das, 2005).

The suppression of plant growth under salt-stress may either be due to osmotic reduction in water availability or to excessive accumulation of ions, known as specific ion effect (Marschner, 1995). There are many reports on osmotic stress and ionic toxicity resulted from salt stress in maize plants (Katerji et al., 2004; Mansour et al., 2005; Eker et al., 2006). Addition of Na₂SO₄ had an adverse effect on the growth of maize. Salinity caused a significant effect on shoot and root lengths, shoots fresh and dry weight and root fresh weight and dry weight. The reason for growth reduction in maize could be due to water shortage and ionic toxicity caused by salinity. The decrease in plant growth may be due to turgor potential which is decreased by water deficit produced by high concentrations of the salts in the soil, Ashraf and Naqvi, (1996).

The present study showed that the growth processes in the maize plants were suppressed which was a result of the disturbed osmotic processes and the toxic effect of SO₄²⁻ and Na⁺. Osmotic effects are due to salt-induced decrease in the soil water potential. Salinity results in a reduction of K⁺ and Ca²⁺ content and an increased level of Na⁺, Cl⁻ and SO₄²⁻, which forms its ionic effects (Mansour et al., 2005).

In the present study, accumulation of Na⁺ and SO₄²⁻ in maize plants was significantly increased due to salt stress and the plant growth ratio decreased as increasing amounts of SO₄²⁻ were added to the soils.

| CONCLUSION |
| It was concluded that salinity had severe effect on growth of Zea Mays. All the growth parameters including root length, shoot length, leaf area, fresh and dry weight of Zea Mays reduced at all levels of added salt. The salt Na₂SO₄ was added in three different concentrations i.e. 50mM to 150mM. There was a significant reduction in growth with increase in salinity levels. The maize variety i.e. 32-B-33 is salt sensitive as the vegetative growth of maize is adversely effected by the addition of salt. |
REFERENCES


