

# Physiological and Ionic Expressions of Different Hybrids of Maize (*Zea Mays L.*) under Different Salinity Levels

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**Abstract** A pot culture experiment was conducted to estimate the behavior of maize under saline soil conditions in the wire house of Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad. There were three treatments with different levels of salinity and equal amount of Ammonium Nitrate ( $\text{NH}_4\text{NO}_3$ ) in all pots including control was applied to three genotypes of Hybrid Maize i.e. 32F10 (Pioneer), King Cross (Auriga), and NK-8441 (Syngenta), in five replications. Treatments were applied according to Completely Randomized Design (CRD). Plant and soil samples were collected for determination of different physiological and ionic expressions. Genotype NK-8441 comparatively performed better at all salinity levels. All studied physiological parameters viz. relative water contents, membrane stability index, total chlorophyll contents,  $\text{CO}_2$  assimilation, stomatal conductance, transpiration rate and photosynthetic rate showed a declining trend at higher salinity level, remarkably. However a very small decline was observed in NK-8441 compared with other genotypes. Due to salinity stress plant uptake of  $\text{K}^+$ ,  $\text{NO}_3^-$ , and N from soil was reduced and  $\text{Na}^+$  uptake was increased significantly as the salinity level was increased. NK-8441 showed its worth by up taking more  $\text{K}^+$ ,  $\text{NO}_3^-$  and N and discouraging  $\text{Na}^+$  uptake.

**Keywords** Salinity, Maize, Physio-Chemical,  $\text{NO}_3^-$ ,  $\text{K}^+$  and  $\text{Na}^+$  Uptake

## 1. Introduction

Maize (*Zea mays L.*) is a vital cereal crop for human as well as for animal utilization and is grown under different conditions in various parts of the world. In Pakistan, maize is the 3<sup>rd</sup> most valuable cereal after wheat and rice. Its grain has high nutrient value and oil is exploited for cooking purposes while green feed is quite rich in protein [11]. Area under maize crop is 1085 000 ha and production of maize for the

year 2012-13 is 4631 000 tones [16]. In view of its increasing importance betterment in agronomical aspects of maize has received big attention in Pakistan especially in saline soil conditions.

Salinity is one of the major constraints of agriculture in the arid and semiarid region. The salt-affected area of Pakistan is 6.67 million hectares [24]. Pakistan falls under arid and semiarid regions where evapotranspiration greatly exceeds precipitation and salts tend to accumulate in upper soil surface. The use of inadequate drainage, saline water and low soil permeability condition contributes to soil salinity. There are various detrimental effects of salt stress in crop plants, responsible for severe decreases in the growth and yield of plants. Osmotic stress (drought problem), ion imbalance, particularly with  $\text{Ca}^{+2}$ ,  $\text{K}^+$  and the direct toxic effects of ions on the metabolic process are the most important and widely studied physiological impairments caused by salt stress [29, 42].

Salt stress, like many abiotic stress factors, also induces oxidative damage to plant cells catalyzed by reactive oxygen species [8]. Excessive buildup of  $\text{Na}^+$  and  $\text{Cl}^-$  damages root membrane and causes ionic imbalances that may discourage potassium uptake by plants [17]  $\text{Na}^+$  and  $\text{Cl}^-$  concentration in different plant parts, tissues, cells and cell organelles increases by increasing salinity [25] N fertilization not only promotes plant growth it may also lessen the effects of salt on plants [13]. Plants take up nitrogen mainly as  $\text{NO}_3^-$  and  $\text{NH}_4^+$  form. When both are present in solution then  $\text{NH}_4^+$  is preferred. Under salinity nitrate consumption is slowed down and salinity reduces  $\text{NO}_3^-$  absorption with the possible consequence of N insufficient in the plant [31].

It is difficult to study plant response to fertilizers under saline conditions due to high concentration of salts and nutritional imbalances. Studies showed that application of fertilizers in saline soils might result in increased, decreased or unchanged plant salt tolerance. In other words, plant response to fertilizers depends on severity of salt stress in the root zone [28] The present study was planned to flourish the knowledge about growth, yield components and to judge the

salt tolerance behavior of maize genotypes and role of nitrogenous fertilizer in enhancing the salt tolerance.

## 2. Materials and Methods

A pot experiment was conducted in the wire house, Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad to estimate the behavior of maize (*Zea mays L.*) genotypes in saline soil conditions. Three genotypes of maize (*Zea mays L.*) 32F10 (Poineer), King Cross (Auriga), and NK-8441 (Syngenta) were tested against three levels of salinity viz. (1) Control (1.2 dS m<sup>-1</sup>) (2) EC<sub>e</sub> 4 dS m<sup>-1</sup> (3) EC<sub>e</sub> 8 dS m<sup>-1</sup>. These saline treatments were selected keeping in view the tolerance and yield potential of the crop. Initially soil samples were collected from research area of University of Agriculture Faisalabad, after then soil was sieved and analyzed to develop salinity with addition of NaCl salt. Salinity was developed artificially in the pots using calculated amount of NaCl salt [24]. Properties of the soil and tap water used for irrigating the pots are as under in Table 1.

The experiment was replicated five times with completely randomized design (CRD). Leaf samples were taken after two months for determining membrane stability index (MSI) and relative water contents (RWC). Chlorophyll contents of each plant were determined with chlorophyll meter. Different parameters like CO<sub>2</sub> assimilation, stomatal conductance, transpiration rate and photosynthetic rate were recorded by Infra Red Gas analyzer (IRGA). Leaf samples were taken again for extraction of leaf sap. Sodium (Na<sup>+</sup>) and Potassium (K<sup>+</sup>) was calculated from the leaf sap. Plants were harvested after three months and separated into shoots

and roots. Soil samples after harvesting the crop were taken and analyzed for sodium (Na<sup>+</sup>) and potassium (K<sup>+</sup>) by Flame Photometer, nitrate (NO<sub>3</sub>) by Spectrophotometer and total nitrogen by Kjaldahl method. The collected data were statistically analyzed by using the Fisher's analysis of variance technique and differences among treatment means were compared by using least significant difference (LSD) test at 5 % probability level with the help of statistical package MSTAT-C version 1.3 [38].

## 3. Results and Discussions

Salinity adversely affected the physiological and ionic characteristics of maize, when exposed to salinity level of 4 dS m<sup>-1</sup> and 8 dS m<sup>-1</sup>.

Effect on salinity on physiological and ionic parameters of Maize: Maize genotype NK-8441 showed better physio-chemical attributes at all salinity levels. Salinity effect on physiological parameters is discussed below:-

Relative Water Contents (RWC): The data presented in the table 2 showed that at all salinity levels control (1.2 dS m<sup>-1</sup>), 4 dS m<sup>-1</sup> and 8 dS m<sup>-1</sup> EC<sub>e</sub> the maximum and the minimum relative water contents were calculated in NK-8441 and King Cross, respectively. Relative water contents decreased significantly with increased in salinity. At all EC<sub>e</sub> levels, the maximum and the minimum relative water contents recorded in the order NK-8441 > 32F10 > King Cross. The results were supported by [19] drought and salinity affected the dry weight content in a different way, resulting from the reduction in the relative water content. [10] also concluded that salinity reduces leaf relative water contents in maize (*Zea mays L.*).

**Table 1.** Properties of soil and tap water used in the experiment

Soil properties			Tap water properties		
Parameters	Value	Units	Parameters	Value	Units
Soil Texture	Sandy loam	-----	RSC	3.40	me L <sup>-1</sup>
Saturation %	29	%	TSS	10.5	mmol L <sup>-1</sup>
EC <sub>e</sub>	1.2	dS m <sup>-1</sup>	EC	1.05	dS m <sup>-1</sup>
pH <sub>s</sub>	7.6	-----	Na <sup>+</sup>	5.2	mmol L <sup>-1</sup>
SAR	8.64	(mmol <sub>c</sub> L <sup>-1</sup> ) <sup>1/2</sup>	SAR	2.01	(mmol <sub>c</sub> L <sup>-1</sup> ) <sup>1/2</sup>
K <sup>+</sup>	107	mM	Ca <sup>+2</sup> +Mg <sup>+2</sup>	4.7	mmol L <sup>-1</sup>
Nitrogen	.0036	%	CO <sub>3</sub> <sup>-2</sup>	Absent	mmol L <sup>-1</sup>
NO <sub>3</sub> -N	.0415	%	HCO <sup>-3</sup>	8.10	mmol L <sup>-1</sup>

**Table 2.** Effect of salinity on physiological parameters of maize

Treatments	RWC	MSI	TCC	Ci	A	E	Gs
(Control)	59.46a	48.13a	27.86a	385.26a	14.74a	4.98a	0.065a
(4 dS m <sup>-1</sup> )	48.06b	42.06b	24.80b	245.73b	9.03b	3.09b	0.046b
(8 dS m <sup>-1</sup> )	21.06c	19.60c	23.00b	133.46c	4.17c	1.99c	0.025c
LSD 5%	5.03	4.46	2.32	15.23	0.65	0.42	0.01
32F10	42.33b	43.13a	25.06b	254.20b	9.26b	3.36b	0.046b
King cross	34.06c	28.00b	22.66c	200.46c	6.86c	2.40c	0.035c
NK-8441	52.20a	38.66a	27.93a	309.80a	11.82a	4.31a	0.056a
LSD 5%	3.76	6.06	1.89	16.59	0.73	0.35	7.06

Means sharing the same letter do not differ significantly at P=5%, Relative Water Contents (RWC), Membrane stability index (MSI), Total chlorophyll contents (TCC), CO<sub>2</sub> Assimilation (Ci), Transpiration Rate (E), Photosynthetic Rate (A)

**Table 3.** Effect of salinity on ionic parameters of maize

Treatments	Leaf Na <sup>+</sup> Level (mM)	Leaf K <sup>+</sup> Level (mM)	Soil Na <sup>+</sup> Level (mM)	Soil K <sup>+</sup> Level (mM)	NO <sub>3</sub> (ppm) soil	N (ppm) soil
(Control)	82.46c	114.33a	66.93a	75.36c	262.60c	17.24c
(4 dS m <sup>-1</sup> )	199.13b	88.86b	103.06b	84.80b	514.80b	42.68b
(8 dS m <sup>-1</sup> )	153.73a	62.93c	133.66c	94.90a	739.46a	68.47a
LSD 5%	4.35	3.05	7.83	1.37	56.29	5.18
32F10	199.26b	86.26b	100.73b	84.86b	506.33b	42.01b
King cross	106.66c	82.86b	113.46c	88.81a	628.73a	55.46a
NK-8441	129.40a	97.00a	89.46a	81.40c	381.80c	30.92c
LSD 5%	5.02	4.33	6.66	1.18	82.65	4.63

Means sharing the same letter do not differ significantly at P=5%, Sodium (Na<sup>+</sup>), Potassium (K<sup>+</sup>), Nitrate (NO<sub>3</sub><sup>-</sup>), Nitrogen (N)

Membrane stability index (MSI): The data presented in the table 2 showed that at all salinity levels control (1.2 dS m<sup>-1</sup>), 4 dS m<sup>-1</sup> and 8 dS m<sup>-1</sup> EC<sub>e</sub> MSI decreased significantly with increase in salinity and maximum MSI was found in NK-8441 while the minimum in King Cross at control (1.2 dS m<sup>-1</sup>) EC<sub>e</sub> level. Maximum and the minimum MSI recorded in the order NK-8441 > 32F10 > King Cross. Salinity reduces MSI by causing changes in morphology and physiology of plants. It reduces the succulence of leaves as a result MSI is reduced. The membrane stability index (MSI) in leaves of sugarcane cultivars under control and salt stress condition showed a decreasing trend with maturity in all the genotypes [14]. Same results were studied by Tas and Basar (2009).

Total chlorophyll contents (TCC): The data presented in

the table 2 showed that at all salinity levels control (1.2 dS m<sup>-1</sup>), 4 dS m<sup>-1</sup> and 8 dS m<sup>-1</sup> EC<sub>e</sub> TCC decreased significantly with increased salinity. The reduction in total chlorophyll content is to be expected under stress conditions. Its stability depends on membrane stability, which under saline condition seldom remains intact [23]. Similar results were also reported by [1, 5, 14, 21, 23, 26, 32, 40]. Total chlorophyll contents of plants may be considered as an indicator in improving new genotypes for salt stress depending on the present or other findings.

Stomatal conductance (GS): The data presented in the table 2 showed that at all salinity levels control (1.2 dS m<sup>-1</sup>), 4 dS m<sup>-1</sup> and 8 dS m<sup>-1</sup> EC<sub>e</sub> maximum and the minimum stomatal conductance recorded in the order NK-8441 > 32F10 > King Cross. [22] during early seedling growth of

maize and sunflower salinity reduces leaf water potential and stomatal conductance. Photosynthesis is an accepted fact that determines the final plant productivity. Salinity decreased the net photosynthetic rate, stomatal conductance, intercellular carbon dioxide concentration and transpiration rate, but increased the leaf temperature of rice [37]

CO<sub>2</sub> Assimilation (Ci): The data presented in the table 2 showed that CO<sub>2</sub> assimilation decreased significantly with increase in salinity at all salinity levels. NK-8441 was better in CO<sub>2</sub> assimilation than 32F10 and King cross. Salinity decreased the net photosynthetic rate, stomatal conductance, intercellular carbon dioxide concentration and transpiration rate, but increased the leaf temperature of rice [37]. Similar results were found by [33].

Transpiration Rate (E): The data (table 2) revealed that transpiration rate decreased significantly with increased salinity level. Transpiration rate recorded in the order NK-8441 > 32F10 > King Cross at all salinity levels of control (1.2 dS m<sup>-1</sup>), 4 dS m<sup>-1</sup> and 8 dS m<sup>-1</sup> EC<sub>e</sub>. Salinity decreased the net photosynthetic rate, stomatal conductance, intercellular carbon dioxide concentration and transpiration rate, but increased the leaf temperature of rice [37].

Photosynthetic Rate (A): The data (table 2) cleared that photosynthetic rate decreased significantly with increase in salinity and maximum Photosynthetic rate was found in NK-8441 while, the minimum in King Cross at control (1.2 dS m<sup>-1</sup>) EC<sub>e</sub> level. At 4 dS m<sup>-1</sup> EC<sub>e</sub> level, the maximum and the minimum Photosynthetic rate was recorded in NK-8441 and King Cross, respectively. At 8 dS m<sup>-1</sup> EC<sub>e</sub> level, NK-8441 was better in photosynthetic rate than 32F10 and King cross. Photosynthesis is an accepted fact that determines the final plant productivity. Salinity decreased the net photosynthetic rate, stomatal conductance, intercellular carbon dioxide concentration and transpiration rate, but increased the leaf temperature of rice [37].

Effect on salinity on ionic expressions of Maize: Salinity has very clear affects on ionic composition of maize and maize grown soil, especially when exposed to salinity index of 8 dS m<sup>-1</sup>. Maize genotype NK-8441 showed better chemical attributes at all salinity levels. Salinity effect on ionic composition of plant and soil is discussed below:-

Leaf Sodium Level (Na<sup>+</sup>): The data presented in the table 3 showed that Na<sup>+</sup> concentration in leaf sap was increased significantly with increased EC<sub>e</sub> levels. At all levels, the maximum Na<sup>+</sup> concentration was recorded for King Cross. The minimum Na<sup>+</sup> concentration was noticed for NK-8441 at all salinity levels. A positive correlation exists between Na<sup>+</sup> exclusion and relative salt tolerance in many crops including barley [34], rice [7] beans and sunflower [4, 6, 20]). Efficient Na<sup>+</sup> exclusion is a good selection criterion for salt tolerance in maize and other glycophytes [4, 9, 30]. The concentration of N, NO<sub>3</sub><sup>-</sup>, P and K was reduced in the salinity treatments, but the concentration of Na<sup>+</sup> and Cl<sup>-</sup> was increased. [12].

Leaf Potassium Level (K<sup>+</sup>): The data (table 3) revealed that K<sup>+</sup> concentration in leaf sap was decreased considerably

with increased EC<sub>e</sub> levels. The minimum K<sup>+</sup> was found in King Cross at all the EC<sub>e</sub> levels, whereas the maximum K<sup>+</sup> concentration was found in NK-8441 which varied significantly at all EC<sub>e</sub> levels. Almost similar results had been observed by [27]. Salt stress induced Na<sup>+</sup> and Cl<sup>-</sup> accumulation it decrease K<sup>+</sup> and Ca<sup>2+</sup> level in shoots and roots, therefore salt decrease relative growth rate of shoots and roots. Decreased K<sup>+</sup> concentration with increased salinity was also reported earlier by [3, 30] in maize.

Soil Sodium Level (Na<sup>+</sup>): The data (table 3) showed that Na<sup>+</sup> concentration in soil was decreased significantly with increased EC<sub>e</sub> levels. At all levels, the minimum Na<sup>+</sup> concentration was recorded for King Cross. The maximum Na<sup>+</sup> concentration at moderate NaCl induced salinity was observed for NK-8441, while at 8 dS m<sup>-1</sup> EC<sub>e</sub> level, the maximum was observed for NK-8441 and minimum for King Cross. Na<sup>+</sup> uptake by plant under saline conditions was more so as a result Na<sup>+</sup> concentration increases in soil as the salinity level increases. [12] the concentration of N, NO<sub>3</sub><sup>-</sup>, P and K<sup>+</sup> was reduced in the salinity treatments, but the concentration of Na<sup>+</sup> and Cl<sup>-</sup> was increased.

Soil Potassium Level (K<sup>+</sup>): The data presented in the table 3 shows that K<sup>+</sup> concentration in soil was increased significantly with increased EC<sub>e</sub> levels. The maximum K<sup>+</sup> was found in King Cross at all the EC<sub>e</sub> levels, whereas the minimum K<sup>+</sup> concentration was found in NK-8441 which varied significantly at all EC<sub>e</sub> levels. K<sup>+</sup> up take from soil under salinity is suppressed by Na<sup>+</sup> uptake, resulting in high concentration of K<sup>+</sup> in saline soils. There is a debate that K<sup>+</sup> influx could be used as an index to salinity tolerance [36]. Increased K<sup>+</sup> concentration may be attributed to K<sup>+</sup> selectivity for absorption.

Soil Nitrate (NO<sub>3</sub><sup>-</sup>): The data (table 3) revealed that analyzed soil NO<sub>3</sub><sup>-</sup> concentration at all salinity levels of control (1.2 dS m<sup>-1</sup>), 4 dS m<sup>-1</sup> and 8 dS m<sup>-1</sup> was minimum for cultivar NK-8441 and maximum for cultivar King Cross. [12] the concentration of N, NO<sub>3</sub><sup>-</sup>, P and K<sup>+</sup> was reduced in the salinity treatments, but the concentration of Na<sup>+</sup> and Cl<sup>-</sup> was increased. [28] Salinity in a straight line can affect nutrient uptake such as Na<sup>+</sup>, reducing K<sup>+</sup> uptake or by Cl<sup>-</sup> reducing NO<sub>3</sub><sup>-</sup> uptake.

Soil Total Nitrogen (N): The data presented (table 3) cleared that N concentration was increased significantly with increased EC<sub>e</sub> levels. At all levels, the maximum N concentration was recorded for King Cross. The minimum N concentration at moderate NaCl induced salinity was observed for NK-8441, while at 8 dS m<sup>-1</sup> EC<sub>e</sub> level, the minimum N concentration was observed for NK-8441 and maximum for King Cross. [2] total dry matter production and root and shoot N contents decreased with increasing salinity in the rooting medium. [18] soil salinity affected crop yield, crop total nitrogen uptake and the nitrogen contribution of the soil. [31] The NH<sub>4</sub><sup>+</sup>: NO<sub>3</sub><sup>-</sup> (25:75) application resulted in increasing the total N contents in plants of control and saline treatments, but did not cause a large decrease in plant Na<sup>+</sup> contents under salinity.

## 4. Conclusions

After investigating the all above mentioned physiological and ionic attributes, results were found significant. Among the three commercial hybrids of maize NK-8441(Syngenta) was found comparatively best variety due to its better mechanism against salinity stress.

On an overall basis NK-8441 (Syngenta) and 32F10 (Pioneer) were proved to be the best at intermediate salinity level. However, at 8 dS m<sup>-1</sup> salinity level NK-8441 proved to be relatively salt tolerant of all cultivars. It also had higher K<sup>+</sup> as well as lower concentration of Na<sup>+</sup> concentration in its leaf sap. It means that it had a relatively better mechanism of Na<sup>+</sup> exclusion. At the same time it had better system of K<sup>+</sup> maintenance in its leaves.

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