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COMPARISON OF PHYSIO-BIOCHEMICAL AND ANTIOXIDANT ENZYMES IN MAIZE DURING EARLY GROWTH STAGE IN RESPONSE TO SALT STRESS

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Abstract

Salinity stress is a major hazard to crops, severely restricting agricultural productivity around the world. Salt stress has a negative impact on the growth, physiological, biochemical, and metabolic processes of maize, resulting in a significant loss in final crop productivity. However, the maize genotypes differ significantly in terms of salinity tolerance. Therefore, this study was conducted to assess the impact of different salinity levels (control, 6 dS m^{-1}, 12 dS m^{-1}) on growth, and physio-biochemical traits of different maize hybrids (P-1543, FS-131, SB-9663, YH-1898, FH-1096, SB-794). The results delineated that salt stress (12 dS m^{-1}) considerably increased the time to start germination (TSG), reduced germination index (GI), and final germination percentage (FGP). Moreover, salt stress (12 dS m^{-1}) also reduced root and shoot growth, biomass production, chlorophyll contents, and relative water contents (RWC). Further, current results depicted that salt stress induced an increase in electrolyte leakage (EL) and activities of antioxidants (APX, CAT and POD). Similarly, the maize hybrids also had significant differences in germination, growth and physio-biochemical traits. In comparison, hybrids FH-1096 and YH-1898 required less TSG and had the highest GI and FGP, whereas hybrids P-1543 and FS-131 needed more TSG and had the lowest GI and FGP. Likewise, the maximum chlorophyll, RWC, carotenoid and antioxidant enzymes activities were recorded in hybrid FH-1096. However, minimum chlorophyll, RWC, carotenoid and antioxidant enzymes activities and maximum EL was noticed in hybrids P-1543, FS-131 and SB-9663. Thus, on the basis of these findings, it can be suggested that maize hybrids FH-1096 and YH-1898 can show tolerance under salt stress conditions.

Key words: Antioxidant; Growth attributes; Maize; Photosynthetic pigments; Salt stress; Germination.

Introduction

Salinity stress (SS) is a major abiotic stress that has a negative impact on crop plant growth and development. Globally, more than 20% of arable and 33% of irrigated soil are facing salinity stress and it has been projected that more than 50% of soils will be affected by salt at the end of 2050 (Jamil *et al*., 2011; Shrivastava & Kumar, 2015, Tessema *et al*., 2022). The effects of salt stress on crop production are more severe in arid and semi-arid environments because of factors such as increased evaporation, ambient temperature, reduced rainfall, and poor soil management measures (de Azevedo Neto *et al*., 2006; Otlewska *et al*., 2020). There are a variety of factors that contribute to the salinization of arable soils. For instance, outmoded irrigational practices, as well as the improper use of manures, have been the primary contributors to excess salt in agricultural fields in recent years (Ouhibi *et al*., 2014; Rasool *et al*., 2022). Thus, the accumulation of Na^+ and Cl^- ions takes place in the soil that results in hyperosmotic and hypertonic conditions, subsequently impede plant retention of water and nutrients from the soil (Ouertani *et al*., 2022). Besides, in plants, salinity stress is firstly reported to reduce seed germination, but later changes development and reproductive activity, finally, significant yield reductions resulted. Salinity also reduces enzyme activity, photosynthesis, membrane structure, hormonal balance, water uptake, and nutrient intake in plants, as well as causing oxidative damage (Seleiman *et al*., 2022).

Higher and more uniform germination is an important factor in yield, especially in salt stress conditions. Salinity stress has been shown to have a significant impact on seed germination, impacting seedling establishment, growth, and development (Kan *et al*., 2016; Zhang *et al*., 2010). Plus, seed germination is reported to be declined as a result of oxidative stress mediated by salinity (Farhangi-Abriz & Torabian, 2017; Zhu, 2016). It also affects the various physiological as well as metabolic processes. The response to such variations induced reductions in leaf area, leaf abscission, necrosis and an increase in leaves thickness and succulence (Ma *et al*., 2017). Salt stress further reduces chlorophyll contents and therefore lowers the photosynthetic efficiency of plants and increases the respiration losses (Parida & Das, 2005). Moreover, it also decreases membrane stability, relative water content, and increases the oxidation of lipids and accumulation of MDA and H_2O2 (Bertrand *et al*., 2015). Additionally, salt stress also induces an ionic imbalance in plants, which causes ionic toxicity, production of ROS and osmotic stress. It also induces the accumulation of ROS in plant cells which further causes damages to proteins, lipids and DNA (Chawla *et al.*, 2013). However, plants have enzymatic and non-enzymatic anti-oxidants which help them to scavenge the ROS and increase their tolerance against different stress conditions (Hassan *et al.*, 2019b; Hassan *et al.*, 2021; Karuppanapandian *et al.*, 2011; Umair Hassan *et al.*, 2020).

The world's population is continuously mushrooming, which in turns increases the food demands. Therefore, it is the need of the hour to increase crop production in salt affected soils to meet the rising food demands. Moreover, by adopting the proper management practices crop production can successfully rise in these soils. Thus, the identification of salt tolerant crops/genotypes is very important to get the maximum production from problematic soils. The wise selection of cultivar is an imperative strategy to improve the crop productivity (Chattha *et al.*, 2017c; Hassan *et al.*, 2019a; Hassan *et al.*, 2019b; Hassan *et al.*, 2021; Hassan *et al.*, 2018; Ilyas *et al.*, 2020). Maize is considered as a moderate salt sensitive crop (Carpici *et al.*, 2010; Ouda *et al.*, 2008)]. The selection and breeding strategies have always been to obtain the maximum production along with better quality in salt stress (Chattha *et al.*, 2017d). Maize being the cross pollinated crop has become highly polymorphic through the natural as well as the domestic evaluation thus it contains the massive variability in which salinity tolerance may exist (Chattha *et al.*, 2017a). It is an indispensable crop across the globe as it has wide range of uses in daily life (Chattha *et al.*, 2017b; Zamir *et al.*, 2020). The genotypes are mostly different in terms of their ability to tolerate salt stress (Krishnamurthy *et al.*, 2007). Therefore, due to its higher economic importance, it is direly needed to characterize the salt tolerant genotypes of maize. With that as context, this work examined the genotypic characterisation and physio-biochemical responses of maize hybrids to various salt stress levels.

Materials and Methods

Study site: This study was performed in the wirehouse of the University of Agriculture, Faisalabad in a completely randomized with a two-factor factorial arrangement. Total of six hybrids (P-1543, FS-131, SB-9663, YH-1898, FH-1096 and SB-794) were tested under different levels of salinity stress i.e., control, 6 dS m-1 and 12 dS m-1. Three replications were maintained in this study.

Soil collection and imposition of salinity stress: The upper 1-10 cm layer of soil was collected from the Agronomy field and a 1:1 combination of silt and soil was thoroughly mixed to fill the pots. The various soil physio-chemical properties were determined using standard methods. The soil was loamy having pH=7.81, EC=0.97 dS m^{-1}, organic matter 0.79%, available N 0.039% and available P and K was 16 and 178 mg kg^{-1}. We took soil sample and prepared the paste by adding water and the paste was left for 2 hours to reach the equilibrium. Afterwards paste was filtered to obtain extract and later on, the soil was over-dried until the constant weight and soil saturation were determined by the given below formula:

$$Saturation\ (\%) = \frac{Loss\ in\ soil\ weight\ on\ drying}{Weight\ of\ soil\ after\ drying} \times 100$$

#However, NaCl quantity required to achieve the 6 and 12 dS m^{-1} levels was calculated by the given below formula:

$$NaCl\ required\ \left(\frac{g}{kg}\right) = \frac{TSS \times 58.5 \times Saturation(\%)}{100 \times 1000}$$

Here, TSS indicating the total soluble salts and it was determined as: TSS = EC_2-EC_1

To achive the desireable EC levels (6 and 12 dS m^{-1}); salt was added @ of 1.18 and 2.36 g/kg soil. A 1:1 combination of silt and soil was thoroughly mixed and pots with a capacity of 8 kg were filled. The soil of each pot was taken and salt was mixed properly in soil and pots were again filled. In this study, total of 54 pots were used and in each pot 10 seeds of each hybrid were sown. The pots were visited regularly and water was applied according to crop needs.

Biochemical observations: The data related to the emergence attributes including the time to start germination, (TSG), time to 50% emergence (T_{50}) and mean germination time (MGT) was determined by following standard protocols. The emergence was recorded on the daily basis by the methods of AOSA (Crosier *et al.*, 1970). And T_{50} was determined by the standard methods as described by Farooq *et al.*, (2005)]. Moreover, the MET was noted by the methods of Ellis and Robert (Ellis & Roberts, 1981) and the emergence index (EI) was determined by the formula as suggested by AOSA (Crosier *et al.*, 1970)]. Similarly, the emergence percentage (FEP) was determined by calculating the final emerged seeds in each pot.

The chlorophyll and carotenoid contents were determined by the protocol of Lichtenthaler (Lichtenthaler, 1987). Fresh leaf samples (0.5 g) were homogenized in 80% methanol solution and the extract was centrifuged and filtered by the filter paper and absorbance was noted at 663, 645 and 480 nm wavelengths. Leaf relative water content (RWC) was determined by the method of Mostofa and Fujita (Mostofa & Fujita, 2013) method. The fresh leaves were taken and their fresh weight was taken and then the leaves sample was dipped for 24 hours in water. Later on, the samples were taken out of water and excess water present on the leaves was removed with a towel and leaves weight was taken and RWC was determined by the following formula:

$$RWC\ (\%) = \frac{FW - DW}{TW - DW} \times 100$$

Leaves were taken and washed to remove any contamination. After that samples were placed in vials containing 10 mL water and incubated at 25°C on a rotary shaker and electrolyte leakage was measured. Catalase (CAT) contents in each hybrid were determined by following the protocols of Aebi (Aebi, 1984). The mixture contained 100 µL of H2O2 (5.9Mm) and 1000 µL buffer with plant extract (100 µL). After that, the absorbance was noticed with a spectrophotometer (240 nm). Moreover, the protocol of Zhang (Zhang, 1992) was used to determine the peroxidase (POD) contents. A reactant mixture was contained: 100 µL extract enzyme + 2700 µL of 50 mM potassium buffers + 100 µL guaiacol and H_2O_2 µL. After that plant samples were homogenized and centrifuged (15,000) and absorbance was noticed at 470 nm. For APX determination, the mixture contained 100-µL enzyme 100 extracts, 100 µL ascorbate (7.5-mM), 100 µL H2O2 (300 mM), and 2.7 mL potassium buffer (25 mM) and after that plant sample were homogenized and absorbance was recorded at 290 nm.

Statistical analysis

The collected data on growth, physiological and biochemical traits were analyzed by analysis of variance technique and LSD test (5% probability) was used for comparing differences among means (Steel & Torrie, 1960).

Results and Discussion

Effects of salt stress on germination traits of maize hybrids: The results indicated that levels of salinity stress (SS) had a significant impact on the germination traits of all maize hybrids. The maximum TSG was recorded (4.72 days) in 12 dS m^{-1} after that 6 dS m^{-1} and minimum TSG was taken at the control level (Table 1). However, all the maize hybrids had a non-significant impact on TGS and all the hybrids took the same time to start germination. The maximum T50 and MGT was also taken by plants grown under 12 dS m^{-1} and the lowest T50 and MGT were taken at control conditions (Table 1). Among maize hybrids; FH-1096 took less time for T50 and MGT whereas hybrid P-1543 took maximum time for 50% and mean germination. Moreover, the maximum germination index (GI) (73%) and final germination percentage (91%) was recorded in the control and the lowest GI (64%) and final germination percentage (78%) were recorded at higher level of salt stress (12 dS m^{-1}). Among maize hybrids, maximum GI and FGP were noticed in FH-1096 and minimum was noted in P-1543 (Table 1). Further, it was noticed that salinity stress significantly increased the TSG, T50 and MGT as compared to the control. The various maize hybrids had different responses to germination characteristics. Our results also indicated that increasing salinity stress significantly increased the germination time and reduced the GI and GP. These results are the same with Geressu and Gezahagn (Rajabi Dehnavi *et al*., 2020) they also noted significant differences among cultivars for germination-related parameters. Moreover, in previous studies it has been also reported that salt stress decreased the germination, GI, GP and increased the time for germination (Almodares *et al*., 2007; Jamil *et al*., 2011; Rajabi Dehnavi *et al*., 2020), Nonetheless, then this reduction in salinity stress attributed to salt-induced high osmotic potential and ionic toxicity which reduced the final germination and GI and GP (Turhan *et al*., 2011; Zhang *et al*., 2010).

Moreover, salt stress also influences the germinating processes by changing the water imbibition by seeds owing lower osmotic potential of germination media that delays the water absorption and therefore reduced the germination of seeds (Jamil *et al*., 2011). On the other hand, higher Na$^+$ ions in the growing medium cause osmotic stress and induce water deficiency resulting in a decrease in water absorption by plant tissues which also causes substantial reduction in seed germination (Dustgeer *et al*., 2021)]. Salinity stress alters enzymatic activities due to the toxic ions (Na$^+$) (Abbruzzese *et al*., 2009) that disrupts enzymatic activities and causes major changes in hormonal balance, protein and nucleic acids metabolism and reduces the seed reserves which also causes significant reduction in germination (Abbruzzese *et al*., 2009; Farhoudi & Tafti, 2011; Gomes-Filho *et al*., 2008). Additionally, by disturbing the metabolic processes salinity stresses the concentration of phenolic compounds which reduces the seed germination (Gomes-Filho *et al*., 2008). Nonetheless, different seed internal factors such as vigor, dormancy and polymorphism and various external factors including light, temperature and water also affect seed germination under salinity stress (Rajabi Dehnavi *et al*., 2020). Thus, hybrid FH-1096 emerged as a salt tolerance as compared to other hybrids. Moreover, it seeds that variations among the maize hybrids for germinating parameters can be due to their inheritance variations and genetic factors (Asfaw, 2011; Ryu & Cho, 2015).

Table 1. Effects of diverse salinity stress levels on germination traits of different maize hybrids.

Salinity levels (SL)	TSG (days)	T50 (days)	MGT (days)	GI (%)	FGP (%)
Control	4.00B	2.83B	4.94B	72.67A	90.78A
6 dSm^{-1}	4.33AB	3.17AB	5.28AB	70.11B	81.28B
12 dSm^{-1}	4.72A	3.44A	5.61A	64.11C	78.06C
LSD≤0.05P	0.40	0.41	0.42	1.94	2.30
Maize hybrids (MH)					
P-1543	4.67	3.56A	6.00A	61.89E	76.44D
FS-131	4.44	3.33A	5.67AB	65.00D	79.11CD
SB-9663	4.11	3.33A	5.33BC	67.56CD	82.22C
YH-1898	4.33	3.00AB	5.00CD	73.33B	89.22B
FH-1096	4.11	2.67AB	4.67CD	77.22A	92.89A
SB-794	4.44	3.00B	5.00D	68.78C	80.33C
LSD≤0.05P	NS	0.56	0.59	2.74	3.25
SL×MH					
LSD≤0.05P	NS	NS	NS	NS	NS

TSG: Time to start germination, T50: Time to 50% germination, MGT: Mean germination time, GI: Germination index, FGP: Final germination percentage. Means with different letters differed at *0.05* P level

Effects of salt stress on the morphology of maize hybrids: The findings showed that SS significantly reduced plant growth and biomass production. The maximum root and shoot length and root and shoot fresh and dry weights were recorded at control conditions (no salt stress); whereas, minimum values for the aforementioned traits were observed at 12 dS m^{-1} (Table 2). Among maize hybrids maximum root and shoot, length were recorded in hybrid FH-1096; however, minimum values were recorded in hybrid P-1543 (Table 2). The maximum leaves per plant (4.72) were recorded at control conditions, but the minimum leaves per plant (4.17) were recorded at 12 dS m^{-1} salt stress level (Table 2). In the case of maize hybrids, maximum leaves per plant were recorded in hybrid FH-1096 and minimum leaves per plant were noticed in hybrid P-1543 (Table 2).

In this study, the reduction of plant roots, and shoot and their biomass production under SS might be due to hormonal imbalance and ionic toxicity that reduced water uptake which leads to a reduction in growth and biomass production (El Naim *et al*., 2012). Salt stress also makes root membranes impermeable to toxic ions and therefore, the plant cannot maintain the optimum stomatal conductance and photosynthetic efficiency thus resulting in a reduction in growth and biomass (Kausar *et al*., 2012; Hannachi *et al*., 2022). However, in control conditions, plants have optimum hormonal balance, water and nutrient uptake which favored better growth with more biomass production (Afshinmehr *et al*., 2013; Rewald *et al*., 2011). Generally, an increase in salt contents in rhizosphere substantially decreased plant growth and resultantly leads to a reduction in the production of leaves/plant (Qados, 2011). In salt stress reduction in nutrient and water uptake and increase in Na^+ and Cl^- in cell walls induced less production of assimilates which decreased leaves/plant (Chartzoulakis, 2005).

Effect of salt stress on the activities of antioxidant enzymes: Salt stress had demonstrable impacts on the physiological traits of all maize hybrids. The maximum RWC (72%) were recorded in control, and the lowest RWC (61%) were noticed at 6 dS m^{-1} salt stress conditions. Maize hybrid FH-1093 showed the maximum RWC (69%) followed by YH-1898, whereas, hybrid P-1543 had the lowest RWC (623%). Moreover, salt stress significantly reduced RWC in maize which is the same as the findings of Ryu and Cho (2015) who also found a considerable decrease in the RWC under SS. The plants cope with the salt stress by reducing the tissues' water contents possibly by lowering the water potential of leaves (Ma *et al*., 2020). Therefore, in this study reduction in RWC under salinity stress might be due to a reduction in the water potential of leaves which indicates the reduction in RWC is linked with a reduction in water uptake.

Further, maximum electrolyte leakage (EL) was recorded at 12 dSm^{-1}; however, minimum EL was found in control conditions (Table 3). In the case of hybrid maximum EL (38%) was recorded in P-1543 and minimum EL (35%) was recorded in FH-1096 (Table 3). Plant cell membranes are a primary site of injury caused due to ionic toxicity (Jahan *et al*., 2018). Thus, EL from the membranes is considered as one of the most imperative criteria to identify the salt-tolerant genotypes (Mansour & Salama, 2004). In this study, an increase in EL can be due to K^+ efflux which is consistent with the outcomes of Demidchik *et al*. (2014). In another study, Ashraf & Ali (2008) also noted a significant increase in EL under K^+ efflux. The maximum chlorophyll a and b and carotenoids were recorded in control whereas a substantial reduction in these photosynthetic pigments was recorded under both levels of salinity stress (Table 2). Hybrid FH-1096 showed maximum contents of chlorophyll a and b and carotenoids; however, hybrids (YH-1898 and hybrid P-1543) had minimum chlorophyll a and b and carotenoids contents (Table 3). Chlorophyll a is a vital part of light-harvesting compounds, whereas Chlorophyll b as pigment act indirectly in photosynthesis (Demidchik *et al*., 2014). The reduction in chlorophyll contents under SS was due to a decrease in the synthesis of pigments due to the salts (Gururani *et al*., 2015). Moreover, rapid leaf maturation might be another reason for a reduction in chlorophyll contents in salt stress. Therefore, a reduction in chlorophyll contents led to a reduction in photosynthetic efficiency which resulted in a reduction in growth and biomass production.

Table 2. Effects of diverse salinity stress levels on the growth of different maize hybrids.

Salinity levels (SL)	RL (cm)	SL (cm)	RFW (g)	RDW (g)	SFW (g)	SDW (g)	LPP
Control	15.67A	61.33A	3.78A	1.71A	16.06A	3.83A	4.72A
6 dSm^{-1}	14.39B	56.11B	3.50AB	1.66B	14.17B	3.08B	4.39B
12 dSm^{-1}	12.72C	55.33B	3.11B	1.49C	13.06C	2.49C	4.17B
LSD≤0.05P	0.67	1.20	0.20	0.03	0.54	0.05	0.32
Maize hybrids (MH)							
P-1543	12.78D	54.11D	3.11BC	1.55D	13.78C	2.92D	4.00C
FS-131	13.22D	54.89CD	3.00C	1.59C	14.11C	3.00C	4.11C
SB-9663	13.67CD	56.44C	3.33BC	1.61C	14.00BC	2.04C	4.44BC
YH-1898	15.11B	59.78B	3.67AB	1.68B	14.78B	3.32B	4.67AB
FH-1096	16.33A	61.67A	4.00A	1.75A	15.56A	3.36A	5.00A
SB-794	14.44BC	58.67B	3.67AB	1.58CD	14.33BC	3.17B	4.33BC
LSD≤0.05P	0.94	1.70	0.57	0.04	0.77	0.05	0.45
SL×MH							
LSD≤0.05P	NS	NS	NS	NS	NS	NS	NS

Means with different letters differed at *0.05* P level. RL: Root length, SL: Shoot length. RFW: Root fresh weight, RDW: Root dry weight, SFW: Shoot fresh weight, SDW: Shoot dry weight, LPP: Leaves per plant

Table 3. Effects of diverse salinity stress levels on physiological traits of different maize hybrids.

Salinity levels (SL)	Relative water content (%)	Electrolyte leakage (%)	Chlorophyll a (mg g^{-1} FW)	Chlorophyll b (mg g^{-1} FW)	Carotenoid (mg g^{-1} FW)
Control	72.39A	33.83C	1.68A	1.33A	0.57A
6 dSm^{-1}	64.17B	35.72B	1.58B	1.06B	0.52B
12 dSm^{-1}	61.22C	39.44A	1.43C	0.80C	0.47C
LSD≤0.05P	1.72	1.04	0.021	0.024	0.011
Maize hybrids (MH)					
P-1543	62.56E	38.22A	1.49E	0.98D	0.48E
FS-131	62.67DE	37.33AB	1.52D	1.00D	0.49DE
SB-9663	65.22CD	36.44BC	1.55C	1.04C	0.50CD
YH-1898	68.33AB	35.33CD	1.60B	1.12AB	0.54B
FH-1096	69.44A	34.78D	1.66A	1.14A	0.57A
SB-794	66.33BC	35.89BCD	1.57C	1.09B	0.52C
LSD≤0.05P	2.43	1.48	0.022	0.023	0.021
SL×MH					
LSD≤0.05P	NS	NS	NS	NS	NS

Means with different letters differed at *0.05* P level

Table 4. Effects of diverse salinity stress levels on the activities of antioxidant enzymes of different maize hybrids.

Salinity levels (SL)	Ascorbate peroxidase (U/mg protein)	Catalase (U/mg protein)	Per-oxidase (U/µg protein)
Control	26.50A	0.71C	0.29C
6 dSm^{-1}	34.50B	0.79B	0.42B
12 dSm^{-1}	44.11C	1.06A	0.53A
LSD≤0.05P	1.40	0.011	0.010
Maize hybrids (MH)			
P-1543	32.00E	0.78E	0.36E
FS-131	33.11DE	0.81D	0.38D
SB-9663	34.11CD	0.84C	0.41C
YH-1898	36.56B	0.89AB	0.44B
FH-1096	38.78A	0.92A	0.47A
SB-794	35.67BC	0.87B	0.43B
LSD≤0.05P	1.89	0.021	0.022
SL×MH			
LSD≤0.05P	NS	NS	NS

Means with different letters differed at *0.05* P level

Effect of salinity stress antioxidant activities: In this study, activities of antioxidant enzymes substantially increased under salt stress, likewise, maize hybrids also had significant difference for anti-oxidant enzymes (Table 4). The maximum contents antioxidants enzymes (APX, CAT and POD) were noticed at 12 dS m^{-1} salt stress level; however, minimum contents of these enzymes were recorded at control conditions (no salt stress). Among maize hybrids; FH-1096 had maximum content of antioxidants enzymes (APX, CAT and POD); but the minimum content of antioxidants enzymes was noticed in hybrid P-1543 (Table 4). The salt tolerance in plants is linked with higher activities of anti-oxidants. The results indicated that the activity of CAT significantly increased under salt stress.

CAT enzyme decomposes the H_2O_2 into H_2O and O^-_2 and therefore protects the plants from the deleterious impacts of SS (Liu *et al.*, 2010). The present increase in CAT under SS salt can be due to the acclimation of young plant metabolism and de-novo synthesis of enzymes (Naliwajski & Skłodowska, 2021). Whereas, POD plays a key role in signaling from the roots to plant leaves which allows young plants to activate defense mechanisms against ROS. Thus, increased POD activity significantly increased the salt tolerance (Aghaei *et al.*, 2009). In this study, maize hybrid FH-1098 showed maximum antioxidant activities which indicates its strong salt tolerance ability compared to other hybrids.

Conclusion

In the present study, Salinity stress considerably affected germination and growth parameters by limiting the plant water relations, photosynthetic pigments, biomass production and antioxidative enzymes activities. Moreover, in all tested maize hybrids, FH-1098 was reported as a more salt-tolerant hybrid compared to other hybrids owing to enhanced antioxidant enzyme activities, photosynthetic pigments, biomass production and lowered electrolyte leakage. Thus, these research findings may be important criteria for selecting genotypes with higher salinity tolerance.

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