February 29, 2020

Phenotyping of Salt Stress Hybrid Maize through Hydroponic Culture at Seedling Stage

Author's Details:

Neelima Hossain, Md. Hasanuzzaman, Masum Billah, Shirin Aktar, Shamim Ara Bagum and M. Shalim Uddin- Molecular Breeding Laboratory, Plant Breeding Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh

DOI: 10.5281/zenodo.3710800

Received Date: 25-Jan-2020 Accepted Date: 17-Feb-2020 Published Date: 29-Feb-2020

Abstract

Maize (Zea mays L.) grows in wide range of agro-ecological environment of the world. Production of maize throughout the world is an evocation to meet global food security. For agriculture, salinity is one of the principal challenges in salt affected zones of the world. An efficient study of 45 test-cross hybrids maize was carried out in a hydroponic culture to find out desirable salt tolerant maize hybrids with two levels of salinity (0 dS m^{-1} and 12 dS m^{-1} NaCl). Ten days old maize seedlings were transplanted to hydroponic pot, seedlings were evaluated after 18 days exposure of salinity. Significant variations were observed for all parameters except root shoot ratio and root dry weight of the all hybrids. Path analysis indicated that SDW (shoot dry weight) highly reliable component of total dry matter. The first five principal components (PCs) explained about 96.0% of the total variation. Cluster analysis placed the 45 hybrid into 5 main groups; among those clusters, group III showed the highest number of relative mean value of traits. From the genotype × traits bi-plot of eight traits of 45 genotypes, the highest positive relationship found in MSL (maximum shoot length), SDW (shoot dry weight) and SPAD, RDW (root dry weight) traits. Through analysis it was concluded that P-16 x IPB911-16 was most salt tolerant genotypes, followed by P-14 x IPB911-16 and P-19 x IPB911-16 and very susceptible genotypes were CZI-26 x IPB911-16, CZI-08 x IPB911-16, P-62 x IPB911-16 and P-1 x IPB911-16. The selected hybrids will be helpful for future maize breeding to develop salt tolerant hybrid maize.

Key words: *Maize, salinity, hydroponic, stress, tolerant*

INTRODUCTION

Maize is the most significant and third number cereal crop in Bangladesh after rice and wheat. It's produced well globally in a vast area of different environmental conditions. (Ranum, Peña-Rosas, et al., 2014). Because, it's used as an essential food for human being, nourish the animal and biofuel. Besides, now a days, it plays a significant role for functional and genetic research (Wang, Wang, et al., 2019).

A The production of maize for 2016-17 is estimated at a record 93.5 million metric tons (Mt) and harvested area is estimated at 17.3 million hectares (Mha) which has a significant contribution as food (Crutzen, Mosier, et al., 2016). It can be an expected devastation in crop yield with the fast growing climatic changes all over the world and the adverse effects are already visible. In the present, maize production is affected by significant abiotic stresses such as salinity, drought, cold or heat stress etc. that are becoming more serious with the changing climate.

It is worthy mentioned that about50% or more yields of crops has been predicted to be reduced as a result of several abiotic stress factors under field conditions (Yusuf, Hasan, et al., 2008).

However, soil salinity is one of the significant environmental stresses that adversely affect plant growth and development. More than 800 million hectares of land throughout the world are salt affected, either by salinity (397 million ha) or the associated condition of sodicity (434 million ha) (Niu, Xu, et al., 2012). Salinity invasion is an increasing problem in the coastal areas through the world (Stanger, 1985). This problem is increasing by changing climate and its related hazards like sea level rise, cyclone and storm surge. Bangladesh coastal region is already under the constant threat of salinity.

Nevertheless, plant growth in saline soils is affected mainly by the reduced availability of water due to high osmotic pressure. Salinity reduces water potentials in the leaves of maize and length and dry mass of the stem (Izzo, Navari-Izzo, et al., 1991), and affects leaf elongation and water transport in xylem vessels in maize, as well as length and conductivity of the root in maize (Khodary, 2004). With the increasing of salinity the reaction of plants is to complex and included alterations in plant morphology, physiology and metabolism (Koyro, 2006). Soil salinity decreases leaf size or area, stems extension and root explosion, interrupts plant water relations and reduces water-use efficiency, disrupts photosynthetic pigments and reduces the gas exchange which lead to a reduction in plant growth and yield (Koyro, 2006). Moreover, the hybrid maize plants had more significant amount of Na^+ (toxic ions) and smaller amount of potassium ions in various plant parts during saline condition. The development of toxic sodium ions in various part of plant has been reduced by foliar selenium and thus regulated significant physiochemical characteristics in maize during saline condition (Ashraf, Akbar, et al., 2018).

Screening for salt tolerant genotypes is prerequisite for any breeding program. Affinity of salinity tolerance was different at different growth stages (Ashraf, Ashraf, et al., 2010). Though, it has positive effects for seedling growth on lateral plant developmental stages and finally provides high yield (Grieve, Francois, et al., 2001, Willenborg, Wildeman, et al., 2005). Many experiment have been conducted to know the effects of salinity at different growth stages for the development of salt tolerant genotypes in maize (Khan, Rao, et al., 2003) wheat (Ali, Khan, et al., 2002) and soybean (Kamal, Qureshi, et al., 2003). Evaluation of maize testcross hybrids using hydroponic method provides a satisfactory way to identify maize lines with superior root characteristics (Woll, Borsuk, et al., 2005) because the environmental influences among plants in the field were also one of the drawbacks to identify superior phenotypes. Keeping in mind all above discussion, a hydroponic experiment was conducted using 45 testcross hybrids maize at two levels of salinity (control and 12 dSm^{-1} NaCl) to find out best salt tolerant maize hybrid that could further be used to evaluate their potential on natural salt affected soil. So, the research was carried out to identify best salt tolerant maize hybrid by evaluating maize genotypes in hydroponic culture on the basis of their growing performance and to evaluate the morpho-physiological traits as selection criteria of maize hybrids tolerant to salt stress.

MATERIALS AND METHODS

Plant materials

Forty five (45) test cross hybrid maize genotypes were used for this experiment.

Experimental Site and Growth Condition

Hydroponic Culture

The experiment was carried out in the green house of Plant Breeding Division, Bangladesh Agricultural Research Institute (BARI), Gazipur-1701 as hydroponic culture, where the temperate was maintained at 28°C-30°C for 14 hours under light and at 22°C for 10 hours under dark conditions. The light intensity of the greenhouse room was 657 μmol m^{-2} s^{-1}, and the relative humidity was 50%. The experiment was conducted with Split plot CRD, specifically, two treatments (control and 12dS.m^{-1} NaCl) were set, and each treatment contained three replications.

After surface sterilization with 0.05% $HgCl_2$ for 10 minutes and washing with de-ionized water three times, the seeds were sown under water saturated quartz granule and covered with dark colored polybag for 4 days in growth room for germination, and kept under light for another 4 days. After the removal of endosperm, the seedlings were wrapped with sponge tightly, and put in the hole of the cover. Each cover has six holes, where four plants were put into for transplanting in the Hoagland solution. After transplanting, continuous air supply was maintained in the pots filled with nutrient solution and the solution was changed after four days.

After four days salt treatment (NaCl 12 dS.m^{-1}) was applied and both normal and treated solutions were being changed in every four days interval. During the solution changing time, the pots were washed with brush for minimizing the contamination because of fungal growth. Culture duration was 18 days in the nutrients solution. After the 18th day, the seedlings were taken out for measurement of the traits listed below.

Recorded data

- Number of Green Leaf (NGL) at harvesting time
- SPAD value at harvesting time: SPAD value measured by SPAD meter (SPAD-502 Plus)
- Maximum Root Length (cm) (MRL): From coleoptile node to last tip of the primary root.
- Maximum Shoot Length (cm) (MSL): From coleoptile node to highest tip of the leaf.
- Root length to shoot length Ratio (RSR): Root length divided by shoot length.
- Root Dry Weight (g) (RDW): After oven dry at 65°C for 7 days, weighed the roots.
- Shoot Dry Weight (g) (SDW): After oven dry at 65°C for 7 days, weighed the shoots and,
- Total Dry Matter (g) (TDM): Root dry weight + shoot dry weight

Statistical analysis

For individual and combined analysis, Split plot Complete Randomize Design (CRD) with two replications were being used. The statistical analysis was performed using Statistical Tool for Agricultural Research (STAR version 2.0.1, 2014), R-stat and Plant Breeding-tools (PBtools, version 1.2, 2014). The path analysis, genotypic and phenotypic correlation coefficients were calculated using R-stat.

RESULTS

Analysis of variance and frequency distribution of traits

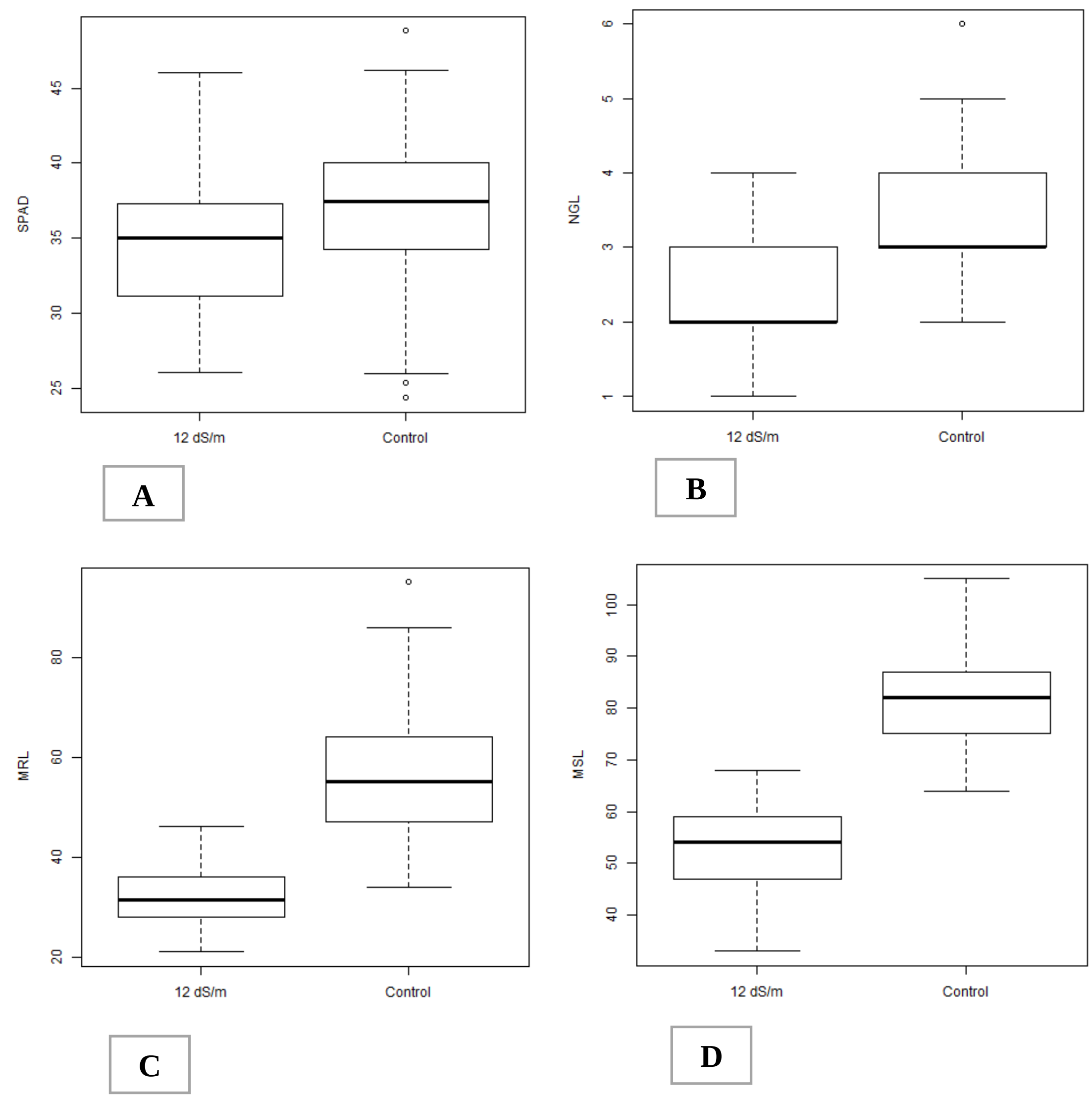
The forty five genotypes were tested by the test cross population to detect the saline sustainable maize plant genotypes. ANOVA (Analysis of variance) for salt and control status separately exposed the large momentous differences within the treatments and control to whole deliberated characters of maize seedlings. Again, ANOVA shown mostly significant variations for all parameters without RSR within the hybrids, treatments and interaction genotypes by the treatments. The Entire parameters shown here significant value except RSR for every hybrid maize genotypes (Table 1). On the other hand, the box plot figure out higher and lower edges quintile and the middle position of this box plot is shown by the median. Each and very parameters were entitled with the normal distribution without few parameters diagonal right and left under control and salt conditions (Fig.1).

Table 1: Combine analysis of variance of the traits determined

Source of variation	Mean square							
	SPAD	NGL	MRL	MSL	RSR	RDW	SDW	TDM

Treatment	252.29*	56.67*	26718.05**	38822.73**	0.23	6.28**	43.87**	83.34**
Error(a)	6.41	1.25	7.45	23.01	0.01	0.01	0.07	0.03
Hybrid	45.18**	0.49**	143.98**	133.29**	0.04	0.08	0.64**	1.04**
Treatment×Hybrid	13.86**	0.62**	148.70**	77.78**	0.03	0.04	0.21	0.27*
Error(b)	7.35	0.26	14.54	14.17	0.01	0.01	0.02	0.01
CV (a) (%)	7.04	37.06	6.19	7.16	15.52	14.65	13.75	6.23
CV (b) (%)	7.54	16.95	8.64	5.62	10.7	10.29	6.9	3.94

NGL= Number of green leave, MSL=Maximum Shoot length (cm), MRL= Maximum Root length (cm), RSR=Root-shoot ratio, SDW=Shoot dry weight (g), RDW=Root dry weight (g), TDM=Total dry matter (g)



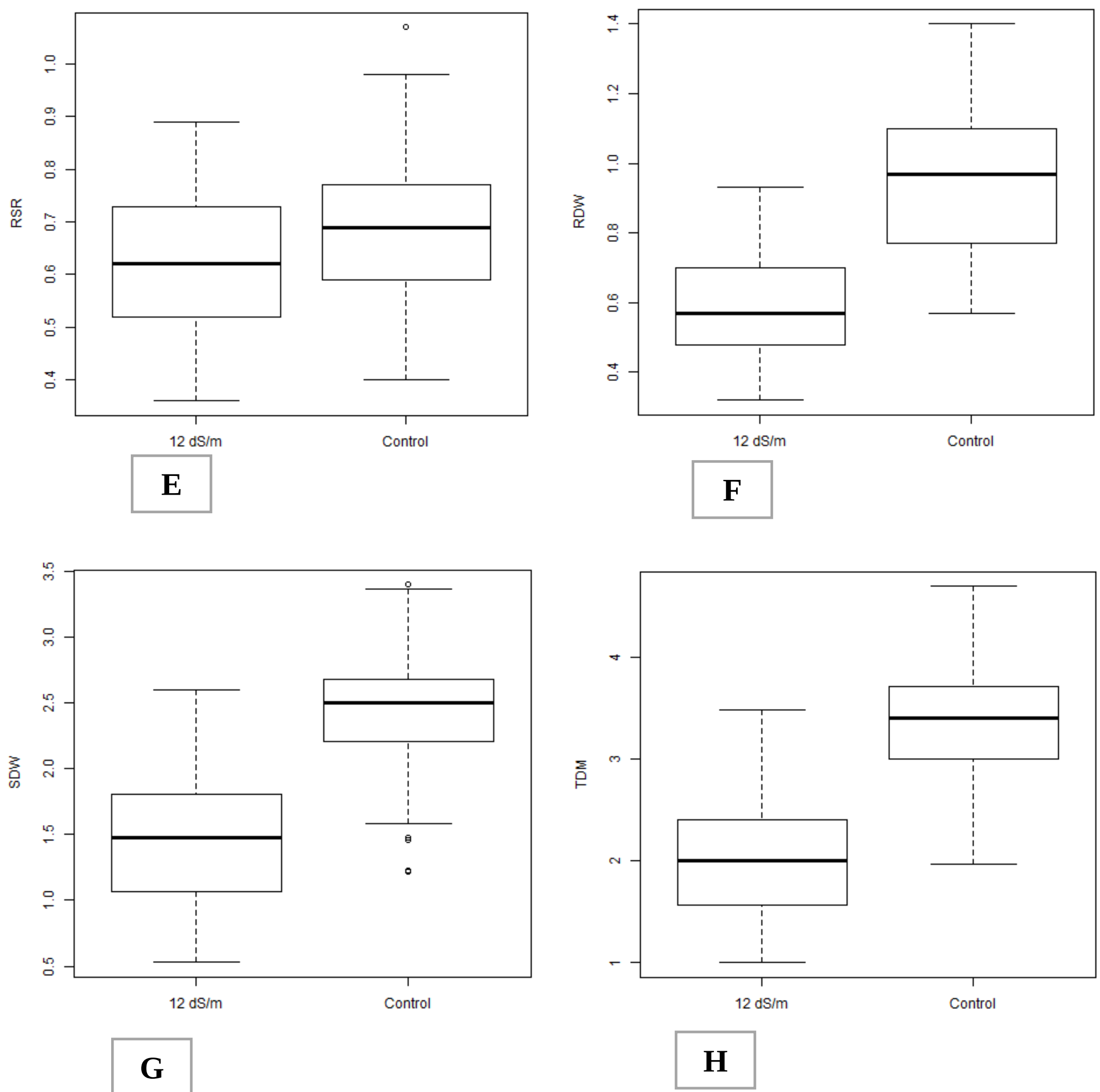


Figure 1: Box plots display comparison under saline and control status within maize hybrids for measured traits.

Path coefficient analysis

Total dry matter (TDM) presences a complicated existence which is powered by various elements and choice based on mainly correlations except taking cause and outcome relevance can be confusing. That's why, the correlation coefficient of genotype were separated through direct and indirect outcomes into the analysis of path coefficient (Table 2) to find out a distinct illustration in this complicated circumstances (Igartua, Gracia, et al., 1994). The most significant positive value of direct outcome are 0.764, 0.95 and 0.442 for SDW, TDM and MRL respectively. This results suggested that SWD is the significantly feasible element of TDM. Oppositely, RSR represented a direct negative outcome on total dry matter and have no outcome by MSL. RDW (Root dry matter) and SPAD also shown the direct positive significant outcome on TDM (Table 2).

Table 2: Path analysis showing direct (bold) and indirect effect of traits on TDM of maize seedling.

	SPAD	NGL	MRL	MSL	RSR	RDW	SDW	Correlation with TDM
SPAD	**0.002**	0.001	0.088	-0.111	0.020	0.104	0.306	0.37*

NGL	0.000	**0.005**	0.257	-0.199	-0.067	0.170	0.374	0.61**
MRL	0.000	0.003	**0.442**	-0.256	-0.189	0.191	0.489	0.75**
MSL	0.001	0.003	0.336	**-0.337**	-0.006	0.215	0.619	0.89**
RSR	0.000	0.001	0.288	-0.007	**-0.291**	0.051	0.038	0.14
RDW	0.001	0.003	0.283	-0.243	-0.049	**0.298**	0.558	-0.45*
SDW	0.001	0.002	0.283	-0.273	-0.015	0.218	**0.764**	0.95**

** Significance in 1% level of probability,* Significance in 5% level of probability.

NGL= Number of green leaves, MSL=Maximum shoot length, MRL= Maximum root length, SDW=Shoot dry weight, RDW=Root dry weight, RSR=Root shoot ratio, TDM=Total dry matter

Cluster analysis

In this study, the first five principal components Analysis (PCs) illustrated near to 96.0% of total variances among this genotypes for the several seedling parameters of hybrid maize (Table 4).The total individuals seedlings of hybrid maize were estimated by the Euclidian distance coefficients (Figure 2). The forty five hybrid maize genotypes were placed into five groups by the cluster analysis. The 1st, 2nd, 3rd, 4th and 5th cluster gradually contained six, eight, four, eighteen and nine genotypes (Table 3).

Table 3: Cluster groups and their containing genotypes name applying Euclidean genetic distance based on all seedling traits measured.

Cluster	Size	The Genotype's Name
I	6	Gen1, Gen4, Gen5, Gen8, Gen9 and Gen30
II	8	Gen2, Gen13, Gen18, Gen26, Gen27, Gen28, Gen29 and Gen44
III	4	Gen2, Gen13, Gen18, Gen26, Gen27, Gen28, Gen29 and Gen44
IV	18	Gen7, Gen11, Gen14, Gen15, Gen16, Gen17, Gen23, Gen24, Gen31, Gen32, Gen33, Gen34, Gen35, Gen37, Gen38, Gen41, Gen43 and Gen45
V	9	Gen10, Gen12, Gen19, Gen20, Gen21, Gen22, Gen25, Gen40 and Gen42

Group III represented in table 5 (relative mean table) the most significant amount of mean value to SPAD, RDW, MSL, SWD and TDM through this cluster range. The most significant amount of relative mean value represented the highest sustainable genotypes by this group (Table 3). Oppositely, the lowest values for relative mean were shown though the SPAD, RDW, MSL, SWD and TDM that has been represented the genotypes consisting on cluster two were impressionable.

Table 4: The first five principal components of trait eigenvectors in maize germplasm

Variables	PC1	PC2	PC3	PC4	PC5
SPAD	0.21	-0.16	0.54	-0.59	0.46
NGL	0.05	-0.33	0.23	0.77	0.44
MRL	0.27	-0.56	-0.30	-0.12	0.05
MSL	0.50	0.18	0.05	0.05	0.30
RSR	-0.01	-0.64	-0.32	-0.16	-0.09
RDW	0.24	-0.24	0.60	0.12	-0.67
SDW	0.51	0.19	-0.32	0.05	0.01
TDM	0.56	0.11	-0.10	0.06	-0.22
Cumulative Proportion	0.36	0.62	0.76	0.88	0.96

Table 5: Relative mean values for five clusters based on eight quantitative traits of 45 maize hybrids

Cluster group	SPAD	NGL	MRL	MSL	RSR	RDW	SDW	TDM
Group I	0.90	0.54	0.42	0.66	0.66	0.47	0.74	0.65
Group II	0.87	0.67	0.50	0.52	0.97	0.64	0.38	0.45
GroupIII	1.10	0.73	0.60	0.77	0.82	0.88	0.75	0.79
GroupIV	0.97	0.78	0.58	0.64	0.91	0.64	0.54	0.56
GroupV	0.91	0.73	0.79	0.68	1.18	0.60	0.75	0.70

The analysis of PCs (Principle component analysis) expressed that seedlings parameters for example RDW, MSL, RSR and MRL were accountable to maximum phenotypic difference, representing that these parameters describe highest differences appear within the hybrid maize lines cultivated. To describes the differences within hybrid maize lines under seedling stage and to identify the large number of lines to LP sustainable in further experiment, attention on the maximum shoot length, maximum shoot length and fresh weight of root appear enough. Since maximum shoot length is more spontaneous to detect the other parameters, it could be applied as an imperceptible characters to assertion of total dry matter. The mean table showed that group number three represents the root-shoot ratio was near about 1(Table5).

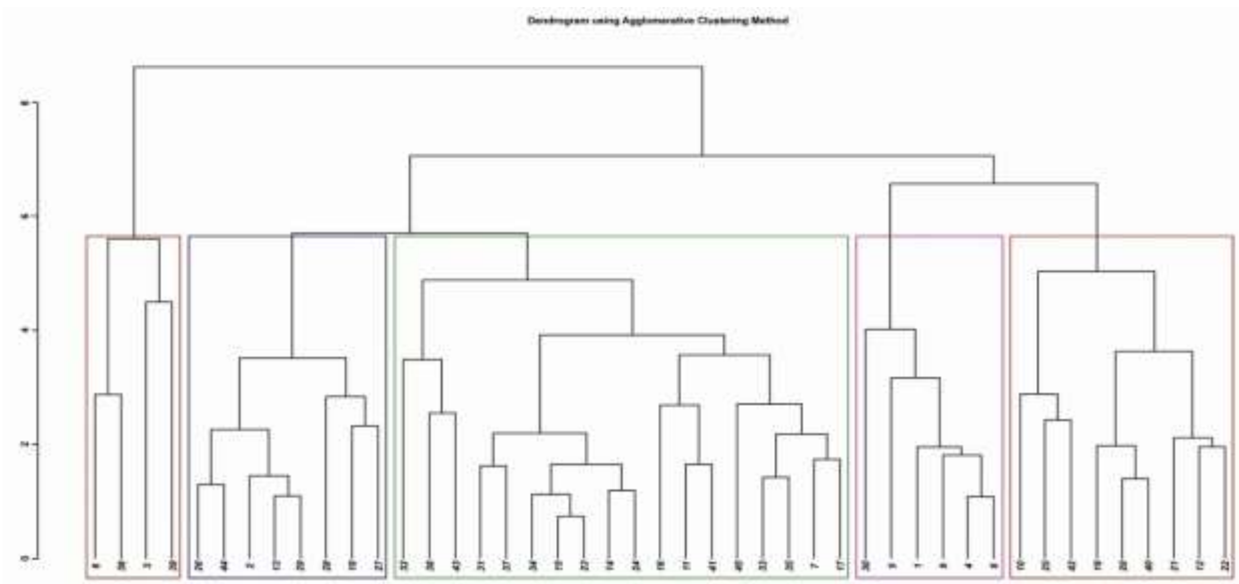


Figure 2: Dendrogram from UPGMA clustering for 45 maize hybrids using Euclidean genetic distance based on all seedling traits measured

Genotype by trait interactions

Forty five genotypes and a two-way matrix of 8 parameters were built up a genotype × traits bi-plot by applying the relative mean value of the characters (Figure 3). This plot concentrates the intelligence from the matrix through PCs, the 62% of whole differences constituted from first two among this dataset. The plot displayed the relevance among the parameters. The cosine angle within the vectors cohesive parameters for the source is proportional to the correlation coefficient among this traits. In this way, the negative correlation was shown by the parameters of opposite side's source and the parameters which were placed each other were shown positive correlation. Again, the traits which were placed 90° to one another with connect to the source were not correlated. Genotype × traits bi-plot displayed highest genotypes with proportionally larger exposure of combinations of sound traits. This outcome suggested that SPAD, MRL, RSR, SDW, RDW and TDM might be contributed to detect the excellent genotypes in prime germplasm and Gen19, Gen24, Gen21, Gen40, Gen 20 accomplished well (Table 3)

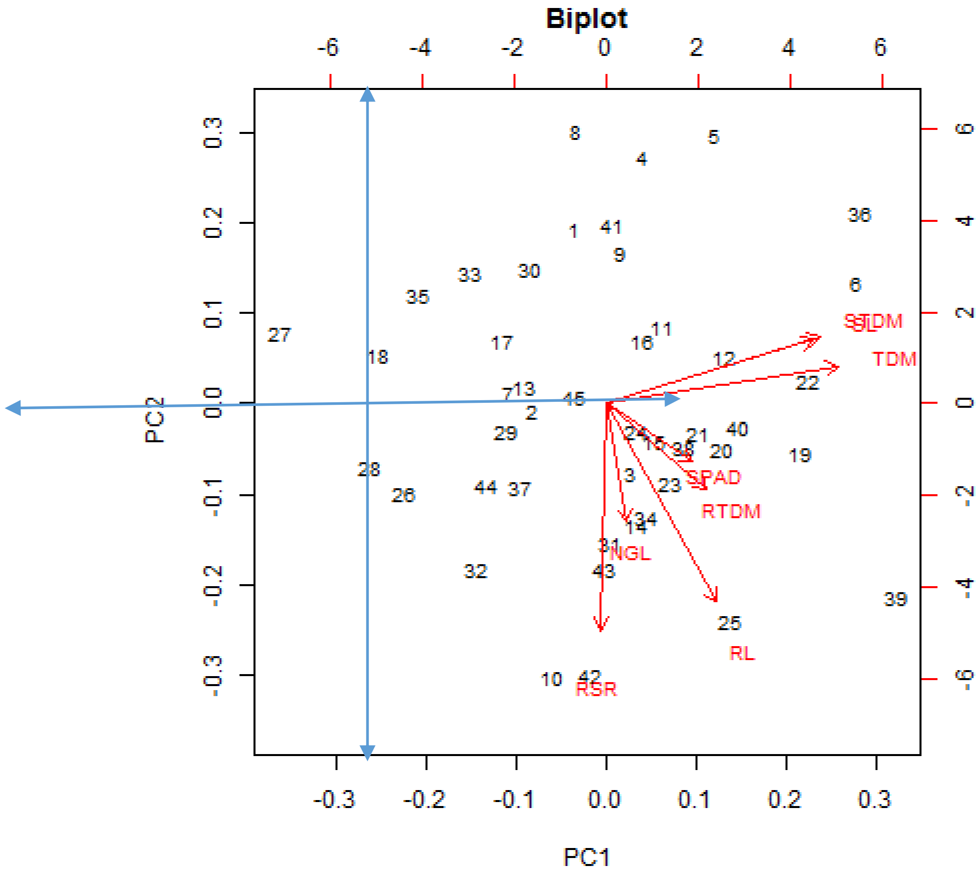


Figure 3: Genotype × trait bi-plot is based on seedling traits of maize.

The 1st two PCs were plotted. Under the values on each PC (principal component) plotted the genotypes and based on the eigenvectors on every PC plotted the parameters (Fig.3).

DISCUSSION

The overall plant heath is assessed by the root-shoot ratio (https://www.sciencebuddies.org/science-fair-projects/references/measuring-plant-growth). Based on the result, the present research investigated that the conclusion of salinity on developing of the forty-five genotypes of hybrid maize. The value expressed that salinity had mostly impressed the whole experimental characters beyond RSR (Table1). Similar result found in this study by the path analysis (Table 2).

SPAD

The plants and few organisms are enabled to cause photosynthesis by the chlorophyll (complicated organic molecule) which is measured by the SPAD meter (https://www.wisegeek.com/what-is-chlorophyll.htm).

This study represented that a remarkable differences in sustainable genotypes for raising NaCl treatments under the seedling stage. Under saline condition, the SPAD value was reduced in assimilate to control (Fig.1A). Although, few categories showed superior SPAD value during saline condition (Table 1). Similarity has been found that saline condition may produce membrane depreciation and increase leaf excision in maize, then conducting to the preparation of oxidizing elements and a decrease in photosynthesis (Sun, Mu, et al., 2018).

Same result also found in the drought condition. It has been revealed that drought effect declined the seedling development by significantly reduced the SPAD value and also decreased the leaf area for entire hybrids maize seedlings that almost declined the plant growth (Aktar, Hossain, et al., 2018).

Again, similar result also found that gas exchange procedures is one of particular expressions of this outcome under changes that increased the photosynthesis (Hu, Tian, et al., 2018).

Leaves

The most crucial photosynthetic part of plant is leaf. The light energy is converted into potential energy within this place that imbibes the chlorophyll pigment (Billah, Latif, et al., 2017). The present study found that under salt treatment, the number of green leaves were displayed significance differences. Leaf number decreased for salinity because it declines the osmotic potential and accelerates the ionic toxicity (Fig.1B).This study also revealed that salt condition decreases the amount of green leaves of entire maize seedlings that was shown by the mean value table (Table 5). Similarity, the increasing of osmotic potential that helps to inhibit the seedling existence under saline condition (Nandhini, Somasundaram, et al., 2018). The previous study found that Salt stress may induce membrane damage and accelerate leaf abscission in maize, consequently leading to the accumulation of oxidizing substances and a decline in photosynthesis (Sun, Mu, et al., 2018).

Salinity effect reduced plant growth by significant reduction in the chlorophyll contents (SPAD value) in all hybrids and similar results were found from the previous experiments (Agong, Yoshida, et al., 2002, Hayat, Hasan, et al., 2010)

The water status of maize plants was assessed in terms of leaf RWC, and the data demonstrated that salt stress significantly reduced leaf RWC by 10.19% as compared with non-stressed control (Tahjib-Ul-Arif, Siddiqui, et al., 2018).

Root length

Root is the most critical organ of plant that helps to provides to plant fixation, water supply, minerals and manures, storage of food and excretion of waste (https://www.studyread.com/importance-of-roots-uses/).

Salt stress decreases the root lengths of all hybrids. It has significant result on root length but this may differ with plant species or genotypes (Yusuf, Hasan, et al., 2008). Some seedling traits were examined to find tolerance to salinity in maize. Here, the length of root of seedlings grown up in control and saline solutions was broadly used; when the seedlings were exposed to salt the root progress reduced quickly (Yusuf, Hasan, et al., 2008). Root of plant organ which provides all the nutrients from growing medium to growing plant and has direct exchange with the medium so rooting activities supplies the useful facts concerning the salt tolerant potential of the plants (Akram, Ashraf, et al., 2010).

This experiment showed that root growth were decreased by the effect of salinity stress (Fig.1C). Similar result is also found in another experiment. They suggested that salinity decreased the root and shoot length of all maize hybrids significantly (Bagum, Billah, et al., 2017). Impact salinity decreased the root length of all maize hybrids significantly (Bagum, Billah, et al., 2017) and (Qayyum, Saeed, et al., 2016).

The process of plant shoot is a complicated network of a no. of various parts entire working to placement the plant sound and growing (https://study.com/academy/lesson/plant-shoot-system-structure-function-quiz.html). The present experiment revealed that positive differences were noticed within the genotypes of maize seedlings and NaCl consolidation with favor of root and shoot length. Under non-stress condition (without saline) shoot length had been accelerated in culture media. Shoot length were reduced under high saline (12 dS.m-1) condition (Fig 1D). The previous study Scientists has been found that shoot length reduced by the accelerating of saline concentrations (Yusuf, Hasan, et al., 2008). Similar outcomes were noticed within maize and tomato (Hoque, Jun, et al., 2015, Mohammad, Shibli, et al., 1998). The decline of shoot length is occurred by excessive accumulation of NaCl in the plant cell wall. Accessory cell wall turns into sturdy because the cell growth reduced by the proficiency of turgor pressure. Similarity, the shoot growth has been inhibited under saline condition because the elongation of cell growth and the cell elongation rate were decreased by the extreme effect of salinity.

Moreover, the maize plants were highly reduced under saline condition about 32.07% if compare with control condition (Tahjib-Ul-Arif, Siddiqui, et al., 2018) and (Qayyum, Saeed, et al., 2016). Euclidian distance coefficients were enumerated for all maize hybrids based on seedling traits. Dendrogram from UPGMA clustering noticed grouping of 45 genotypes of maize into five clusters (Fig.2). Similarly espial has been found by the experiment of five cluster analysis on 29 maize varieties under salt tolerant condition (Billah, Latif, et al., 2017). The five Cluster groups (I, II, III, IV and V) were displayed the 6, 8, 4, 18 and 9 hybrid genotypes, respectively (Table 3). Though, genotypes appears from the cluster I, III,IV and V shown highest SPAD values in balance with control (Table 5) in this experiment and same result found in drought condition (Aktar, Hossain, et al., 2018).

The eight parameters with 45 genotypes were also figure out a comparative data among the traits by the two-way form of genotypes and traits bi-plot (Fig. 3). Same result found under salinity condition (Billah, Latif, et al., 2017) and drought condition (Aktar, Hossain, et al., 2018). In our present study, the PCs analysis expressed that the maize seedlings parameters suppose maximum shoot and root length, root dry weight and root-shoot ratio were indebted for maximum phenotypic differences. It also indicated that among the maize line experiment, maximum parameters were shown variation. During the seedling stage, maximum shoot length and root length were enough to describe the differences within the maize lines. Maximum shoot length is more facile to count than other parameters and it might be applied as a secondary trait for showing of TDM (Table 4). We also found that saline condition also reduced the root weight after drying. So it was indicated that the biomass production was decreased because of plant growth decline. Consequently, the most significant amount of root dry weight were shown under control condition than the saline stress **(Fig.1F).** Similarity, Lowest amount of root dry weight has been found for entire corn hybrids due to acceleration of salinity rate (Akram, Malik, et al., 2007). Oppositely, salt stress has been reduced the growth and development of some other plant genotypes (Yusuf, Hasan, et al., 2008). Spontaneously, researcher also found the decline of development in black seeds during saline stress (Hussain, Majeed, et al., 2010). The index of seed germination is also decreased by the saline condition (Bagum, Billah, et al., 2017).

This experiment also displayed that the entire hybrids maize SDW (shoot dry weight) were positively reduced by the NaCl treatment under hydroponic culture **(fig.1G).** Again, this experiment also admitted with the other previous similar experiment result such as the traits of vegetative growth and accelerating salinity were negatively correlated between each other (Hussein, Balbaa, et al., 2007). Root shoot ratio of maize seedlings was near to 1 in Group3 of cluster mean table (Table 5). Total Dry Matter (TDM) also declined during salt treatment as salinity decreased the biomass production **(Fig.1H).** Similar outcomes were noticed for cotton and wheat plants (Meloni, Oliva, et al., 2001, Sarwar, Ashraf, et al., 2004).Similarity, the physiological drought and photosynthetic decline could be occurred by the low absorption of water during saline treatment time that helps to decline the crop production (Tahjib-Ul-Arif, Siddiqui, et al., 2018).

CONCLUSION

Due to measurement of salinity sustainable within hybrid maize genotypes, we exhibited one deft and screening procedure. The 45 hybrid maize genotypes were evaluated at two levels (0 and 12dS.m-1 NaCl) during seedling stage by this process to detect genotypes which are sustainable under saline condition. During salt treatment, various traits were exposed significant variation. According to our experimental result, we concluded that

Gen19 (P-16 x IPB911-16) was the superior salt tolerant genotype respected by Gen36 and Gen39 and Gen5, Gen4, Gen27 and Gen28 were extremely susceptible genotypes. According to the desire of sustainable maize hybrids under salt stress, the experiment given guidelines. This findings will helpful for further application and also significant to the other breeders who want to improve the salt tolerant varieties of hybrid maize. On the basis of genetic phenomenon, more study will be required.

REFERENCES

i. *Akram, M., M.Y. Ashraf, R. Ahmad, E.A. Waraich, J. Iqbal and M. Mohsan. 2010. Screening for salt tolerance in maize (Zea mays L.) hybrids at an early seedling stage. Pakistan Journal of Botany 42: 141-154.*

ii. *Akram, M., M.A. Malik, M.Y. Ashraf, M.F. Saleem and M. Hussain. 2007. Competitive seedling growth and K/Na ratio in different maize (Zea mays L.) hybrids under salinity stresS. Pak. J. Bot 39: 2553-2563.*

iii. *Ashraf, M.A., M. Ashraf and Q. Ali. 2010. Response of two genetically diverse wheat cultivars to salt stress at different growth stages: leaf lipid peroxidation and phenolic contents. Pakistan Journal of Botany 42: 559-565.*

iv. *Bilgin, O., I. Baser, K. Korkut, A. Balkan and N. Saglam. 2008. The impacts on seedling root growth of water and salinity stress in maize (Zea mays indentata Sturt.). Bulgarian Journal of Agricultural Sciences 14: 313-320.*

v. *de Azevedo Neto, A.D., J.T. Prisco, J. Enéas-Filho, C.E.B. de Abreu and E. Gomes-Filho. 2006. Effect of salt stress on antioxidative enzymes and lipid peroxidation in leaves and roots of salt-tolerant and salt-sensitive maize genotypes. Environmental and Experimental Botany 56: 87-94.*

vi. *Grieve, C., L. Francois and J. Poss. 2001. Effect of salt stress during early seedling growth on phenology and yield of spring wheat. Cereal research communications: 167-174.*

vii. *Hayat, S., S.A. Hasan, M. Yusuf, Q. Hayat and A. Ahmad. 2010. Effect of 28-homobrassinolide on photosynthesis, fluorescence and antioxidant system in the presence or absence of salinity and temperature in Vigna radiata. Environmental and Experimental Botany 69: 105-112.*

viii. *Hoque, M.M.I., Z. Jun and W. Guoying. 2015. Evaluation of salinity tolerance in maize (Zea mays L.) genotypes at seedling stage. Journal of BioScience & Biotechnology 4.*

ix. *Hussain, K., A. Majeed, K. Nawaz and M.F. Nisar. 2010. Changes in morphological attributes of maize (Zea mays L.) under NaCl salinity. American Eurasian Journal of Agricultural Environmental Science 8: 230-232.*

x. *Hussein, M., L. Balbaa and M. Gaballah. 2007. Salicylic acid and salinity effects on growth of maize plants. Research Journal of Agriculture and Biological Sciences 3: 321-328.*

xi. *Igartua, E., M. Gracia and J. Lasa. 1994. Characterization and genetic control of germination-emergence responses of grain sorghum to salinity. Euphytica 76: 185-193.*

xii. *Izzo, R., F. Navari-Izzo and M.F. Quartacci. 1991. Growth and mineral absorption in maize seedlings as affected by increasing NaCl concentrations. Journal of Plant Nutrition 14: 687-699.*

xiii. *Kamal, A., M.S. Qureshi, M.Y. Ashraf and M. Hussain. 2003. Salinity induced changes in some growth and physio-chemical aspects of two soybean [Glycine max (l.) Merr.] Genotypes. Pakistan Journal of Botany 35: 93-97.*

xiv. *Khan, A.A., S.A. Rao and T. McNeilly. 2003. Assessment of salinity tolerance based upon seedling root growth response functions in maize (Zea mays L.). Euphytica 131: 81-89.*

xv. *Khodary, S. 2004. Effect of salicylic acid on the growth, photosynthesis and carbohydrate metabolism in salt-stressed maize plants. International Journal of Agricultural Biology 6: 5-8.*

xvi. *Koyro, H.-W. 2006. Effect of salinity on growth, photosynthesis, water relations and solute composition of the potential cash crop halophyte Plantago coronopus (L.). Environmental and Experimental Botany 56: 136-146.*

xvii. *Mansour, M., K. Salama, F. Ali and A. Abou Hadid. 2005. Cell and plant responses to NaCl in Zea mays L. cultivars differing in salt tolerance. Gen. Appl. Plant Physiol 31: 29-41.*

xviii. *Meloni, D.A., M.A. Oliva, H.A. Ruiz and C.A. Martinez. 2001. Contribution of proline and inorganic solutes to osmotic adjustment in cotton under salt stress. Journal of Plant Nutrition 24: 599-612.*

xix. *Mohammad, M., R. Shibli, M. Ajlouni and L. Nimri. 1998. Tomato root and shoot responses to salt stress under different levels of phosphorus nutrition. Journal of Plant Nutrition 21: 1667-1680.*

xx. *Paterniani, E. 1990. Maize breeding in the tropics. Critical Reviews in Plant Sciences 9: 125-154.*

xxi. *Raghuwanshi, K. and S. Duhoon. 2004. Analysis of variance and frequency distribution of different characters in sesame (Sesamum indicum L.). Sesame and Safflower Newsletter.*

xxii. *Ranum, P., J.P. Peña-Rosas and M.N. Garcia-Casal. 2014. Global maize production, utilization, and consumption. Annals of the New York Academy of Sciences 1312: 105-112.*

xxiii. *Sarwar, G., M.Y. Ashraf and M. Naeem. 2004. Genetic variability of some primitive bread wheat varieties to salt tolerance. Pakistan Journal of Botany 35: 771-778.*

xxiv. *Stanger, G. 1985. Coastal salinization: a case history from Oman. Agricultural water management 9: 269-286.*

xxv. *Willenborg, C.J., J.C. Wildeman, A.K. Miller, B.G. Rossnagel and S.J. Shirtliffe. 2005. Oat germination characteristics differ among genotypes, seed sizes, and osmotic potentials. Crop Science 45: 2023-2029.*

xxvi. *Woll, K., L.A. Borsuk, H. Stransky, D. Nettleton, P.S. Schnable and F. Hochholdinger. 2005. Isolation, characterization, and pericycle-specific transcriptome analyses of the novel maize lateral and seminal root initiation mutant rum1. Plant Physiology 139: 1255-1267.*

xxvii. *Yan, W. 2013. Biplot analysis of incomplete two-way data. Crop Science 53: 48-57.*

xxviii. *Yusuf, M., S.A. Hasan, B. Ali, S. Hayat, Q. Fariduddin and A. Ahmad. 2008. Effect of Salicylic Acid on Salinity-induced Changes in Brassica juncea. Journal of Integrative Plant Biology 50: 1096-1102.*

xxix. *2002. Tomato response to salt stress. XXVI International Horticultural Congress: Advances in Vegetable Breeding 637.*

xxx. *Akram, M., M.Y. Ashraf, R. Ahmad, E.A. Waraich, J. Iqbal and M. Mohsan. 2010. Screening for salt tolerance in maize (Zea mays L.) hybrids at an early seedling stage. Pakistan Journal of Botany 42: 141-154.*

xxxi. *Akram, M., M.A. Malik, M.Y. Ashraf, M.F. Saleem and M. Hussain. 2007. Competitive Seedling Growth And K/Na Ratio In Different Maize (Zea Mays L.) Hybrids Under Salinity Stress. Pak. J. Bot 39: 2553-2563.*

xxxii. *Aktar, S., N. Hossain, M.G. Azam, M. Billah, P.L. Biswas, M.A. Latif, et al. 2018. Phenotyping of Hybrid Maize (Zea mays L.) at Seedling Stage under Drought Condition. American Journal of Plant Sciences 9: 2154.*

xxxiii. *Ali, Z., A.S. Khan and M.A. Asad. 2002. Salt tolerance in bread wheat: Genetic variation and heritability for growth and ion relation. Asian J. Plant Sci 1: 420-422.*

xxxiv. *Ashraf, M.A., A. Akbar, A. Parveen, R. Rasheed, I. Hussain and M. Iqbal. 2018. Phenological application of selenium differentially improves growth, oxidative defense and ion homeostasis in maize under salinity stress. Plant Physiol. Biochem. 123: 268-280.*

xxxv. *Ashraf, M.A., M. Ashraf and Q. Ali. 2010. Response of two genetically diverse wheat cultivars to salt stress at different growth stages: leaf lipid peroxidation and phenolic contents. Pak J Bot 42: 559-565.*

xxxvi. *Bagum, S., M. Billah, N. Hossain, S. Aktar and M.S. Uddin. 2017. Detection of salt tolerant hybrid maize as germination indices and seedling growth performance. Bulgarian Journal of Agricultural Science 23: 793-798.*

xxxvii. *Billah, M., M. Latif, N. Hossain and M. SHALIM UDDIN. 2017. Evaluation and selection of salt tolerant hybrid maize under hydroponics culture. Research on Crops 18.*

xxxviii. Crutzen, P.J., A.R. Mosier, K.A. Smith and W. Winiwarter. 2016. N2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels. Paul J. Crutzen: A Pioneer on Atmospheric Chemistry and Climate Change in the Anthropocene. Springer. p. 227-238.

xxxix. Grieve, C., L. Francois and J. Poss. 2001. Effect of salt stress during early seedling growth on phenology and yield of spring wheat. Cereal research communications: 167-174.

xl. Hayat, S., S.A. Hasan, M. Yusuf, Q. Hayat and A. Ahmad. 2010. Effect of 28-homobrassinolide on photosynthesis, fluorescence and antioxidant system in the presence or absence of salinity and temperature in Vigna radiata. Environmental and Experimental Botany 69: 105-112.

xli. Hoque, M.M.I., Z. Jun and W. Guoying. 2015. Evaluation of salinity tolerance in maize (Zea mays L.) genotypes at seedling stage. Journal of BioScience & Biotechnology 4.

xlii. Hu, W., S. Tian, Q. Di, S. Duan and K. Dai. 2018. Effects of exogenous calcium on mesophyll cell ultrastructure, gas exchange, and photosystem II in tobacco (Nicotiana tabacum Linn.) under drought stress. Photosynthetica 56: 1204-1211.

xliii. Hussain, K., A. Majeed, K. Nawaz and M.F. Nisar. 2010. Changes in morphological attributes of maize (Zea mays L.) under NaCl salinity. American Eurasian Journal of Agricultural Environmental Science 8: 230-232.

xliv. Hussein, M., L. Balbaa and M. Gaballah. 2007. Salicylic acid and salinity effects on growth of maize plants. Research Journal of Agriculture and Biological Sciences 3: 321-328.

xlv. Igartua, E., M. Gracia and J. Lasa. 1994. Characterization and genetic control of germination-emergence responses of grain sorghum to salinity. Euphytica 76: 185-193.

xlvi. Izzo, R., F. Navari-Izzo and M.F. Quartacci. 1991. Growth and mineral absorption in maize seedlings as affected by increasing NaCl concentrations. Journal of plant nutrition 14: 687-699.

xlvii. Kamal, A., M.S. Qureshi, M.Y. Ashraf and M. Hussain. 2003. Salinity induced changes in some growth and physio-chemical aspects of two soybean [Glycine max (l.) Merr.] genotypes. Pak. J. Bot 35: 93-97.

xlviii. Khan, A.A., S.A. Rao and T. McNeilly. 2003. Assessment of salinity tolerance based upon seedling root growth response functions in maize (Zea mays L.). Euphytica 131: 81-89.

xlix. Khodary, S. 2004. Effect of salicylic acid on the growth, photosynthesis and carbohydrate metabolism in salt-stressed maize plants. Int. J. Agric. Biol 6: 5-8.

l. Koyro, H.-W. 2006. Effect of salinity on growth, photosynthesis, water relations and solute composition of the potential cash crop halophyte Plantago coronopus (L.). Environmental and Experimental Botany 56: 136-146.

li. Meloni, D.A., M.A. Oliva, H.A. Ruiz and C.A. Martinez. 2001. Contribution of proline and inorganic solutes to osmotic adjustment in cotton under salt stress. Journal of Plant Nutrition 24: 599-612.

lii. Mohammad, M., R. Shibli, M. Ajlouni and L. Nimri. 1998. Tomato root and shoot responses to salt stress under different levels of phosphorus nutrition. Journal of plant nutrition 21: 1667-1680.

liii. Nandhini, D.U., E. Somasundaram and M.M. Amanullah. 2018. Effect of rhizobial nod factors (lipochitooligosaccharide) on seedling growth of blackgram under salt stress. Legume Research: An International Journal 41.

liv. Niu, G., W. Xu, D. Rodriguez and Y. Sun. 2012. Growth and Physiological Responses of Maize and Sorghum Genotypes to Salt Stress. ISRN Agronomy 2012: 12. doi:10.5402/2012/145072.

lv. Qayyum, A., H.M. Saeed, M. Hanif, E. Noor, W. Malik, S. Liaqat, et al. 2016. Exploitation of variability for salinity tolerance in maize hybrids (Zea mays L.) at early growth stage. African Journal of Agricultural Research 11: 4206-4213.

lvi. Ranum, P., J.P. Peña-Rosas and M.N. Garcia-Casal. 2014. Global maize production, utilization, and consumption. Annals of the New York Academy of Sciences 1312: 105-112.

lvii. Sarwar, G., M.Y. Ashraf and M. Naeem. 2004. Genetic variability of some primitive bread wheat varieties to salt tolerance. Pakistan Journal of Botany 35: 771-778.

lviii. Stanger, G. 1985. Coastal salinization: a case history from Oman. Agricultural water management 9: 269-286.

lix. Sun, Y., C. Mu, H. Zheng, S. Lu, H. Zhang, X. Zhang, et al. 2018. Exogenous Pi supplementation improved the salt tolerance of maize (Zea mays L.) by promoting Na+ exclusion. Scientific reports 8: 16203.

lx. Tahjib-Ul-Arif, M., M.N. Siddiqui, A.A.M. Sohag, M.A. Sakil, M.M. Rahman, M.A.S. Polash, et al. 2018. Salicylic acid-mediated enhancement of photosynthesis attributes and antioxidant capacity contributes to yield improvement of maize plants under salt stress. Journal of plant growth regulation 37: 1318-1330.

lxi. Wang, M., Y. Wang, Y. Zhang, C. Li, S. Gong, S. Yan, et al. 2019. Comparative transcriptome analysis of salt-sensitive and salt-tolerant maize reveals potential mechanisms to enhance salt resistance. Genes & genomics: 1-21.

lxii. Willenborg, C.J., J.C. Wildeman, A.K. Miller, B.G. Rossnagel and S.J. Shirtliffe. 2005. Oat germination characteristics differ among genotypes, seed sizes, and osmotic potentials. Crop Science 45: 2023-2029.

lxiii. Woll, K., L.A. Borsuk, H. Stransky, D. Nettleton, P.S. Schnable and F. Hochholdinger. 2005. Isolation, characterization, and pericycle-specific transcriptome analyses of the novel maize lateral and seminal root initiation mutant rum1. Plant Physiology 139: 1255-1267.

lxiv. Yusuf, M., S.A. Hasan, B. Ali, S. Hayat, Q. Fariduddin and A. Ahmad. 2008. Effect of Salicylic Acid on Salinity-induced Changes in Brassica juncea. Journal of integrative plant biology 50: 1096-1102.

lxv. (https://www.sciencebuddies.org/science-fair-projects/references/measuring-plant-growth).

lxvi. (https://study.com/academy/lesson/plant-shoot-system-structure-function-quiz.html)

lxvii. (https://www.studyread.com/importance-of-roots-uses/)