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Effects of Salinity on Seedling Growth of Four Maize (*Zea Mays* L.) Cultivars Under Hydroponics

Snehasish Bose

Department of Seed Science and Technology,

Bangladesh Agricultural University, Mymensingh, Bangladesh.

Oli Ahmed Fakir

Bangladesh Agricultural Research Institute,

Benarpota, Satkhira, Bangladesh.

Mahbubul Islam

Bangladesh Agricultural Research Institute, Gazipur, Bangladesh.

Md Khairul Alam (Corresponding author)

Murdoch University, Perth, Western Australia, Australia.

E-mail: khairul.krishi@gmail.com

A. K. M. Zakir Hossain & Alamgir Hossain

Department of Crop Botany, Bangladesh Agricultural University,

Mymensingh, Bangladesh.

M. H. Rashid

Global Centre for Environmental Remediation (GCER),

University of Newcastle, Callaghan-2308, NSW Australia.

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Abstract

Growth and development of a crop or even cultivars within a species of a crop respond to soil salinity since germination. A hydroponic experiment was conducted at Plant Physiology Laboratory, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, Bangladesh, during the period from December 2015 to July 2016 to investigate the effect of NaCl on morphological characters and growth of maize (*Zea mays* L.) seedlings. The experiment comprised two levels (0 dS m^{-1} and 8 dS m^{-1}) of salinity for hydroponic experiment, designed in two factorials Complete Randomized Design (CRD) with three replications on four cultivars *viz. Kaveri - 244+, BHARAT Hybrid Sultan 702, Getco seeds GP – 901, Essence –Platinum*. Results indicated that root and shoot length, number of leaves $plant^{-1}$, fresh and dry mass production varied with NaCl stress which indicating that some cultivars of maize seedlings are highly susceptible to concentrated NaCl. However, among tested cultivars, *Essence –Platinum* showed the best performance considering the seedlings growth and other parameters. *BHARAT Hybrid Sultan 702, Getco seeds GP – 901* showed the highest sensitivity to NaCl stress in this experiment based on the above parameters studied.

Keywords: Hydroponic, NaCl stress, root length, sensitivity and shoot length

1. Introduction

Of the 1128 million hectare (Mha) of salt-affected area in the world (Wicke *et al.*, 2011), 226 Mha of land are irrigated (Pitman & Läuchli, 2002). Farmers grow maize (*Zea mays* L.) as an important food grain in all climates from tropical to warm prevailed in various parts of the world. In 2016, world maize production was approx. 1067 million tons (USDA, 2016). The crop meets up human diet with the nutritional quality of the grain, while stressful abiotic conditions such as cold temperature, water and salinity stresses reduces its performance in terms of production (Fita *et al.*, 2015). Therefore, study on the tolerance of maize cultivars to salinity through evaluation and selection of maize cultivars is a great necessity so that an efficient technique can be developed for the purpose (Hoque *et al*., 2015). The effect of salinity on a crop is variable at different growth stages (Banziger *et al*., 2007). A very high genotypic variability in maize cultivars exists for resistance to salinity and drought at the seedling stage. Diverse genotypes of the crop have also been selected for resistance to drought and salinity stresses (Maiti *et al.*, 2012).

In recent studies, considerable variations were observed in the root, shoot length and biomass of different hybrids at different salinity levels (Cramer *et al.*, 1990; Maiti *et al*., 1996, Maiti *et al*., 2012). The effect of increased salinity concentrations at germinating stage and seedling stage of maize are more adverse than the effects at later stages of the growth (Lianes *et al*., 2005, Maiti *et al.*, 2012). Salinity causes several biochemical changes in various crops which have been documented in the literature. Maize crop at the germination stage transported high amount of Na^{+} and Cl^{-} to the growing part of shoot and in course of time, K^{+} and Ca^{2+} concentrations decreased in the tissues located in embryonic part (Ashraf and Wahid, 2000.). Seed lipids during germination break down in order for supplying sugars in soluble forms in the metabolism of the growing embryo (Kochak-Zadeh *et al.*, 2013). Several studies have been undertaken to understand the mechanism of tolerance to salinity in maize and other crops (Tester and Davenport, 2003, Datta *et al.*, 2009, Khan *et al.*, 2003, Nordquist *et al.*, 1992). The effects of salinity on plant growth are associated with osmotic ion and oxidative stress. Halophytes and glycophytes got adjusted osmotically with the increase in accumulated solutes in organic and inorganic forms (Shrivastava and Kumar, 2015) which eventually causes greater decrease in cell solute potential than external salt concentration. This may be attributed to balancing of the accumulated organic solutes in the cytosol with the solute potential of the ions-dominated-vacuoles (Slam *et al.*, 2015). A positive correlation between osmolyte accumulation and the adaptation to stress has been well documented. Molecular mechanism of salt tolerance has been well acknowledged by different authors (Gupta and Huang, 2014).

When plants go through salinity stress, characteristic changes begin from germination until maturity (Munns, 2002) which can be becoming unproductive or wilting and doughtiness, even if soils are wet and moist. The increasing amount of lands degraded by salinity and population increase at the same time drive researchers to develop crops capable of growing under saline conditions so that salinity affected soils can be brought under cultivation (Munns *et al*., 2006; Yamaguchi & Blumwald, 2005). Maize, a crop which coverage is increasing every year for its various purpose of use, is very salt-sensitive, shows obvious signs of stress, including wilting even when there is adequate soil moisture (Farooq *et al.*, 2015). Ouda *et al.* (2008) recorded retarded maize growth characters and yield potential grown under salinity stress. Again, they also observed contrasting results of moderately sensitiveness of the crop with C4 metabolic characters to salinity to soil salinity. Genetic variations for salt tolerance in maize crop were also recorded by Maiti *et al.* (1996). Different researchers found early seedling stage of maize and of all crops the sensitive period mostly affected by salinity stress while growth of crops decreased with increase in salinity (Shalhevet, 1995). Seedling weight and growth rate and root parameters under stress condition are selected traits in studying maize in terms of salt tolerance and/or resistance. So, the present study aims at evaluating the following objectives.

a To find out the effect of salinity on growth and development of maize seedlings in hydroponic culture.

b To examine the salinity tolerance inconsistency among the maize cultivars.

2. Materials and Methods

Planting Materials

The seeds of four maize varieties namely *cv. Kaveri-244+*, *cv. BHARAT Hybrid Sultan 702, cv. Getco seeds GP–901, cv. Essence–Platinum* were collected from Bangladesh Agriculture Research Institute (BARI) and used as experimental materials.

Experimental Laboratory

The Experiment was conducted at Crop Physiology Laboratory, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, Bangladesh during the period from December, 2015 to July, 2016.

Pot Preparation

The black colored pots were taken with Hogland's full strength nutrient solutions and an aeration pump was attached to supply oxygen into the water. After this, the experimental pots were laid out as per treatments and design.

Figure 1. Preparation of black color pots with maize seedlings

Experimental Design

The experiment was laid out in Completely Randomized Design (CRD) with three replications having two treatments comprising NaCl application. The individual pot size was 8L. Each treatment received equal amount of macro and micro nutrients. Total number of water tank used in this study were (4×3×2) = 24. The treatments were randomly distributed to the tank. All the experiments were conducted in a growth room at 25 ℃ under a 12 hour-light and 12 hour-dark regime, 70% relative humidity and pH adjusted at 6.5.

Application of NaCl and Nutrients

During germination stage, NaCl solution of 8 dSm^{-1} concentration was sprayed to the seeds on Petri dishes for T_2 and distilled water was sprayed to the seeds on Petri dishes of control treatments to ensure 0 dS m^{-1}. All other nutrients except NaCl were incorporated to the tank at recommended dose (Table 1). Eight (8) dS m^{-1} NaCl solutions were added to the water into the tank at an eight days interval.

Hydroponic Experimental Set Up

One-week-old seedlings were transferred to continuously aerated nutrient solution in 8L plastic tank on Styrofoam blocks with 4 holes and three plants per hole, supported with sponge. The solution was renewed with fresh nutrient solutions in 8 days interval. The composition of the nutrient solution was presented below:

Table 1. Nutrient sources and the recommended dose used for the experiment

Source	Dose
NH_4NO_3	500 μM
$Ca(NO_3)_2$	500 μM
$MgSO_4$	200 μM
KH_2P0_4	100 μM
$FeC1_3$	2 μM
H_2BO_3	11 μM
$MnC1_2$	2 μM
$ZnC1_2$	0.35 μM
$CuCl_2$	0.2 μM
$(NH_4)_6Mo_70_4$	0.1 μM

Data Collection

Data on the following parameters at the transfer day of seedling to plastic tank on Styrofoam blocks (0 Das) and 14 days after transfer (14 DAS) were recorded. The following morphological characteristics at selected stages of seedlings were collected: (a) Root length (b) Shoot length (c) No. of leaves/plant (d) Fresh weight of root and shoot (e) Dry weight of root and shoot. After collection of data of maize seedlings, 0 and 14 DAS maize seedling's root and shoot of selected varieties was collected and dried. The seedlings were collected and prepared to study the fresh and dry weight. The weights of 4 fresh seedlings were recorded and the seedlings were placed in an oven for 24 hrs at 80±2 ℃. Then the dry weights were measured using an electrical balance.

Statistical Analysis

Data were statistically analyzed for analyses of variance (ANOVA) using the M-STAT Statistical Computer Package Programme in accordance with the principles of Completely Randomized Design (CRD). Duncan’s Multiple Range Test (DMRT) was used to compare variations among the treatments.

3. Results and Discussion

Effect of NaCl levels on crop characters of maize grown in hydroponic culture

Root length

Figure 2. Effect of NaCl on root length of maize (*Zea mays* L.)

The effect of variety and NaCl on root length was interactively significant ($p < 0.01$) (Figure 2 and 3). The highest root length was observed in the treatment combination of *Essence-Platinum* with 0 dS m^{-1} NaCl (512 mm) which was statistically similar to *Getco seeds GP – 901* (under stress condition) and the lowest was recorded in the treatment combination of *BHARAT Hybrid Sultan 702* with 8 dS m^{-1}NaCl (201 mm).

The significant differences observed among cultivars and salinity (NaCl levels) with respect root length is similar to study of Hoque *et al*. (2015) and Ashraf *et al*. (2005). No salt (0 dS m^{-1}) in culture medium significantly enhanced root length. As root growth is highly sensitive to high salt concentrations in the medium. That is why roots are rapidly reduced or prevented by salinity (Ashraf *et al*., 2005). The decrease in root growth can also be attributed to root damage by salinity stress or stunted growth of leaves under salinity level increase. In spite of decreasing the root length of all cultivars at 14 DAS under increased salinity level, *Getco seeds GP – 901* and *Essence –Platinum* cultivars had significantly higher root length than *Kaveri - 244+* and *BHARAT Hybrid Sultan 702* cultivars.

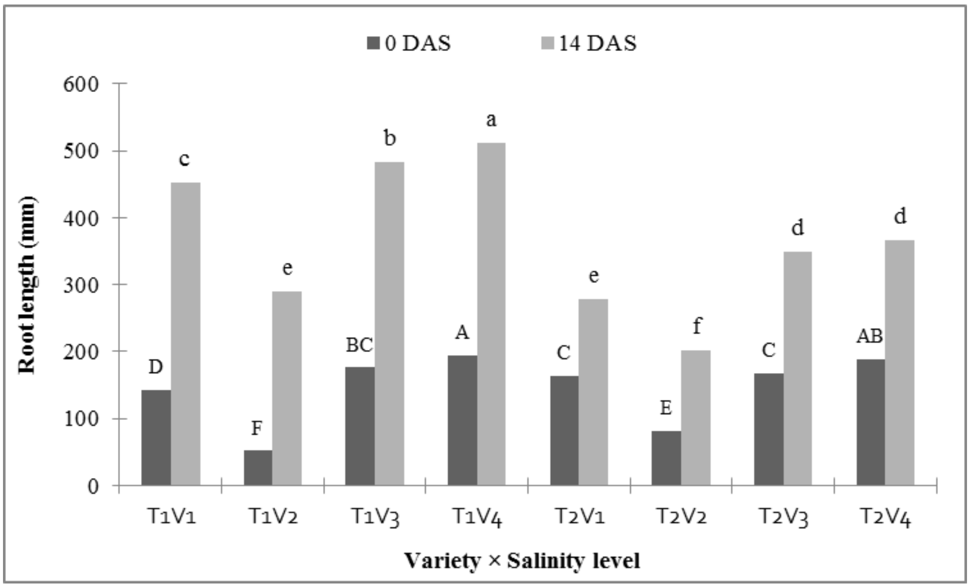

Figure 3. Combined effect of salinity level and varieties on root length of maize cultivars

Here, T_1 and T_2 mean 0 dS m^{-1} and 8 dS m^{-1}, respectively; maize cultivars were V_1: *Kaveri - 244+*, V_2: *BHARAT Hybrid Sultan 702*, V_3: *Getco seeds GP – 901*, and V_4: *Essence –Platinum*. Least Significant Difference ($LSD_{0.05}$) for 0 DAS and 14 DAS are 14.2 and 28.7, respectively. Columns with the same letter are not significantly different from each other.

Shoot Length

Effect of variety in combination with salinity on shoot length at 0 and 14 DAS was significant ($p < 0.05$) (Table 2). At 14 DAS, the highest shoot length was recorded in the treatment combination of *Essence-Platinum* and 0 dS m^{-1} NaCl (476 mm). The lowest shoot length was recorded in *BHARAT Hybrid Sultan 702* with 8 dS m^{-1} NaCl (197 mm). Under stress condition, *Getco seeds GP – 901* and *Platinum-Essence* had statistically similar shoot length. A 44% decrease in shoot length was observed in *BHARAT Hybrid Sultan 702* followed by 20 % in Essence –Platinum with the increase in salinity level. All the maize cultivars had decreased shoot growth with increased NaCl concentration (Pessarakli and Kopec, 2009). Similar results were observed by Hoque *et al.* (2015) in maize, Mohammad *et al.* (1998) in tomato and by Gill and Singh (1989) in rice. The reduction in shoot length is due to excessive accumulation of salts in the cell wall elasticity (Hoque *et al.*, 2015). Additionally, there soon appears secondary cell with rigid cell walls which might results in decreased cell enlargement.

Table 2. Combined effect of salinity level and varieties on shoot length of maize

Treatment	Variety	Shoot length (mm)	
		0 DAS	14 DAS
T_1	V_1	214c	466a
	V_2	70 d	352 c
	V_3	224 bc	462 a
	V_4	259a	476 a
T_2	V_1	229 b	377 b
	V_2	59 e	197 d
	V_3	224 b	378 b
	V_4	252 a	377 b
$LSD_{0.05}$		9.7	22.0
Level of significance		**	**
CV (%)		2.9	3.3

Here, T_1 and T_2 means 0 dSm^{-1} and 8 dSm^{-1}, respectively; maize cultivars were V_1: *Kaveri - 244+*, V_2: *BHARAT Hybrid Sultan 702*, V_3: *Getco seeds GP – 901*, and V_4: *Essence –Platinum*. ** = Significant at 1% level of probability.

Number of leaves plant^{-1}

The interaction effect of variety and NaCl level on no. of leaves plant^{-1} was significant (Table 3). The highest no. of leaves plant^{-1} was recorded in the treatment combination of *Essence-Platinum* with 0dSm^{-1}NaCl at 14 DAS (14.4). On the other hand, the lowest no. of leavesplant^{-1} was observed in *BHARAT Hybrid Sultan 702* with 8 dS m^{-1} NaCl (4.4) at 14 DAS. Leaf number was decreased with increasing in salt concentration in all maize genotypes except *Getco seeds GP–901*.The number of leaves of the studied cultivars was varied in response to salinity stress. With the increase in salinity level from 0 $dsm^{-1}$to 8 dsm^{-1}, number of leaves was highly affected in *Kaveri–244+*, though the lowest leaves was recorded with *BHARAT Hybrid Sultan 702*. *BHARAT Hybrid Sultan 702* with no salinity also had lower leaf numbers at 14 DAS. Among other cultivars, *Getco seeds GP–901* had increased numbers of leaves with 8 ds m^{-1} than with no salinity condition. This behavior indicates a reduction in the appearance of new leaves except *Getco seeds GP–901* could be associated with the osmotic stress pointed out by Munns *et al.* (2002) and Munns and Tester (2008).

The slight increase in shoot biomass in *Kaveri - 244+* and decrease in root biomass does not show consistent performance. Besides, biomass of *Kaveri - 244+* is much lower than *Getco seeds GP – 901* and *Essence –Platinum*.

Table 3. Combined effect of salinity level and varieties on no. of leaves plant^{-1}

Treatment	Variety	No. of leaves plant^{-1}	
		0 DAS	14 DAS
T_1	V_1	4.9	10.7c
	V_2	1.7	5.0e
	V_3	5.9	10.4 c
	V_4	9.0	14.4a
T_2	V_1	4.6	7.9 d
	V_2	1.4	4.4 e
	V_3	7.0	11.3c
	V_4	9.0	13.0 b
$LSD_{0.05}$		0.8	0.9
Level of significance		NS	**
CV (%)		8.0	5.4

Here, T_1 and T_2 means 0 dS m^{-1} and 8 dSm^{-1}, respectively; maize cultivars were V_1: *Kaveri–244+*, V_2: *BHARAT Hybrid Sultan 702*, V_3: *Getco seeds GP – 901*, and V_4: *Essence –Platinum*. ** = Significant at 1% level of probability, NS=Non-significant.

Fresh Weight

Variety with salinity level varied fresh weight of root and shoot at 0 and 8 dS m^{-1} ($p < 0.01$) (Figure 3). The highest fresh weight of root and shoot (23.09 and 22.96 g plant^{-1}, respectively) were recorded in the treatment combination of *Essence – Platinum* and 0 dS m^{-1} NaCl. The lowest fresh weight of root and shoot (3.2 and 2.3 g plant^{-1}, respectively) were observed in *BHARAT Hybrid Sultan 702* with 8 dS m^{-1} NaCl. Higher NaCl content might cause clampdown early seedling growth due to osmotic stresses, accordingly shoot and root fresh weight reduced considerably as salt concentration increased (Giaveno *et al*., 2007). Root fresh weight decreased with increased salinity stress. As the root length and root mass decreased with the higher salinity level, the fresh root growth also decreased. Hoque *et al*. (2015), Hameed *et al*. (2008) also claimed that fresh weight of root got mostly adversely affected by the increased salt level. The increase in salinity levels decreases the overall biomass production (Hussain *et al.*, 2009).

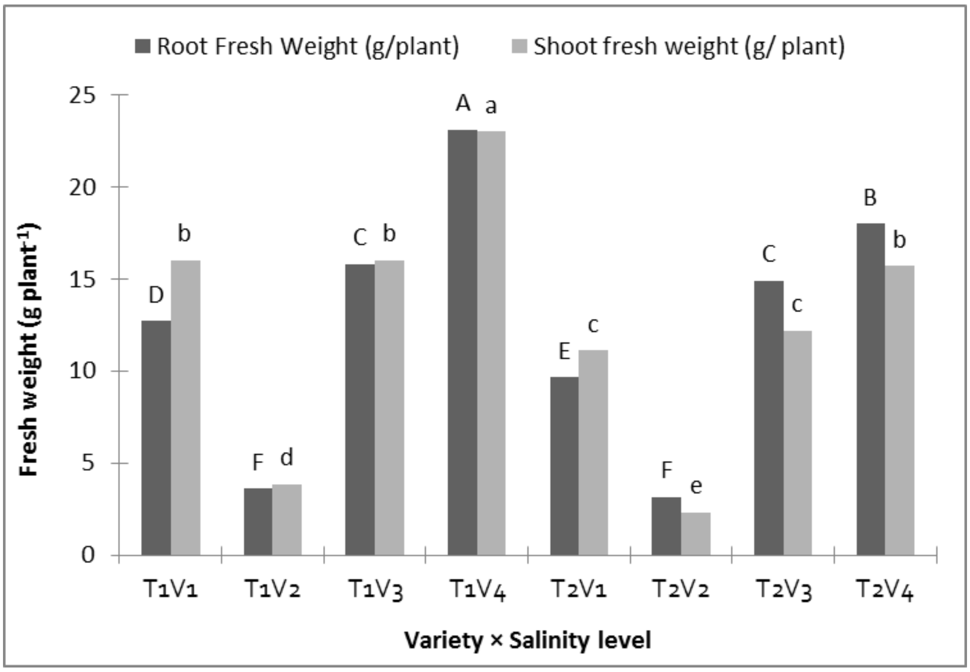

Figure 4. Combined effect of salinity level and varieties on fresh weight of root and shoot

Here, T_1 and T_2 mean 0 dS m^{-1} and 8 dS m^{-1}, respectively; maize cultivars were V_1: *Kaveri - 244+*, V_2: *BHARAT Hybrid Sultan 702*, V_3: *Getco seeds GP – 901*, and V_4: *Essence –Platinum*. $LSD_{0.05}$ for root fresh weight and shoot fresh weight are 1.25 and 1.13, respectively. Columns with the same letter are not significantly different from each other.

Dry weight

The interaction effect of variety and NaCl level on dry weight of root and shoot with 0 dS m^{-1} and 8 dS m^{-1} were significant (Table 4). The highest dry weight of root and shoot (0.98 g $plant^{-1}$ and 1.33 g $plant^{-1}$, respectively) were recorded in the treatment combination of *Essence – Platinum* with 0dSm^{-1}NaCl. On the other hand, the lowest dry weight was observed in *BHARAT Hybrid Sultan 702* with 8 dS m^{-1} NaCl (0.17 g $plant^{-1}$) and (0.21 g $plant^{-1}$), respectively. Root dry weight of all maize cultivars except *Kaveri - 244+* showed a decline towards increase in salinity level (Akram *et al.*, 2007). As a significant reduction in root and shoot biomass was recorded under increased salinity, so the dry biomass also reduced (Hussain *et al.*, 2009).

Table 4. Combined effect of salinity level and varieties on dry weight of root and shoot

Treatment	Variety	Root dry weight (g)	Shoot dry weight (g)
T_1	V_1	0.45e	0.89d
	V_2	0.23 f	0.23 e
	V_3	0.80 b	0.97 c
	V_4	0.98 a	1.33 a
T_2	V_1	0.42 e	0.90 d
	V_2	0.17 f	0.21 e
	V_3	0.60 d	0.86 d
	V_4	0.68 c	1.17 b
$LSD_{0.05}$		0.077	0.055
Level of significance		**	**
CV (%)		8.72	2.86

Here, T_1 and T_2 means 0 dSm^{-1} and 8 dSm^{-1}, respectively; maize cultivars were V_1: *Kaveri - 244+*, V_2: *BHARAT Hybrid Sultan 702*, V_3: *Getco seeds GP – 901*, and V_4: *Essence –Platinum*. ** = Significant at 1% level of probability.

Considering the reduction of dry mass production under NaCl results showed that the reduction of dry mass due to NaCl toxicity was minimum in *Essence – Platinum* and a slight increase in *Kaveri - 244+*. On the other hand, the maximum reduction in dry mass production was observed in *BHARAT Hybrid Sultan 702* indicating these genotypes were more susceptible to NaCl toxicity than the other genotypes in maize. The slight increase in shoot biomass in *Kaveri - 244+* and decrease in root biomass does not show consistent performance. Besides, biomass of *Kaveri - 244+* is much lower than *Getco seeds GP – 901* and *Essence –Platinum*.

4. Conclusions

The interaction effect of variety and NaCl on root and shoot length, no. of leaves $plant^{-1}$ was significant. The highest numbers of leaves $plant^{-1}$, fresh and dry weight of root and shoot were recorded in the treatment combination of *Essence –Platinum* with control (0 dS m^{-1} NaCl). In genotypes, the highest root and shoot length was observed in *Essence –Platinum* which resulted the highest dry mass per plant at 0 and 14 DAS. In contrast, the lowest fresh and dry weight was observed in *BHARAT Hybrid Sultan 702*. From the results, it could be concluded that all the studied *Zea mays* cultivars were variably affected in growth and development of seedlings by 8 dS m^{-1} level of salinity; among the cultivars *Essence*

–*Platinum* was found comparatively more tolerant under 8 dS m^{-1} level of saline condition than the other varieties in respect of growth and development.

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