Madras Agric. J., 103 (10-12): 333-337, December 2016
https://doi.org/10.29321/MAJ.10.001044

Studies on Plant Growth and Gas Exchange Parameters of Maize Hybrids under Saline Water Irrigation on Alfisol

B. Nandhini Devi* and T. Chitdeshwari
Department of Soil Science and Agriculture Chemistry
Tamil Nadu Agricultural university, Coimbatore - 641 003

Salinization of cultivated land is increasing globally due to saline water irrigation and inherent soil salinity. A considerable variation in salinity tolerance of maize hybrids was reported widely hence selection of tolerant maize hybrids to saline water irrigation is of great significance in utilising saline water for irrigation. The present study was conducted to identify the maize hybrids tolerant to saline water irrigation under green house condition. Six maize hybrids were chosen and irrigated with saline water having varied inherent salinity levels (0.6, 3.2, 4.8, 6.7 and 8.9 dS m^{-1}) and grown on Alfisol for 30 days. Plant growth attributes and gas exchange parameters were recorded on 30 day after sowing and significant variations were observed among the genotypes for different salinity levels. Increasing levels of irrigation water salinity decreased the plant growth attributes, photosynthetic activity and dry matter production of all maize hybrids. However, TNAU Maize hybrid CO 6 registered higher dry matter production and photosynthetic activity with better stress tolerance index (76.8%). All the maize hybrids tolerated the irrigation water salinity upto 3.2 dS m^{-1} while TNAU maize hybrid CO 6 thrives well even upto 4.8 dS m^{-1}, which indicated its efficiency to tolerate water salinity.

Key words: Saline water, Maize, Salt tolerance, Growth attributes, Photosynthetic efficiency

Agriculture sector is one of the major consumer of water hence wherever good quality water is scarce, poor quality water has been considered as an alternative for use in agriculture. As soil salinity is one of the main important constraints for agricultural production, better understanding of the mechanisms that enable plants to tolerate salt stress is necessary for exploiting saline water resources for agriculture. With the steady increase in population, especially in the under-developed countries of the world and the concomitant decline in new agriculture lands, the need to tackle soil stresses is essential (Ali *et al*., 2008).

Salinity affects plants in many ways such as osmotic effects, specific-ion toxicity and many nutritional disorders (Läuchli & Epstein, 1997). It not only affects the morphology, but also modifies plant metabolisms thus limiting their growth which depends on many factors such as genotype, plant age, ionic strength and composition of the irrigation water. Plants undergo characteristic changes from the time salinity stress is imposed until they reach maturity (Munns and Tester, 2008). Nevertheless, a plant affected by salinity cannot be productive and will exhibit wilting and doughtiness, even in wet and moist soil. Above the salinity threshold, a plant performance will be deteriorated and yield has been declined. Burgeoning population growth and land degradation by salinization led plant scientists to develop salt-tolerant crops by various approaches (Yamaguchi & Blumwald, 2005; Munns *et al.*, 2006; Muhammad *et al.,* 2010). Therefore, screening techniques are the basis for any successful breeding programme specifically for biotic and abiotic stresses.

Next to wheat and rice, maize is the third most important cereal crop grown all over the world under wide range of environmental conditions. Maize is one of the moderately salt-sensitive field crop, showing obvious signs of stress, including wilting even when there is adequate soil moisture, dull leaves, and gray leaf tips (Ouda *et al.*, 2008). Screening salinity tolerance of crops in the field is difficult, due to spatial heterogeneity of soil physico-chemical properties and seasonal fluctuations in rainfall. Hence, the present investigation was planned to screen maize hybrids for saline water irrigation with various inherent salinity levels and to describe the effect of irrigation water salinity on seedling growth of maize hybrids.

Materials and Methods

A pot culture experiment was conducted with six maize hybrids and five irrigation water salinity (EC) levels on Alfisol. Based on the chemical composition five different irrigation water samples differing in electrical conductivity (0.3, 3.2, 4.8, 6.7 and 8.9 dS m^{-1}) were used for conducting the experiment. A non-calcareous, sandy loam textured soil having pH of 7.22 and 0.44 dS m^{-1} electrical conductivity was used for the experiment. Pots of two kilogram capacity was chosen and filled with one kilogram of processed soil and irrigation was given with water having different levels of EC at alternate days. Six maize hybrids *viz.*, CO 6, CO 7, CO 8, CO 10, 900

*Corresponding author email: nandhu.sac@gmail.com

M Gold and NK 6240 were sown in the pots and one plant per pot was maintained. Nutrients were applied basally as per fertiliser recommendation and the crops were grown upto 30 days and harvested. Plant growth attributes such as plant height, root length, dry matter production and chlorophyll content were recorded. Measurements of gas exchange parameters were also attempted on the first fully expanded leaf using a portable photosynthesis system, infra-red gas analyser (IRGA model). The photosynthetic rate, stomatal conductance and transpiration rate were measured between 8:00 to 10:00 am after 30 days of salt stress. Relative chlorophyll content (SPAD index) was also determined on the first fully expanded leaf, by registering three readings per leaf with a portable Minolta chlorophyll meter SPAD-502. Based on the dry matter production (DMP), the stress tolerance index was calculated for different EC levels of irrigation water to identify the best tolerant maize hybrid under saline water irrigation and the data were statistically analyzed with factorial completely randomized design using three replicates at $p = 0.05$.

Results and Discussion

Saline water irrigation significantly influenced most of the growth variables of maize hybrids. Higher growth attributes were noted in the maize hybrids irrigated with non-saline water (0.6 dSm^{-1}). Increasing water salinity decreased the plant growth parameters in all the maize hybrids and the degree of reduction varied among the hybrids which might be due to their differential genetic potential in exclusion and absorption of ions.

Table 1. Effect of irrigation water salinity on shoot length (in cm) of maize hybrids

Maize Hybrids	EC levels (dS m^{-1})					
	0.6	3.2	4.8	6.7	8.9	Mean
CO 6	55.5±1.5	46.2±1.8	42.1±1.7	39.1±1.1	35.5±1.1	43.7
CO 7	54.0±1.8	45.8±1.9	42.5±2.1	37.1±1.1	32.4±0.9	42.4
CO 8	56.0±2.0	35.9±1.4	27.0±1.5	27.1±0.9	19.0±1.0	33.0
CO 10	45.2±1.9	37.8±0.8	36.0±1.0	29.5±1.3	25.8±0.8	34.9
NK 6240	51.5±1.8	46.0±1.5	35.2±1.2	35.4±1.1	28.0±0.9	39.2
900 M GOLD	47.5±1.6	42.0±1.4	37.2±1.3	33.4±1.4	29.5±1.3	37.9
Mean	51.6	42.4	36.7	33.9	28.4	38.6
	EC	G	EC x G			
SE(d)	0.33	0.37	0.82			
CD (P=0.05)	0.66**	0.73**	1.64**			

Table 2. Effect of irrigation water salinity on root length (in cm) of maize hybrids

Maize Hybrids	EC levels (dS m^{-1})					
	0.6	3.2	4.8	6.7	8.9	Mean
CO 6	19.4±0.7	15.3±0.9	13.2±0.9	10.60±0.3	8.70±0.7	13.4
CO 7	18.5±1.2	14.9±1.1	12.6±0.5	9.80±1.0	7.50±0.9	12.7
CO 8	16.8±1.0	14.1±0.5	10.5±0.7	8.30±0.5	6.20±0.8	11.2
CO 10	17.1±0.9	14.3±1.2	11.7±1.1	8.20±0.8	7.10±1.0	11.7
NK 6240	18.3±1.4	14.5±0.9	11.9±0.5	9.70±0.7	6.80±1.3	12.2
900 M GOLD	17.9±1.6	14.3±0.4	11.2±1.3	8.70±1.0	6.50±1.1	11.7
Mean	18.0	14.8	11.8	9.20	7.10	12.2
	EC	G	EC x G			
SE(d)	0.11	0.12	0.28			
CD (P=0.05)	0.22**	0.25**	0.56**			

Growth parameters

High genetic variability in salinity tolerance with different seedling traits such as shoot length, root length, dry weight of all the six maize hybrids were observed. Shoot length was affected significantly with increase in irrigation water salinity (Table 1) and the rate of reduction in shoot length at 8.9 dSm^{-1} was markedly higher in comparison to non-saline water (0.6 dSm^{-1}). The order of lesser reduction in shoot length was : CO 6 > CO 7 > NK 6240 > 900M gold > CO 10 > CO 8. Increasing water salinity decreased the root length of maize hybrids considerably (Table 2) and ranged from 6.2 to 19.4 cm. Maximum reduction in mean root length was observed in CO 8 (11.2 cm) and minimum was observed in CO 6 (13.4 cm). The reduction in shoot and root length is due to excessive accumulation of Na^{2+} and other toxic ions in plant cells which affects cell wall elasticity. Similar reduction in shoot and root length due to irrigation water salinity was reported by Pessarakli and Kopec (2009).

Table 3. Effect of irrigation water salinity on dry matter production (g plant^{-1}) of maize hybrids

Maize Hybrids	EC levels (dS m^{-1})					
	0.6	3.2	4.8	6.7	8.9	Mean
CO 6	4.93±0.8	4.59±0.6	4.23±1.2	3.64±0.6	2.68±1.0	4.01
		(6.88)	(14.1)	(26.1)	(45.6)	(23.2)
CO 7	4.62±0.5	4.24±0.3	3.87±0.8	3.05±0.9	2.27±0.8	3.61
		(8.19)	(16.7)	(34.0)	(50.9)	(27.3)
CO 8	4.18±0.9	3.60±0.2	2.97±0.6	2.11±1.1	1.47±0.4	2.87
		(14.0)	(29.1)	(49.6)	(64.9)	(39.4)
CO 10	4.28±0.8	3.77±0.7	3.09±0.3	2.44±0.4	1.66±0.7	3.05
		(11.9)	(27.8)	(43.1)	(61.1)	(36.0)
NK 6240	4.54±0.9	4.12±1.0	3.71±0.9	3.08±0.7	2.13±1.1	3.52
		(9.21)	(18.3)	(32.1)	(53.1)	(28.2)
900 M GOLD	4.39±1.1	3.91±0.5	3.27±1.3	2.46±0.6	1.82±0.6	3.17
		(11.2)	(25.7)	(43.9)	(58.7)	(34.9)
Mean	4.49	4.04	3.52	2.80	2.01	3.37
		(10.2)	(21.9)	(38.1)	(55.7)	(31.5)
	EC	G	EC x G			
SE(d)	0.04	0.05	0.11			
CD (P=0.05)	0.09**	0.10**	0.22*			

*Parenthesis indicates per cent yield reduction

Table 4. Effect of irrigation water salinity on stress tolerance index (%) of maize hybrids

Maize Hybrids	EC levels (dS m^{-1})				
	3.2	4.8	6.7	8.9	Mean
CO 6	93.1	85.8	73.9	54.4	76.8
CO 7	91.8	83.8	66.0	49.1	72.7
CO 8	86.0	70.9	50.4	35.1	60.6
CO 10	88.1	72.2	56.9	38.9	64.0
NK 6240	90.8	81.7	67.9	46.9	71.8
900 M GOLD	88.8	74.3	56.1	41.3	65.1
Mean	89.8	78.1	61.9	44.3	68.5
	EC	G	EC x G		
SE(d)	0.94	1.15	2.30		
CD (P=0.05)	1.89**	2.31**	4.63*		

Dry matter production (DMP) of crops also declined with increasing water salinity (Table 3) and the per cent reduction varied between 6.88 to 64.9. The lowest reduction in DMP due to salinity was observed with TNAU maize hybrids CO 6 (23.2%) followed by CO 7 (27.3%) which indicated their tolerance to saline water irrigation. Greater reduction in DMP of crops at higher water salinity could be

Table 5. Effect of irrigation water salinity on Chlorophyll content of maize hybrids

Maize Hybrids	EC levels (dS m^{-1})					
	0.6	3.2	4.8	6.7	8.9	Mean
CO 6	37.3±0.9	36.4±0.8	34.3±0.7	33.2±0.9	30.2±0.6	34.3
CO 7	36.9±0.6	34.3±0.5	32.8±0.3	30.7±0.6	29.7±0.9	32.9
CO 8	34.7±0.4	32.0±0.3	30.1±0.4	28.7±1.5	25.2±0.7	30.1
CO 10	35.0±0.3	32.9±0.4	31.1±0.8	28.9±1.7	27.0±0.5	31.0
NK 6240	36.1±0.5	33.8±0.6	32.2±0.9	30.1±0.9	28.4±0.8	32.1
900 M GOLD	35.8±0.6	33.0±0.4	31.9±0.5	29.8±0.8	27.6±0.7	31.6
Mean	36.0±0.5	33.7±0.5	32.1±0.6	30.2±1.0	28.0±0.5	32.0
	EC	G	EC x G			
SE(d)	0.24	0.26	0.58			
CD (P=0.05)	0.48**	0.53**	NS			

attributed to the root zone salinity and sensitivity of the crops to irrigation water salinity (Ashraf *et al*., 2008; Ahmadi and Ardekani, 2006). All maize hybrids were tolerant to saline water irrigation upto 3.2 dSm^{-1} with less than 15 per cent reduction in DMP.

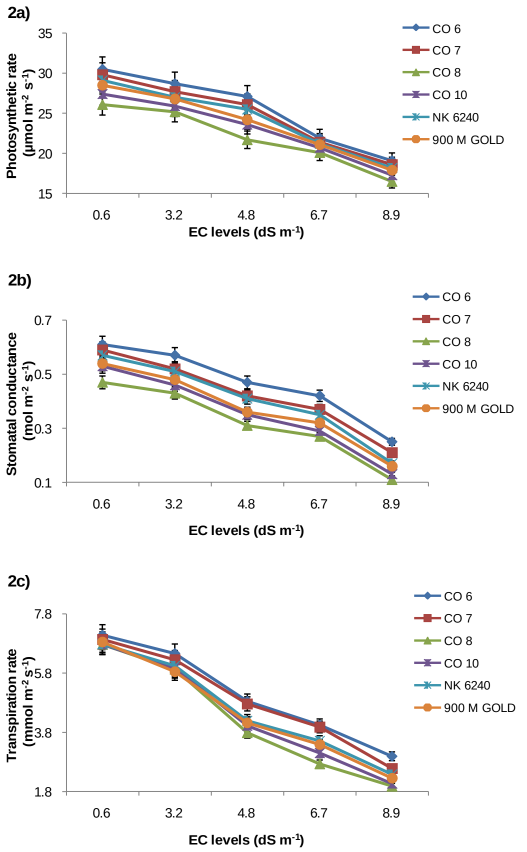

Fig 1.Photosynthetic activity of maize hybrids a. Photosynthetic rate b. Stomatal conductance c. Transpiration rate

However, TNAU maize hybrid CO 6 (14.2%) has maintained its tolerance upto 4.8 dSm^{-1}. Stress tolerance index computed for the maize hybrids based on DMP ranged between 93.1 and 35.1% (Table 4) and the highest mean STI was observed in CO 6 (76.8 %) followed by CO 7 (72.7%). The result of the present study was in agreement with the results achieved by Giaveno *et al.* (2007) in screening tropical maize for salt tolerance. The same result was published by Prajuabmon *et al*. (2009) also who reported that three cultivars of rice seedlings grown under high salinity had registered greater reduction in shoot length, fresh and dry weight of shoot and root.

Gas exchange measurements

Photosynthesis, stomatal conductance, transpiration and chlorophyll content were greatly decreased with increase in irrigation water salinity at 30 DAS (Figure 1a, b & c). Some studies well correlate with the maintenance of gas exchange with salt tolerance in plants (James *et al*., 2006, Munns and Tester, 2008). Photosynthetic rate of maize hybrids (Fig. 1a) ranged from 16.5 to 30.5 µmol m^{-2} s^{-1}. Highest mean value was recorded in CO 6 (25.5 µmol m^{-2} s^{-1}) followed by CO 7 (24.7 µmol m^{-2} s^{-1}) and the lowest photosynthetic rate was observed in CO 8 (20.9 µmol m^{-2} s^{-1}). Similar trend was observed in stomatal conductance (Fig. 1b), transpiration rate (Fig. 1c) and chlorophyll content (Table 5) and the values varied from 0.11 to 0.61 mol m^{-2} s^{-1}, 1.98 to 7.08 mmol m^{-2} s^{-1} and 25.2 to 37.3 (SPAD) respectively. The highest mean values of all the parameters were observed in CO 6 and the lowest in CO 8.

Salinity stress has been shown to reduce the overall growth and productivity of plants by disturbing several physiological and biochemical processes like photosynthesis, ion homeostasis and enzyme activities (James *et al.,* 2006, Gomes-Filho *et al.*, 2008, Hasegawa, 2013). Our results are in agreement with those previously reported for different crops such as sorghum, cowpea and cotton (Freitas *et al.*, 2011), maize (Azevedo Neto *et al.,* 2005), and pea (Noreen and Ashraf, 2009). It has been reported that reduction in photosynthesis by low stomatal conductance, which causes CO2 availability during early exposure to salt stress, while biochemical limitations arises due to long-term salt exposure (Silva *et al.,* 2011).

Thus, the reduction in photosynthesis in maize plants was caused by stomatal closure and decreasing transpiration rate (Shahbaz *et al.*, 2010).

Screening at early stage of plant growth is a simple and fairly reliable technique for determining differences with respect to salt tolerance of maize hybrids. In this study, increasing water salinity reduced the plant growth attributes, biomass, chlorophyll content and gas exchange measurements in all the maize hybrids. It can be concluded that all maize hybrids can be grown with minimum DMP reduction and relatively higher stress tolerance index upto an irrigation water salinity of 3.2 dSm^{-1}. While, TNAU maize hybrid CO 6 can be grown even upto 4.8 dSm^{-1}, indicating its efficiency to tolerate saline water irrigation

References

Ahmadi, S.H. and Ardekani, J.N. 2006. The effect of water salinity on growth and physiological stages of eight canola (Brassica napus) cultivars. *Irrig. Sci*., **25**: 11–20.

Ali, Z., Khan, A.S. and Asad, M.A. 2008. Salt tolerance in bread wheat: genetic variation and heritability for growth and ion relation. *Asia J. Plant Sci*., **1**: 420-422.

Ashraf, M., Athar, H.R., Haris, P.J.C. and Kwon, T.R. 2008. Some prospective strategies for improving crop salt tolerance. *Adv. Agron*., **97**:45-110.

Azevedo Neto, A.D., Prisco, J.T., Eneas-Filho, J., Medeiros, J.R. and Gomes Filho, E. 2005 Hydrogen peroxide pre-treatment induces salt-stress acclimation in maize plants. *Journal of Plant Physiology*, **162**:1114-1122.

Freitas, V.S., Alencar, N.L.M., Lacerda, C.F., Prisco, J.T. and Gomes-Filho, E. 2011. Changes in physiological and biochemical indicators associated with salt tolerance in cotton, sorghum and cowpea. *African Journal of Biochemistry Research*, **5**:264-271.

Giaveno, C.D., Ribeiro, R.V., Souza, G.M. and De Oliveira, R.F. 2007. Screening of tropical maize for salt stress tolerance. *Appl. Biotech*., **7**: 304-313.

Gomes-Filho, E., Lima, C.R.F.M., Costa, J.H., Silva, A.C.M., Lima, M.G.S., Lacerda, C.F. and Prisco, J.T. 2008. Cowpea ribonuclease: properties and effect of NaCl salinity on its activation during seed germination and seedling establishment. *Plant Cell Reports*, **27**:147-157.

Hasegawa, P.M. 2013. Sodium (Na+) homeostasis and salt tolerance of plants. *Environmental and Experimental Botany*, **92**:19-31.

James, R.A., Munns, R., Von Caemmerer, S., Trejo, C., Miller, C. and Condon, T.A.G. 2006. Photosynthetic capacity is related to the cellular and subcellular partitioning of Na+, K+and Cl- in salt-affected barley and durum wheat. *Plant, Cell and Environment*, **29**: 2185-2197.

Läuchli, A. and Epstein, E. 1997. Plant responses to saline and sodic conditions. In K.K. Tanji (ed). Agricultural salinity assessment and management. ASCE manuals and reports on engineering, p.138.

Muhammad Akram, Muhammad Yasin Ashraf, Rashid Ahmad, Ejaz Hmed Waraich, Javed Iqbal and Muhammad Mohsan. 2010. Screening for salt tolerance in maize (Zea mays L.) hybrids at an early seedling stage. *Pak. J. Bot.*, **42(1)**: 141-154.

Munns, R., James, R.A. and Läuchli, A. 2006. Approaches to increasing the salt tolerance of wheat and other cereals. *J. Exp. Bot.,* **57**: 1025-1043.

Munns, R. and Tester, M. 2008. Mechanisms of salinity tolerance. *Annual Review of Plant Biology*, **59**:651-681.

Noreen, Z. and Ashraf, M. 2009. Assessment of variation in antioxidative defense system in salt treated pea (Pisum sativum L.) cultivars and its putative use as salinity tolerance markers. *J. Plant Physiology,* **166**:1764-1774.

Ouda, S.A.E., Mohamed, S.G. and Khalil, F.A. 2008. Modeling: The effect of different stress conditions on maize productivity using yield-stress model. *Int. J. Natural Eng. Sci.,* **2(1)**: 57-62.

Pessarakli, M. and Kopec, D.M. 2009. Screening various ryegrass cultivars for salt stress tolerance. *J. Food Agric. Environ.,* **7(3)**: 739-743.

Prajuabmon, A., Theerakulpisut, P., Kijwijan, B. and Muangsan, N. 2009. In vitro investigation on salt tolerant characteristics of rice seedlings (*Oryza sativa* L.). Research *J. Agric. and Biological Sci*., **5**: 423-427.

Shahbaz, M., Ashraf, M., Akram, N.A., Hanif, A., Hameed, S., Joham, S. and Rehman, R. 2010. Salt-induced modulation in growth, photosynthetic capacity, proline content and ion accumulation in sunflower (*Helianthus annuus* L.). *Acta Physiologiae Plantarum*, **33**:1113-1122.

Silva, E.N., Ribeiro, R.V., Ferreira-Silva, S.L., Viegas, R.A. and Silveira, J.A.G. 2011. Salt stress induced damages on the photosynthesis of physic nut young plants. *Scientia Agricola*, **68**: 62-68.

Singh, A.K. and Dubey, R.S. 1995. Changes in chlorophyll a and b contents and activities of photosystems I and II in rice seedlings induced by NaCl. *Photosynthetica*, **31**: 489-499.

Yamaguchi, T. and Blumwald, E. 2005. Developing salt-tolerant crop plants: challenges and opportunities. *Trends in Plant Science*, **10**: 615-620.

Received after revision : December 28, 2016; Accepted : December 31, 2016