Tolerance to salinity of maize genotypes (*Zea mays* L.) during germination and early growth

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Abstract
The aim of the study was to assess the salt tolerance of three Bulgarian maize landraces (*Zea mays* L.) during germination and early seedling stage under seven levels of NaCl salinity (0, 25, 50, 75, 100, 125 and 150 mM) and also to find a relationship between salt stress and seedling growth. Increasing NaCl concentration caused a decrease in the germination percentage (G, %), the coefficient of velocity of germination (CVG, % day^{-1}), the germination rate index (GRI) and the Timson germination index (TGI) and prolonged the mean germination time (MGT, day). Significant negative effects of salinity on shoot and root length, shoot and root fresh and dry weight of maize was found. Decrease in shoot length was more pronounced compared to roots for 73E840 and A9E0660, while for B5E0055 decrease in root length was more pronounced compared to shoot length. At the germination stage genotypes showed high to very high tolerance to the investigated salinity levels. At the highest salinity level (150 mM NaCl), A9E0660 was characterized as genotype with low tolerance to shoot growth, while 73E840 with medium and B5E0055 with high tolerance. B5E0055 showed low tolerance to root growth, while A9E0660 and 73E840 medium tolerance. In general the investigated maize genotypes were significantly more tolerant to salt stress at germination than at early seedling growth stage. Linear regression analysis was implemented to find the relationship between salinity and studied germination and seedling characteristics and between germination and seedling characteristics.

Key words: maize; salinity; germination characteristics; seedling characteristics; correlation; linear regression

INTRODUCTION

Salinity stress is one of the most serious abiotic stress factors limiting crop productivity. Salinity disrupts plant morpho-physiological processes due to osmotic disturbance and ionic stress. The negative impact of salinity on plant growth and metabolism has been attributed, principally, to enhanced Na+ ion uptake, which causes an excess of Na+ ions in plant tissues (Yohannes & Abraha, 2013; Agami, 2013; Aliu et al., 2015; Farooq et al., 2015). Soil salinity may affect the germination of seeds either by creating osmotic potential external to the seeds preventing water uptake or through the toxic effects of Na+ and Cl- ions on germinating seed (Khodadad, 2011; Sholi, 2012).

Maize (*Zea mays* L.) is the third most important cereal crop after rice and wheat and is grown under a wide spectrum of soil and climatic conditions. It belongs to the plants with C4 metabolism and is moderately sensitive to salt stress, but initial growth stages of maize are sensitive to salinity stress (Ouda et al., 2008; Carpıcı et al., 2009; Huqe et al., 2021; Sabagh et al., 2021; Iqbal et al., 2020). Increased salinity caused a significant reduction in germination percentage, germination rate, and root and shoots length and fresh root and shoots weights; nonetheless, wide intraspecific genetic variation for salt resistance exists in maize (Jamil et al., 2006; Sholi, 2012; Zhang & Zhao, 2011; Aliu et al., 2015; Nuurismaan et al.,2018; Hoque et al., 2021; Sabagh et al., 2021).

Huqe et al. (2021) noted that the introduction of salt-tolerant maize genotypes and selection of existing suitable maize cultivars would be the better options to meet the challenge of increasing food demand. According to Ahmed et al. (2017) is very important to know what extent of salinity a maize variety can tolerate at germination and early seedling growth stage. This information will help to identify salt tolerant varieties and/or genotypes and to develop saline soil management strategies. Aliu et al. (2015) noted that hybrids are less sensitive to salinity than populations because they were not genetically improved. Due to the genetic variability of populations and their responsiveness to salinity, they can serve as a good starting material for breeding of genotypes resistant to salinity stress. Therefore the present study was initiated to investigate the salt tolerance of Bulgarian corn landraces (*Zea mays* L.) during germination and early seedling stage and also find a relationship between salt stress and growth.

MATERIALS AND METHODS

Seeds of three Bulgarian landraces collected in 1978 (73E840, belong to *Zea mays* L. *var. semiindurata* Kulesch.), 2009 (A9E0660, belong to *Zea mays* L. *indentata* Sturt.) and 2015 (B5E0055, belong to *Zea mays* L. *convar. saccharata* Körn) years and maintained in the active collection in the National genebank were used. The seeds were surface sterilized by dipping the seeds in 30% etanol solution for 3 minutes and rinsed thoroughly with distilled water and air-dried before being used in the germination tests to avoid any fungal attacks. Six different concentrations of NaCl (25, 50, 75, 100, 125 and 150 mM) were used as treatments and deionized water was used as the control. For each variant of the experiment, two replicates of 25 seeds were germinated between rolled filter paper (Grade FT 55) with 25 ml of respective test solutions. The papers were replaced every 2 days to prevent accumulation of salts. Seeds were allowed to germinate at 25±1 ºC for 7 days. Seeds were considered germinated when radicle had extended at least 1 mm. The number of germinated seeds was recorded daily until a constant count was achieved. From the germination counts several germination characteristics were studied including: germination percentage (G, %) as final count after 7 days (G, %), coefficient of velocity of germination (CVG, % day^{-1}), germination rate index (GRI), mean germination time (MGT, day), germination index (GI) and Timson germination index (TGI). Coefficient of velocity of germination (CVG, % day-1) was calculated according to Kader & Jutzi (2004). Germination rate index (GRI, % day-1), germination index (GI) and mean germination time (MGT, day) were calculated according to the formula of Kader (2005). The Timson germination index (TGI) was calculated according to Al-Ansari & Ksiksi (2016).

The data for the shoot and root length (cm) (ShL and RL), fresh weigh (mg) of shoot and root (FWSh and FWR) and dry weight (mg) of shoot and root (DWSh and DWR) were measured seven days after germination. Dry weights were measured after drying at 80°C for 24 h into an oven.

Salt tolerance was calculated by the formula given from Mujeeb-ur-Rahman et al. (2008). The evaluation of the accessions was on the following scale:

Salt Tolerance Index	**Degree of tolerance**
> 80%	very high
80-60%	high
60-40%	medium
40-20%	low
< 20%	very low

Data were analysed by analysis of variance (ANOVA), Duncan's multiple range test (Duncan, 1955). Correlation and single regression analyses were also carried out for the data obtained to test the significance of the independent variables on the dependent variable. Data were analysed using the statistical program IBM SPSS Statistics 22.0.

RESULTS AND DISCUSSIONS

Seed germination is the most sensitive stage in the life cycle of the plant. Imbibition and following germination is characterized as a major structural and functional change in seed development. Seeds are normally dormant, the event of germination must happen in a particular time, that is with imbibition. Therefore seed germination offers an excellent system to study its development and concomitant effect by salt (Shonjani, 2002).

Salt stress influences seed germination primarily by sufficiently lowering the osmotic potential of the soil solution to retard water absorption by seeds, by causing sodium and/or chloride toxicity to the embryo or by altering protein synthesis (Khayatnezhad & Gholamin 2011; Farooq et al., 2015).

The Effect of different salinity levels on the investigated germination characteristics are presented in Figure 1. Increasing NaCl concentration caused a decrease in the germination percentage (G, %), the coefficient of velocity of germination (CVG, % day^{-1}), the germination rate index (GRI) and the Timson germination index (TGI) and extended the mean germination time (MGT, day). Our results were similar to the findings reported by many researchers (Souza & Cardoso, 2000; Alebrahim et al., 2008; Farsiani & Ghobadi, 2009; Bakht et al., 2011; Khayatnezhad & Gholamin, 2011; Khodarahmpour et al., 2012; Yohannes & Abraha, 2013; Hoque et al., 2014; Aliu et al.,2015; Diriba et al.,2016; Ahmed et al., 2017; Nuurismaan et al., 2018).

Several studies have investigated the effect of the salinity on maize crop, and found that the effect was genotype specific (Zhang & Zhao, 2011; Khayatnezhad & Gholamin, 2011; Khodarahmpour et al., 2012; Aliu et al., 2015; Diriba et al., 2016). In our study Duncan multiple range test was applied to compare the differences between the means of genotype and salinity stress levels. Different maize genotypes had different response to the salinity stress (Khodarahmpour et al., 2012). In comparison with A9E0660 and B5E0055, 73E840 genotype had the lowest average value of germination at untreated variant (90%) and after the treatments of 50, 75, 100 and 150 mMol NaCl. 73E840 genotype also showed the maximum reduction in germination percentage at the highest level of NaCl (with 20% in compare with control variant). A9E0660 and B5E0055 were not differ significantly ($p \leq 0.05$) from each other at different salinity levels according to the Duncan test. It was recorded not significant reduction in the germination percent at the salt levels from 25 to 125 mM NaCl for both accessions (Fig.1). Aliu et al. (2015) also reported for no significant decrease in mean germination values at 50 and 100 mM NaCl salt concentrations for all investigated maize cultivars.

Mean germination time (MGT, day) increase with decrease in the osmotic potential in NaCl solution (Khodarahmpour et al., 2012). Hoque et al. (2014) noted that increase of mean germination time (MGT) indicates that germination is delayed comparatively. In our study the lowest value (2.06) was recorded in treatment with 0 mMol NaCl for A9E0660, while the highest in treatment with 150 mM NaCl for 73E840. There were no significant differences between studied accessions at salinity levels 50 mM, 75 mM, 100 mM and 150 mM for the MGT (Figure 1).

CVG as an indicator of the rapidity of germination varied between 38.04 % day^{-1} to 48.49% day^{-1}. The highest value was recorded for A9E0660 at 0 mM NaCl, while the lowest for 73E840 at 150 mM NaCl. The studied genotypes were not differ significantly ($p \leq 0.05$) from each other at 50, 75, 100 and 150 salinity levels. At 125 mM NaCl, the accessions were grouped into three groups according to Duncan test at the level of statistical significance $p \leq 0.05$ (Fig.1).

At the highest salt level GRI varied between 29.00 and 39.03. A9E0660 and B5E0055 produced maximum germination rate index and were not differ significantly ($p \leq 0.05$) from each other at different salinity levels (Fig.1). Our results are in agreement with Khodarahmpour et al., (2012), which reported that germination percentage and germination rate are linearly decreased by decrease in osmotic potential of NaCl solution and the maximum germination rate and percentage are obtained at zero level of applied salts. Cicek & Cakirlar (2002) noted that the main reason of reducing germination rate are the toxic effects of certain ions and higher concentration of salt disturbs the water potential in the medium which hinders water absorption by germinating seeds.

The mean GI decreased with increased the salinity levels. The lower GI value denotes a lower percentage and rate of germination (Kader, 2015). At 150 mM NaCl the lowest value was recorded for 73E840, respectively 386, while for A9E0660 and B5E0055 GI values were not differ significantly ($p \leq 0.05$) from each other (Fig.1). Similar result was also observed by Zhang & Zhao (2011), Hoque et al. (2014).

The TGI showed the highest values at 0 mM NaCl and the lowest at 150 mM NaCl. At the highest concentration of salinity stress TGI value varied

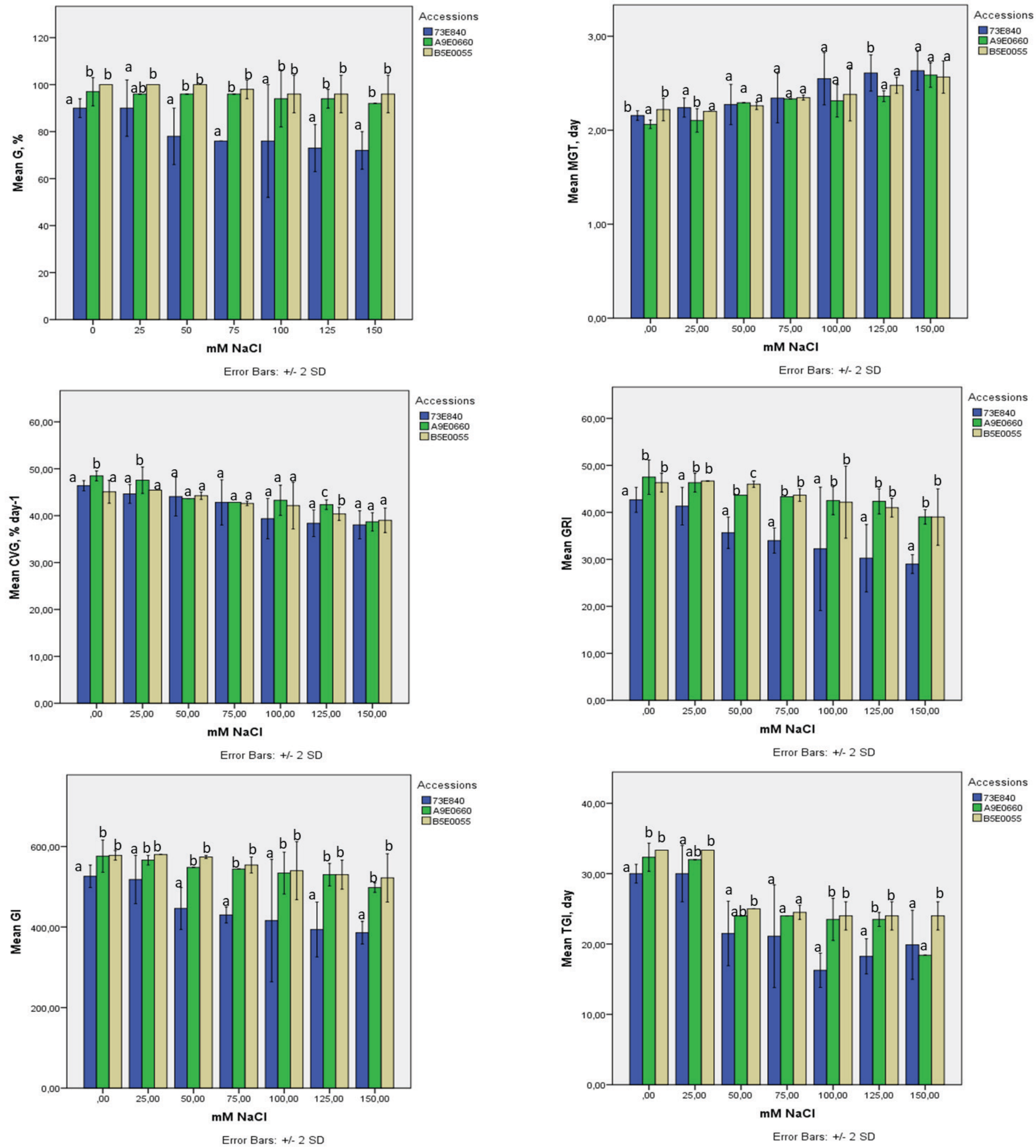

Figure 1. Effect of different salinity levels on germination percentage (G, %), coefficient of velocity of germination (CVG, % day^{-1}), germination rate index (GRI), germination index (GI), mean germination time (MGT, day) and Timson germination index (TGI) for three maize genotypes. Data presented are mean ± SD (Standard deviation). Different letters indicate a significant difference among genotypes according to Duncan´s multiple range test at 0.05 level.

between 18 and 24. The B5E0055 genotype differed significantly from the other two genotypes (Fig.1).

As a salt-sensitive crop, shoot growth in maize is strongly inhibited in the first phase of salt stress (Khayatnezhad & Gholamin, 2011; Hesa, 2011; Farooq et. al., 2015). The reduction being strongest particularly at the higher level of salt treatment compared to control. The suppression of shoot and root growth may either be due to osmotic reduction in water availability or to extreme accumulation of ions, known as specific ion effect (Sozharajan & Natarajan, 2016).

In our study the greatest inhibition in shoot length was recorded for 73E840 at salinity level from 25 to 100 mM NaCl. At the highest NaCl concentration, B5E0055 showed statistically proven the highest shoot length value in compare with other two genotypes, while A9E0660 had the lowest value, respectively. The root length ranged from 2.78 cm to 9.41 cm. At high salinity concentration, 73E840 showed the greatest reduction, following from B5E0055, respectively. A significant inter-genotype variation also was observed under studied salt concentrations.

Giaveno et al. (2007) reported that shoots are more affected than the root system, owing to an emergency mechanism that intensifies nutrient and water uptake to prevent plant death in stressful conditions. In the opposite Yohannes & Abraha (2013) in their study found that salt stress inhibits radicle growth more than primary shoot growth. In our study decrease in shoot length was more pronounced compared to roots for 73E840 and A9E0660, while for B5E0055 decrease in root length was more pronounced compared to shoot length. B5E0055 also showed the significant increase in Sh/R ration in compare with the other two genotypes as well as with compare with the control variant. There were significant differences among genotypes for Sh/R ration at different salt concentrations (Figure 2).

Mean seedling length ranged from 5.10 cm to 15 cm. Of the all genotypes, A9E0660 showed the highest seedling length at all salt levels, but it was differ significantly from other two genotypes only at 25 mM, 50 mM, 100 mM and 150 mM NaCl solutions (Fig.2).

Duncan multiple range test also showed that there were significant differences among genotypes

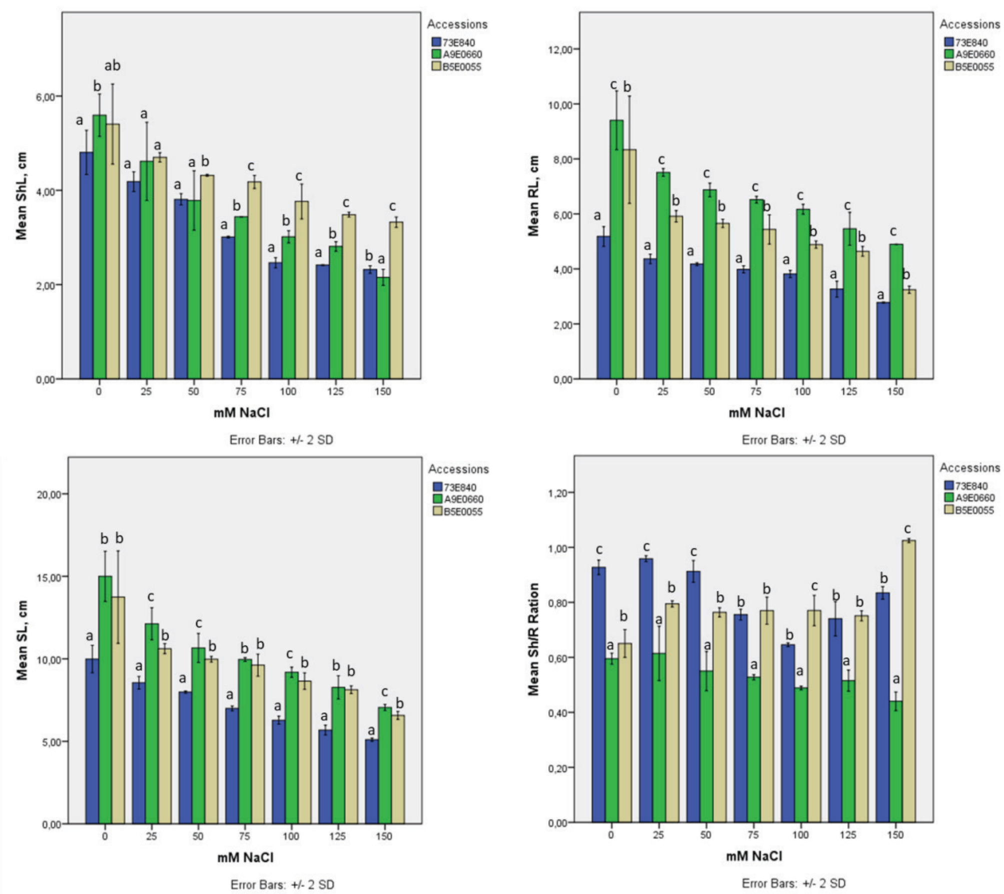

Figure 2. Effect of different salinity levels on shoot length (ShL, cm), root length (RL, cm), seedling length (SL, cm) and shoot/root ration (Sh/R, cm) for three maize genotypes. Data presented are mean ± SD (Standard deviation). Different letters indicate a significant difference among genotypes according to Duncan´s multiple range test at 0.05 level.

for root and shoot fresh and dry weight. Figure 3 showed that fresh and dry shoot and root weights of all genotypes were strongly and negatively affected by increasing salt treatments. At the highest concentration of NaCl (150 mM) the greatest reduction in fresh shoot weight was recorded for 73E840 and A9E0660, while the lowest for B5E0055. A9E0660 and B5E0055 showed statistically proven the highest dry shoot weight values in compare with 73E840. Among the genotypes, the lowest fresh and dry root weight were recorded for B5E0055 at all salinity levels. According to Nuurismaan et al. (2018) the combination of osmotic and specific ion effects of Cl- and Na+ result of salinity that are the reason of reducing the shoot dry weight. Salt stress increased the metabolic energy cost and reduced carbon gain resulting decreased in root dry weight.

Significant negative effect of salinity on shoot and root length, shoot and root fresh and dry weight of maize were found from other researchers (Gholamin & Khayatnezhad, 2010; Khayatnezhad et al., 2010; Yohannes & Abraha, 2013; Turan et al., 2010; Carpici et al., 2010; Khodarahmpour et al., 2012; Khayatnezhad & Gholamin, 2011; Sozharajan & Natarajan, 2016; Diriba et al., 2016; Ahmed et al., 2017; Nuurismaan et al., 2018).

The salt tolerance index is a reliable criterion for preliminary selection in early growth stage of maize (Carpici et al., 2010). In table 1 are presented the salt tolerant index of studied genotypes at germination and early seedling stage. The salt tolerance indices of accessions decreased with increase of salt concentration. Our results were in line with the findings of Khayatnezhad & Gholamin (2011).

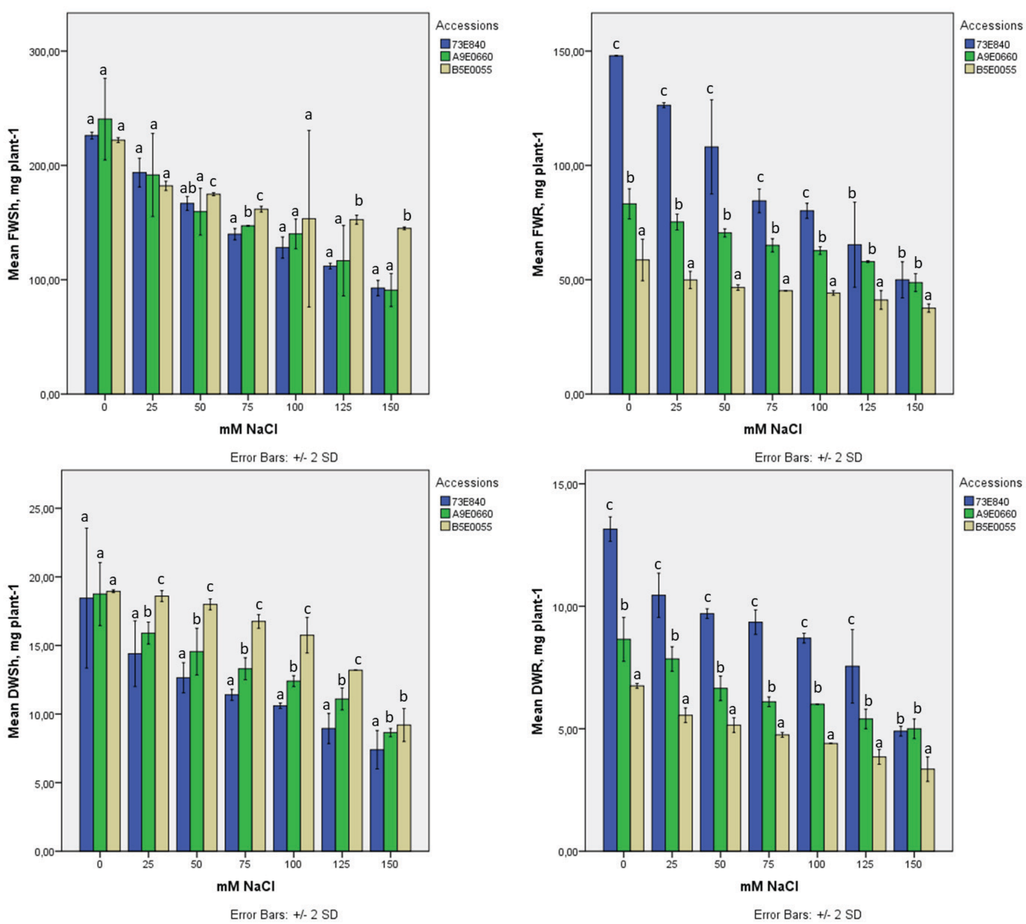

Figure 3. Effect of different salinity levels on fresh shoot weight (FWSh, mg plant^{-1}) and fresh root weight (FWR, mg plant^{-1}), dry shoot weight (DWSh, mg plant^{-1}) and dry root weight (FWR, mg plant^{-1}) for three maize genotypes. Data presented are mean ± SD (Standard deviation). Different letters indicate a significant difference among genotypes according to Duncan´s multiple range test at 0.05 level.

There were recorded the more significant genotypic variation in the seedling stage in compare with the germination stage. At the germination stage genotypes showed high to very high tolerance. The salt tolerant index varied from 80% (for 73E840 at 150 mM NaCl) to 100% (for A9E0660 and B5E0055 at 25 mM NaCl, for B5E0055 at 50 mM NaCl, respectively). A9E0660 and B5E0055 demonstrated a better tolerance to salt stress than 73E840. At the levels of salinity from 25 to75 mM NaCl, shoot tolerant index ranged between 61.48% for A9E0660 (at 75 mM NaCl) and 87.10 % for 73E840 (at 25 mM NaCl). The genotypes showed high tolerance to shoot growth. At salinity concentrations 100-150 mM NaCl, B5E0055 showed a better tolerance to salt stress than other both genotypes. At the highest salinity level (150 mM NaCl), A9E0660 was characterized as genotype with low tolerance to shoot growth, while 73E840 with medium and B5E0055 with high tolerance.

There were recorded significant differences between studied genotypes at 25, 50, 100 and 150 mM NaCl salinity levels for root salinity tolerant index. Also, it was clearly determined that B5E0055 significantly differed from other both genotypes at salinity stress with 75 and 125 mM NaCl. At the highest salinity level B5E0055 showed low tolerance to root growth, while A9E0660 and 73E840 medium tolerance. Total seedling tolerant index varied from 47% for A9E0660 at 150 mM NaCl to 85.63% for 73E840 at 25 mM NaCl. At salinity stress from 25 to 100 mM solution of NaCl, genotypes showed high tolerance to seedling growth, except of 73E840, that demonstrated very high tolerance at the lowest salinity level. At high stress (125-150 mM NaCl) genotypes showed medium tolerance. The proven higher tolerant seedling index was registered for 73E840 at 150 mM NaCl.

In general the investigated maize genotypes were significantly more tolerant to salt stress at germination than at early seedling growth stage (Table 1). Our results are in agreement with the results obtained from Rahman et al. (2000) and Carpıcı et al. (2009).

Table 1. The salt tolerant indices of studied maize genotypes at germination and early seedling stage

Accession number	Salinity levels					
	25 mM NaCl	50 mM NaCl	75 mM NaCl	100 mM NaCl	125 mM NaCl	150 mM NaCl
GSTI						
73E840	100.00bA	86.67aA	84.44aA	84.44aA	81.11aA	80.00aA
A9E0660	98.97aA	98.97aB	98.97aB	96.91aA	96.91aB	94.85aB
B5E0055	100.00aA	100.00aB	98.00aB	96.00aA	96.00aB	96.00aB
ShSTI						
73E840	87.10fA	79.29eB	62.64dA	51.30cA	50.26abA	48.28aB
A9E0660	82.48dA	67.65cA	61.48cA	53.89bA	50.22bA	38.52aA
B5E0055	86.96eA	79.93dB	77.34dB	69.66cB	64.48bB	61.52aC
RSTI						
73E840	84.27fC	80.60eC	76.93dB	73.65cC	63.03bB	53.67aC
A9E0660	79.85fB	73.10eB	69.32dB	65.60cB	58.05bAB	52.05aB
B5E0055	70.96eA	67.85dA	65.21dA	58.61cA	55.67bA	38.93aA
SSTI						
73E840	85.63fB	79.97eB	70.06dB	62.89cA	56.89bAB	51.08aB
A9E0660	80.83fA	71.07eA	66.40dA	61.23cA	55.13bA	47.00aA
B5E0055	77.26fA	72.60eB	69.98dB	62.95cA	59.13bB	47.82aA

GSTI -germination salt tolerant index, ShSTI-shoot salt tolerant index, RSTI- root salt tolerant index, SSTI- total seedling salt tolerant index

Subscripts (a-d) with different letters in the column indicated significant difference among mean ($p \leq 0.05$, using Duncan multiple range test)

Subscripts (A-B) with different letters in the row indicated significant difference among mean ($p \leq 0.05$, using Duncan multiple range test)

Genetic variability for salt tolerance was reported in maize by Khan et al. (2003), Radić et al. (2007), Khayatnezhad & Gholamin (2011), Huqe et al. (2021). Giaveno et al. (2007) indicated the presence of genetic variability for germination, but no association between germination and early seedling growth under salt stress.

The Pearson phenotypic correlation coefficients for 14 of studied parameters are presented in Table 2. The results indicated that the most of characteristics had a positive significant correlation with each other. MGT correlated significantly negative with all traits except with Sh/R ration, where correlation was non-significantly positive. It was also observed that Sh/R ration correlated significantly only with RL (-0,520**), SL (-0,275*) and FWR (0,291*). The associations of GRI (r=-0,038, r=-0.079), GI (r=-0,131, r=-0.189), TGI (r=0,221, r=0.209), RL (r=0,027, r=0.081), and SL (r=0,129, r=0.17) with FWR and DWSh were non-significant. Diriba et al. (2016) also found positive and significant correlation between germination percentage (GP) and root length and noted that the positive significant correlation between germination rate and root length as well as relationship between shoot length and root length indicates that maize genotypes responded to salt stress more or less in a similar manner. A significant and strong positive correlation between shoot

Table 2. Pearson correlation coefficients between studied 14 germination and seedling characteristics in 3 maize genotypes

	G	MGT	CVG	GRI	GI	TGI
G	1					
MGT	-0.473**	1				
CVG	0.447**	-0.996**	1			
GRI	0.935**	-0.745**	0.727**	1		
GI	0.977**	-0.650**	0.628**	0.988**	1	
TGI	0.619**	-0.791**	0.800**	0.766**	0.731**	1
ShL	0.560**	-0.800**	0.808**	0.723**	0.682**	0.877**
RL	0.624**	-0.704**	0.710**	0.770**	0.716**	0.674**
SL	0.643**	-0.792**	0.799**	0.806**	0.754**	0.802**
Sh/R Ration	-0.212	0.037	-0.032	-0.23	-0.197	0.123
FWSh	0.461**	-0.816**	0.827**	0.655**	0.600**	0.824**
FWR	-0.265*	-0.422**	0.431**	-0.038	-0.131	0.221
DWSh	0.605**	-0.799**	0.797**	0.769**	0.722**	0.789**
DWR	-0.342**	-0.442**	0.459**	-0.079	-0.189	0.209

	ShL	RL	SL	Sh/R Ration	FWSh	FWR	DWSh	DWR
ShL	1							
RL	0.726**	1						
SL	0.886**	0.962**	1					
Sh/R Ration	0.191	-0.520**	-0.275*	1				
FWSh	0.951**	0.657**	0.820**	0.233	1			
FWR	0.278*	0.027	0.129	0.291*	0.460**	1		
DWSh	0.913**	0.705**	0.837**	0.054	0.866**	0.215	1	
DWR	0.291*	0.081	0.170	0.214	0.473**	0.962**	0.249*	1

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Germination percentage (G), coefficient of velocity of germination (CVG), germination rate index (GRI), mean germination time (MGT), germination index (GI) and Timson germination index (TGI), the shoot length (ShL), root length (RL), shoot/root ration (Sh/R Ration), fresh weigh of shoot (FWSh), fresh weigh of root (FWR), dry weight of shoot (DWSh) and dry weight of root (DWR) length, shoot fresh weight, root dry weight and shoot dry weight under both control and salt stress conditions was found from Huqe et al. (2021). Aliu at al. (2015) obtained negative and significant correlation between mean germination time, final germination percentage and germination index (Table 2.).

Linear regression analysis was implemented to find the relationship between salinity and studied germination and seedling characteristics. Linear regression showed very weak negative significant relationship between salt stress and mean germination (R^2=0.106, p=0.009). A strong negative significant relationship was noted between salt stress and CVG and between salt stress and TGI, indicating that 74.31% of CVG variance and 60.1% from TGI variance could be predicted from salinity. Strong significant positive relationship was examined between mean germination time and salinity (R^2=0.732, p=0.012). GRI and GI had weak significant relationship with salinity (R^2=0.338, p=0.000 and R^2=0.243, p=0.000) (Fig. 4).

Linear regression showed very strong negative significant relationship between salt stress and ShL (R^2=0.771, p=0.000), SL (R^2=0.634, p=0.000), FWSh (R^2=0.795, p=0.000) and DWSh (R^2=0.726, p=0.009). Moderate significant negative relationship was examined between salinity and RL (R^2=0.442, p=0.000). The relationship between salinity and FWR and DWR was weak but significant (R^2=0.322, p=0.000; R^2=0.377, p=0.000 respectively), while non-significant very weak relationship was recorded between salinity and Sh/R ration (R^2=0.14, P=0.449) (Fig.5).

Very strong significant positive relationships were examined between G, GRI (R^2=0.875, p=0.000) and GI (R^2=0.954, p=0.000). Germination had strong negative significant association with SL (R^2=0.634, p=0.000), FWSh (R^2=0.795, p=0.000) and DWSh (R^2=0.796, p=0.000).The relationship between G and MGT (R^2=0.222, p=0.000) was weak and significantly negative. Weak significant positive relationships were recorded for G and CVG (R^2=0.200, p=0.000), TGI (R^2=0.383, p=0.000), ShL (R^2=0.314, p=0.000), RL (R^2=0.389, p=0.000), while negative between G and FWR (R^2=0.322, p=0.04) and DWR (R^2=0.376, p=0.006). Very weak non-significant re-

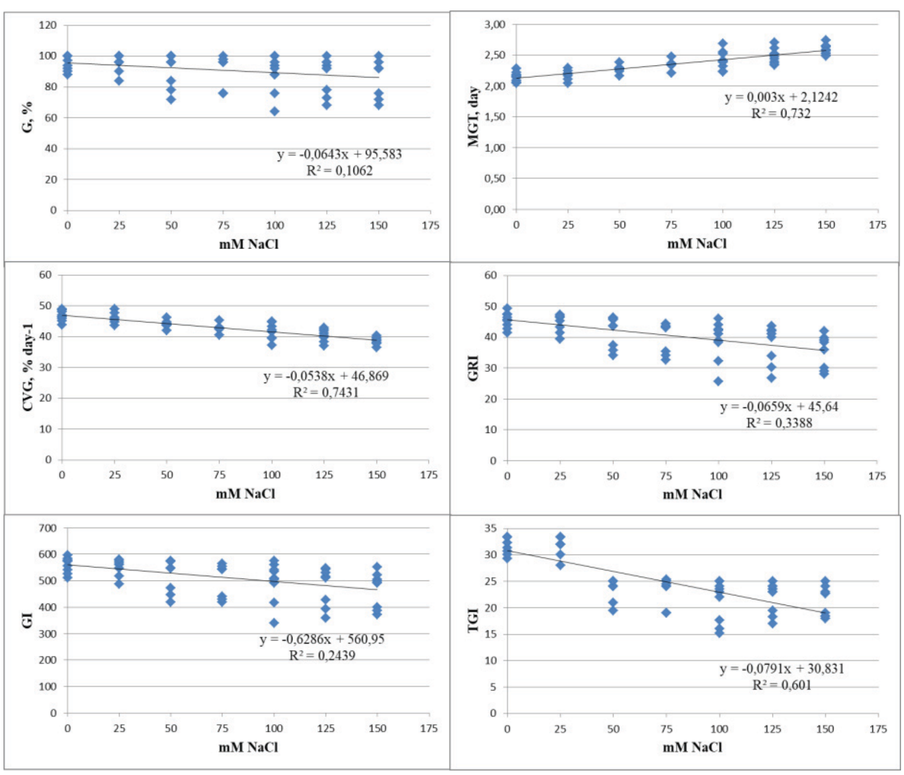

Figure 4. Relationship between salinity (mM NaCl) and germination (G), coefficient of velocity of germination (CVG, % day^{-1}), germination rate index (GRI), germination index (GI), mean germination time (MGT, day) and Timson germination index (TGI) in three maize genotypes

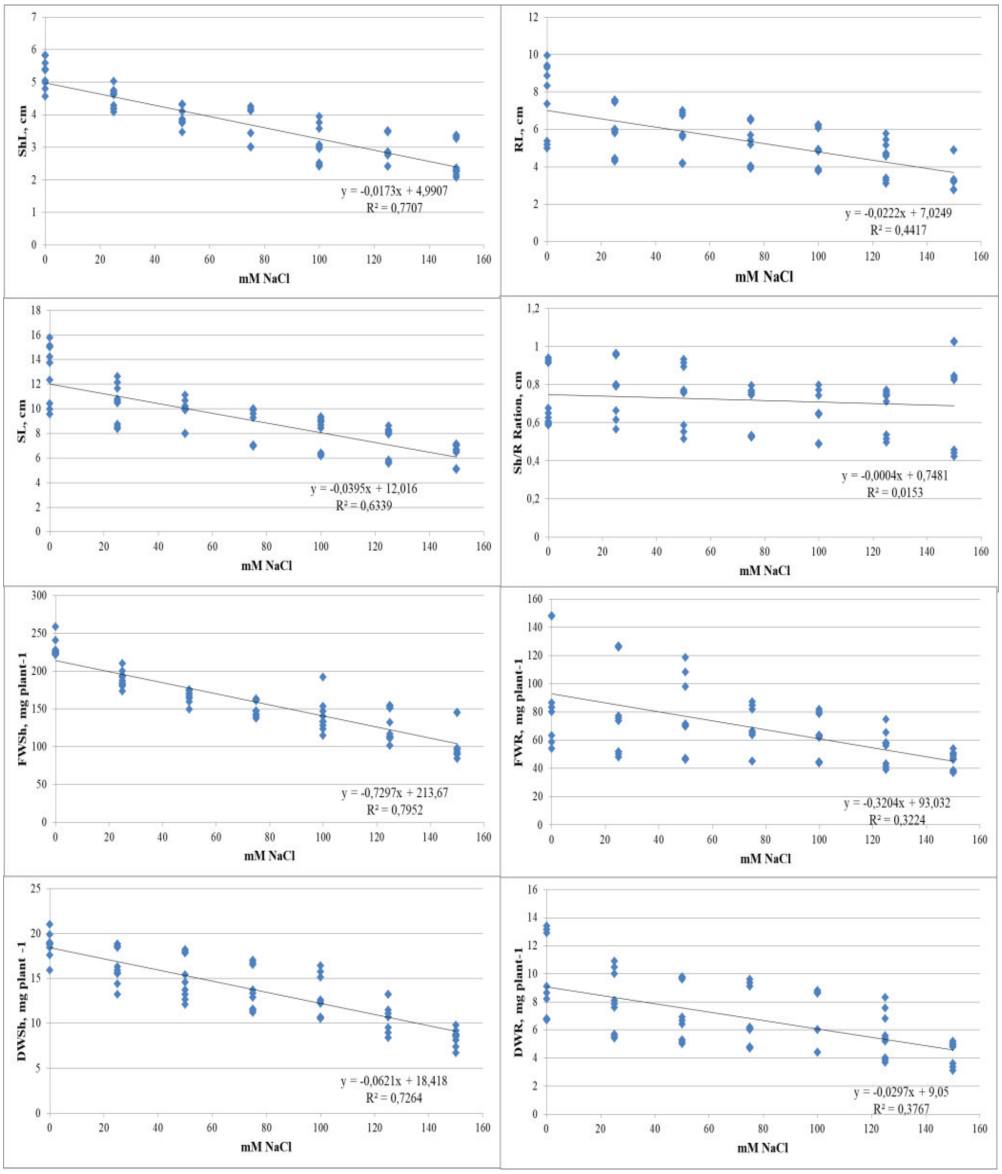

Figure 5. Relationship between salinity (mM NaCl) and shoot length (ShL, cm), root length (RL, cm), seedling length (SL, cm), shoot/root ration (Sh/R, cm), fresh shoot weight (FWSh, mg plant^{-1}) and fresh root weight (FWR, mg plant^{-1}), dry shoot weight (DWSh, mg plant^{-1}) and dry root weight (FWR, mg plant^{-1}) in three maize genotypes

lationship was investigated between germination and Sh/R ration (R^2=0.04, p=0.09) (Fig. 6, Fig. 7).

CONCLUSION

The studied three Bulgarian corn landraces under salinity stress showed that germination and seedling growth characteristics were affected in different degree by salinity and that the effect was genotypically specific. The salt stress inhibited shoot growth more than root growth in 73E840 and A9E0660 genotypes, while in B5E0055 roots were more affected than the shoots. In general the investigated maize genotypes were significantly more tolerant to salt stress at germination than at early seedling growth stage. At the germination stage genotypes showed high to very high tolerance to salt stress. At the highest salinity level (150 mM NaCl), A9E0660 showed the low tolerance to shoot growth, while 73E840 medium and B5E0055 high tolerance. B5E0055 had low tolerance to root growth, while

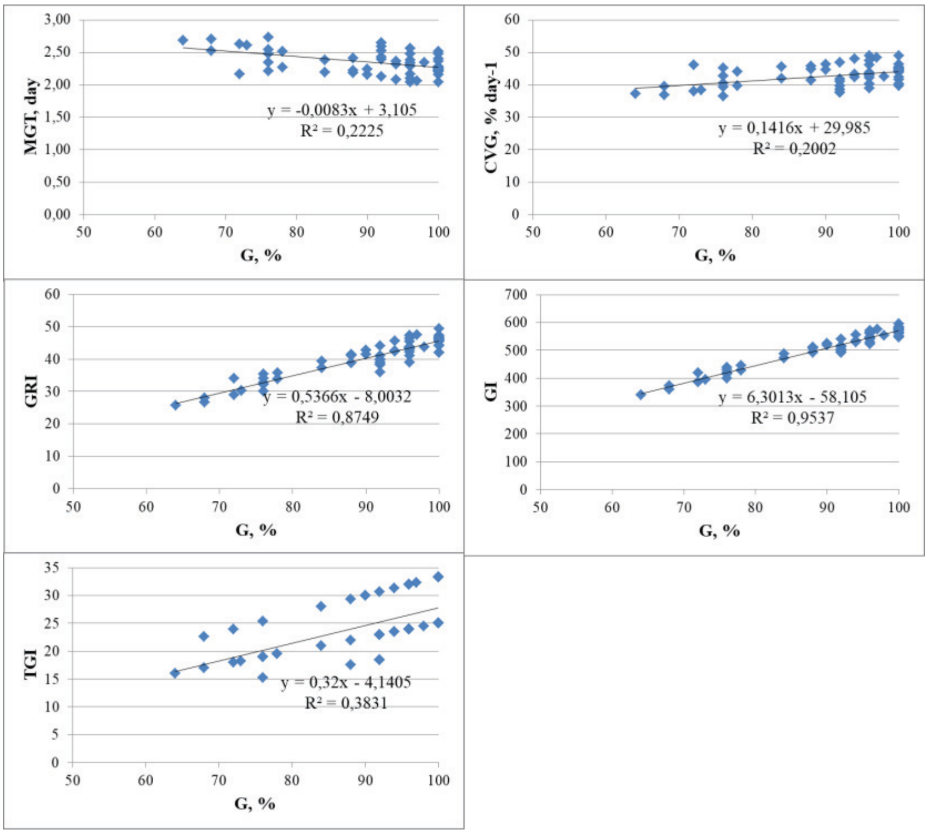

Figure 6. Relationship between germination (G, %) and coefficient of velocity of germination (CVG, % day^{-1}), germination rate index (GRI), germination index (GI), mean germination time (MGT, day) and Timson germination index (TGI) in three maize genotypes

A9E0660 and 73E840 medium tolerance. A strong significantly negative relationship was established between salt stress and CVG, TGI, ShL, SL, FWSh and DWSh, while the relationship between salinity and MGT was strong and significantly positive. The highest positive relationship was determined between G, GRI and GR, while the highest negative between G and SL, FWSh, and DWSh.

Further study is needed to test the different maize genotypes at varying degree of NaCl salinity.

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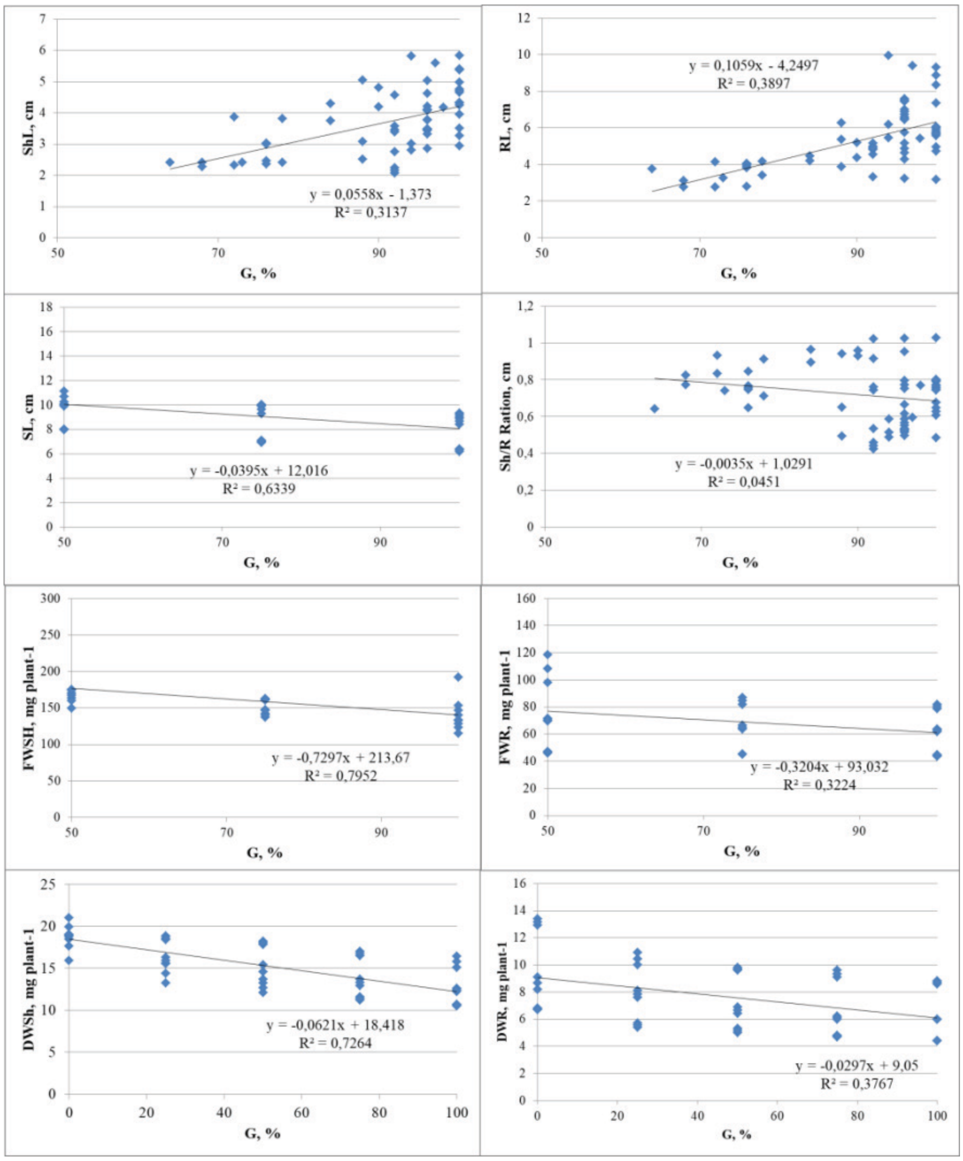

Figure 7. Relationship between germination (G, %) and shoot length (ShL, cm), root length (RL, cm), seedling length (SL, cm), shoot/root ration (Sh/R, cm), fresh shoot weight (FWSh, mg plant^{-1}) and fresh root weight (FWR, mg plant-1), dry shoot weight (DWSh, mg plant^{-1}) and dry root weight (FWR, mg plant^{-1}) in three maize genotypes

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