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Response of seven tomato (*Lycopersicon esculentum* Mill.) cultivars produced in Benin to salinity stress at young plant stage

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ABSTRACT

In this study, we evaluated the salt resistance level of seven tomato cultivars Akikon, Tounvi, Thorgal, F1 Mongal, Padma, Petomech and TLCV15 at young plant stage. The experiment was laid out as a Randomized Complete Design (RCD) with four replications in a greenhouse. Three-week old plants from the seven cultivars were submitted in pots containing a mixture of potting soil and sand to five NaCl concentrations: 0; 30; 60; 90 and 120 mM NaCl corresponding respectively to an electric conductivity of 0.221; 3.827; 6.47; 10.56 and 14.02 $dS.m^{-1}$ by irrigation every two days. Plant growth parameters were evaluated after two weeks. Salt effect caused a reduction of young plant growth whatever the growth parameter considered with a significant difference among cultivars. Growth of cultivars Padma, Akikon and Petomech was more affected by salt stress with two or three growth parameters significantly reduced at 30 mM NaCl whereas no growth parameter was significantly affected at less than 60 mM NaCl for cultivars Thorgal and Tounvi. Thus, cultivars Akikon, Petomech and Padma appeared as the most sensitive to salt stress. In contrast, cultivars Tounvi and Thorgal appeared as the most salt-resistant. Cultivars F1 Mongal and TLCV15 had intermediary behavior.

Introduction

Salt stress is one of the major environmental constraints limiting agricultural productivity (Rozema and Flower, 2008; Abdel-Latef, 2010). More than 800 million hectares are affected by high salt concentration in the substrate (Munns and Tester, 2008) including half of irrigated areas (Wang et al., 2003). Plant growth is compromised by salinity at all developmental stages, but sensitivity varies greatly at different stages (M'barek et al., 2001; Mallek-Maalej et al., 2004). Crop production in saline areas largely depends upon successful germination, seedling emergence and establishment and efficient reproductive phase (Bartels and Sunkar, 2005). Although most and eventually all cultivated plants are glycophyte species, their overall responses to increasing NaCl dose appear to be species-specific (Wouyou et al., 2016 and 2017; Kpinkoun et al., 2018 and 2019; Kinsou et al., 2019). Moreover, within a given species, a substantial variation in salt sensitivity may occur among cultivars (Ould Mohandi et al., 2011; Manaa et al., 2011).

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetable plants in the world. It is consumed fresh, cooked or processed: through canning, processed into juice, pulp, paste, or a variety of sauces (Zhang et *al*. 2016). According to FAO (2010), tomato is grown in 170 countries under various climates. The climate of Benin is favorable for its farming throughout the country. The South of Benin which provides the highest production, about 80% of the national production included the coastal zone which is most strongly affected by salinity (Ezin et al., 2012). Our preliminary data (not yet published) indicate that water used by market gardeners in some areas including non-coastal regions have conductivities and salinities higher than the accepted standards for crop irrigation. It was reported that the salts presented in soil and irrigation water negatively affected tomato seed germination, plant growth and consequently reduced yields (Ezin et al., 2012). It is also well known that a large genetic variation of tolerance to salt level exists among tomato genotypes (Ould Mohandi et al., 2011; Manaa et al., 2011). However, despite a substantial amount of literature on response of tomato to salinity stress, little information is available on salt resistance of tomato cultivars produced in Benin. In our previous study, we have demonstrated that there is a variability of relative salt-stress resistance among the same tomato cultivars at the germination stage (Kinsou et al., 2019). Since salt-resistance at the germination stage is not necessarily correlated with salinity resistance at subsequent developmental stages, the present study aims at evaluating NaCl stress effects on young plant growth of the same seven tomato cultivars grown in Benin.

Materials and methods

Plant material

Seven cultivars including two local cultivars (Akikon and Tounvi) and five improved varieties (F1 Mongal, Petomech, Padma, Thorgal and TLCV15) were used. Seeds of cultivars Akikon, Tounvi and TLCV15 were provided by the National Institute of Agricultural Research of Benin (INRAB) whereas those of the four other cultivars were bought from the company 'Bénin Semences'.

Experimental conditions

The experiment was carried out in a screen house at Center of Agricultural Research of Agonkanmey (Abomey-Calavi, Republic of Benin) from January to march 2018. Plants were cultivated at a temperature of 26°C/22 day/night with natural light and a relative humidity of 55%. Seeds were incubated for germination in tanks filled with potting moistened soil for two weeks.

Young seedlings were then transferred to earthen small pots of 5.8 cm diameter and 6 cm height containing a mixture of potting soil and sandy loam soil 50:50 (one plant/pot) and cultivated for one week before stress application. Plants of the five cultivars were submitted to salt stress in earthen big pots of 11.3 cm diameter and 14 cm height filled with 3 kg of a same mixture. Treatments consisted of plant irrigation every two days with 100 ml/pot of salt solution of 0; 30; 60; 90 or 120 mM NaCl corresponding respectively to an electric conductivity of 0.221; 3.827; 6.47; 10.56 and 14.02 $dS.m^{-1}$ determined by a conductimeter (VWR; CO310). The experiment was laid out as a Completely Randomized Design (CRD) with two factors and four replications. The two considered factors were cultivars (with five levels) and salt-concentrations (with five levels).

Experiment evaluation

Plants height, leaf number, leaf area, root length, shoot and root fresh and dry matters were measured before stress application (X_0); they were measured again after 2 weeks of treatment (X_1). For dry matter determination, fresh samples were transferred to an oven at 80 °C for 72 hours. Plants Relative Growth was calculated for each growth parameter as $(X_1 - X_0)/ X_0$.

Statistical analysis

All the experiments were performed twice independently. For all parameters, each value was presented in the form of mean ± standard error with a reading of four independent samples per treatment. The analysis of the main effects of stress intensity and/or cultivars was based on a one-way and two-ways analysis of variance (ANOVA). The disparities among the means were compared through Students, Newman and Keuls (SNK) test. All statistical analyses were performed by GenStat discovery (GenStat, 2003).

Results

Overall behavior of the seven tomato cultivars with regard to salt stress

The two-ways analysis of variance revealed a significant effect of salt stress for all the growth parameters taken into account, a significant disparity among cultivars and a significant interaction between salt-stress intensity and cultivars except for leaf number (Table 1).

Response of plant aerial part to salt stress

Plant height

Salt stress reduced clearly plant height in several cultivars tested (Fig. 1). NaCl induced a significant ($p \leq 0.001$) reduction of relative plant height growth in all cultivars except cv. Thorgal (Fig. 2). The reduction was significant from 30 mM NaCl for cultivars Akikon and F1 Mongal whereas it was significant from 90 mM for cultivars Padma and TLCV15. These results showed that salt effect on plant height inhibition was more accentuated in cultivars Akikon and F1 Mongal than the five other cultivars among whom Thorgal was the less affected.

Leaf number

Fig. 3 presents NaCl effect on relative leaf number growth after two weeks of stress. NaCl induced a significant ($p \leq 0.001$) reduction of RLNG only in cultivars Tounvi, Akikon, Padma and F1 Mongal. The reduction was significant from 30 mM NaCl for cultivars Akikon and Padma whereas it was significant at 120 mM for cultivar Tounvi. These results indicated that salt effect on leaf number inhibition was more accentuated in cultivars Akikon and Padma than the five other cultivars.

Shoot fresh mass

NaCl induced a significant ($p \leq 0.001$) reduction of relative shoot fresh mass growth in all cultivars (Fig. 4). However the reduction was significant from 30 mM for cultivars Akikon and Petomech whereas it was significant from 90 mM for cultivars Tounvi, Padma, Thorgal and TLCV15. These results indicated that salt effect on shoot fresh mass inhibition was more accentuated in cultivars Akikon and Petomech than the five other cultivars.

Shoot dry mass

Fig. 5 presents NaCl effect on relative shoot fresh mass growth after two weeks of stress. NaCl induced a significant ($p \leq 0.001$) reduction of shoot fresh mass in all cultivars except for TLCV 15. Among the six cultivars significantly affected, Akikon and Padma were the most affected. These results indicated that salt effect on shoot dry mass inhibition was more accentuated in cultivars Akikon and Padma than the five other cultivars.

Leaf area

NaCl induced a significant ($p \leq 0.001$) reduction of relative leaf area growth in all cultivars (Fig. 6). The reduction was significant from 30 mM NaCl and from 60 mM NaCl respectively for cultivars TLCV15 and Padma whereas it was significant only at 120 mM NaCl for cultivars F1 Mongal and Petomech. Among the seven cultivars, cv. TLCV15 followed by Padma were the most affected.

Response of roots to salt stress

Root length

NaCl induced a significant ($p \leq 0.001$) reduction of relative root length growth except for Padma and Thorgal (Table 2). The reduction was significant from 30 mM NaCl for cultivar TLCV 15 whereas it was significant only at 120 mM for cultivar Petomech. These results indicated that salt effect on root length inhibition was more accentuated in cultivars TLCV15.

Root fresh mass

NaCl induced a significant ($p \leq 0.001$) reduction of relative root fresh mass growth in all cultivars

(Table 3). The reduction was significant from 30 mM NaCl for cultivars Padma and Petomech whereas it was significant only at 120 mM NaCl for cultivar TLCV15. These results revealed that among the seven cultivars, cvs Padma and Petomech were the most affected and TLCV15 the less affected.

Root dry mass

Table 4 presents NaCl effect on root relative dry mass growth after two weeks of stress. NaCl induced a significant (p≤0.001) reduction of RRDMG in all cultivars except cv. TLCV15. The reduction was significant from 30 mM NaCl for cultivar Petomech whereas it was significant at 120 mM for cultivars Padma and Thorgal. These results indicated that salt effect on root dry mass inhibition was more accentuated in cultivar Petomech and less accentuated in cv. TLCV15 than the five other cultivars.

Table 1. Results of two ways analysis of variance for different growth parameters for seven tomato cultivars cultivated in the presence of different NaCl concentrations

Growth parameter	Stress	Cultivar	Interaction Stress × Cultivar
PH	41.968***	166.772***	9.978***
RL	177.038***	46.39***	97.203***
SFM	6281.389***	8708.313***	1224.122***
RFM	4464.569***	14230.508***	2113.59***
SDM	5401.103***	8876.212***	1803.598***
RDM	5274.100***	17311.236***	3942.413***
LN	12.306***	5.767***	3.244 ns
LA	1149.517***	4159.674***	276.982***

*** : difference significant at p≤0.001; ns : difference non significant.

Table 2. Effect of different NaCl concentrations (0, 30; 60; 90 and 120 mM) on root relative length growth of seven tomato cultivars after two weeks of stress : *Values are means*±SE (n = 4)

Cultivars	NaCl concentrations (mM)				
	0	30	60	90	120
AKIKON	7.787±0.867a	6.096±0.274a	3.616±0.35b	2.79±0.079b	2.06±0.256b
F1 MONGAL	6.111±0.389a	5.183±0.299ab	4.478±0.326bc	3.5±0.425cd	2.45±0.295d
PADMA	4.12±0.606a	4.026±0.436a	3.229±0.597a	2.792±0.333a	2.489±0.421a
PETOMECH	5.244±0.264a	3.607±0.54ab	3.3407±0.842ab	3.467±0.428ab	2.755±0.128b
THORGAL	3.484±0.886a	3.758±0.631a	4.032±0.731a	3.222±0.837a	4.274±0.831a
TLCV 15	5.195±0.331a	2.811±0.466b	2.286±0.178b	2.933±0.617b	2.219±0.228b
TOUNVI	6.774±0.742a	5.232±0.381ab	4.351±0.244b	3.524±0.377bc	2.298±0.28c

Means with different letters within a line were significantly different (p≤0.001)

Table 3. Effect of different NaCl concentrations (0, 30; 60; 90 and 120 mM) on root relative length growth of seven tomato cultivars after two weeks of stress : *Values are means* ± SE (n = 4).

Cultivars	NaCl concentrations (mM)				
	0	**30**	**60**	**90**	**120**
F1 MONGAL	19.831±2.573a	13.242±1.845ab	11.05±1.229bc	8.485±1.317bc	5.938±0.262c
PADMA	17.347±2.605a	8.5485±1.683b	11.1±2.071ab	4.609±0.829b	3.844±0.736b
PETOMECH	11.073±1.225a	6.467±1.339b	6.13±1.185b	5.067±0.805b	2.13±0.531b
THORGAL	12.167±1.252a	11.125±0.541ab	8.333±0.872abc	7.292±1.566bc	5.667±0.76c
TLCV 15	6.521±0.957a	4.318±0.684ab	4.4571±0.981ab	3.575±0.78ab	2.361±0.418b
TOUNVI	36.277±3.239a	29.769±3.23ab	22.277±0.943bc	17.023±2.837c	12.777±2.325c

Means with different letters within a line were significantly different (p≤0.001).

Table 4. Effect of different NaCl concentrations (0, 30; 60 ; 90 and 120 mM) on root dry mass of seven tomato cultivars after two weeks of stress : *Values are means* ± SE (n = 4).

Cultivars	NaCl concentrations (mM)				
	0	**30**	**60**	**90**	**120**
AKIKON	63.182±11.529a	41.273±9.411ab	32.091±6.25ab	26.727±6.008b	17.636±1.971b
F1 MONGAL	25.625±2.043a	20±2.639ab	16±0.986b	12.5±0.818b	11.625±3.027b
PADMA	18.609±2.343a	16.348±3.609ab	12.043±3.359ab	8.217±1.304ab	5.826±0.988b
PETOMECH	8.92±0.463a	5.36±0.866b	5±0.636b	5.04±0.601b	2.96±0.778b
THORGAL	16.8±2.462a	15±1.883ab	14.2±2.354ab	11.267±2.085ab	7.533±0.969b
TLCV 15	6.15±1.882a	4.6±0.497a	5.4±0.983a	4.45±0.878a	4.35±0.801a
TOUNVI	34.428±3.987a	23.571±4.032ab	21.286±1.766bc	16.928±0.863bc	10.357±0.756c

Means with different letters within a line were significantly different (p≤0.001).

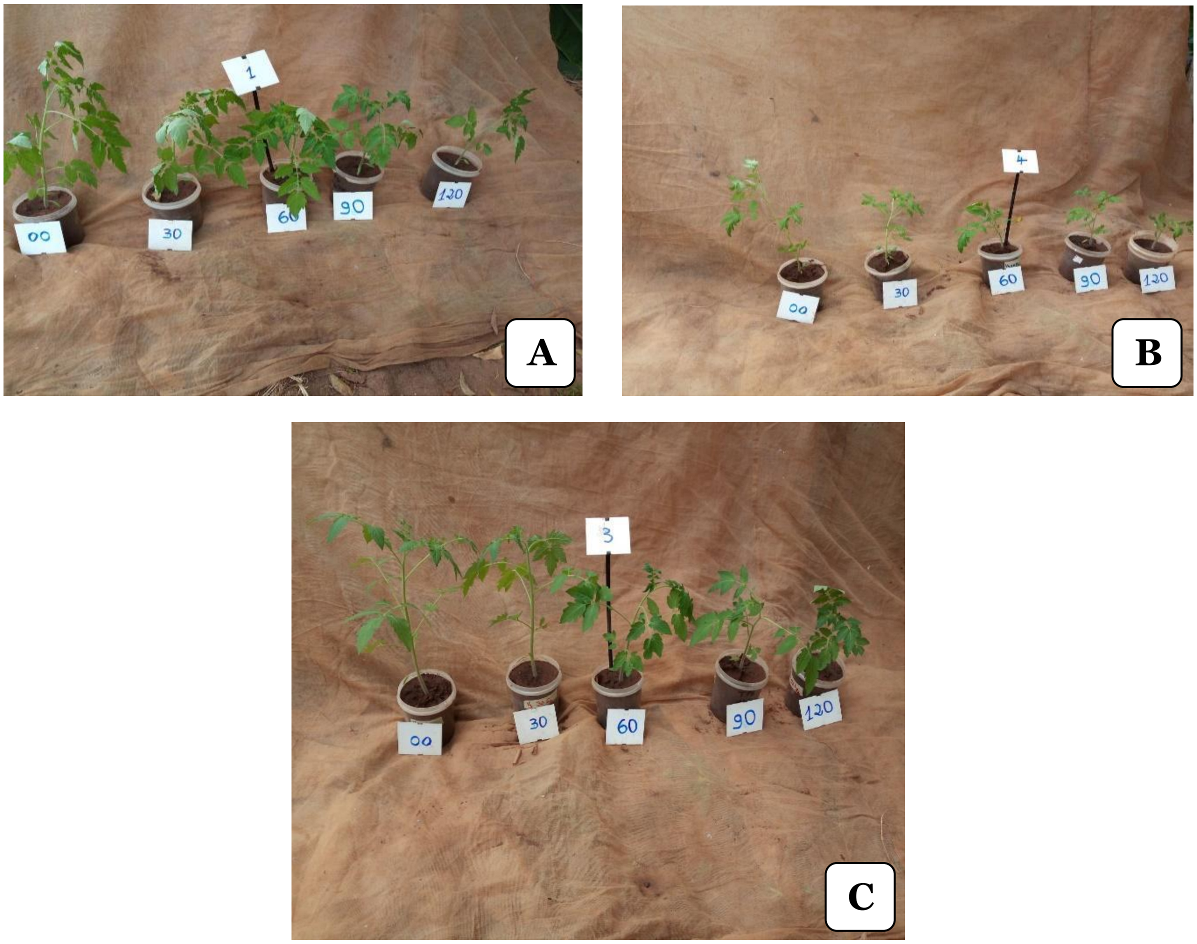

Fig. 1: Plant height of tomato plants (A: Cv. Akikon; B: Cv. TLCV15 and C: Cv. F1 Mongal) after two weeks of culture in the presence of different NaCl concentrations (0, 30, 60, 90 and 120 mM).

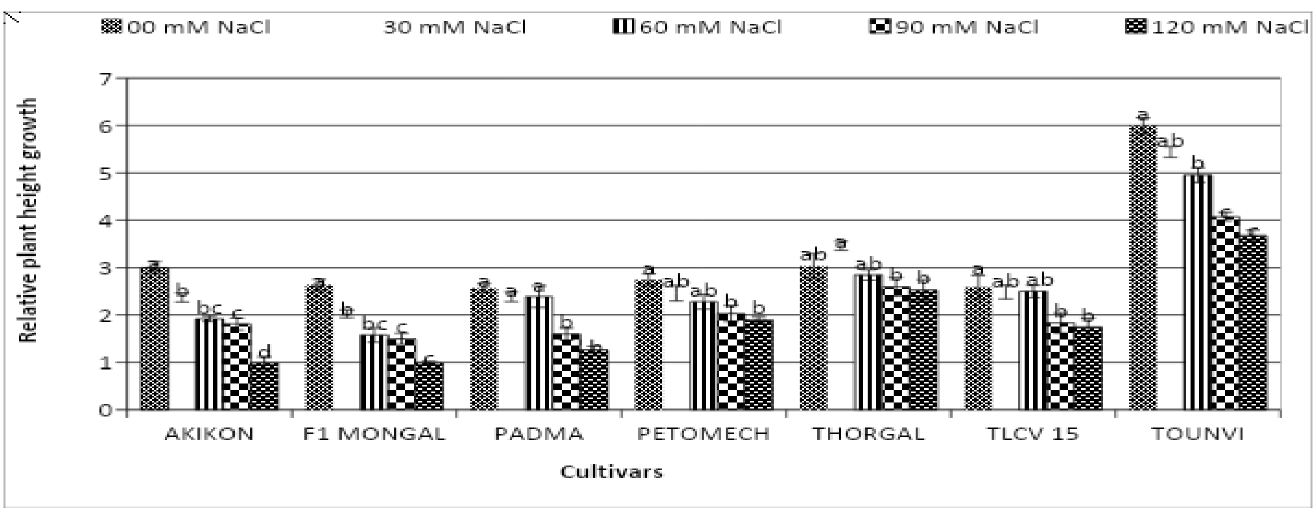

Fig. 2: Relative height growth of seven tomato cultivars under different NaCl concentrations (n = 4; vertical bars are standard errors). Values within cultivar with same letter are not significantly different at $p \leq 0.001$.

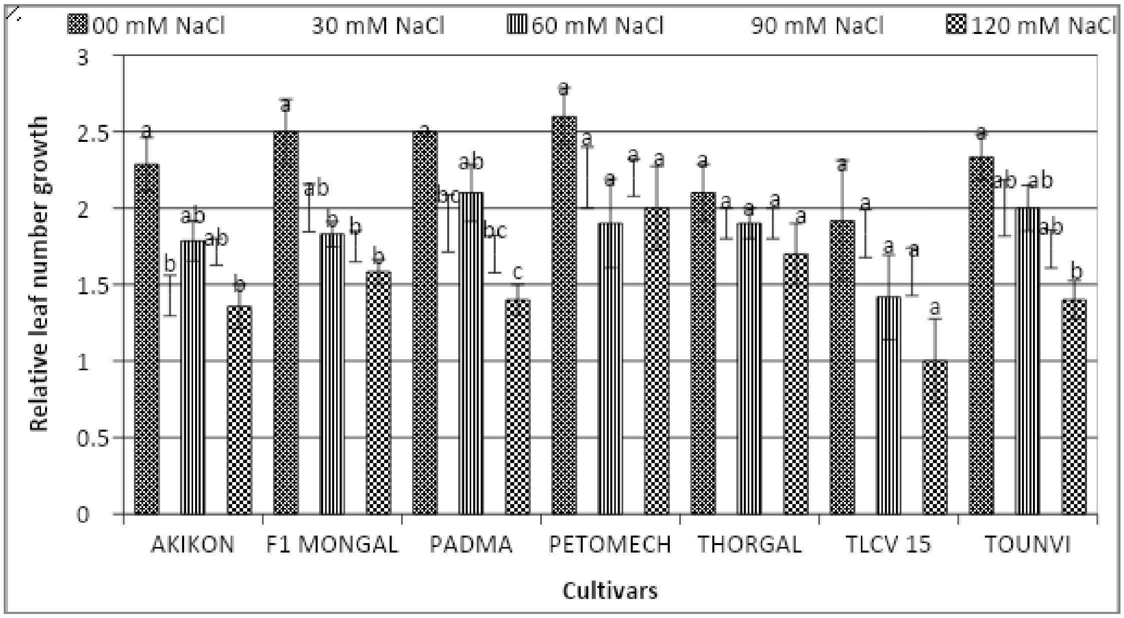

Fig. 3: Relative Leaf number growth of seven tomato cultivars under different NaCl concentrations (n = 4; vertical bars are standard errors). Values within cultivar with same letter are not significantly different at $p \leq 0.001$.

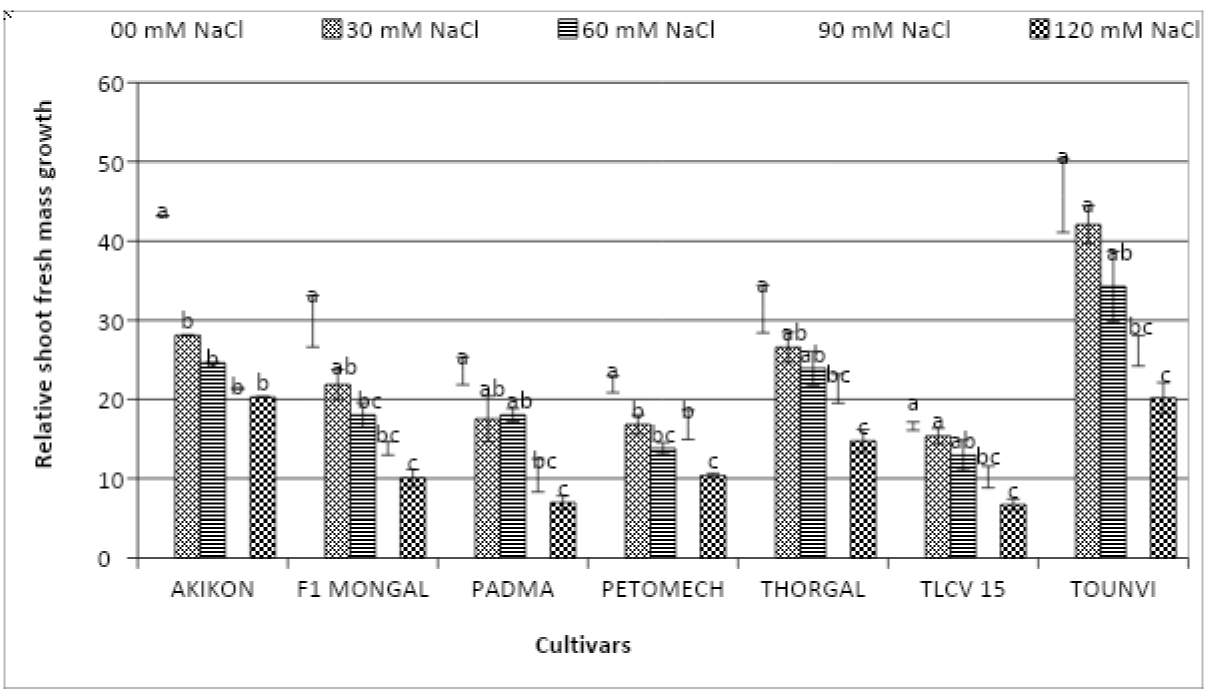

Fig. 4: Relative shoot fresh mass growth of seven tomato cultivars under different NaCl concentrations (n = 4; vertical bars are standard errors). Values within cultivar with same letter are not significantly different at $p \leq 0.001$.

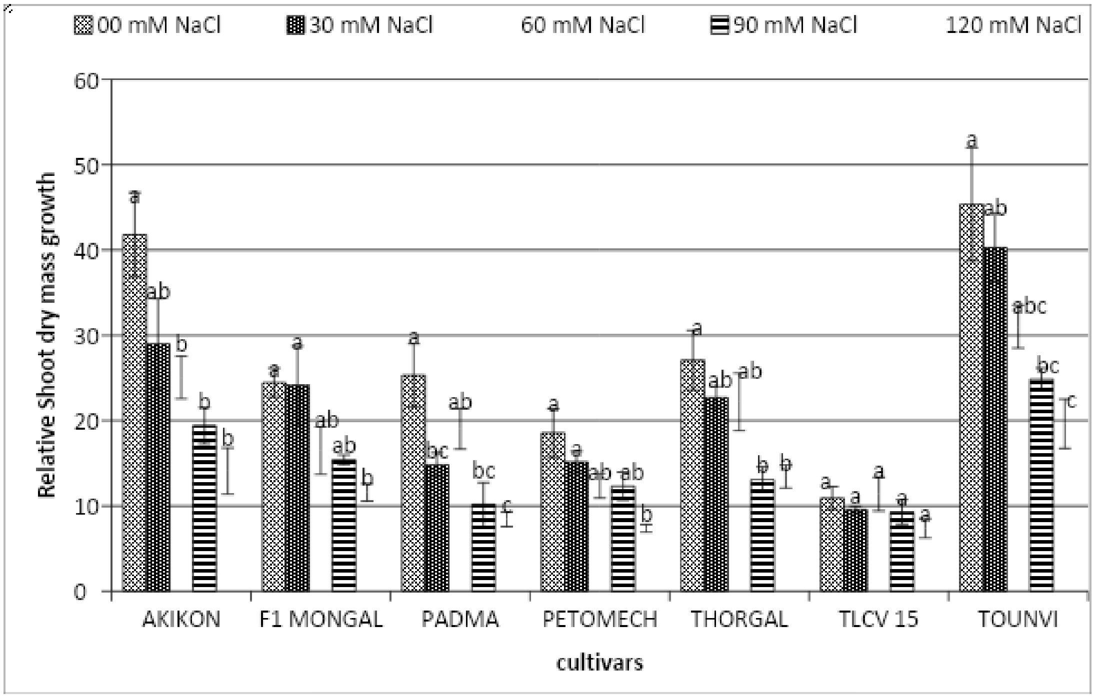

Fig. 5: Relative shoot dry mass growth of seven tomato cultivars under different NaCl concentrations (n = 4; vertical bars are standard errors). Values within cultivar with same letter are not significantly different at $p \leq 0.001$.

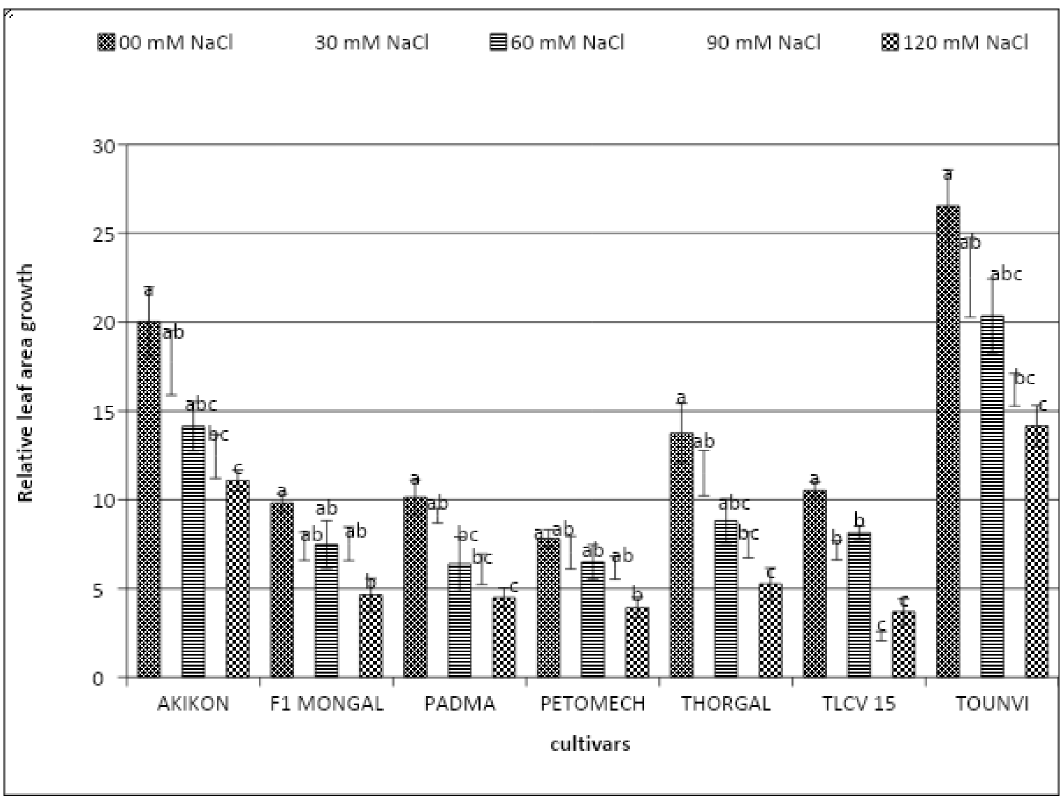

Fig. 6: Relative leaf area growth of seven tomato cultivars under different NaCl concentrations (n = 4; vertical bars are standard errors). Values within cultivar with same letter are not significantly different at $p \leq 0.001$.

Discussion

NaCl effect results in plant shoot and root growth inhibition. Growth inhibition is a common response of plant to salt stress in several plant species such as sugarcane (Gandonou et al., 2012; Gandonou and Skali Senhaji, 2015), amaranth (Omami et al., 2005; Omami and Hammes 2006; Wouyou et al., 2017); pepper (Sikha et al., 2013; R'him et al., 2013; Kpinkoun et al., 2019). Similar results were also reported in other tomato cultivars (Abir et al., 2006; Albacete et al., 2008; Ould Mohamdi et al., 2011; Abdelgawad et al., 2019).

It is well known that the detrimental effect of NaCl in plant biomass accumulation could be due to three dysfunctions in plant nutrition: water stress resulting from a decrease in external osmotic potential; accumulation of toxic ions (Na^+ and Cl^-) and/or imbalance in absorption of other major ions such as K^+, Ca^{++} and Mg^{++}. According to Rasool et al. (2013), these three factors had direct effect on plant growth and development. It is therefore relevant to suggest that the growth reduction observed in the tested tomato cultivars was due to one or a combination of two, or all the three factors. Additional study is necessary to determine which factor is the most detrimental for our tomato cultivars growth.

Our results revealed no reduction for growth of cultivars Tounvi and Thorgal at 30 mM NaCl whatever the growth parameter whereas three of the growth parameters were significantly reduced at 30 mM for cultivars Akikon, Padma and Petomech. These observations indicated that the response of tomato plants to salt stress depend either on the NaCl concentration used or the cultivar tested as previously reported in amaranth species (Amukali et al., 2015; Wouyou et al., 2017). Cultivars responded also differently according to the growth parameter taken into account: For example, for cultivar Akikon, shoot growth parameters (PH, LN and SFM) were the most sensitive to NaCl stress whereas for Tounvi the three root growth parameters (RL, RFM and RDM) and PH were the most affected. Thus, it was not easy to select few growth parameters as reference for salt stress study in tomato cultivars (Bacha et al., 2015; Arbaoui, 2016) as it was the case for *Amaranthus cruentus* cultivars (Wouyou et al., 2017). Some previous studies revealed that salt sensitivity varied significantly among cultivars of the same vegetable species. It is the case for amaranth (Omami and Hammes, 2006; Wouyou et al., 2016; 2017), pepper (Kpinkoun et al., 2018; 2019), cabbage (Gouveitcha et al., 2020). Our results confirm this tendency as a significant difference was observed among cultivars' response against NaCl stress. The local cultivar Tounvi and the improved cultivar Thorgal appeared as the most salt resistant among the seven cultivars studied. In contrast, cultivars Akikon, Petomech and Padma behaved as the most salt sensitive cultivars. The two other cultivars (F1 Mongal and TLCV15) had intermediary salt resistance.

Studying the salt resistance of the same cultivars at germination stage, we have concluded that among the same seven tomato cultivars, F1 Mongal followed by Tounvi and Akikon appeared as salt-resistant whereas Petomech was salt-sensitive. So cultivar Akikon which was one of the most-salt resistant at germination stage appears as a sensitive cultivar at young plants stage. Moreover, cultivar F1 Mongal which was one of the most-salt resistant at germination stage appears as moderately resistant at young plants stage. These results revealed that stress resistance at different development stages does not behave as an interdependent characteristic as reported in sugarcane (Gandonou and Skali Senhaji, 2015), amaranth (Wouyou et al., 2017) and wheat (Sahoo et al., 2018). Thus, salt resistance of a given tomato cultivar at germination stage does not guarantee its salt resistance at further growth stage. However, cultivars Tounvi (resistant) and Petomech (sensitive) maintained their salt-resistant status either at germination stage or at young plant stage.

Conclusion

Our research showed that NaCl salt stress inhibited tomato young plant growth with a variable response according to the cultivar. Among the seven cultivars, local Tounvi and improved Thorgal appeared as the most-salt resistant whereas improved Petomech and Padma, and local Akikon appeared as the most salt sensitive at young plant stage. So the two local cultivars evaluated showed contrast behavior: Tounvi appeared as relative salt-resistant whereas Akikon appeared as salt sensitive at young plant stage.

Conflict of interests

Authors have declared that no conflict of interests exist.

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