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Research Article

Effect of salinity on tomato (*Solanum lycopersicum* L.) seedlings native to arid zones of Mexico

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Salinization causes degradation in arid zones and irrigated soils, producing negative effects on crops such as tomato (*Solanum lycopersicum* L.). In order to identify native tomato phenotypes tolerant to salinity, 10 advanced lines were evaluated at three levels of electrical conductivity in Puebla, Mexico. Seeds were sown in Peat moss® substrate in 200-cavity polyethylene trays. They were irrigated with Steiner nutrient solution plus NaCl at 5, 7 and 9 dS·m^{-1}. Treatments were set up under a split-plot design and four replications. Salinity at 7 and 9 dS.m^{-1} compared to 5 dS.m^{-1} negatively affected: plant height with a reduction of 6.8% and 30.6% respectively; stem diameter 5.8% and 15.3%; number of leaves 2% and 11.1%, and total dry matter production 8.5% and 28.4%. The petiole K^+ content decreased 5.9 and 14.9% at 7 and 9 dS.m^{-1}. Nitrates were statistically equal in each EC. In contrast, Ca^{2+} increased 23.2% at 7 dS.m^{-1}; however, at 9 dS.m^{-1} it decreased to 15.4%. The native tolerant materials according to the Salinity Susceptibility Index (SSI) were: F5=0.89, PRV-1=0.81, F4=0.55; these can be used for further evaluation in production and as salinity tolerant rootstocks.

Key words: Salinity, tolerance, native tomato, NaCl, electrical conductivity.

INTRODUCTION

Soil salinization has become one of the major environmental and socioeconomic issues globally and this is expected to be exacerbated further with projected climatic change (Hassani et al., 2021). In Mexico, salinization affects 3.2% of the land and is one of the main causes of degradation in arid zones and irrigated soils (Lopez-Alvarez et al., 2021). Salinization negatively affects plants by causing leaf necrosis, reduced germination and growth, lower fruit weight, among others (Costan et al., 2020). In grasses and legumes, it reduces yield, dry matter, leaf number, height, germination and nitrogen fixation (Darambazar et al., 2022).

The presence of ions such as Cl^-, Na^+, NO_3^-, SO_4^- and NH_4^+ causes an infertile soil with low nitrogen content that requires supplementation with fertilizers; it also affects plant growth, interferes with the uptake of other ions and causes critical nutrient deficits (Minhas et al., 2020 and Wali et al., 2021, He et al., 2022).

Salinity tolerance depends on the inherent ability of plants to resist the effects of high amounts of salts on their roots or leaf tissues without adverse effects (Wani et al., 2020). Tolerance characteristics are only shown when unfavorable environmental factors act on the plant. Some plants show great phenotypic plasticity; in others, tolerance

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shows a polygenic basis (Hernández, 2019). This adaptation is genetically fixed and transmitted from generation to generation to ensure the survival of the species and to form a more tolerant population (Pritzkow et al., 2020).

Tomato (*Solanum lycopersicum* L.) cultivation is affected by salinity; therefore, the search for tolerant materials is of great benefit (Alam et al., 2021and Da Silva et al., 2022). Variability in response to salinity has been detected in wild tomato species, some being more tolerant than others and can be used as a source of genes for improvement (Pailles et al., 2020).

Salt tolerance is a relative ability of plants to produce satisfactory yields or sustain in saline soils (El Moukhtari et al., 2020, Dubey et al., 2021) and varies across different stages of plant development. Plants exhibit different salinity response mechanisms, such as exclusion, excretion, succulence and osmotic salt adjustment (Rahman et al., 2021,Hao et al., 2021). Resistance involves the development of special physiological mechanisms, which allow the organism to survive in conditions that would be inhibitory or lethal for non-resistant species or individuals (Hernández, 2019). This also depends on the type of crop, variety, growth stage, water use in the soil, as well as soil structure and water evaporation (Minhas et al., 2020).

Soil salinity and sodicity impair plant height, root length, emergence of new roots, accumulation of fresh and dry matter, as well as the very survival of organisms (Hailu et al., 2021). The selection of individuals or populations tolerant to this limiting factor should be based on indices calculated from performance in stressed and non-stressed environments, when the breeder is looking for cultivars capable of adapting to a wide range of environments (Oladosu et al., 2019). Generally, the selection of the most appropriate index will depend on the selection objective in the area (Baker, 2020).

In this regard, in Mexico, (Sanjuan et al., 2015) evaluated the response of 48 native tomato lines and commercial controls at five levels of Electrical Conductivity (EC) with NaCl in the nutrient solution and found that salinity reduced leaf number, stem diameter, leaf area and plant height. In addition, 75% of the materials evaluated showed tolerance to salinity based on the Salinity Susceptibility Index, SSI $\leq$ 1 (Tabassum et al., 2021). To advance in the study of salinity tolerance in native tomato materials, the objective was to evaluate the response at the seedling stage of 10 advanced lines of native tomato and commercial controls at three levels of electrical conductivity of the nutrient solution generated with NaCl.

MATERIALS AND METHODS

The experiment was carried out in the greenhouse of the Centro de Bachillerato Tecnológico Agropecuario (CBTa No.79), located in San Sebastián Zinacatepec, Puebla, whose geographical coordinates are 18° 17’ 30” and 18° 23’ 00” North Latitude, 97° 09’ 18” and 97° 15’ 54” West Longitude, and an altitude of 1100 m. Ten advanced tomato lines (F3, F4, F5, F6, F7, PRV-1, PRV-4, PRV-9, F12-1, PRV-14) and two commercial controls (hybrid rootstock Top 2024 and Reserva, the latter is considered as not tolerant to salinity) were evaluated.

The seeds were sown in 200-cavity polystyrene trays. From sowing until ten days after germination (dag) the seeds were irrigated daily with natural water from the site using a backpack sprayer until the substrate in each tray was completely wetted. The physicochemical characteristics of the irrigation water were: pH= 7.4; EC (dS m^{-1})=3.5; cations (Ca^{2+}=11.8; Mg^{2+}=10.4; Na^{+}=12. 8; K^{+}=0.3 in meq/L) and anions (SO_4=8.97; HCO_3= 11; Cl= 9; CO_3= 3.2; N-NO_3= 1.78 in meq/L) and B=4 (ppm), with an EC of 4.1 dS m^{-1} and pH of 8.1. Two salinity treatments (7 and 9 dS.m^{-1}) and a control (5 dS m^{-1}) were applied with 50% Steiner nutrient solution, 10.66 g of Calcium Nitrate (Haifa-cal GG 15.5-0-0+26 CaO), 15. 51 g potassium nitrate (multi-K-S 12-0-46+4 SO_3), 0.23 mL phosphoric acid, and 19.45 g reagent grade NaCl to generate 7 dS.m^{-1} and 45.05 g to generate 9 dS m^{-1} prepared in 20 liters of natural site water.

At 35 days of seedling age, a destructive sampling was carried out taking four plants per replicate to measure the following variables: Plant Height (PHE), Stem Diameter (SD), Number of Leaves (NL). For the variables Leaf Dry Matter (LDM), Root Dry Matter (RDM), Stem Dry Matter (SDM) and Total Dry Matter (TDM), the root, stem and leaves of each seedling were separated. The plant samples were dried in a RIOSSA® oven at a temperature of 80˚C for 72 hours until a constant weight was obtained. Subsequently, the samples were weighed with an Adventurer TM OHAUS analytical scale, and total dry matter was obtained by summation.

The Salinity Susceptibility Index (SSI) was calculated with the averages of total dry matter (TDM=LDM+RDM+SDM) of each replicate (Tabassum et al., 2021). Only two extreme values of total dry matter were considered. Genotypes subjected to 5 dSm^{-1} were considered without salt stress and those subjected to 9 dSm^{-1} with salt stress, the EC of 7 dSm^{-1} was discarded. The following equation was used: $SSI=[1-(Ys/Yp)] / [1-(\bar{Y}s/\bar{Y}p)]$, where: Ys=total dry matter of a genotype with salt stress, Yp= total dry matter of a genotype without salt stress, $\bar{Y}s$=average total dry matter of all genotypes with stress, $\bar{Y}p$= average total dry matter of all genotypes without stress, Where: SSI >1 indicates susceptibility and <1 indicates salinity tolerance (Tabassum et al., 2021). At 45 days of seedling age, a second destructive sampling was carried out, where four plants were taken randomly per repetition, to perform the Petiole Cell Extract (PCE) and measure the concentration of K^{+}, NO_3^{-} and Ca^{2+} in ppm with LAQUAtwin HORIBA® equipment. The lines and controls were evaluated using a strip plot design. The large plots were the salinity doses, and the small plots were the ten lines evaluated with the two controls. Three replicates were used for each conductivity (5, 7 and 9 dSm^{-1}) and ten plants per replicate. Data were analyzed in the Statistical Analysis System (SAS, Version 9.1) using Analysis of Variance; interaction and Tukey mean comparison ($P \leq 0.05$).

RESULTS

Plant height, stem diameter and number of leaves

As EC increased with NaCl, for conductivities of 7 and 9 dSm^{-1} relative to EC of 5 $dS\text{-}m^{-1}$, Plant Height (PH) showed a linear reduction of 6.82% and 30.6%, respectively (Figure 1a). Top 2024 presented greater height (22.5 cm), compared to lines F7, PRV-1, PRV-4, F12-1, F3, F4 and Reserva (16.2 cm) with lower height and statistically similar averages (Tables 1 and 2 ALTP). Stem Diameter (SD) was reduced 5.8% and 15.3% at levels of 7 and 9 $dS\text{-}m^{-1}$ with respect to 5 $dS\text{-}m^{-1}$ (Figure 1b). The most outstanding line was PRV-14 (3.38 mm). The lines with the smallest stem diameter (Tables 1 and 2) were F3, F4, F5, F6, F7, PRV-1, PRV-4, PRV-9, F12-1, PRV-14, Top 2024 and Reserva (3.06 mm). Number of leaves (NL) was reduced by 2.02% and 11.12% at levels 7 and 9 $dS\text{-}m^{-1}$ with respect to 5 $dS\text{-}m^{-1}$ (Figure 1c). The outstanding line was PRV-14 and the controls Top 2024 and Reserva (6.6) (Tables 1 and 2). The lowest number of leaves was presented by lines F3, F4, F5, F6, F7, PRV-1, PRV-4, PRV-9, F12-1 (5.5).

Leaf, root, stem and total dry matter

Leaf Dry Matter (LDM) at 5 and 7 $dS\text{-}m^{-1}$ showed no statistical differences; on the other hand, at 9 $dS\text{-}m^{-1}$ the reduction was 22.5% with respect to the previous EC (Figure 1d). (Shahid et al., 2022) showed higher LDM (0.265 g) with respect to the Top 2024 control and the other lines (0.1901 g), which were lower (Tables 1 and 2). Root Dry Matter (RDM) was reduced 32.64% in EC of 9 $dS\text{-}m^{-1}$ with respect to 5 $dS\text{-}m^{-1}$, however, 5 and 7 $dS\text{-}m^{-1}$ were statistically equal (Figure 1e). There were no statistical differences between lines and controls (Tables 1 and 2). Stem Dry Matter (SDM) presented a 35.64% reduction in 9 $dS\text{-}m^{-1}$ with respect to 5 and 7 $dS\text{-}m^{-1}$ which were statistically similar (Figure 1f). Line PRV-14 stood out (0.161 g) against F7 and PRV-1 (Tables 1 and 2) with lower stem dry matter (0.110 g).

In Total Dry Matter (TDM= DLM + RDM + SDM) there were no statistical differences in EC reduction at 5 and 7 $dS\text{-}m^{-1}$, but there was for 9 $dS\text{-}m^{-1}$, 28.4% with respect to the previous EC (Figure 1g). Line PRV-14 presented higher total dry matter (0.488 g) compared to those with lower total dry matter F7 and PRV-1 (0.3305 g). The other lines presented values intermediate to this range (Tables 1 and 2). (Sanjuan et al. 2015) found that dry matter production in native tomato was negatively affected by EC.

Root dry matter presented a linear reduction in EC of 8, 10 and 12 $dS\text{-}m^{-1}$ with reductions of 17% and 31% in relation to the treatments with 4 and 6 $dS\text{-}m^{-1}$, this differed by 1.64% with respect to EC 9 $dS\text{-}m^{-1}$. In stem dry matter for conductivities 8, 10 and 12 $dS\text{-}m^{-1}$ the loss was 43 and 53% in relation to the 4 dS-m-1 treatment, while in 6 dS-m-1 it was 18% in relation to that obtained in 4 $dS\text{-}m^{-1}$. With respect to 7 $dS\text{-}m^{-1}$ the difference was 1.12% and 7.36% for 9 $dS\text{-}m^{-1}$. In LDM, there were no statistical differences between conductivities 4, 6 and 8 $dS\text{-}m^{-1}$; however, in 10 and 12 $dS\text{-}m^{-1}$ the reduction was 19%. With respect to 9 $dS\text{-}m^{-1}$ the difference was 3.5% and was similar in 5 and 7 $dS\text{-}m^{-1}$ as there were no statistical differences. In TDM, no statistical differences were observed between 4 and 6 $dS\text{-}m^{-1}$; however, with 8 $dS\text{-}m^{-1}$ there was a 20% reduction, while between 10 and 12 $dS\text{-}m^{-1}$ the reduction was 35% in relation to the control. For 9 $dS\text{-}m^{-1}$ it only differed by 0.9% and was similar at 5 and 7 $dS\text{-}m^{-1}$, being statistically equal.

K^+, NO_3^- and Ca^{2+} Levels: The Petiole Cell Extract (PCE) at 45 days after germination (dag) determined that K^+ levels decreased 5.93% and 14.98% in the EC of 7 and 9 $dS.m^{-1}$ with respect to 5 $dS.m^{-1}$ (Figure 1h). The control Reserva accumulated the highest amount of K^+ (2177.8 ppm) compared to the Top 2024 control with the lowest amount (1633.3 ppm). The 10 lines were located at intermediate levels of the range (Tables 1 and 2). Llanderal et al. (2014) found that at 163 days after transplanting (dat), K^+ concentrations in the petiole of tomato cv 'Canaria' were on average 4584 ppm, with a maximum value of 6447 ppm and a minimum of 3010 ppm. With the above interval at 45 days, the maximum level would be close to 1506.3 ppm and the minimum to 701.8 ppm, which is below the range reached by advanced lines subjected to salt stress; this agrees with (Bodale et al., 2021) who mention that adequate amounts of potassium are important contributors in crop adaptation to abiotic stress, such as drought, salinity and frost.

For NO_3^- content (Figure 1i) there was no significant statistical difference between EC levels (1700 ppm). Line PRV-9 accumulated the highest levels (1988.9 ppm) followed by the control Reserva with low levels (1455.6 ppm); the other lines and the control Top 2024 were at intermediate values (Tables 1 and 2) NO_3^-. In Ca^{2+} levels there was an increase of 23.2% at 7 $dS.m^{-1}$, in the case of 9 $dS.m^{-1}$ it was reduced to 15.4%, both with respect to 5 $dS.m^{-1}$ (Figure 1j). The highest Ca^{2+} levels were found in line PRV-14 (3155.6 ppm). The controls Top 2024 and Reserva accumulated lower amounts (1666.65 ppm) and intermediate levels were reached by the other lines (Tables 1 and 2).

Salinity Susceptibility Index (SSI)

In this research, the Salinity Susceptibility Index (Tabassum et al., 2021) was chosen, which specifies that a value less than one means that it is a salinity tolerant phenotype. The results of the present work indicated that 70% of the lines (F3, PRV-4, F12-1, F6, PRV-9, PRV-14 and F7) and the control Top 2024 showed dry matter reduction > to 27%, with an SSI >1, classifying them as susceptible (in the range of SSI 1.06 to 1. 45), while Reserva and the remaining 30% of the lines (F5, PRV-1 and F4), had an SSI <1 and dry matter reduction < 27%, which showed signs of tolerance to salt stress; in these genotypes the SSI interval was 0.16 to 0.89 (Table 3). Yp: Unstressed to 5 $dS.m^{-1}$; Ys: Stressed to 9 $dS.m^{-1}$; PR (%); Percentage Reduction of Total Dry Matter; TDML: Total Dry Matter Lost; SSI: Salinity Susceptibility Index (>1=salinity sensitive; <1=salinity tolerant); VC: Variation Coefficient.

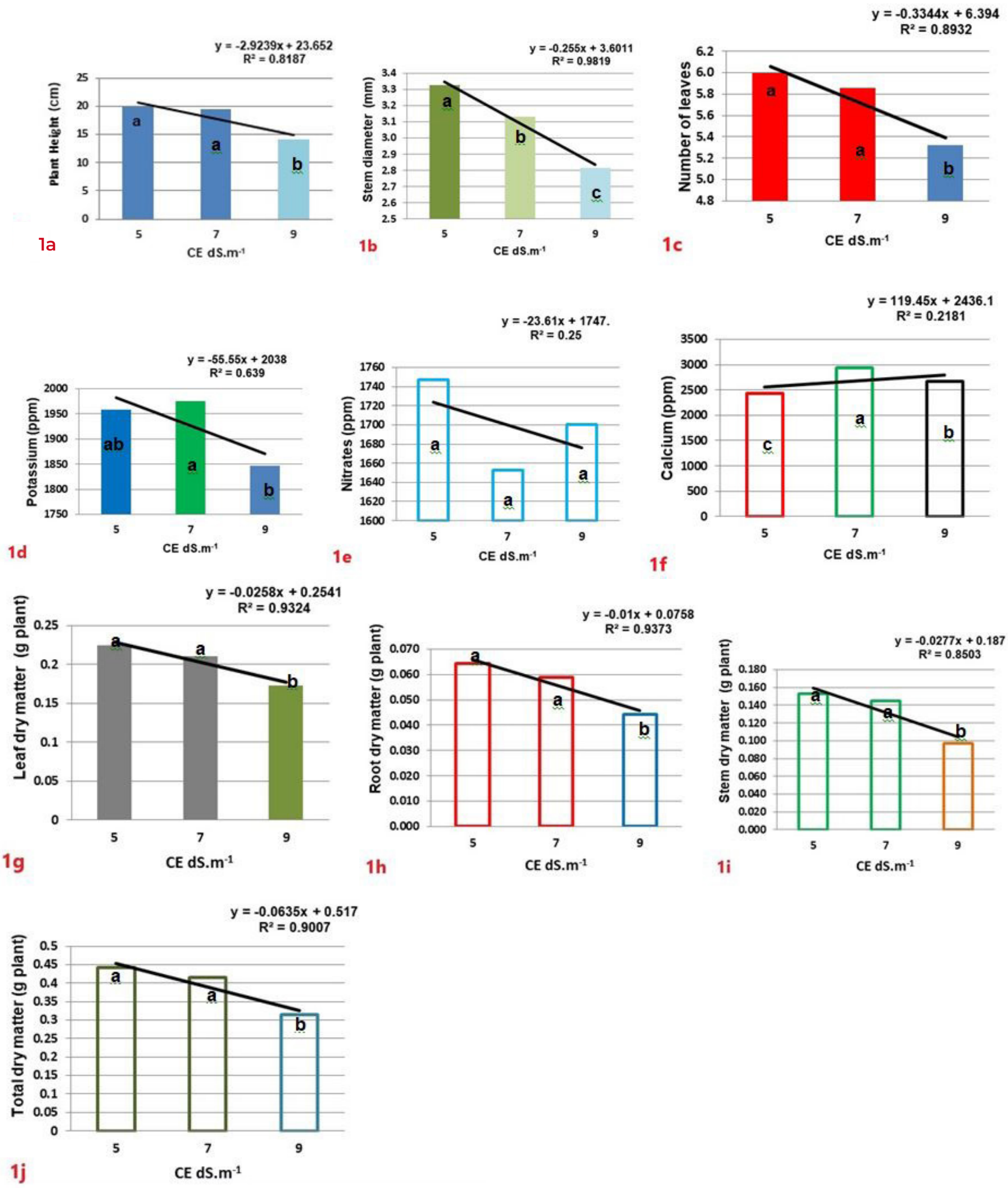

Figure 1. Effect of Electrical Conductivity (EC) in the nutrient solution on: a) Plant height, b) Stem diameter, c) Number of leaves, d) Potassium, e) Nitrates, f) Calcium, g) Leaf dry matter, h) Root dry matter, i) Stem dry matter and j) Total dry matter.

Table 1. Plant Height (PHE), Stem Diameter (SD), Number of Leaves (NL), Potassium (K^+), Nitrates (NO_3^-), Calcium (Ca^{2+}), Leaf Dry Matter (LDM), Root Dry Matter (RDM), Stem Dry Matter (SDM) and Total Dry Matter (TDM) in 10 advanced lines of native tomato, evaluated at three levels of electrical conductivity.

LINES	PHE	SD	NL	K^+	NO_3^-	Ca^{2+}	LDM	RDM	SDM	TDM
	cm	mm		ppm			g. plant^{-1}			
F3	16.5 ^{b}	3.06 ^{b}	5.5 ^{b}	1966.7 ^{abcd}	1711.1 ^{abc}	2766.7 ^{ab}	0.194 ^{b}	0.049 ^{a}	0.127 ^{ab}	0.369 ^{bc}
F4	16.2 ^{b}	3.07 ^{b}	5.4 ^{b}	2033.3 ^{abc}	1566.7 ^{bc}	2888.9 ^{ab}	0.208 ^{b}	0.055 ^{a}	0.129 ^{ab}	0.392 ^{abc}
F5	18.5 ^{ab}	3.09 ^{b}	5.5 ^{b}	1955.6 ^{abcd}	1788.9 ^{abc}	3022.2 ^{ab}	0.203 ^{b}	0.056 ^{a}	0.138 ^{ab}	0.397 ^{abc}
F6	19.9 ^{ab}	3.09 ^{b}	5.6 ^{b}	1922.2 ^{abcd}	1811.1 ^{ab}	3055.6 ^{ab}	0.202 ^{b}	0.055 ^{a}	0.149 ^{ab}	0.406 ^{abc}
F7	16.5 ^{b}	2.95 ^{b}	5.6 ^{b}	1933.3 ^{abcd}	1811.1 ^{ab}	2911.1 ^{ab}	0.162 ^{b}	0.046 ^{a}	0.114 ^{b}	0.322 ^{c}
PRV-1	15.6 ^{b}	2.98 ^{b}	5.2 ^{b}	2100 ^{ab}	1777.8 ^{abc}	2577.8 ^{b}	0.173 ^{b}	0.060 ^{a}	0.106 ^{b}	0.339 ^{c}
PRV-4	16.6 ^{b}	3.10 ^{b}	5.4 ^{b}	1788.9 ^{bcd}	1722.2 ^{abc}	2922.2 ^{ab}	0.188 ^{b}	0.069 ^{a}	0.120 ^{ab}	0.378 ^{bc}
PRV-9	18.8 ^{ab}	3.08 ^{b}	5.6 ^{b}	2000 ^{abc}	1988.9 ^{a*}	2555.6 ^{b}	0.197 ^{b}	0.050 ^{a}	0.141 ^{ab}	0.388 ^{abc}
F12-1	16.0 ^{b}	3.02 ^{b}	5.3 ^{b}	1877.8 ^{abcd}	1611.1 ^{bc}	2911.1 ^{ab}	0.181 ^{b}	0.054 ^{a}	0.119 ^{ab}	0.354 ^{bc}
PRV-14	20.4 ^{ab}	3.38 ^{a*}	6.3 ^{a}	1733.3 ^{cd}	1677.8 ^{abc}	3155.6 ^{a*}	0.261 ^{a}	0.066 ^{a}	0.161 ^{a*}	0.488 ^{a*}
Top 2024	22.5 ^{a*}	3.14 ^{b}	6.6 ^{a}	1633.3 ^{d}	1477.8 ^{bc}	1522.2 ^{c}	0.193 ^{b}	0.053 ^{a}	0.146 ^{ab}	0.392 ^{abc}
Reserva	16.1 ^{b}	3.12 ^{b}	6.9 ^{a}	2177.8 ^{a*}	1455.6 ^{c}	1811.1 ^{c}	0.269 ^{a}	0.056 ^{a}	0.129 ^{ab}	0.454 ^{ab}
Average	17.8	3.09	5.7	1926.9	1700	2675	0.203	0.056	0.132	0.39
VC (%)	19.6	4.16	7.04	11.51	12.47	12.52	15.8	44.84	21.97	17.42
MSD	5.56	0.205	0.64	353.54	337.83	533.77	0.051	0.04	0.046	0.108

Note: (*) Values with different Lines within each column are statistically different chemicals of native tomato

Table 2. Average variables at levels 5, 7 and 9 dS.m-1 of advanced lines of native tomato.

LINES	PHE	SD	NL	K^+	NO_3^-	Ca_2^+	LDM	RDM	SDM	TDM
	CM	mm		ppm			$g.plant^{-1}$			
F3	20.33	3.34	6.08	2,033	1,933	2,600	0.25	0.06	0.17	0.48
F4	15.84	3.25	5.42	1,800	1,467	2,867	0.21	0.06	0.13	0.40
F5	23.43	3.28	5.5	2,100	1,933	2,433	0.21	0.06	0.14	0.41
F6	25.01	3.35	5.92	1,933	2,000	2,700	0.24	0.07	0.19	0.50
F7	17.06	3.23	5.92	1,900	1,667	2,533	0.19	0.05	0.13	0.37
PRV-1	16.84	3.16	5.25	2,233	1,933	2,367	0.19	0.06	0.11	0.36
PRV-4	18.44	3.42	5.58	1,700	1,467	2,800	0.23	0.07	0.15	0.45
PRV-9	24.58	3.31	6	2,000	2,167	2,167	0.22	0.06	0.18	0.46
F12-1	21.18	3.33	5.58	2,067	1,900	2,600	0.20	0.07	0.16	0.43
PRV-14	22.12	3.69	6.67	1,500	1,300	2,667	0.29	0.08	0.18	0.55
Top 2024	27.27	3.35	7.25	1,900	1,500	1,567	0.21	0.09	0.16	0.45
Reserva	17.72	3.20	6.75	2,333	1,700	1,800	0.26	0.06	0.14	0.46
Average	19.93^{a}	3.33^{a}	5.99^{a}	1958^{ab}	1747^{a}	2425^{c}	0.22^{a}	0.06^{a}	0.15^{a}	0.44^{a}
F3	16.09	3.05	5.33	2,033	1,800	3,200	0.17	0.05	0.12	0.34
F4	18.28	3.1	5.5	2,233	1,567	3,100	0.22	0.06	0.15	0.43
F5	23.79	3.22	6	1,933	1,733	3,733	0.23	0.06	0.18	0.47
F6	19.94	3.09	5.58	1,967	1,567	3,500	0.20	0.06	0.15	0.41
F7	21.45	2.97	5.75	1,967	1,900	3,167	0.16	0.04	0.13	0.34
PRV-1	15.85	3.08	5.42	2,167	1,567	2,667	0.18	0.09	0.12	0.39
PRV-4	17.33	3.09	5.42	1,800	1,800	3,000	0.19	0.09	0.13	0.41
PRV-9	17.67	3.18	5.5	1,900	1,867	2,933	0.20	0.05	0.14	0.40
F12-1	16.31	3.08	5.58	1,967	1,333	3,167	0.19	0.05	0.12	0.37
PRV-14	20.33	3.4	6.75	1,900	1,833	3,533	0.29	0.07	0.19	0.55
Top 2024	25.89	3.15	6.47	1,533	1,433	1,667	0.20	0.04	0.17	0.40
Reserva	16.43	3.16	7	2,300	1,433	1,567	0.28	0.06	0.13	0.47
Average	19.39^{a}	3.13^{b}	5.86^{a}	1975^{a}	1653^{a}	2936^{a}	0.21^{a}	0.06^{a}	0.15^{a}	0.41^{a}
F3	13.03	2.79	5	1,833	1,400	2,500	0.16	0.04	0.09	0.29
F4	15.46	2.86	5.17	2,067	1,667	2,700	0.19	0.05	0.11	0.34
F5	12.13	2.78	4.92	1,833	1,700	2,900	0.17	0.05	0.09	0.31
F6	14.66	2.84	5.17	1,867	1,867	2,967	0.17	0.04	0.1	0.32
F7	13.28	2.64	5.08	1,933	1,867	3,033	0.14	0.04	0.08	0.26
PRV-1	14.06	2.7	4.83	1,900	1,833	2,700	0.15	0.04	0.09	0.28
PRV-4	14.04	2.78	5.08	1,867	1,900	2,967	0.15	0.04	0.08	0.28
PRV-9	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
14.29	2.77	5.17	2,100	1,933	2,567	0.16	0.04	0.1	0.31	0.64
F12-1	10.61	2.65	4.75	1,600	1,600	2,967	0.15	0.04	0.08	0.27
PRV-14	15.55	3.06	5.58	1,800	1,900	3,267	0.2	0.05	0.11	0.37
Top 2024	17.79	2.93	6.22	1,467	1,500	1,333	0.18	0.04	0.11	0.32
Reserva	14.12	3	6.92	1,900	1,233	2,067	0.27	0.05	0.12	0.44
Average	14.09^{b}	2.82^{c}	5.32^{b}	1847^{b}	1700^{a}	2664^{b}	0.17^{b}	0.04^{b}	0.10^{b}	0.31^{b}
DMS	1.939	0.072	0.228	125.78	118	188.2	0.017	0.014	0.016	0.038

Note: (*) Values with different letters within each column are statistically different (Tukey, P≤0,05); MSD:Minimal Significant Difference.

Table 3. Tolerance and susceptibility to salinity of advanced native tomato lines and commercial controls according to SSI.

Línes	Total dry matter (g plant^{-1})				SSI
	Yp	Ys	TDML	PR (%)	
F3	0.48	0.29	0.19	40	1.45
PRV-4	0.45	0.28	0.17	38	1.39
F12-1	0.43	0.27	0.16	37	1.36
F6	0.50	0.32	0.18	36	1.32
PRV-9	0.46	0.31	0.15	33	1.20
F7	0.37	0.26	0.11	30	1.09
Top 2024	0.45	0.32	0.13	29	1.06
F5	0.41	0.31	0.10	24	0.89
PRV-1	0.36	0.28	0.08	22	0.81
F4	0.40	0.34	0.06	15	0.55
Reserva	0.46	0.44	0.02	4	0.16
Media	0.44	0.32	0.13	28.4	1.04
Standard deviation	0.054	0.050	0.054	10.44	0.383
VC (%)	12	16	42	37	37
0.46	0.46	0.46	0.46	0.46	0.46

DISCUSSION

Plant height, stem diameter and number of leaves

(Sanjuan et al., 2015) found that tomato plant height decreased with increasing conductivity with NaCl and that stem diameter decreased 6.1% and 12.8% at levels of 6 and 8 dS-m^{-1}, relative to 4 dS-m^{-1} and was reduced by 3.65% and 0.85% at EC 7 and 9 dS-m^{-1}. The number of leaves at EC 6, 8 and 10 dS-m^{-1} did not show statistical differences; however, its reduction was 6% compared to levels of 4 dS-m^{-1}. At 7 dS-m^{-1} the difference was 3.98% and 5.12% for 9 dS-m^{-1} and the reduction was 12% at 12 dS-m^{-1}.

K^+, NO_3^- and Ca^{2+} Levels

1300 mg L^{-1} of nitrate in the petiole of the tomato plant is a high level, an intermediate level is 1000 mg L^{-1} and a low level of nitrate corresponds to concentrations lower than 850 mg L^{-1} (Wang et al., 2022). In reference to the above, it can be affirmed that the lines and controls presented optimal nitrate levels in the petiole. In the vegetative stage and at the beginning of fruit formation, tomato plants show high nitrate concentrations in the petiole (Shahid et al., 2022).

(Llanderal et al., 2014) found that at 163 dat, Ca^{2+} concentrations in the petiole of tomato cv 'Canaria' averaged 5546 ppm, a minimum of 4094 ppm and a maximum of 7557 ppm. At 45 days it approaches 1761.9 ppm as a maximum level and a minimum of 954.5 ppm. These levels are below those accumulated by the lines, which is probably due to the increase in salinity and the adaptation of the lines to the stress.

CONCLUSION

The EC of 7 and 9 dS.m^{-1} of the NaCl nutrient solution affected plant height (6.82% and 30.6%), stem diameter (5.8% and 15.3%), number of leaves (2.02% and 11.12%) and total dry matter yield (28.4%) of the advanced native tomato lines and commercial controls.

Petiole K^+ levels decreased 5.93% and 14.98% at EC of 7 and 9 dS.m^{-1} with respect to 5 dS.m^{-1}. Nitrates remained constant with increasing salinity. In Ca^{2+} there was an increase of 23.2% at 7 dS.m^{-1}, whereas at 9 dS.m-1 it was reduced to 15.4% with respect to 5 dS.m^{-1}. The advanced native tomato lines tolerant to salinity according to the SSI were F5=0.89; PRV-1=0.81; F4=0.55 and Reserva=0.16, which can be used for further production evaluations and as rootstocks tolerant to salinity.

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