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PRODUCTION OF TOMATO SEEDLINGS UNDER SALINE IRRIGATION

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ABSTRACT - Processing tomato is the most important vegetable crop of the Brazilian agribusiness and few researches have been conducted to evaluate the tolerance of this crop to saline stress. In this study, the effects of five levels of salinity of the irrigation water (1, 2, 3, 4 and 5 dS m^{-1}) and three equivalent proportions of Na:Ca:Mg (1:1:0.5, 4:1:0.5 and 7:1:0.5) were tested on the emergence and vigor of processing tomato, cultivar IPA 6. Seeds were sowed in expanded polystyrene tray (128 cells) and each tray received 1 L of water after sowing. The trays were piled and, four days after sowing, they were placed on suspended supports in a greenhouse. Irrigation was accomplished daily from the fifth day after sowing. Only dry weight of shoot and root was affected by sodium proportions, while linear reductions of the speed of emergence, stem length and the dry weight of shoot and root were observed with increasing salinity. Root was more affected than shoot by salinity and relative growth ratio increased with salinity levels on the 14-21 days after sowing period, indicating that the crop showed a certain increase of salinity tolerance with the time of exposure to salts.
Key words: *Lycopersicon esculentum*, water quality, sodium, plant growth.

PRODUÇÃO DE MUDAS DE TOMATE SOB IRRIGAÇÃO SALINA

RESUMO - O tomate para processamento industrial é a mais importante hortaliça do agronegócio brasileiro e poucas pesquisas têm sido conduzidas para avaliar a tolerância dessa cultura ao estresse salino. Neste estudo, testaram-se os efeitos de cinco níveis de salinidade da água de irrigação (1, 2, 3, 4 e 5 dS m^{-1}) e três proporções equivalentes de Na:Ca:Mg (1:1:0,5, 4:1:0,5 e 7:1:0,5) na germinação e vigor do tomateiro industrial, cultivar IPA 6. A semeadura foi realizada em bandejas de poliestireno expandido (128 células) e cada bandeja recebeu 1 L de água após a semeadura. As bandejas foram empilhadas e, quatro dias após a semeadura, colocadas em suportes suspensos em um ambiente protegido. A irrigação foi realizada diariamente a partir do quinto dia após a semeadura. Apenas a massa seca da parte aérea e da raiz foi afetada pelas proporções de sódio, enquanto que reduções lineares da velocidade de emergência, comprimento da haste e massa seca da parte aérea e da raiz foram observadas com o aumento da salinidade. A raiz foi mais afetada do que a parte aérea pela salinidade da água de irrigação e a taxa de crescimento relativo aumentou com os níveis de salinidade no período 14-21 dias após a semeadura, indicando que a cultura apresentou um certo aumento na tolerância à salinidade com o tempo de exposição aos sais.
Palavras-chave: *Lycopersicon esculentum*, qualidade da água, sódio, crescimento.

INTRODUCTION

Tomato is a widely distributed annual vegetable crop, which is consumed fresh, cooked or after processing: by canning, making into juice, pulp, paste, or as a variety of sauces. According to Filgueira (2003), "tomato is the most important vegetable in Brazil considering the socio-economical aspects". In 2004, 3.4 million tons were produced in Brazil, being the eighth producer in the world (FAO, 2005).

Soil moisture is probably the most important factor affecting germination of crops seeds. The optimum soil moisture for germination of tomato is at 50-75% of field capacity (FAWUSI &

AGBOOLA, 1980), but the rate and degree of water uptake for germination is affected by water content and also by temperature and salinity of the soil or substrate (PICKEN *et al*., 1986). In many species the effect of salinity on germinating seeds is not only on lowering the percentage of germination, but also on lengthening the time needed to complete germination (TESTER & DAVENPORT, 2003). Blanco *et al*. (2003) verified for maize and soybean that the speed of emergence was more affected by salinity than the percentage of germination and similar results were found for wheat and barley (MER *et al*., 2000). Cuartero & Muñoz (1999) stated that "germination of tomato seeds is reduced at relatively low NaCl concentrations, but there is an outstanding difference among the various genotypes"; at 80 mM NaCl, a decrease in the percentage of germination was observed for some accessions, while concentrations above 265 mM was needed to reduce germination of *L. esculentum* 'Edkawy'.

Jiménez *et al*. (2002) verified that germination of *Phaseolus* species varied among the 28 accessions used, some of them showing higher percentage of germination at 60 or 120 mM NaCl, although in almost all accessions germination was delayed in response to salt stress. The percentage of germination of melon seeds was reduced only for ECw above 13.5 dS m^{-1} (SIVRITEPE *et al*., 2003). Asch & Wopereis (2001) observed that the germination of three rice cultivars was affected by ECw over 6 dS m^{-1} and the percentage of germination at eight days after sowing was above 90% for ECw up to 4 dS m^{-1}, except for the sensible cultivar.

Processing tomato occupies large area in the Northeast region of Brazil, where waters used for irrigation have low to medium salinity, but the improper irrigation management has caused the soil salinization (HOLANDA & AMORIM, 1997). The objective of this study was to evaluate the emergence and initial development of processing tomato irrigated with saline water with different proportions of sodium.

MATERIAL AND METHODS

The experiment was conducted in Campina Grande, PB (7º15'18" S, 35º52'28" W and altitude of 550 m). According to classification of Köppen adapted to Brazil (COELHO & SONCIN, 1982), the climate of the area is of the type Csa, which represents a semi-humid climate, with hot and dry summer and rains in autumn and winter.

The treatments were composed of five salinity levels, represented by the electrical conductivity of the water (ECw = 1, 2, 3, 4, and 5 dS m^{-1}) and three equivalent proportions of Na:Ca:Mg (P1 = 1:1:0.5, P2 = 4:1:0.5 and P3 = 7:1:0.5) in the irrigation water. The experiment was conducted in a completely randomized factorial design of 5 x 3 with four replications and 64 seedlings per replication. To achieve the desired ECw and proportion of Na, Ca and Mg, the waters used for irrigation of the tomato were prepared from the tap water, which was diluted with distilled water or salinized with NaCl, $CaCl_2.2H_2O$ and $MgCl_2.2H_2O$ after analysis. The amounts of salts or distilled water to be added were determined in order to obtain the desired ECw of the respective treatments with an equivalence of 1:1:0.5, 4:1:0.5 and 7:1:0.5 for Na:Ca:Mg, using the relationship $mmol_c\ L^{-1}$ = ECw x 10 (RHOADES *et al*., 1992).

Seeds of processing tomato, cultivar 'IPA 6', were sown in expanded polystyrene tray (128 cells) on May 6, 2000, using the commercial substrate Plantmax® composed of vermiculite, perlite, pinus bark and peat. Two seeds were sown in each cell and each tray received 1 L of water after sowing, which was sufficient to promote drainage at the bottom. The trays were piled and a plastic sheet was placed between two adjacent trays and, four days after sowing, the trays were placed on suspended supports in a greenhouse. Irrigation was accomplished daily from the fifth day after sowing (DAS).

The number of emerged plants was determined at 5, 7, 9 and 14 DAS, and speed of emergence (SE) was determined according to Vieira & Carvalho (1994).

$$SE = \frac{E_5}{5} + \frac{E_7}{7} + \frac{E_9}{9} + \frac{E_{14}}{14} \quad (1)$$

where E_i = number of emerged plants in the day i.

Ten seedlings per replication were used to determine stem length (SL), dry weight of shoot (DWS) and root (DWR) and root/shoot ratio (R/S) on 7, 14 and 21 DAS. The trays were taken to laboratory in the night of the previous day to the evaluations and the stem was cut close to soil and measured. The seedlings were dried in an air-forced oven at 65ºC for 72 h. The root system was washed to remove the substrate and dried as previously mentioned.

From the total dry weight (TDW) obtained in each measurement, the absolute growth rate

(AGR) and the relative growth rate (RGR) were calculated (BENINCASA, 1988):

$$TDW = DWS + DWR \qquad (2)$$

$$AGR = \frac{TDWf - TDWi}{t} \qquad (3)$$

$$RGR = \frac{Ln(TDWf) - Ln(TDWi)}{t} \qquad (4)$$

where TDWf and TDWi are the final and initial total dry weight and t the time interval between measurements.

The values obtained for each variable were analyzed by the analysis of variance and test F. When significant, the effects of the salinity levels were evaluated by polynomial regression and the effects of the different proportions of sodium were appraised by the test of Tukey (GOMES, 2000).

RESULTS AND DISCUSSION

Salinity and sodium proportion did not affect the percentage of germination (Table 1), but water salinity, represented by electrical conductivity of the irrigation water (ECw), delayed the emergence by reducing the speed of emergence (SE) of 3.46% for each unitary increase of ECw above 1 dS m^{-1} (Figure 1).

These results were in discordance to the statements of Cuartero & Muñoz (1999), who related that the germination of tomato is reduced even at relatively low NaCl concentrations. However, these authors show that there are differences in the ability of _L. esculentum_ accessions to germinate in a saline medium, which are evident even at moderate salt concentrations.

Stem length (SL) was affected by water salinity, with reduction of 4.96, 8.96 and 9.05% for each unitary increase of ECw above 1 dS m^{-1} at 7, 14 and 21 days after sowing (DAS), respectively (Figure 2). Reduction of SL or plant height with increasing salinity was also observed for precocious-dwarf cashew (CARNEIRO _et al_., 2004), peach palm (FERNANDES _et al_., 2003) and West Indian cherry (GURGEL _et al_., 2003). On the other hand, Mer _et al_. (2000) did not find differences of SL for barley and wheat growing in soil with electrical conductivity of the saturation extract up to 8 dS m^{-1} for six weeks.

Dry weight of shoot (DWS) was reduced by 6.5, 10.2 and 8.9% at 7, 14 and 21 DAS, respectively, for each unitary increase of salinity above 1 dS m^{-1} (Figure 3). Dry weight of root (DWR) was not affected by salinity for the

Table 1. Mean values for percentage of germination (PG), speed of emergence (SE), stem length (SL), dry weight of shoot (DWS) and root (DWR) and root/shoot ratio (R/S) of tomato seedlings, under different salinity levels and proportions of sodium in the irrigation water.

Source of variation	PG	SE	SL			DWS			DWR			R/S		
			7 DAS	14 DAS	21 DAS	7 DAS	14 DAS	21 DAS	7 DAS	14 DAS	21 DAS	7 DAS	14 DAS	21 DAS
	%	plant d^{-1}	------------ mm -------			------------------------ mg --------------------								
Water salinity														
1 dS m^{-1}	93	22.7	31.0	66.6	118.3	77	486	1448	18	103	339	0.241	0.211	0.236
2 dS m^{-1}	94	23.4	30.5	62.43	114.4	69	410	1245	17	96	304	0.256	0.233	0.244
3 dS m^{-1}	92	21.7	26.4	49.43	100.6	51	299	1060	16	65	274	0.307	0.221	0.261
4 dS m^{-1}	91	20.8	25.7	48.83	87.48	53	322	1020	15	59	271	0.298	0.185	0.269
5 dS m^{-1}	91	20.0	25.8	43.8	76.86	61	297	942	16	62	230	0.278	0.207	0.245
Regression#	-	L**	L**	L**	L**	L**	L**	L**	-	L**	L**	Q*	-	Q*
Proportion Na:Ca:Mg$^{\xi}$														
P1 (1:1:0.5)	91 a	21.5 a	28 a	54 a	100 a	65 a	375 a	1209 a	17 a	77 a	294 a	0.269 a	0.204 a	0.244 a
P2 (4:1:0.5)	93 a	21.8 a	29 a	55 a	100 a	61 a	373 a	1126 b	16 a	81 a	286 ab	0.275 a	0.217 a	0.259 a
P3 (7:1:0.5)	93 a	21.8 a	27 a	53 a	98 a	60 a	341 b	1094 b	16 a	73 a	271 b	0.283 a	0.212 a	0.251 a
CV (%)	3.9	5.6	12.4	18.2	19.0	13.1	25.3	20.9	19.1	32.4	17.4	20.5	17.1	10.2

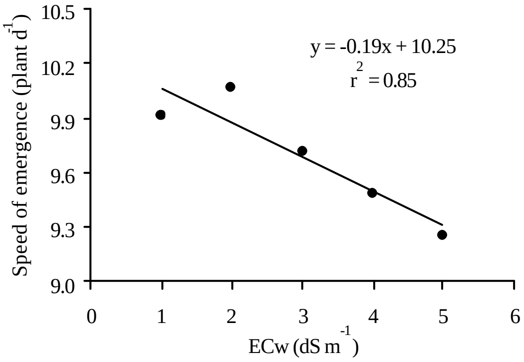

Figure 1. Regression equation for the effects of water salinity (ECw) in the speed of emergence of processing tomato seedlings.

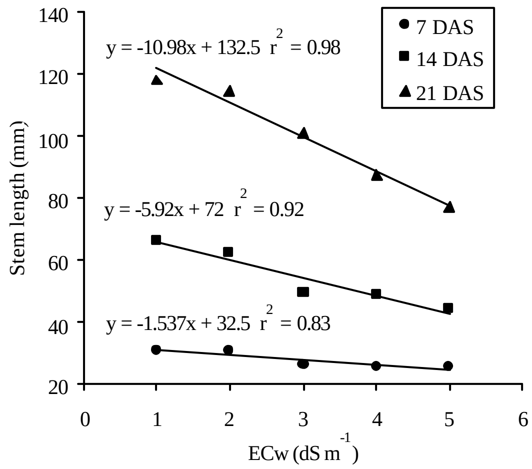

Figure 2. Regression equations for the effects of water salinity (ECw) in the stem length of processing tomato seedlings at 7, 14 and 21 days after sowing (DAS).

measurements performed at 7 DAS, but at 14 and 21 DAS decreased by 11.7 and 7.5%, respectively, per unit increase of salinity above 1 dS m^{-1}. The lower reduction of DWS at 21 DAS in relation to 14 DAS is probably related to osmotic adjustment, as a result of changes in intracellular concentrations of organic and inorganic composts (ASPINALL, 1986; MOFTAH & MICHEL, 1987).

Various reasons are possible for the reduced root growth under salt stress: cell growth restriction, because of the low water potential of external medium; interference of the saline ions with the plant's nutrition or the toxicity of accumulated ions leading to cell death (CUARTERO & MUÑOZ, 1999). Cuartero & Muñoz (1999) stated that the tomato root growth is less affected by salinity than the shoot growth.

In a general way, salinity inhibited more the DWS than the DWR, which reveals the ability of the plants in maintaining a higher root surface for water uptake, in response to the reduction of the osmotic potential of the soil solution. Higher reduction of DWS was also found in rice (YOUNIS *et al*., 2003), soybean (ESSA, 2002), soursop (NOBRE, 2002) and for other crops.

Root/shoot ratio (R/S) showed a quadratic relation with ECw for the measurements performed at 7 and 21 DAS (Figure 3). Increase of R/S in mild salinity is an adaptation

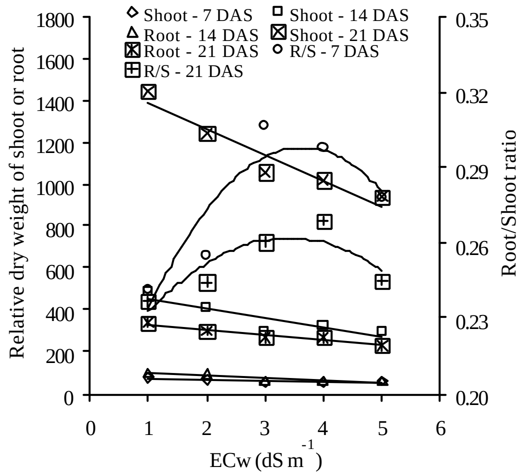

Figure 3. Regression curves for the effects of water salinity (ECw) on the dry weight of shoot of processing tomato seedlings at 7, 14 and 21 days after sowing (DAS), dry weight of root at 14 and 21 DAS and on the root/shoot ratio at 7 and 21 DAS.

mechanism of the plants to the stress conditions, which produce more roots to absorb water and nutrients for the same shoot biomass, or the result of higher reduction in shoot than in root growth. The increase occurred at 7 DAS was due to the reduction of shoot, once the DWR was not affected by ECw. Therefore, at 21 DAS, higher R/S values for the mild salinity were due to the higher reduction of DWS (8.9%) in relation to DWR (7.5%). Reduction of R/S in the measurement performed at 21 DAS, in relation to that performed at 7 DAS, reveals that root was more affected by salinity than the shoot along time. The reduction of R/S, calculated from the regression equations, were 3.3, 12.1, 18.0, 22.3 and 25.5% for plants irrigated with water of ECw of 1, 2, 3, 4 and 5 dS m^{-1}, respectively.

Rodriguez *et al*. (1997) found reduction of R/S of tomato seedlings when the concentration of

NaCl was raised from zero to 100 mM, but the saline treatment was applied 13 days after emergence. Thus, the sudden increase of root medium salinity probably caused the death of roots and reduced the root/shoot ratio.

Absolute (AGR) and relative (RGR) growth rate where affected linearly by the water salinity for all periods, and sodium proportions affected AGR only in the 7-14 DAS period, with reduction of 8.71% for P3 in relation to P1 (Table 2). AGR decreased of 7.8 and 11.4% at the first

Table 2. Summary of analysis of variance (test F) and mean values for absolute and relative growth rate (AGR and RGR, respectively) of tomato seedlings, under different salinity levels and proportions of sodium in the irrigation water.

Source of variation	AGR		RGR	
	7-14 DAS	14-21 DAS	7-14 DAS	14-21 DAS
	-------mg d^{-1} -------		----mg mg^{-1} d^{-1} ----	
Water salinity				
1 dS m^{-1}	70.6	171.3	0.263	0.158
2 dS m^{-1}	60.0	149.1	0.253	0.161
3 dS m^{-1}	42.4	138.6	0.241	0.186
4 dS m^{-1}	44.7	129.8	0.246	0.174
5 dS m^{-1}	40.2	116.2	0.219	0.173
Regression[#]	L**	L**	L**	L*
Proportion Na:Ca:Mg[ξ]				
P1 (1:1:0.5)	52.8 ab	150.2 a	0.243 a	0.173a
P2 (4:1:0.5)	53.7 a	136.9 a	0.251 a	0.163a
P3 (7:1:0.5)	48.2 b	135.8 a	0.239 a	0.174a
CV(%)	0.28	0.21	0.11	0.13

[ξ] Different letters in the same column indicate different means by the test of Tukey ($P < 0.05$). [#] L=Linear. *, ** Significant at 0.05 and 0.01 of probability by test F, respectively

and second time intervals, respectively; RGR decreased of 3.6% at the first time interval and increased 2.6% at the second time interval, for each unitary increase of ECw above 1 dS m^{-1} (Figure 4).

Reduction of AGR with salinity has been reported for West Indian cherry (GURGEL *et al*., 2001), precocious dwarf-cashew (CARNEIRO, 2001) and soursop (NOBRE, 2002). Accordingly to Cuartero & Muñoz (1999), the leaf growth rate of tomato is reduced with salinity and it has been related to reduction in cell turgor, to wall rheological properties and to reduction in photosynthetic rate. On the other hand, the increase of RGR with salinity in the 14-21 DAS period is an indicative that the cultivar IPA 6 has a high efficiency in producing dry matter per unit

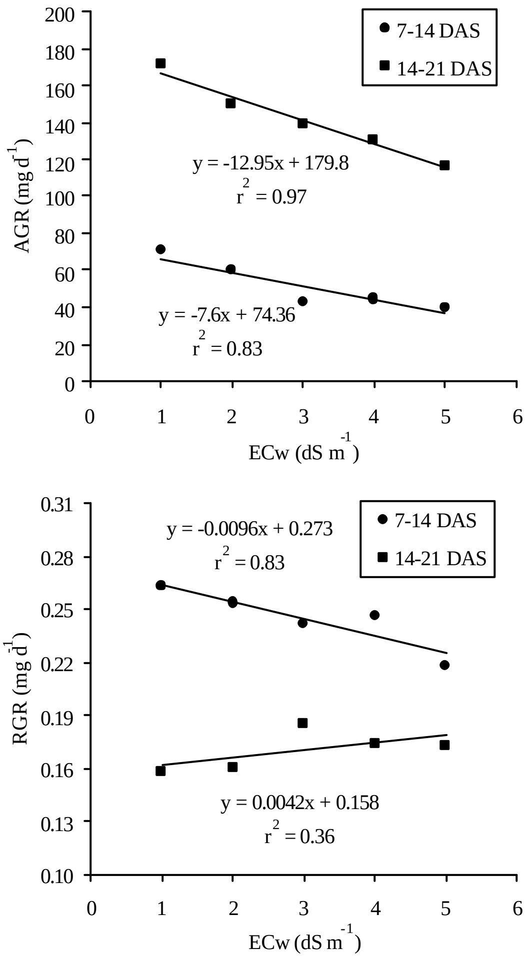

Figure 4. Regression equations for the effects of water salinity (ECw) in the absolute (AGR) and relative (RGR) growth rate of processing tomato seedlings at 7-14 DAS and 14-21 DAS periods.

of preexistent dry matter, resulting in a higher tolerance to salinity in the end of the experimental period. Decrease of RGR with the water salinity in the beginning of the developmental stage followed by an increase in the late stage was also observed for lettuce (VIANA *et al*., 2004). This phenomenon is called "hardening", which expresses the ability of the crop in adapting to a stress factor when the plant is submitted to this factor since its early stage of development, resulting in higher capacity of growth in later stages in the presence of the same stress factor (TAIZ & ZEIGER, 2002).

CONCLUSIONS

Saline waters up to 5 dS m^{-1} did not affect the percentage of germination of tomato, but the speed of emergence was reduced with increasing

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salinity levels;

The dry weight of shoot and root are reduced by water salinity and sodium proportions;

Tomato root is more affected than shoot by salinity;

Seedlings of tomato, cultivar IPA 6, have a higher capacity of accumulating dry matter with increasing water salinity in the later developmental stages.

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