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Chilli tolerance (*Capsicum annuum* L.) submitted to different concentrations of NaCl- of irrigation water

*Tolerancia a la salinidad de chiles (*Capsicum annuum *L.) sometidos a diferentes concentraciones de NaCl- en agua de riego*

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ABSTRACT

The *Capsicum annuum* L. is a vegetable of great importance in the world. In Brazil, has been one of the most consumed in the country, however in some regions like the Northeast, the production of the crop undergoes large reductions due to the irrigation water salinity in function of semi-arid climate leading to losses in the field. Due to this fact, the objective of this research was to evaluate the chili growth (*Capsicum annuum* L.) subjected to various irrigation water salinity levels. The experiment was conducted in the greenhouse of the Universidade Estadual da Paraíba, Campus IV. We adopted a design entirely randomized, with five treatments (1.0; 1.5; 2.0; 2.5 e 3.0 dS m^{-1} de CE) and seven repetitions, the data were subjected to analysis of variance using the test F to 1 and 5% probability and posteriorly when significant was used the analysis of regression, using the SISVAR® software. The analyzed variables were: Total leaf area; mass of dry matter from the leaf; stalk; root; aerial and total part; besides the leaf area ratio; specific leaf area; leaf weight ratio; aerial part and root ratio and relative water content. The culture of chili All big tolerates 2.15 dS m^{-1} without affecting the production of dry matter.

Key words: Abiotic stress, Protected environment, Salinity.

RESUMEN

El Capsicum annuum *L. es una hortaliza de gran importancia en el mundo. En Brasil, es una de las más consumidas en el país, pero en algunas regiones como el Nordeste se observan grandes perdidas en rendimiento debido a la salinidad del agua de riego y el clima semiárido. El objetivo de este ensayo fue evaluar la producción de ají (*Capsicum annuum *L.) sometido a diferentes niveles de salinidad en el agua de riego. El experimento se realizó en el invernadero agrícola de la Universidad Estadual de Paraíba, Campus IV. El diseño experimental fue de bloques completamente al azar, con cinco tratamientos (1,0; 1,5; 2,0; 2,5 y 3,0 dS* m^{-1} *de CE en agua de riego y siete repeticiones. Los datos fueron sometidos al análisis de varianza utilizando la prueba F a 1 y 5% de probabilidad, para separación de medias se utilizó el análisis de regresión, empleando el software SISVAR®. Se midieron diversas variables como peso fresco y porcentaje de materia seca de tallo, raíz y hojas; área foliar total; número de hojas; peso fresco y materia seca del area foliar. Los resulatdos sugieren que el cultivo chile tolera 2,15 dS* m^{-1} *de conductividad eléctrica en agua de riego, sin afectar la producción total.*

Palabras clave: estrés abiótico, protección ambiental, salinidad.

Introduction

The culture of chili (*Capsicum annuum* L.) stands out as one of the vegetables more consumed in Brazil, especially in the Southeast and Northeast regions (Carmo *et al.*, 2015). In the state of São Paulo, one of the largest producers, the chili production em 2016 was of 7.239.218 and the value of the farming production obtained striking winnings of de 39.69% from this culture (IEA, 2016).

In the Northeast region predominates the semi-arid climate and due to these conditions, the culture production is affected by the salts contained in the ground and in the irrigation water, which,

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between other causes can be associated with the low precipitation and evapotranspiration (Niu *et al.*, 2010). The saline stress is, worldly, one of the great abiotic threats to vegetal life, capable of causing significant reductions in the cultures yield in the affected areas, compromising important vegetable processes as plant nutrition, cell metabolism and photosynthesis (Malcolm *et al.*, 2003). Beyond that, stands out between the main causes for the abandonment of arable areas.

The irrigation water quality and its management have fundamental importance to ensure the success in the establishment of the culture in the field. The utilization of water for irrigation depends on its chemical conditions, on the physical-chemical characteristics of the ground and the water demand of the crop, a high content of salts present in the soil or in the irrigation water can cause an increase in the osmotic potential which prevents the capitation of water and alters the non-selective absorption of nutrients nutrients (Almeida *et al.*, 2010).

The species tolerance can be determined by its fitness in accepting variable salt levels, in function to the genotype used, phenological phase and condition of stress (Brito *et al.*, 2014; Oliveira *et al.*, 2015; Albuquerque *et al.*, 2016), as well the water application plan, and the salt exposition period (Costa *et al.*, 2013). The culture of chili is evaluated as moderately sensitive, bearing content of soil salts between 1.3 e 3.0 dSm^{-1} without losing the productive capacity (Ayers & Westcot, 1999). The stress caused by salts can initiate several negative reactions to the plants as dysfunctions in the membrane permeability of the cells, modification on the photosynthesis process, stomatal conductance and consequently in plant development (Aktas *et al.*, 2006).

Material and Methods

The experiment was conducted during the period of November of 2013 to February of 2014, in the greenhouse of the Universidade Estadual da Paraíba (UEPB), Campus IV, Catolé do Rocha, PB, located at the following coordinates (6020'38"S; 37044'48"W) and at an altitude of 275 meters from the sea level, with maximum temperature of 44 ºC and minimum of 22 ºC.

The seeding was done with buckets with the capacity of 7 liters, seeding 5 seed per container in the profundity of 1 cm. The substrate used was derived from the California worm humus and vegetal ground in the proportion of 1:1. Samples of the ground and the humus were sent to the Irrigação e Salinidade lab (LIS) from the Centro de Tecnologia e Recursos Naturais from the Universidade Federal de Campina Grande (UFCG). As well as the samples of water from the amazon well, used for the irrigation of the experiment, which presented the following attributes (Table 1).

The irrigation was done in two shifts (7 and 17 hours). The water used in the irrigation was stored in a container with 30-liter capacity, in which were done the addition of NaCl till we got the wanted concentrations (1.0; 1.5; 2.0; 2.5 e 3 dS m^{-1}). The electrical conductivity of the irrigation water (CEai) were monitored weekly with the help of a portable conductivity meter.

Table 1. Results from chemical analysis of the soil, worm humus and irrigation water in the study of different salty levels in All big chili plants.

	pH	CE	P	K	Ca	Mg	Al	Na	T	V	O.M
	H_2O	dS/m				cmolc/dm³				%	
Soil	8.20	1.53	3.27	0.26	5.09	1.66	0.00	0.26	7.71	100	1.19
	pH	CE	P	K	Ca	Mg	Al	Na	S	NaCl	BA
	H_2O	dS/m					cmolc/dm³				
Humus	7.38	2.11	55.14	1.41	35.4	19.32	0.00	1.82	57.95	1.82	56.13
	pH	CE	Ca	Mg	Na	K	CO_3^{-2}	HCO_4^{-2}	Cl	RAS	WC
		dS m^{-1}				mmolc L^{-1}					
Water	8.13	1.0	2.61	2.96	5.5	0.49	0.44	3.67	4.97	3.29	C_3S_1

O.M = Organic Matter; BA = Base addition; Cl = Chlorides ; WC= Water classification.

After 7 days from the emergency was done the thinning of the less developed plants, separating one plant per vase. The seeding, weeding, irrigation, fertilization, the base of worm humus and the breaking of the surface of the substrate were done, manually were done manually.

After 64 days of seeding, the following variables were evaluated: Total Leaf Area (AFT), Mass from the Dry Matter of the Leaf (MMSF), Stalk (MMSC), Root (MMSR), Aerial Part (MMSPA) and Total Part (MMST), besides the Leaf Area Ratio (LAR), Specific Leaf Area (ELA), Leaf Weight Ratio (RPF), Aerial Part Root Relation (APRR), Succulence Degree (GS) and Relative Water Content (EWC). All the variables related to the dry matter were taken to the greenhouse with 48 h air circulation and posteriorly weighted with a digital balance. Posteriorly were done the ELA and LAR parameters, according to Benincasa, (2003) using the formula: Unitary Leaf Area, Total Plant Area.

We determined the leaf area of all plants considered useful using the equation of Tivelli *et al.* (1997), also used by Araújo *et al.* (2014).

AF=K*L*C
AFT=AF*NF

Where,

AF: Unitary Leaf Area;
AFT: Total Leaf Area;
NF: number of leafs
K: value correlation coefficient 0,60;
L: leaf width and
C: length.

ELA= AFT/MMSF
LAR= AFT/MMST

ELA: Specific leaf area;
AFT: Total Leaf Area;
MMSF: Mass from the Dry Matter of the Leaf;
LAR: Leaf Area Ratio;
MMST: Mass from the total dry matter.

We also calculated the relative water content according to the Fernandes (2000) methodology using the following formula:

EWC (%)= (MMS-MMF)/(MMT-MMF) X 100

MMS: Dry matter mass;
MMF: Fresh matter mass;
MMT: Turgid matter mass.

The Leaf mass ratio was calculated according to Magalhães (1979) with the following formula:

RMF=MMSF/MMST

Next was the relation between the aerial/root parts.

APRR=MSPA/MSR

We adopted an entirely randomized design, with five levels of conductivity coming from the NaCl (1.0; 1.5; 2.0; 2.5 e 3.0 dS m^{-1}) and seven repetitions. The data were subjected to analysis of variance using the test F to 1 and 5% probability and posteriorly when significant was used the analysis of regression, using the SISVAR® software (Ferreira, 2014).

Results and Discussion

The variance analysis showed that 90% of the evaluated parameters, from that, 97% were highly significant. The electrical conductivity levels differ in all evaluated variables, demonstrating the expressive effect of the CEai in the chili development. We observed adjust to the linear model in all variable, except the MDML y MDMAP. The quadratic regression was not significant only in the RPF (Table 2).

In relation to the dry mass, the maximum values found were of 4.56 g with CE of 1.98 dS m^{-1}, 3.64 g with CE de 1.83 dS m^{-1} and 8.07 g with CE de 2.35 dS m^{-1}, for leafs, stalk and root respectively (Figure 1A), we notice that from the 2 dS m^{-1} of electric conductivity the mass values of dry matter present reduction in the different types of vegetable material, in exception of the dry mass from the root which holds maximum concentration point of 2.35 ds m^{-1}. This can be associated with salt stress which can cause morphological, physiological and biochemical alteration in critical levels, interfering with the absorption and transportation of water and nutrients to the plant (Filippou *et al.*, 2014; Monteiro *et al.*, 2014). We read Lemos *et al.* (2012) also working with chili culture, verified that it reduced from 2.5 dS.m^{-1}, for the dry mass of the leaf and of the stalk, being verified linear effect.

The mass of the dry matter from de aerial part (MDMAP) obtained maximum value of 8.17 g in the CE of 1.93 dS m^{-1} and minimum of de 4.7 g

Table 2. Summary of analysis of variance for the biometric and physiological parameters in chili All big Big (*Capsicum annuum* L.) subjected to concentrations of CEai in the salinity tolerance.

FV	FD	Medium Square				
		MDML	MDMS	MDMR	MDMAP	MTDM
CE dS m^{-1}	4	7.61**	4.02**	57.95**	16.01**	104.13**
Linear	1	0.12^{ns}	2.26*	109.53**	3.44^{ns}	74.16**
Quadratic	1	24.30**	6.73**	78.52**	56.60**	268.42**
Deviation	2	3.01**	3.55**	21.88**	1.99^{ns}	36.97**
Residue	30	0.47	0.38	1.32	0.90	2.49
CV		19.34	19.96	19.60	14.33	12.64
Average		3.54	3.08	5.86	6.62	12.48

SV	FD	Medium Square				
		ELA	LAR	LMR	APRR$^{x^2}$	EWC
CE dS m^{-1}	4	21155.57**	123233.41**	0.02**	0.74**	168.90**
Linear	1	47524.06**	202954.19**	0.06**	2.62**	209.16**
Quadratic	1	34038.88**	258506.18**	0.0002^{ns}	0.35**	238.87**
Deviation	2	1529.67*	15736.64^{ns}	0.02**	0.006^{ns}	113.78**
Residue	30	343.15	5292.14	0.002	0.02	16.77
VC		22.04	25.51	17.85	13.39	5.15
Average		84.03	285.15	0.29	1.16	79.51

**,* y ns: Significant in 1 to 5% in the F test, respectively; and Nonsignificant. Data transformed into X². Source of variation (SV), Freedom degree (FD), Regression (R), Variation Coefficient (VC), Total leaf area (TLA), Mass of the dry matter of the leaf (MDMSL), Mass of the dry matter of the stalk (MDMS), Mass of the dry matter of the root (MDMR), Mass of the dry matter of the aerial part (MDMAP), Mass of the total dry matter (MTDM), Leaf area ratio (LAR), Especif leaf area (ELA) Leaf mass ratio (LMR), Aerial part root relation (APRR) and relative water content (RWC).

in the CE of 3 dS m^{-1} (Figure 1B), differing from the study conducted by Lima *et al.* (2005) which evaluated the initial growth subjected to the salinity of the irrigation water and observed values that varied from 5.35 to 4.00 Mg. Garcia *et al.* (2010) affirmed that, with the increase in salinity of the soil, possibly occurs the decline of the osmotic potential of the soil solution, causing the reduction of the water matrix potential, generating a resistance of the plants in absorbing water, e and with the increase in the osmotic pressure, the plants will not have efficiency in generation power of suction to overcome this potential, therefore they will not accomplish to absorb water, affecting the cell expansion causing decrease in the TLA e thus in the accumulation of MDMAP. The quick result of the salt stress is the so-called "physiological dry" coming from this decrease from the osmotic potential reported (Matos *et al.*, 2013).

The maximum accumulation of dry matter of the total plant (MTDM) was of 15.94 g in the CE of 2.1 dS m^{-1} (Figure 1C), we notice that due to the salt level has been a positive effect in the plant's nutrition till certain level, occurring posteriorly toxicity caused by the excess of salinity. Bojórquez-Quintal *et al.* (2014) studying the tolerance mechanisms to salt in chili habanero (*Capsicum chinense* Jacq.) plants in two varieties that exhibit different sensibilities to the salt stress, between them the 'Rex' variety, more tolerant than the 'Chichen-Itza' variety testify a concentration of 150 mM of NaCl through seven days for a culture in hydroponic conditions, and observed high impact on the growth of the two varieties with significant reduction of dry and fresh wieght induced by NaCl in both the genotypes, in the fresh weight the reduction was greater in 'Chichen-Itza' (75%), than the reduction in the 'Rex' variety (50%).

Analysing the ratio dry matter of leaf (LMR) and the ratio aerial part root (APRR), we notice a negative linear effect, while it caused an increase of the salt concentration in the solution, it also caused a reduction in both variables. The LMR varied from 0.349 in the CEai of 1 dS m^{-1} to 0.227 in the CE of 3 dS m^{-1} (Figure 2D) and the APRR varied from 1.54 g to 0.76 g (Figure 2E). On this, we notice a

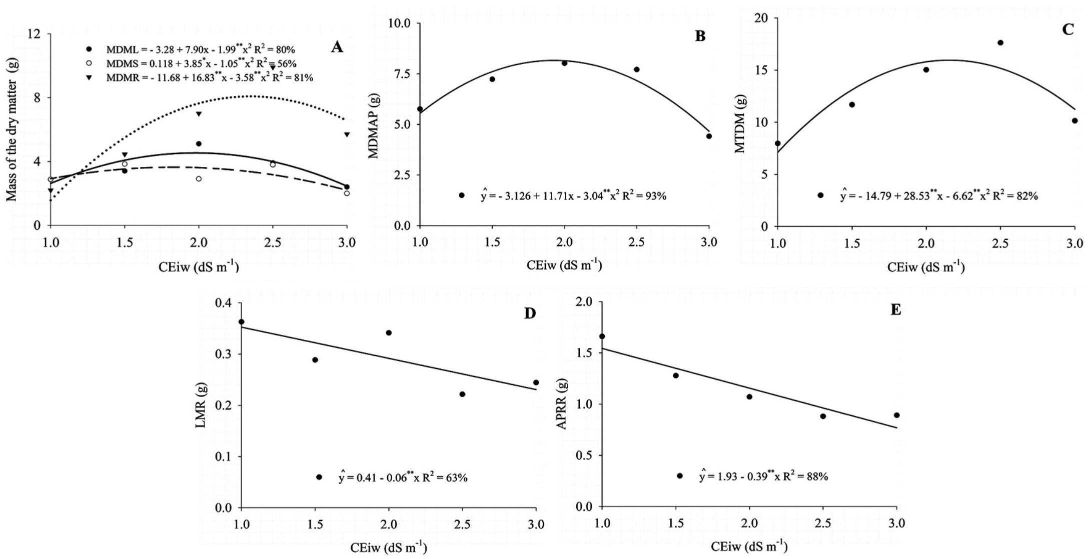

Figure 1. Mass of the dry matter of the leaf, stalk and root (A), Mass of the dry matter of aerial part (B), Mass of the total dry matter (C), leaf mass ratio (D) and Aerial part root relation (E) under applications of CEai concentrations in chili plants (*Capsicum annuum* L.).

behavior of the plants to destine the biomass to the root part, due to the deep roots having more fitness in extracting nutrients and water fro the soil as a response to the salt stress (Matos *et al.*, 2013).

The LAR was reduced while the electrical conductivity increased, having the minimum value of 37.63 g/cm^2 with the CE of 2.35 dS m^{-1} (Figure 2A). Oliveira *et al.*, (2015) observed maximum values of LAR for the chili culture of 118 and 129 cm^2 g^{-1} in the direct planting system (DP) and conventional planting (CP), decreasing due to time till reach constant values near 22 and 20 cm^2 g^{-1}, respectively. The ELA variable obtained indexes of 168.35 g/cm^2 in the CE of 2.26 dS m^{-1} (Figure 1B). Freitas *et al.* (2014) also verified the reduction of the leaf area due to the increase of the CE, a referred to this behavior as one of the initial responses to the salt stress that has been attributed to the decrease of the expansion of the leaf surface and cell division.

The water content (EWC) varied from 87.66% in the CE 1 dS m^{-1} to 73.14% in the CE 3 dS m^{-1} (Figure 2C). Similar behavior was found by Bojórquez-Quintal *et al.* (2014) which observed that the EWC in the Chichen-Itza chili variety sensitive to salinity, when subjected to concentrations of 150 mM of NaCl was significantly lower than the one in control.

In general, the results show a bigger increase of root in relation to the aerial part, which influenced in the reduction fo the leaf area and great degree of succulence that can be associated with mechanisms of osmotic adjust by the plant.

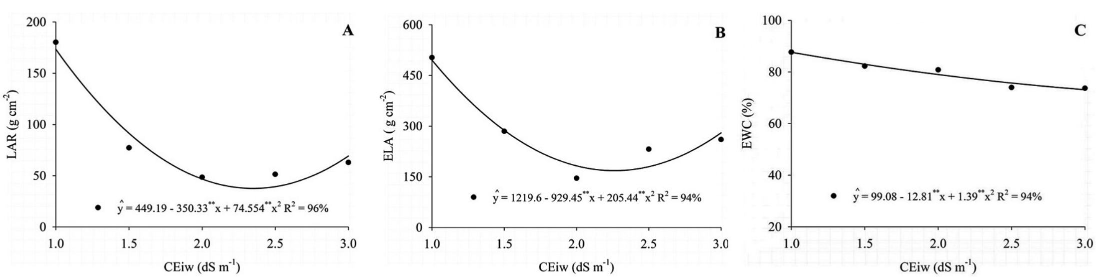

Figure 2. Leaf area ratio (A), Especif leaf area (B), Relative water content (C) under applications of CEai concentrations in chili plants (*Capsicum annuum* L.).

Conclusion

The chili is considered as moderately tolerant to salinity because starting from 2 dS m^{-1}, the osmotic adjust mechanisms are not sufficient to inhibit the action of NaCl and the chili plants All big tolerate CEai to 2.15 dS m^{-1} without affecting the production of dry matter.

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