GROWTH AND WATER CONSUMPTION OF TWO BEAN SPECIES UNDER IRRIGATION WITH SALINE WATER

CRESCIMENTO E CONSUMO DE ÁGUA DE DUAS ESPÉCIES DE FEIJÃO SOB IRRIGAÇÃO COM ÁGUA SALINA

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ABSTRACT

Salinity is an important environmental problem, specially in regions where irrigation with low quality water is practiced. In this sense, an experiment was carried out from May 2005 to August 2005 at Federal University of Paraiba, Areia, Brazil aiming to evaluate the growth and water consumption of *Phaseolus vulgaris* e *Vigna unguiculata*, irrigated with different salinity levels. The treatments were distributed in a completely randomized design, in factorial arrangement 6 x 2 referring to electrical conductivity levels of water irrigation (ECw), as follows: 0.0; 1.5; 3.0; 4.5; 6.0 e 7.5 dS m-1 and two bean species, respectively, with four repetitions and six pots in each parcel. The stem diameter, shoot and root dry mass and water consumption of bean plants were evaluated. Increasing water salinity level, the results of all variables decreased drastically for both species. *Phaseolus vulgaris* species is more deleteriously affected by water salinity than *Vigna unguiculata*.

Key words: *Phaseolus vulgaris*, *Vigna unguiculata*, salinity

RESUMO

A salinidade é um importante problema ambiental, especialmente em regiões onde a irrigação com água de qualidade inferior é praticada. Neste sentido, um experimento foi conduzido entre maio e agosto de 2005 na Universidade Federal da Paraíba, Areia, Brasil com o objetivo de avaliar o crescimento e consumo de água das espécies *Phaseolus vulgaris* e *Vigna unguiculata*, irrigadas com diferentes níveis de salinidade. Os tratamentos foram distribuídos em delineamento inteiramente casualizado, em esquema fatorial 6 x 2 referentes à condutividade elétrica da água de irrigação (EC_w), como segue: 0,0; 1,5; 3,0; 4,5; 6,0 e 7,5 dS m^{-1} e duas espécies de feijão, respectivamente, com quatro repetições e seis vasos por parcelas. O diâmetro do caule, matéria seca de raízes e parte aérea e consumo de água das plantas de feijoeiro foram avaliadas. Incementando-se o nível de salinidade da água da irrigação, os resultados de todas as variáveis decresceram drasticamente para ambas as espécies. *P. vulgaris* foi mais deleteriamente afetada pela salinidade da água que *V. unguiculata*.

Palavras-chave: *Phaseolus vulgaris*, *Vigna unguiculata*, salinidade

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INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is one of the most consumed foods in Brazil, especially for poor class, so it is a typical and important crop of small farmers in Brazil (ANTUNES et al., 1995). In addition, the cowpea bean (*Vigna unguiculata* L. Walp), also known as 'macassar' bean, presents a fundamental, social and economic importance for Northeastern part of Brazil, constituting the main protein source in rural population nutrition, as proposed NASCIMENTO et al. (2004).

In Northestern Region of Brazil, the use of saline water (ECw > 1,5 dS m^{-1}, according to AYERS and WESTCOT, 1999) for irrigation has been necessary. This use promotes the increment on saline levels of soil with the possibility of reaching critic values and negatively influence growth and development of crops, mainly those classified as sensible to salinity effects, as bean, according to crop saline classification proposed by MAAS (1984) and DOORENBOS and KASSAM (1979).

Salinity reduces water availability (osmotic effect) and has a toxic effect, through action of saline complexes or specific action of sodium, chlorate, sulfate, carbonate and bicarbonate ions as reported MUNNS (2002) and HU and SCHMIDHALTER (2004) and confirmed by CAVALCANTE and CAVALCANTE (2006). Sodium ion promotes clay dispersion and soil structure degradation, thus a deleterious effect on soil physics (AYERS and WESTCOT, 1999; SILVA et al., 2005). Therefore, salinity is a limiting factor of geographical species distribution in natural habitats, constituting an increasingly severe environmental and agricultural problem in arid and semiarid regions of the world (SHANNON, 1986), including Brazil.

Salt tolerance of cultivated Leguminosae species has been studied by many techniques during different developmental stages of the plant, using saline solutions (MORENO-LIMÓN et al., 2000), natural saline water or soil and artificial salinity on soil (JOHANSEN et al., 1990). In relation to bean, SOARES et al. (2006) reported that bean is considered a not tolerant crop to salinity of irrigation water, with a potential extreme reduction of 50% on developmental parameters whether irrigated with water of ECw up to 2.4 dS m^{-1}, but it depends on saline complex of the water. Also in study about bean, BAYUELO-JIMÉNEZ et al. (2002) informed that plant dry mass is reduced in 62.41% if irrigated with saline water.

The study had as objective to evaluate the influence of saline levels of water irrigation on growth and water consumption of two bean species, *P. vulgaris* e *V. unguiculata*.

MATERIAL AND METHODS

Plant materials and growth conditions

Seeds for plant formation of the two bean species Phaseolus vulgaris and Vigna unguiculata released from Brazilian Agricultural Research Corporation (EMBRAPA) were used in this study.

The experiment was carried out from May 2005 to August 2005 in a green house of the Centre of Agrarian Sciences, Federal University of Paraiba, Brazil, located at the geographical coordinates 6'58"S and 35'41"W, at 575 m high. During this period, the air temperature ranged from 23 to 38 °C. Air humidity fluctuated between 45 and 85% respectively for day and night between day and night.

The substrate consisted of soil obtained from layer until 0.30 m deep of an Oxisol distrofic, medium texture (EMBRAPA, 1999). After homogenized, the substrate was dried under air conditions, passed to a sieve of 2 mm mesh and conditioned in black polyethylene pots filled with 10 L. See soil physical and chemical characteristics in Table 1.

Ten seeds were sown in each experimental unit at 2 cm deep and once daily irrigated with good water quality. After stabilization of germination, the two most vigorous seedlings were used for salinity study.

There were six levels of saline irrigation water (ECw) at 0.0; 1.5; 3.0; 4.5; 6.0 and 7.5 dS m^{-1}. Saline irrigation waters were obtained by adding soluble salts in distilled water (0.016 dS m-1), according to recommendations of CAVALCANTE et al. (2005) and were composed by 50% of NaCl, 20% of $MgCl_2$, 20% of $CaCl_2$ and 10% of Na_2SO_4. The water supply was done manually based on a daily evaporation of 5 mm and corrected according to the bean culture coefficient (Kc) reported by PEREIRA and ALLEN (1997), direct on soil; leaves were not washed. Plants were daily irrigated (once a day) during the experiment.

For leaching of salts, monthly, the soil was washed with water of ECw 0.5 dS m^{-1} to reduce the substrate salinity to values below 2.0 dS m^{-1}, according to recommendations of ZHU (2001).

Measurements of seedling

At the end of the experiment plant stem diameter was measured with a digital paquimeter (300 mm/12"–0,01 mm/.0005", Digimess, São Paulo, Brazil) at 10 cm high. Dry mass (roots and shoots) were measured after drying samples at 70 ºC for 48 hours in an air forced oven. All observations and measurements were performed from twelve seedlings.

Water consumption of plants was also registered through difference between water applied, evaportranspiration and water drained from the pot.

Statistical design and data analyses

Treatments were setup by following a completely randomized statistical design, and each treatment had four replications and six pots in each parcel. The species were placed in the main plots, with the salt concentrations in submain plots for statistical analyses.

Statistical analyses included analysis of variance (ANOVA), polynomial regression for mean separation of ECw results and simple correlation between dependent variables studied. Means separation on data was conducted using Tukey test (FERREIRA, 2000). Terms were considered significant at $P \leq 0.01$ using the SAS software.

TABLE 1 – Physical and chemical characteristics of the soil used in the experiment.

Physical characteristics		Chemical characteristics	
Granulometry (g kg^{-1})		pH in water, 1:2.5	4.6
Sand	580.50	Organic matter (g kg^{-1})	33.81
Silte	93.50	Phosphorus (mg dm^{-3})	3.60
Clay	32.00	Potassium (mg dm^{-3})	87.35
Soil density (kg dm^{-3})	1.12	Calcium (mmol$_c$ dm^{-3})	31.50
Particle density (kg dm^{-3})	2.60	Magnesium (mmol$_c$ dm^{-3})	19.00
Porosity (%)	57.00	Sodium (mmol$_c$ dm^{-3})	3.05
Umidity retention (kg kg^{-1})		Sum of bases (mmol$_c$ dm^{-3})	53.55
0.033 MPa	0.15	Exchangable acidity (mmol$_c$ dm^{-3})	
1.500 MPa	0.11	Hidrogenium	55.90
Field capacity (gravimetry)	0.27	Aluminium	5.50
Textural class	Average -clay	Cationic exchangeable capacity (mmol$_c$ dm^{-3})	117.35
		Saturarion of bases (%)	46.00

RESULTS AND DISCUSSION

For all the parameters adopted for plant evaluation, the variance analyses (Table 2) show significant differences as among saline levels such as between bean species, for all variables studied and, additionally, only for stem diameter of plants the interaction between two factors analyzed (bean species and saline levels) was not significant.

TABLE 2 – Results of variance analysis of shoot dry mass (SDM), root dry mass (RDM), stem diameter (SD) and plant water consumption (PWC) of two bean species irrigated with different levels of water salinity.

Source	"F" value			
	SDM	RDM	SD	PWC
Saline level (S)	1506.21**	3029.56**	17.30**	166.74**
Bean species (B)	4947.06**	7520.21**	0.11^{ns}	69.82**
Interaction S x B	103.01**	4021.64**	2.48^{ns}	5.39**
C.V.	1.30	3.92	12.01	3.72

NS = non-significant; ** Significantly different ($P \leq 0.01$)

In a general form, a negative effect of salinity was observed with EC$_w$ increase for all variables, independently of bean species.

Figure 1A shows a progressive reduction on plant water consumption (PWC) with EC$_w$ increase from 0.0 to 7.5 dS m^{-1} for both bean species as predicts the linear decreasing model with a fit minimum of 0.96 (*P. vulgaris*) and 0.84 (*V. unguiculata*). EC$_w$ increase affected plant growth and development, thus in agreement with SANTANA et al. (2003), also studying the influence of water salinity on bean plants. Plants irrigated with EC_w of 7.5 dS m^{-1} consumed (32.7% *P. vulgaris* and 44.0% *V. unguiculata)* less water than those irrigated with 0.0 dS m^{-1} $EC_{w,}$ demonstrating that *P. vulgaris* was less deleteriously affected by EC_w than *V. unguiculata* (Figure 2A). HILLLEL (1999) reported that plant water consumption is drastically influenced by high salinity levels due to reduction on tissue osmotic potential, and, consequently, less root water absorption. In contrast, HU and SCHMIDHALTER (2004) concluded that, the reduction on water uptake as function of salinity can be compensated by other parts with lower salinities and increasing root activity; this tendency was not registered in the present study.

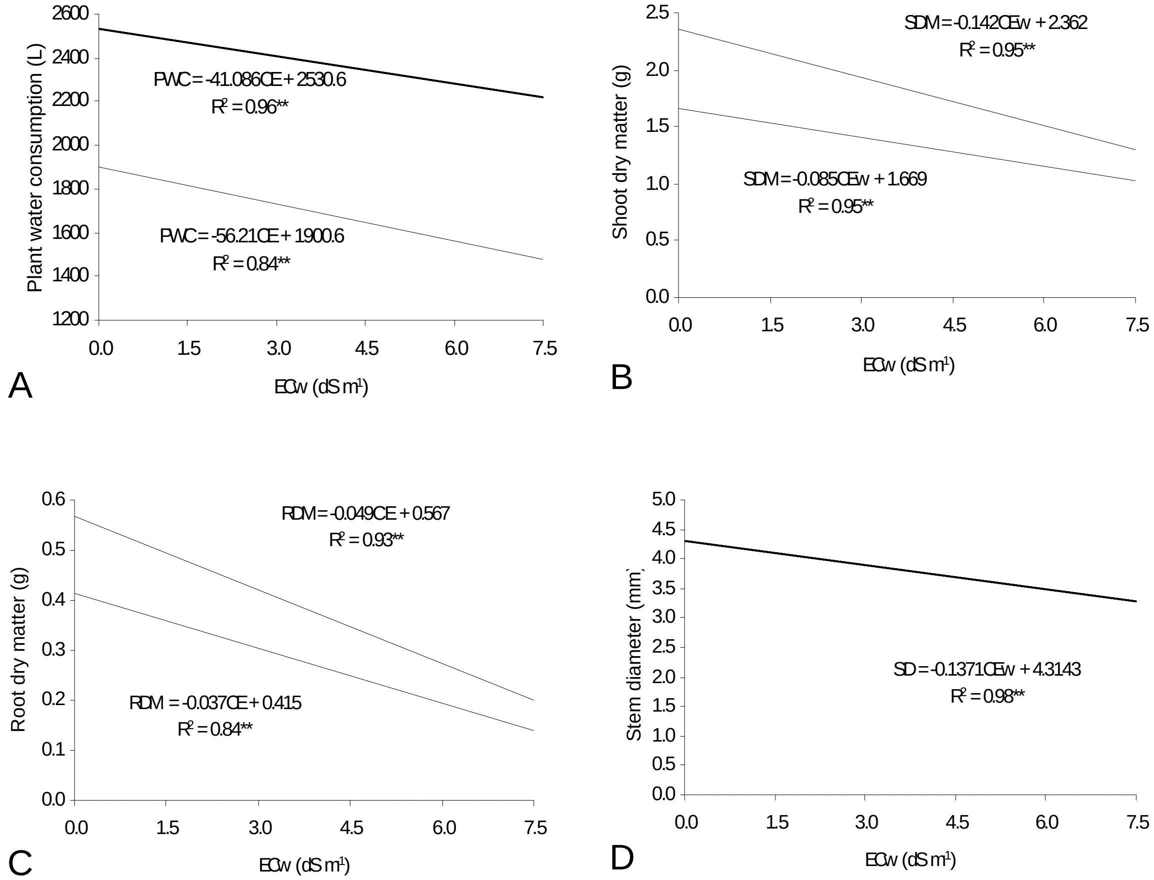

FIGURE 1 – Effect of irrigated saline water on (A) shoot dry matter (SDM), (B) root dry matter (RDM), (C) plant water consumption (PWC) and (D) stem diameter (SD), on two bean species. *P. vulgaris* (——) *V. unguiculata* (- - - -). ** Significant ($P \leq 0.01$)

In spite of shoot dry matter (SDM), both bean species presented the same tendency and data of both species were better adjusted to linear model, as function of saline levels (Figure 1B). Although *P. vulgaris*, independent of saline level, has presented higher SDM than *V. unguiculata* (Figure 2B), with EC_w increase from 0.0 to 7.5 dS m^{-1}, SDM was more reduced in *P. vulgaris* 48.3% than in *V. unguiculata* 35.8%. These quantitative results are close to values of SOARES et al. (2006) who reported that bean is considered a not tolerant crop to salinity of irrigation water, with a potential extreme reduction of 50% on developmental parameters whether irrigated with water of EC_w up to 2.4 dS m^{-1}. *P. vulgaris* reduction recorded 48.3% is below 62.41% informed by BAYUELO-JIMÉNEZ et al. (2002), that compared SDM of this species under non-stressed and salt-stressed conditions.

As also observed for other dependent variables, root dry matter (RDM) had a linear decrease with EC_w increase (Figure 1C), as also concluded BAYUELO-JIMÉNEZ et al. (2002); these authors also observed significant interaction between saline levels and bean species investigated, that demonstrates genetic variability between species and interdependence between factors (salinity and bean species). Similarly, *P. vulgaris* presented average values significantly above *V. unguiculata* species, thus in agreement with the present work, as can be seen in Figure 2C. On the other hand, from the lower to the higher EC_w, *V. unguiculata* presented reduction of nearly 81% while *P. vulgaris* 62%, following the same tendency registered for plant water consumption (Figure 1A). As also reported by STOREY et al. (2003), the root system is one of the most important characters for salt stress because roots are in contact with soil and absorb water from soil, nevertheless MUNNS (2002) suggests that little is known and salinity effect on root system is, still nowadays, an enigma.

After germination, the biological criterion that clearly expresses the osmorregulation of plants to salts is the root system (PARIDA and DAS, 2005; CAVALCANTE and CAVALCANTE, 2006) that evidences the superiority of *P. vulgaris* in relation *V. unguiculata* (Figure 1).

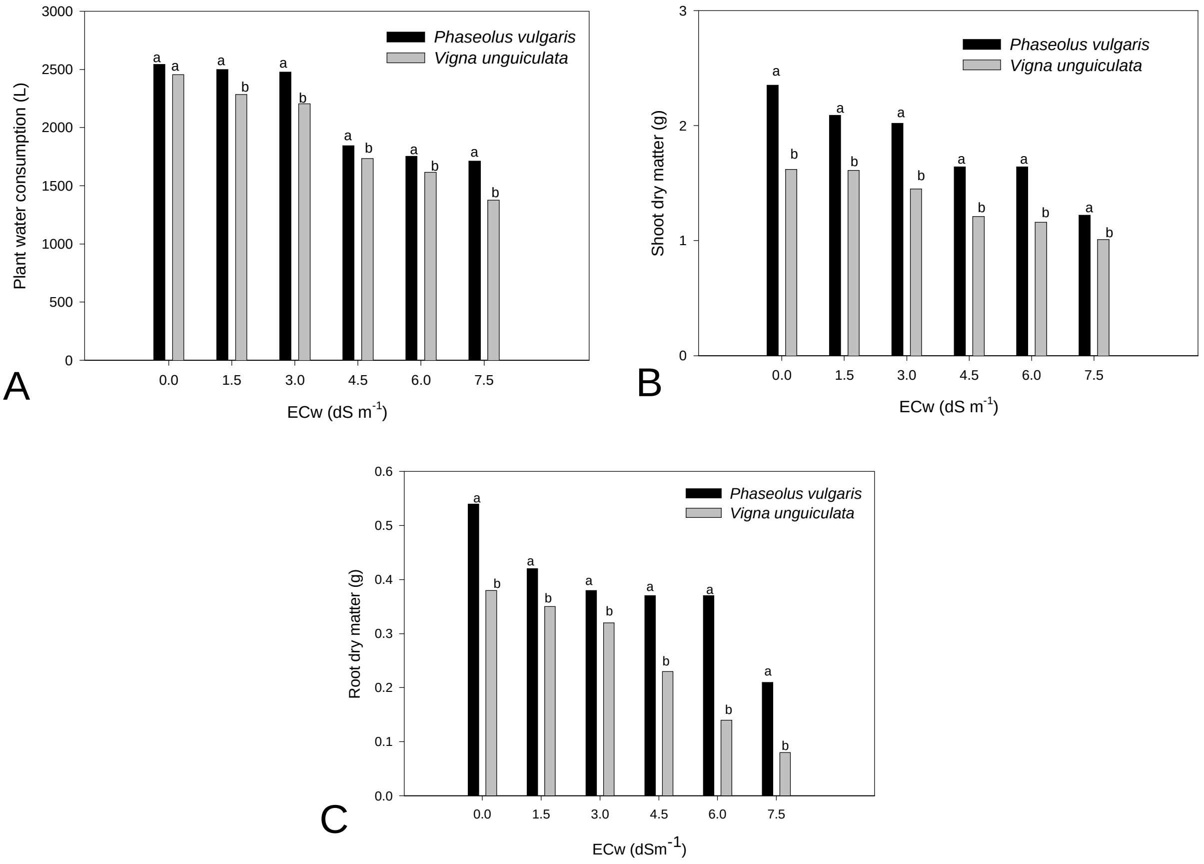

FIGURE 2 – Effect of irrigated saline water (CE_w) on plant water consumption (A), shoot dry matter (C) and root dry matter (C) on two bean species. plant water consumption of two bean species. Within measured species, bars accompanied by different letters are significantly different ($P \leq 0.01$).

Plant stem diameter was significantly reduced by EC_w increase. This sensitivity shows a tendency to level off with increasing values of EC_w as predicts the linear decreasing model with a fit minimum of 0.98 (Figure 1D). The direct contact of roots with the adversely saline environment contributes with a faster and higher salt absorption that deleteriously affects plant organs, interfering the stem diameter growth (TAIZ and ZEIGER, 2002). Due to similarity of data, it is verified that there was no statistical difference between bean species (Table 2), therefore the effect can be represented by a straight line or equation resulting from mean values of bean species, as can be perceived in Figure 1D.

Significant positive correlations ($P<0.01$) between variables studied on both bean species were registered. According to FERREIRA (2000) parameter, each of these correlations is classified as linear, positive and highly significant, because all correlation coefficients (r) showed in Table 3 are above 0.8. These results show that both bean species had the same behavior under irrigation with the same EC_w, and, in addition, that EC_w affected all the plant, including root and shoot dry mass production, stem diameter and plant water consumption. These results support similar findings of FOOLAD (1996) and BAYUELO-JIMÉNEZ et al. (2002), respectively salinity studies about tomato and bean.

TABLE 3 – Correlation coefficients between *P. vulgaris* (*P.v.*) and *V. unguiculata* (*V.u.*) bean species for shoot dry mass (SMD), root dry mass (RMD), stem diameter (SD) and plant water consumption (PWC) under irrigation with different EC_w.

Variáveis		SDM		RDM		SD		PWC	
	Especie	*P.v.*	*V.u.*	*P.v.*	*V.u.*	*P.v.*	*V.u.*	*P.v.*	*V.u.*
SMD	*P.v.*	-	0.96**	0.97**	0.94**	0.97**	0.96**	0.97**	0.92**
	V.u.		-	0.93**	0.91**	0.95**	0.96**	0.98**	0.87**
RDM	*P.v.*			-	0.99**	0.90**	0.99**	0.97**	0.98**
	V.u.				-	0.85**	0.99**	0.96**	1.00**
SD	*P.v.*					-	0.89**	0.93**	0.82**
	V.u.						-	0.99**	0.98**
WC	*P.v.*							-	0.94**
	V.u.								-

** Significantly different (P<0.01)

CONCLUSIONS

The results of this study indicate that: i) With EC_w increase, dry mass production, stem diameter and plant water consumption of *Phaseolus vulgaris* and *Vigna unguiculata* bean species are inhibited; ii) *Phaseolus vulgaris* species is more deleteriously affected by water salinity than *Vigna unguiculata*; iii) Both bean species present growth and water consumption significantly reduced if irrigated with water salinity of 3.0 dS m^{-1} or higher.

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Recebido em 13/07/2007
Aceito em 26/03/2008