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# Growth and yield of guava irrigated with saline water and addition of farmyard manure

## ABSTRACT

The guava production in northeast of Brazil has rapidly increased and moderately saline waters are commonly used in its irrigation. Considering that the use of marginal waters may be harmful to salt-sensitive crops, an experiment was carried out in a greenhouse to evaluate the effects of electrical conductivity of the irrigation water ( $EC_w = 0, 2, 4, 6$  and  $8 \text{ dS m}^{-1}$ ) and addition of farmyard manure (0 and  $3 \text{ kg } 100\text{kg}^{-1}$  of substrate) in development and yield of guava, cv. 'Paluma'. Irrigation waters were prepared with 70% of NaCl and 30% of  $\text{CaCl}_2$  on equivalent basis, and plants were irrigated three times a week and leaching was applied every 30 days to avoid excessive accumulation of salts in soil. Plants were cultivated in plastic containers of 15 cm diameter and 40 cm height with 13 kg of substrate and were harvested at 200 days after transplanting. Plant height, dry matter of all plant parts, leaf area, root/shoot ratio and water consumed were reduced by increase in  $EC_w$ , while the presence of organic matter allowed higher values for most variables. Toxicity symptoms were observed even for the lowest saline water treatment ( $2 \text{ dS m}^{-1}$ ), and dry matter was more partitioned to leaves than to root in saline conditions, contrary to observed in treatment irrigated with distilled water.

**Key words:** *Psidium guajava* L., leaf area, toxicity, water consumption, dry matter partitioning

## Crescimento e produção da goiaba irrigada com água salina e adição de esterco de curral

## RESUMO

No Nordeste do Brasil, a produção de goiaba tem aumentado de forma rápida e águas moderadamente salinas são, em geral, comumente utilizadas para irrigação. Considerando-se que o uso de águas de qualidade marginal pode ser prejudicial para culturas sensíveis aos sais, conduziu-se um experimento em ambiente protegido, a fim de avaliar os efeitos da condutividade elétrica da água de irrigação ( $CE_e = 0, 2, 4, 6$  e  $8 \text{ dS m}^{-1}$ ) e da adição de esterco de curral (0 e  $3 \text{ kg } 100\text{kg}^{-1}$  de substrato) no desenvolvimento e produção da goiaba, cv. 'Paluma'. As águas de irrigação foram preparadas com 70% de NaCl e 30% de  $\text{CaCl}_2$  em proporção equivalente; as plantas foram irrigadas três vezes por semana; a cada 30 dias, para evitar excesso de sais no solo, fez-se a lixiviação. As plantas foram cultivadas em recipientes plásticos de 15 cm de diâmetro e 40 cm de altura com 13 kg de substrato e foram colhidos aos 200 dias após o transplantio. A altura, matéria seca de todas as partes, área foliar, relação raiz/parte aérea e consumo de água pelas plantas, reduziram com o aumento da  $CE_e$ , enquanto a presença de matéria orgânica possibilitou maiores valores para quase todas as variáveis. Sintomas de toxidez foram observados até para o tratamento de salinidade mais baixa ( $CE_e = 2 \text{ dS m}^{-1}$ ) e a matéria seca foi mais particionada para as folhas que para a raiz, nas condições salinas, ao contrário do que se observou no tratamento irrigado com água destilada.

**Palavras-chave:** *Psidium guajava* L., área foliar, toxidez, consumo de água, partição de matéria seca

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## INTRODUCTION

Production of guava (*Psidium guajava* L.) in Brazil has increased greatly during the last years, this increase being from 281,000 t in 2001 to 408,000 t in 2004 (IBGE, 2006). It is cultivated along a large part of the Brazil, from the northeastern to southern regions, in a wide diversity of climates and with high yields. In northeast of Brazil, guava produces twice a year under irrigated conditions and it is commercialized in the internal and external market. However, in arid and semi-arid areas where the irrigation water has high salt content during dry periods, the development of guava seedlings is affected by salinity (Cavalcante et al., 2005).

The four reasons that are usually mentioned as responsible for reduction of plant growth under salt-stressed conditions are: osmotic stress resulting in low availability of water, specific ion toxicity due to metabolic process in the cell, nutritional imbalance caused by specific ion toxicity, and combination of any two of the above-mentioned factors (Al-Yassin, 2004). In addition, the salinity stress combined with high prevailing temperatures of semi-arid region is a potential negative interaction and could result in enhanced uptake of salts due to increase in transpiration, thus plant is not able to open stomata and its leaf temperature increases (Mittler, 2006).

The salinity of the irrigation water affects the amount of deep percolation for a given depth of applied water because evapotranspiration is related to salinity and it depresses crop growth, thus reducing crop evapotranspiration - ETc (Letey, 1999). Besides this, Rhoades & Loveday (1990) state that the salinity effects on evapotranspiration are predominantly water stress effects, with a decrease in osmotic potential of soil water reducing the water availability for plants. Probably, both effects influence ETc and their combined effects result in the reduction of ETc and, consequently, in the reduction of the plant development and yield (Blanco & Folegatti, 2003).

Different models have been proposed to express the reduction of relative yield of crops with increase in soil salinity. The stepwise model (Maas & Hoffman, 1977) is most common and assumes that relative yield (Yr) is equal to one (100%) up to a soil salinity level where the tolerance limit of crop is reached and beyond this limit yield starts decreasing linearly with increasing salinity accordingly to the expression  $Yr = 1 - b(EC - ECT)$ , where b is the linear coefficient of the regression, EC is the mean soil salinity ( $dS m^{-1}$ ) and ECT is the threshold salinity ( $dS m^{-1}$ ). van Genuchten (1983) showed that the response of crops to salinity may vary and regression is not always well adjusted to the stepwise model, so the modified discount function,  $Yr = 1/[1+(EC/C_{50})^P]$ , can be used, where  $C_{50}$  is the soil salinity that causes a 50% reduction of yield ( $dS m^{-1}$ ) and P is a constant that represents the response curve shape.

The accumulation of salt in mature leaves of more salt-sensitive species could lead to toxic effects, i.e. accelerated leaf senescence and/or chlorosis and necrosis; increased loss of viable leaf area should then reduce photosynthesis, and levels of essential hormones, to growth-limiting levels, and new growth is further inhibited (Neumann, 1997).

The application of organic manure to soil is a practice that improves physical and chemical characteristics of the soil, as well as may contribute to enhance tolerance of crops to salt stress by increasing drainage and soil water retention (Liang et al., 2004). In non-saline condition, higher production of guava was obtained when plants received 80 kg of organic manure per plant plus NPK fertilizer, compared to plants that received only manure or NPK (Muhammad et al., 2000). Increasing fruit formation, fruit weight and yield of guava was found when plants received different types of organic manure, compared to NPK fertilizer (Naik & Babu, 2007).

Before increasing further cultivated area with guava in Brazil, it is necessary to know the effects of different management practices and saline stress on plant development and yield. Thus, the objectives of this study were to determine the effects of salinity of irrigation water and addition of organic manure on growth, yield, water consumption and dry matter partitioning of guava, cv. 'Paluma'.

## MATERIAL AND METHODS

The experiment was carried out in Campina Grande, PB ( $7^{\circ} 15' 18'' S$ ,  $35^{\circ} 52' 28'' W$  and altitude of 550 m), from May to November, 1998. During this period, minimum, maximum and mean temperatures were 18, 33 and  $23^{\circ} C$ , respectively, the mean relative humidity varied from 57 to 97%, and wind velocity at 2 m height was  $4.2 m s^{-1}$  (data measured in a conventional weather station, outside the greenhouse).

The treatments were composed of five water salinity levels (electrical conductivity of the irrigation water - ECw = 0, 2, 4, 6 and  $8 dS m^{-1}$ ) and two levels of farmyard manure (M0 = no manure, M1 = 3 kg of manure per 100 kg of substrate). The experiment was a 5x2 factorial and it was conducted in a completely randomized design with six replications each composed of two plants.

Irrigation waters of different levels of salinity were prepared by adding salts (70%NaCl + 30%CaCl<sub>2</sub> on equivalent basis) to distilled water, and in the recipients belonging to M1, 3 kg of farmyard manure was mixed in 100 kg of soil. The results of the physical and chemical analysis of the soil were: sand, silt and clay = 715, 148 and  $137 g kg^{-1}$ , respectively; bulk density =  $1.420 kg dm^{-3}$ ; moisture at field capacity (-10 kPa) and wilting point (-1500 kPa) = 187, 66 and  $28 g kg^{-1}$ , respectively; ECe =  $0.55 dS m^{-1}$ ; SAR =  $1.76 (mmol L^{-1})^{0.5}$ ; exchangeable K, Ca, Mg and Na = 0.38, 0.62, 3.0 and  $2.37 cmol_c kg^{-1}$ , respectively.

The soil was packed in PVC recipients having 15 cm of diameter and 40 cm of height, with an internal perforated plastic bag to facilitate drainage. Each recipient received 13 kg of soil, in which 65 g of simple superphosphate was added and mixed before packing.

Guava seedlings were obtained by cuttings of the cultivar 'Paluma' and one seedling was transplanted in each recipient. The seedlings were pruned to 12 cm height after transplanting and only one bud was allowed to develop to form the plant shoot. Water was added to recipients until saturation and soil

was covered with plastic to avoid evaporation during three days and was weighed afterwards to determine the moisture content at field capacity.

Irrigations were performed three times a week and volume of water applied in each recipient was determined by the difference between its weight at field capacity and at the moment of irrigation. Leaching equivalent to 20% was applied every 30 days to avoid excessive salt build up in soil, and the water depth was calculated by  $V = Va/0.8 - Va$ , where V is the volume of water (L) to be applied to leach salts accumulated in the soil and Va is the accumulated volume of water (L) since last leaching.

Determination of soil moisture at field capacity was repeated every 30 days, at the time of leaching, to adjust the volume of irrigation water to the actual plant biomass; thus, the recipients were weighed 24 h after leaching and the recorded weight was used as the new weight at field capacity. Fertilizers were applied monthly 24 h after leaching, consisting of 0.187 g of N, 0.236 g of K and 0.067 g of Mg per plant, diluted in 0.5 L of water. Foliar fertilization was applied twice a week with a solution containing N, P, K, Ca, Mg, B, Cu, Fe and Mn, except during the flowering period.

Plant height (PH), number of leaves (NL), leaf area (LA) and dry weight of leaf (DWL), stem (DWS), fruit (DWF) and root (DWR) were measured at 200 days after planting. PH was measured from soil surface to plant tip. The leaves of three plants in each treatment were collected and using previously established correlation between LA and dry weight, LA of each leaf was determined. All plants were harvested and separated in leaf, stem, fruit and root and dry weight of each part was determined after drying at 65 °C until constant weight. Leaf area of each plant was estimated by the DWL and its relation with area. All leaves that fell during the experimental period were also collected to compute the number of leaves and dry weight; the value was added to NL and DWL, respectively. The water consumed by plant during whole period (200 days) was estimated from the total amount of water applied in each recipient minus the leaching.

Results were analyzed by the analysis of variance and F test. When significant, the effects of water salinity levels were evaluated by polynomial regression and the effects of the farmyard manure by the test of Tukey (Gomes, 2000). The stepwise regression model (Maas & Hoffman, 1977) and the modified discount function (van Genuchten, 1983) were applied when possible to determine the parameters of salinity tolerance of the crop.

## RESULTS AND DISCUSSION

### Plant growth and yield

All plant growth variables were affected by the electrical conductivity of the irrigation water (ECw) and only the dry weight of fruits (DWF) and root/shoot ratio were not affected by the addition of farmyard manure (M) to soil (Table 1).

Cubic models represented better the effects of ECw on DWR, DWS and DWF than the linear and quadratic models,

**Table 1.** Mean squares of plant height (PH), number of leaves (NL), leaf area (LA), dry weight of root (DWR), stem (DWS), leaves (DWL) and fruits (DWF) and root/shoot ratio (R/S) of guava, under different salinity levels of the irrigation water (ECw) and farmyard manure (M)

**Tabela 1.** Quadrados médios da altura de planta (PH), número de folhas (NL), área foliar (LA), peso seco da raiz (DWR), caule (DWS), folhas (DWL) e frutos (DWF) e relação raiz/parte aérea (R/S) da goiaba, sob diferentes níveis de salinidade da água de irrigação (ECw) e esterco de curral (M)

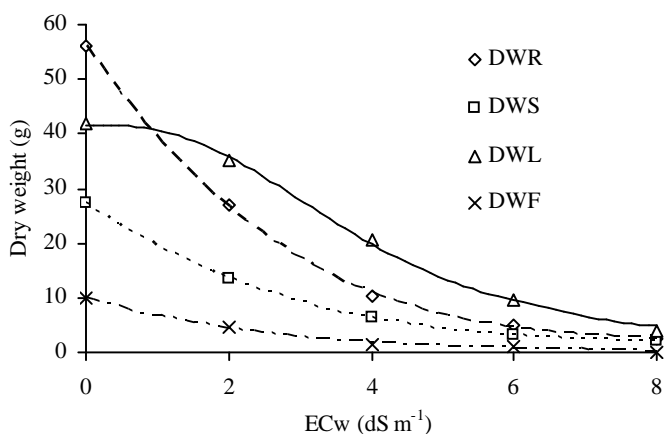
Source of variation	PH	NL	LA	DWR	DWS	DWL	DWF	R/S
ECw	3330 **	45.0 **	11760812 **	4963 **	1578 **	2637 **	162 **	0.18 **
Linear	12774 **	148.5 **	42182184 **	16789 **	5121 **	10323 **	537 **	0.55 **
Quadratic	136	4.2 **	1203	2967 **	1079 **	28	92 **	0.18 **
Cubic	348 **	3.0 **	3417620 **	93	110 **	182 **	11	0.00
M	1005 **	1.8 **	55172 **	70 *	165 **	278 **	0	0.01
ECw x M	40	0.4	3473	5	57 **	14	7	0.00
CV(%)	12.9	6.7	4.7	2.8	19.9	14.4	44.6	18.0

\*, \*\* significant at 0.05 and 0.01 level of probability by the Test F, respectively

while the modified discount function (van Genuchten, 1983) was adjusted to DWL (Figure 1).

All variables were reduced by salinity independent of the type of response. Number of leaves showed a “plateau” response to ECw, with threshold salinity of 3.4 dS m<sup>-1</sup> and per unit decrease for the relative data of 0.174; leaf area and plant height adjusted better to the modified discount function, with C<sub>50</sub> of 3.82 and 5.67 dS m<sup>-1</sup>, respectively, and the root/shoot ratio showed a quadratic variation (Figure 2).

The mean leaf area (cm<sup>2</sup> per leaf) was 40.7 cm<sup>2</sup> for treatment irrigated with distilled water, which was close to the 40.9 cm<sup>2</sup> reported by Corrêa et al. (2004) for the cultivar ‘Paluma’.



$$DWR = -0.1ECw^3 + 2.36ECw^2 - 19.14ECw + 56.3, R^2 = 1$$

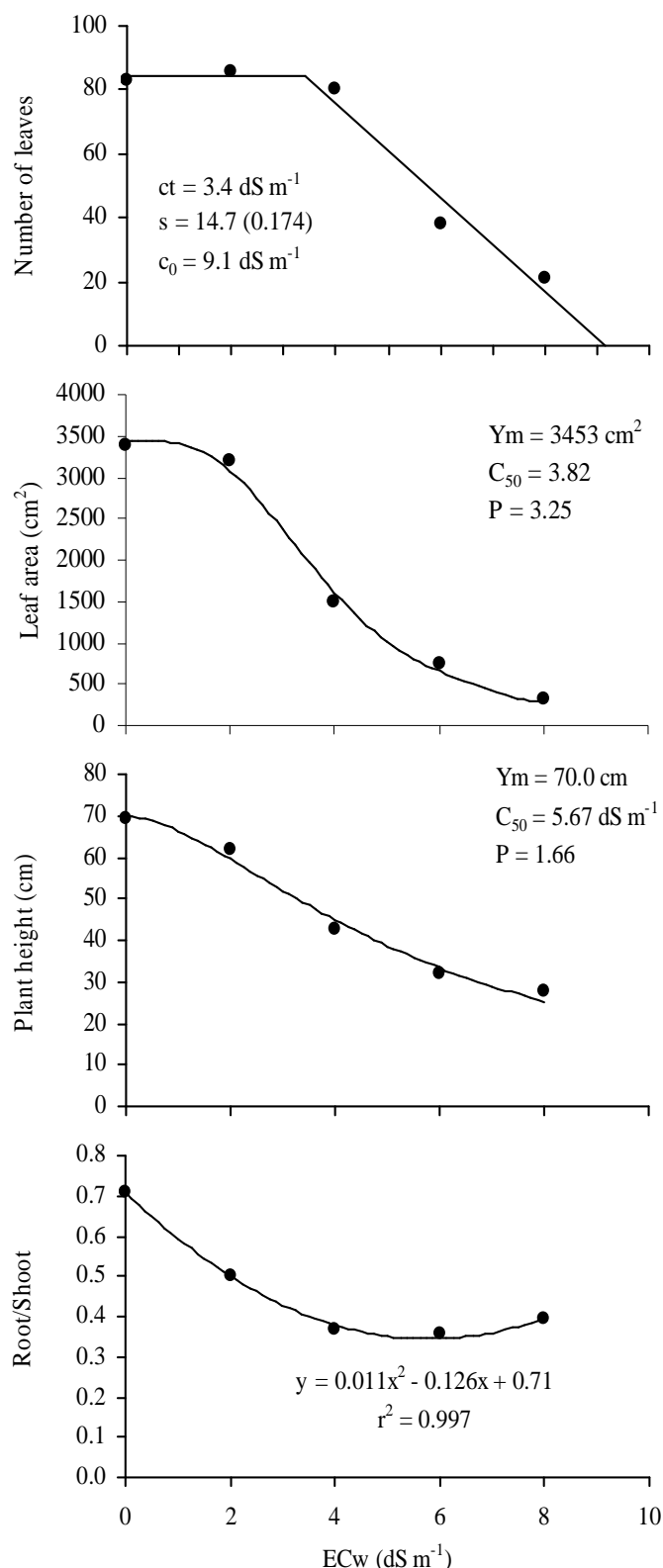
$$DWS = -0.0416ECw^3 + 1.02ECw^2 - 8.64ECw + 27.2, R^2 = 1$$

$$DWL = Ym = 41.5 \text{ g}, C_{50} = 3.87 \text{ dS m}^{-1}, P = 2.80$$

$$DWF = -0.029ECw^3 + 0.055ECw^2 - 3.77ECw + 10, R^2 = 0.99$$

**Figure 1.** Regression equations for the effects of electrical conductivity of the irrigation water (ECw) on dry weight of root (DWR), stem (DWS), leaves (DWL) and fruits (DWF) of guava, 200 days after transplanting

**Figura 1.** Equações de regressão para efeitos da condutividade elétrica da água de irrigação (ECw) no peso seco da raiz (DWR), caule (DWS), folhas (DWL) e frutos (DWF) de goiaba, 200 dias após o transplante



**Figure 2.** Response functions of the number of leaves, leaf area, plant height and root/shoot ratio of guava 'Paluma' in relation to the electrical conductivity of the irrigation water (ECw), 200 days after transplanting. Obs.: Number in brackets is the slope for relative data

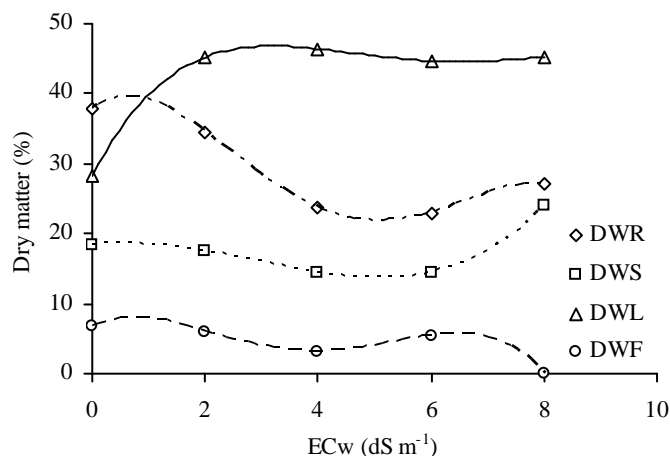
**Figura 2.** Funções de resposta do número de folhas, área foliar, altura de planta e relação raiz/parte aérea de goiaba 'Paluma', em relação à condutividade elétrica da água de irrigação (ECw), aos 200 dias após o transplantio. Obs.: O número entre parênteses é a declividade para os dados relativos

Decrease of DWL was mainly due to reduction of LA up to 3.4 dS m<sup>-1</sup> ECw and thereafter because of reduced number of leaves. Thus the effects of NL and LA were additive in reducing DWL for higher ECw levels. Reduction of DWL, NL and LA were of 90, 80 and 90%, respectively, for ECw of 8 dS m<sup>-1</sup> compared to treatment irrigated with distilled water. These results agree with those obtained by Távora et al. (2001) who observed that the LA was more affected by salinity than NL. Under saline conditions, reduction of LA is a result of decreasing turgor of leaf cells due to the reduced water uptake by roots, followed by leaf shrinking (Munns et al., 2000; Hillel, 2000). Katerji et al. (2005a) found that at the end of the experiment the leaf senescence of durum wheat was lower in the more saline treatments, which was ascribed to the osmotic adjustment.

The leaves were the most producer of dry matter for all ECw, except for treatment irrigated with distilled water (Figure 3). Cavalcante et al. (2005) found that the most of the dry matter was partitioned to leaves for ECw of 0.5 and 1.5 dS m<sup>-1</sup>, but there was no fruit when plants were harvested, at 200 days after sowing, and roots suppressed slightly leaves for the ECw of 3 dS m<sup>-1</sup>.

In spite of dry matter of different parts of plant varied with ECw, the main effect of salinity on dry matter partitioning was reducing DWR and increasing DWL, which suggests that the salinity affected root more than shoot.

Application of farmyard manure increased the plant height, number of leaves, leaf area and the dry weight of roots, stem and leaves (Table 2). The effect of addition of manure to soil depends on the soil condition: in non-sodic soil, the organic matter may improve the physical, chemical and biological characteristics of the soil (Laguë et al., 2005; Bronick & Lal, 2005), but organic matter may increase soil dispersion in sodic or saline-sodic soils (Santos & Muraoka, 1997). In this



**Figure 3.** Dry matter partitioning of guava 'Paluma' under different levels of electrical conductivity of the irrigation water (ECw) 200 days after transplanting. Obs.: DWR, DWS, DWL and DWF - Dry weight of roots, stem, leaves and fruits, respectively

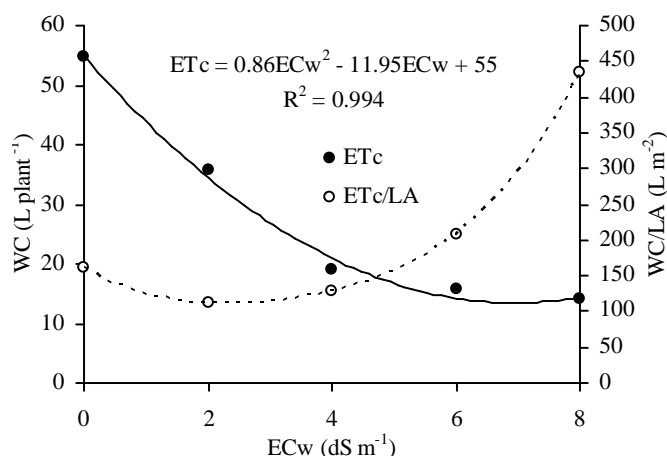
**Figura 3.** Partição de material seca da goiaba 'Paluma' sob diferentes níveis de condutividade elétrica da água de irrigação (ECw), aos 200 dias após o transplantio. Obs.: DWR, DWS, DWL e DWF - Peso seco da raiz, caule, folhas e frutos, respectivamente

**Table 2.** Mean values of plant growth variables of guava for treatments with and without application of farmyard manure

**Tabela 2.** Valores médios das variáveis de crescimento das plantas de goiaba para os tratamentos com e sem aplicação de esterco de curral

Variable	Farmyard manure (%)#	
	0	3
Plant height (cm)	47.2 b	51.1 a
Number of leaves	59.2 b	64.4 a
Leaf area (cm <sup>2</sup> plant <sup>-1</sup> )	1783 b	1869 a
Dry weight of roots (g)	19.0 b	21.4 a
Dry weight of stem (g)	10.5 b	14.1 a
Dry weight of leaves (g)	19.9 b	24.6 a

# Different letters in the same line indicate means significantly different by the test of Tukey ( $P < 0.05$ )



**Figure 4.** Total guava water consumption (WC) and WC per unit of leaf area (WC/LA) under different levels of electrical conductivity of the irrigation water (ECw) during the 200 days of the experimental period

**Figura 4.** Consumo total de água da goiaba (WC) e WC por unidade de área foliar (WC/LA) sob diferentes níveis de condutividade elétrica da água de irrigação (ECw), durante os 200 dias do período experimental

study, the organic matter improved the soil structure and soil surface did not show crust formation and presented better infiltration rate (visually evaluated, not measured), which allo-

wed higher rate of respiration of roots and increased plant growth.

### Water consumption

During the 200 days of the experimental period, the total total water consumed by guava was reduced drastically with ECw up to 4.5 dS m<sup>-1</sup>, with reduction from 55 to 19 L plant<sup>-1</sup> for ECw of 0.0 and 4.0 dS m<sup>-1</sup>, respectively, and tended to remain constant for ECw beyond 4 dS m<sup>-1</sup>, with minimum water consumption (WC) of 14 L plant<sup>-1</sup> observed for treatment of 8.0 dS m<sup>-1</sup> (Figure 4).

Besides the severe reduction of WC with ECw, the WC per unit of leaf area increased with salinity beyond 4 dS m<sup>-1</sup>. This shows that guava tried to maintain the water uptake unaltered, increasing the water flux to the leaves as water salinity increased. Similar variation in per unit leaf area water consumption was estimated from the data reported by Katerji et al. (2005a, 2005b) for sensitive and drought-tolerant varieties of durum wheat and for drought-sensitive varieties of faba bean and chickpea.

Reduction of evapotranspiration (or water consumption) of crops with salinity could be related to reduction of osmotic potential of soil solution and to reductions in morphological and/or physiological parameters like leaf area, stomatal density and stomatal closure (Aranda et al., 2001).

### Toxicity symptoms

Typical symptoms of salt (Na<sup>+</sup> and Cl<sup>-</sup>) toxicity in most sensitive species are characterized by chlorosis followed by necrosis of tip and margins of leaves, working back through the leaf. These symptoms were observed for all treatments irrigated with saline water, being more severe in treatment of 8 dS m<sup>-1</sup>, with complete cessation of growth (Figure 5). The symptoms were, therefore, due to the toxicity of Na<sup>+</sup> and Cl<sup>-</sup>, once the boron was absent in the irrigation water.

Damage occurred at relatively low ion concentrations for sensitive crops (Ayers & Westcot, 1999), thus the occurrence of toxicity symptoms for treatment of low ECw (2 dS m<sup>-1</sup>) indicates that guava 'Paluma' is sensitive to salinity.



**Figure 5.** Toxicity symptoms in guava leaves: (A) the first symptoms, yellowing of leaf borders in treatment of irrigation water salinity (ECw) of 2 dS m<sup>-1</sup>; (B) the evolution of the symptom from left (without symptom) to right (chlorosis and necrosis), common for all saline treatments; (C) the advanced stage of toxicity, with cessation of growth in treatment of ECw of 8 dS m<sup>-1</sup>

**Figura 5.** Sintomas de toxidez em folhas de goiaba: (A) primeiros sintomas, amarelecimento das bordas das folhas no tratamentos de salinidade de água de irrigação (ECw) de 2 dS m<sup>-1</sup>; (B) evolução do sintoma a partir da esquerda (sem sintoma) para a direita (clorose e necrose), comum para todos os tratamentos salinos; (C) estágio avançado de toxidez, com paralização do crescimento no tratamento de ECw de 8 dS m<sup>-1</sup>

## CONCLUSIONS

Increase in electrical conductivity of the irrigation water (ECw) reduces growth and yield of guava 'Paluma'. Dry matter was more partitioned to leaves and less to roots with increase in water salinity, with reduction of the number of leaves for ECw above 3.4 dS m<sup>-1</sup>. Toxicity symptoms in leaves were observed even for the low level of salinity (2 dS m<sup>-1</sup>), which reveals that guava 'Paluma' is sensitive to salinity.

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