WATER SALINITY AND INITIAL DEVELOPMENT OF FOUR GUAVA (*Psidium guajava* L.) CULTIVARS IN NORTH-EASTERN BRAZIL

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A B S T R A C T

The North-eastern part of Brazil has problems with high salt content in water and soil. An experiment was carried out to evaluate the effects of irrigation water salinity on seedling emergence and initial development of four guava cultivars (*Psidium guajava* L.): ‘Pentecoste’, ‘Paluma’, ‘Surubim’ and ‘IPA B-38’. This was done in a completely randomized design with irrigation water having five electrical conductivity (EC_w) levels: 0.5; 1.5; 3.0; 4.5 and 6.0 dS m^{-1}. Salinity considerably inhibited the seedling emergence, plant height, stem diameter, leaf area and dry mass content roots (RDM), stems (SDM) and leaves (LDM) in all cultivars tested. After emergence, all plants irrigated with water with EC_w higher than 4.5 dS m^{-1}, died. The dry mass content was highest in leaves, followed by roots and stems. Guava is more sensitive to salt during seedling formation. Seedlings irrigated with EC_w above 1.5 dS m^{-1} do not form plants of quality suitable for planting.

Key words: guava, water salinity, seedling production

INTRODUCTION

Guava (*Psidium guajava* L.), is popular in the world fruit market, although still little known in some countries. It is valued for its favourable scent, flavour and mineral-protein content, and the cultivation of this tropical fruit became recognised as an economically promising activity for Brazil. In the North-eastern region of Brazil, where supplemental irrigation is used, guava can produce a yield of above 30 Mg ha^{-1} (Gonzaga Neto et al., 1982). However, in arid and semi-arid regions, where the salinity of water (EC_w) used for irrigation can increase during dry periods, adverse effects on seedling production and development of guava can occur. Guava plant is ranked as being salt-sensitive or reasonably salt-sensitive by Ayers and Westcot (1999) and confirmed by Cavalcante and Cavalcante (2006).

Salinity affects the germination, growth and developmental phases of most plants (Bernstein, 1964) including fruit species such as passion fruit, *Passiflora edulis* (Cavalcante et al., 2005), mango, *Mangifera indica* (Zuazo et al., 2004), pine cone, *Annona squamosa* (Lima et al., 2001) and guava, *Psidium guajava* (Pereira, 2000; Távora et al., 2001; Ebert et al., 2002).

Saline complex in water is in equilibrium with soil. Therefore, the continuous use of low quality water for agriculture, with reasonable and high salinity level ($0.75 < EC_w < 3.0$ dS m^{-1} and $ECw > 3.0$ dS m^{-1} respectively), provokes toxic problems for plants and may cause physical degradation of soil. In this situation, monitoring irrigation water quality has high importance for seedling production (Ayers and Westcot, 1999).

With increasing saline concentration, the water availability in soil (water and osmotic potentials) is remarkably reduced, making water absorption by roots more difficult. During the germination phase, this phenomenon promotes higher salt absorption by seeds, giving rise to a depreciative effect on the germination process (Mayer and Poljakoff-Mayber, 1989).

Kaul et al. (1988) studied the effects of sodium chloride, sodium sulphate and calcium chloride on guava and showed that increased medium EC_w inhibited germination and root and hypocotyl growth. They also concluded that sodium chloride was more deleterious than calcium chloride and sodium sulphate. Makhija et al. (1980) and Hooda and Yamdagni (1991) evaluated the salinity influence on guava growth at various phenological phases and concluded that saline stress inhibited plant growth most during the germination phase. This is contradicted by results of experiments done by Pereira (2000), which indicated that 'Pentecoste', 'Paluma', 'Surubim' and 'IPA B-38' guava cultivars are more salt sensitive during the seedling formation phase.

Hence, the aim of this paper was to investigate the effects of irrigation water salinity on the germination and initial development of four guava cultivars.

MATERIAL AND METHODS

Plant materials

Four guava cultivars were used: ‘Pentecoste’ with white pulp and ‘Paluma’, ‘Surubim’ and ‘IPA B-38’ with red pulp.

Growth conditions

The experiment was carried out in a canvassed shelter of the Centre of Agrarian Sciences, Federal University of Paraíba, Brazil. The air temperature ranged between 23-28°C during the day and between 15-18°C at night. The relative humidity fluctuated between 45 and 85%. Under the experimental conditions, the temperature varied from 24-25°C and the air humidity was below 80%.

The substrate consisted of washed sand, humus and bovine manure (sand : humus : manure = 1:1:1) with C/N ratio of 12:1 and was filled into 5.0 l black polyethylene pots measuring 25 cm in height and 18 cm in diameter. The initial electrical conductivity in the soil solution was approximately 4.9 dS m^{-1}. Before sowing, the substrate was washed with water (EC_w = 0.5 dS m^{-1}) to obtain an EC value of below 2.0 dS m^{-1} in soil solution (Lima et al., 2001).

Saline irrigation water was obtained by the dilution of high dam saline water (EC_w = 27.0 dS m^{-1}) with distilled water (Cavalcante et al., 2001) in order to obtain five levels of salinity (EC_w 0.5; 1.5; 3.0; 4.5 and 6.0 dS m^{-1}). During the experiment, the water supply was administered every 48 h at volume sufficient to meet the evapotranspiration requirements, according to Allen et al. (1998).

Determination of seedling emergence

Ten seeds were sown in each pot. The number of emerged seedlings was recorded daily until stabilization of the emergence process. A previous study (Annonimous, 1992), showed that germination percentages, under the non-saline conditions, were 51% for ‘Pentecoste’ and ‘Paluma’, 45% for ‘Surubim’ and 53% for ‘IPA B-38’. The average number of emerged seeds was divided by 10 and multiplied by the value obtained for each cultivar in the laboratory tests.

Measurements of seedling growth

Sixty days after emergence all seedlings irrigated with water with EC_w 4.5 and 6.0 dS m^{-1} died. Therefore, the factorial design 5 x 4 was reduced to 3 x 4, which involved only EC_w levels 0.5, 1.5 and 3.0 dS m^{-1} and the respective genotypes. Plant height was measured with a millimetre ruler, stem diameter with a digital paquimeter (300 mm/12”-0,01 mm/ 0005”, Digimess, Săo Paulo, Brazil) and leaf area was measured at 60, 120 and 180 days after sowing (DAS). Leaf area was first estimated according to the length and the maximum width of leaves, and then corrected by the factors obtained from coefficients between the real area and the estimated area of each cultivar. The factors of each cultivar were; 0.758 for ‘Pentecoste’, 0.743 for ‘Paluma’, 0.745 for ‘Surubim’ and 0.758 for ‘IPA B-38’.

At 180 day after sowing, the dry mass content in roots (RDM), stems (SDM) and leaves (LDM) was determined.

Statistical analysis

Treatment was administered in a randomized complete design. Statistical analyses included analysis of variance (ANOVA) and polynomial regression to mean separation of EC_w results using SAS software. Means separation on the data was conducted using Tukey's test (Ferreira, 2000) at $P \leq 0.01$. For statistic evaluation, the seedling emergence data was transformed to arcsen $[x\ (\%)/100]^{1/2}$, according to David's test.

RESULTS

Since significant interactions between guava cultivars and EC_w were not registered, the regression analyses of all dependent variables were performed with means of cultivars at each EC_w.

Water salinity significantly affected guava seed germination. The increase in irrigation water's EC inhibited seedling emergence of all guava cultivars tested with a minimum fit of 0.97 (Tab. 1).

Salinity affected also further seedling development. With time elapsing, saline effects remarkably increased (Fig. 1), which is shown by a drastic decrease in plant height, stem diameter and leaf area, especially 180 days after sowing.

Increasing EC_w from 0.5 to 3.0 dS m^{-1} resulted in a notable reduction in plant height; by 29.11% in 'Pentecoste', 20.04% in 'Paluma', 39.81% in 'Surubim' and 74.37% in 'IPA B-38'.

Plant development, expressed by stem diameter, steadily decreased with EC_w increasing (Fig.1), and the highest reductions were observed at the 180 DAS. Under the same EC_w level (1.5 and 3.0 dSm^{-1}) 'Paluma' showed the lowest decrease of stem diameter.

Guava leaves showed different reaction pattern to increased salinity. The increase of water salinity level did not reduce leaf area after 60 days of sowing. However, in older seedlings water with EC above 1.5 dS m^{-1} caused significant reduction of leaf area, which reduced the biological value of seedlings (Fig. 1).

The highest dry mass content, under any water salinity, was in leaves. The dependency between dry mass accumulation in each organ and salinity of irrigation water was most remarkable in the root system (Fig. 2). Under irrigation with the lower ionic concentration in irrigation water (Fig. 2A), 'Paluma' was least affected. However, this cultivar also presented the highest reduction rate in dry mass content during EC_w increase from of 0.5 to 3.0 dS m^{-1}.

The EC_w of 4.5 dS m^{-1}, and higher, were toxic for all guava plants – at this water salinity all plant growth indices stopped, independently of cultivar (Fig. 1).

DISCUSSION

Our results show that the inhibitory salinity affected seedling emergence of all cultivars, as reported previously by Pereira (2000). This confirms that cultivars of the same species can present a similar tendency under the same conditions of salinity during the seedling emergence phase, which was proposed by Bernstein (1964).

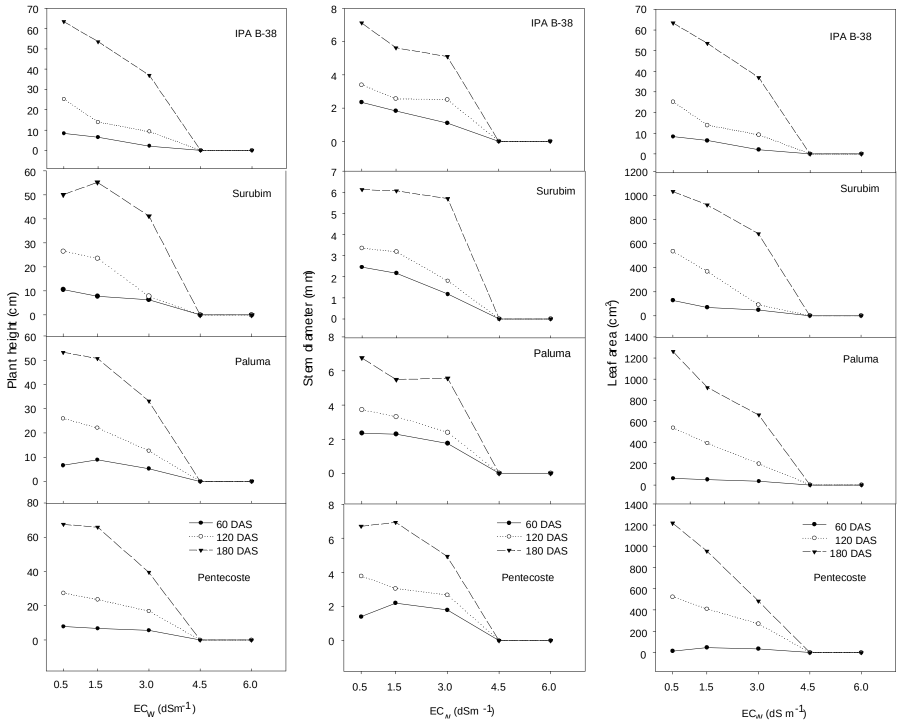

Figure 1. Effect of irrigation water salinity (EC_w) on plant height, stem diameter and leaf area of four guava cultivars measured 60, 120 and 180 days after sowing (DAS)

Table 1. Regression coefficients of seedling emergence (SE), plant height, stem diameter, leaf area and dry mass content in roots (RDM), stems (SDM) and leaves (LDM) as a function of water salinity

Variable (Y)	$Y = A*EC_w + B$			
	A	B		R^2
SE	- 4.100	32.220		0.97**
Plant height	- 6.565	38.110		0.99**
Stem diameter	- 0.442	4.367		0.99**
RDM	- 1.280	6.165		0.88**
SDM	- 0.923	5.033		0.99**
	$Y = A*(EC_w)^2 + B*EC_w + C$			
	A	B	C	R^2
Leaf area	- 236.800	694.850	326.930	0.99**
LDM	- 0.636	0.642	7.190	0.99**

**Significant at $p \leq 0.01$

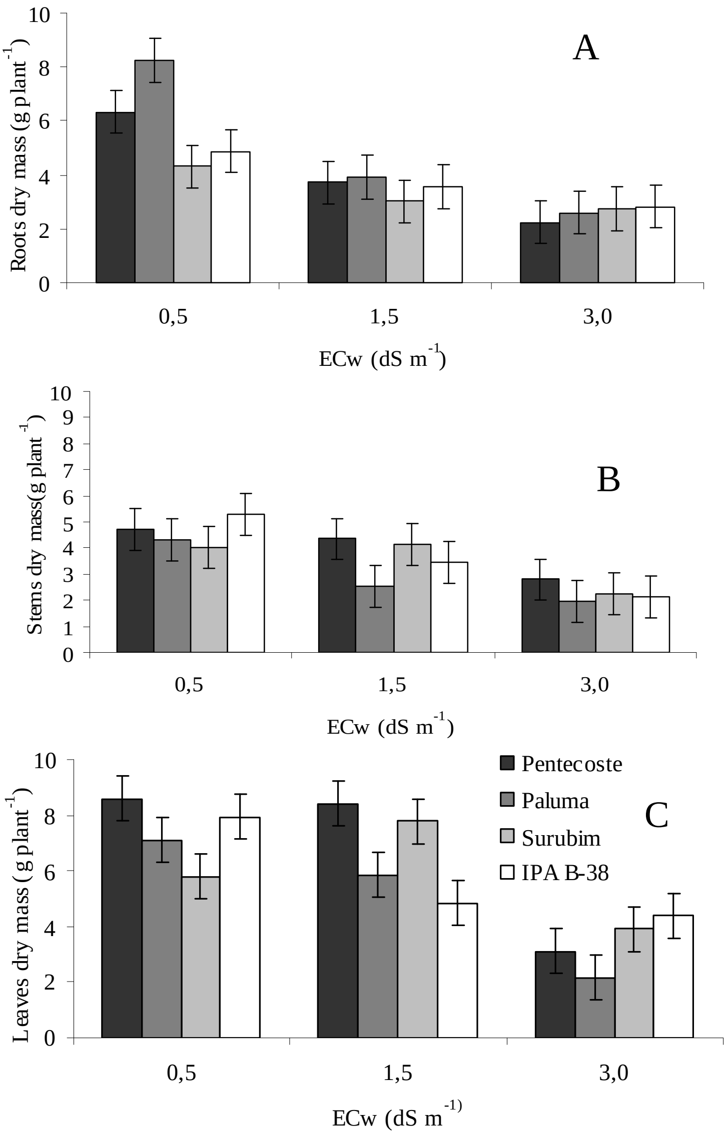

Figure 2. Effect of irrigation water salinity (EC_w) on dry mass content in roots, stems and leaves of four guava cultivars

Salinity affects all the developmental stages of plants (Hu and Schmidhalter, 2004), but seed germination is one of the most important phases for the saline evaluation of plant species due to the sensitivity of embryonic axis to the contact with salts (Mauromicale and Licandro, 2002).

Strogonov (1964) studied the physiological basis of plant reaction to saline stress and concluded that salt damage is most severe during vegetative stage. Likewise, Pereira (2000) and Távora et al. (2001) came to the same conclusion. However, Hooda and Yamdagni (1991) reported that guava is more salt sensitive during germination than during the initial growth phase.

Analysis of plant height increase until 180 DAS show that guava cultivars had their growth affected differently under the same saline stress, as reported previously by Bernstein (1964). Regression analysis data of saline levels and plant height identified linear correlation (Tab. 1) with a 0.99 minimum fit, which agrees with findings of Meloni et al. (2001).

Plants irrigated with the water of lowest EC (0.5 dS m^{-1}) had the thickest stems, but this did not resulted in seedlings of good quality, as also reported by Pereira (2000) and Távora et al. (2001). As can be seen in Figure 1, stem diameter was strongly influenced by EC_w and plant age, as expected. This sensitivity shows a tendency to level off with increasing EC_w values, as predicts the linear regression model with a fit minimum of 0.99, as presented in Table 1.

Leaf area was not as affected by salinity as was the plant height and stem diameter, but this doesn't indicate salt tolerance or osmotic adjustment. Previous research results suggest that saline stress is more pronounced in plants during their initial growth phase, when EC_w is increasing up to the levels of reasonable and severe toxicity (0.75 < EC_w < 3.0 dS m^{-1} and EC_w > dS m^{-1}, respectively) (Ayers and Westcot, 1999; Parida and Das, 2005). Salt stress also results in a considerable decrease in the fresh and dry mass content in leaves, stems, and roots (Chartzoulakis and Klapaki, 2000). The highest losses of plant mass were registered with EC_w 3.0 dS m^{-1}, independently of plant organ or cultivar, as also found by Ayers and Westcot (1999).

The linear regression analysis of RDM data (Tab. 1) shows a tendency for the RDM to level off with an EC_w increase at a fit minimum of 0.88, as was also shown by Ebert et al. (2002) in a study on NaCl-stressed guava seedlings. In this study, plants irrigated with water with EC_w = 0.5 dS m^{-1} accumulated 56% more RDM than those irrigated with water having EC of 3.0 dS m^{-1}, which contradicts results obtained by Munns (2002).

Many authors believe that the root system is the most affected plant organ by salinity because it has a direct contact with salts in soil solution and that most of cellular and molecular mechanisms of plant osmorregulation and salt tolerance is related to roots (Ayers and Westcot, 1999; Cavalcante et al., 2001). Whether this was the case, cultivars 'Surubim' and 'IPA B-38' were superior over 'Pentecoste and Paluma' in reaction to water salinity under the same EC_w (Fig. 2). Munns (2002) reported that cultivars of the same species can present different salt tolerances under the same saline condition, what agrees with the work presented.

In relation to SDM, the 'Surubim' cultivar (Fig. 2B) had significantly higher dry mass content under an intermediate water EC (1.5 dS m^{-1}). This parameter shows that the deleterious effect of EC_w enhances the differences of salinity effects on guava cultivars, in relation to dry mass accumulation. Generally, water salinity increase from 0.5 dS $m^{-1}$to 3.0 dS m^{-1} causes a reduction of nearly 50% in SDM. As was also the case for RDM, SDM decrease showed a tendency to level off at increased EC_w, as predicts the linear regression presented in Table 1, with a fit minimum of 0.99.

In all cultivars tested, LDM was higher than SDM and RDM under any water salinity. This agrees with results on seedlings of passion fruit and pine cone irrigated with dam saline water reported by Lima et al. (2001). Decrease of dry mass accumulation at elevated water salinity was also reported by Ebert et al. (2002).

The reduction of LDM under ECw of 1.5 dS m^{-1} demonstrates that guava cultivars 'Surubim' and 'IPA B-38' are more resistant to salt stress than 'Pentecoste' and 'Paluma'. Marcelis and Van Hooijdonk (1999) indicate the importance of leaves in saline stress reaction studies, revealing that reduction of LDM in plants also reduces in almost 80% plant growth due to decrease in leaf area, light perception and stomatal gas exchange.

As proposed by Lauchi and Epstein (1984), Kaul et al. (1988), Hooda and Yamdagni (1991) and Lima et al. (2001), dry mass accumulation reflects the physiological status of salt stressed roots.

CONCLUSIONS

Our studies show the following:

- With the increase of water salinity, the seedling emergence, plant height, stem diameter, leaf area and dry mass production of roots, stems and leaves of guava are inhibited;
- Seedlings irrigated with water salinity of 4.5 and 6.0 dS m^{-1} died;
- Guava is more sensitive to salinity during the seedling formation phase;
- Guava seedlings can not be irrigated with water salinity above 1.5 dS m^{-1}.

REFERENCES

Allen R.G., Pereira L.S., Raes D., Smith M. 1998. Crop evapotrasnpiration-guidelines for computing crop water requirements. FAO, Irrigation and Drainage Papers 56, Rome.

Annonimous 1992. Regras para análise de sementes. Ministério da Agricultura e Reforma Agrária, Brasília, 365 p.

Ayers R.S., Westcot D.W. 1999. A qualidade da água na agricultura. UFPB, Campina Grande, 153 p.

Bernstein L. 1964. Salt tolerance of plants. USDA Infor. Bull. 283, Washington, 23 p.

Cavalcante L.F., Cavalcante I.H.L. 2006. Uso da água salina na agricultura. In: Cavalcante L.F., Lima E.M. (eds), Algumas frutíferas tropicais e a salinidade. FUNEP, Jaboticabal, pp. 1-12.

Cavalcante L.F., Carvalho S.S., Lima E.M., Feitosa Filho J.C., Silva D.A. 2001. Desenvolvimento inicial da gravioleira sob fontes e níveis da salinidade da água. REVISTA BRASILEIRA DE FRUTI-

CULTURA. 23(2): 455-459.

Cavalcante L.F., Costa J.R.M., Oliveira F.K.D., Cavalcante Í.H.L., Araújo F.A.R. 2005. Produção do maracujazeiro-amarelo irrigado com água salina em cova protegidas contra perdas hídricas. IRRIGA. 10(3): 229-240.

Chartzoulakis K., Klapaki G. 2000. Response of two greenhouse pepper hybrids to NaCl salinity during different growth stages. SCI. HORT. 86: 247-260.

Ebert G., Eberle J., Ali-Dinar H., Ludders P. 2002. Ameliorating effects of $Ca(NO_3)_2$ on growth, mineral uptake and photosynthesis of NaCl-stressed guava seedlings (*Psidium guajava* L.). SCI. HORT. 93: 125-135.

Ferreira P.V. 2000. Estatística experimental aplicada ŕ Agronomia. 3th edition. UFAL, Maceió, 682 p.

Gonzaga Neto L., Bezerra J.E.F., Abramof L., Pedrosa A.A. 1982. Cultivo da goiabeira (*Psidium guajava* L.) nas condiçőes do Vale do Rio Moxotó.. Empresa Pernambucana de Pesquisa Agropecuária, Recife, 8p. (Instruçőes Técnicas, 5).

Hooda P.S., Yamdagni R. 1991. Salt tolerance of guava (*Psidium guajava* L.) and amla (*Emblica officinalis*) at germination stage. RES. DEV. REP. 8(1): 36-38.

Hu Y., Schmidhalter U. 2004. Limitation of salt stress to plant growth. In: Hock E., Plant Toxicology (4th ed.), Marcel Dekker Inc., New York, pp. 191-224.

Kaul M.K., Mheta P.K., Baskshi R.K. 1988. Note on effect of different salts on seed germination of *Psidium guajava* L. cv. L-49 (Sadar). CURR. AGRIC. 12(1-2): 83-85.

Lauchi A., Epstein E. 1984. Mechanisms of salts tolerance for plants. CALIFORNIA AGRIC. 38(10): 18-20.

Lima K.L., Cavalcante L.F., Feitosa Filho J.C. 2001. Efeito de fontes e níveis de salinidade da água de irrigação sobre a germinação e o crescimento da pinheira. ENGENHARIA AGRÍCOLA. 21(2): 135-144.

Makhija M., Dhankhar O.P., Singhrot R.S. 1980. Effect of soil salinity levels on growth and leaf mineral composition of guava (*Psidium guajava* L.). HARYANA J. HORT. SCI. 9(1-2): 21-25.

Marcelis L.F.M., Van Hooijdonk J. 1999. Effect of salinity on growth, water use and nutrient use in radish (*Raphanus sativus* L.). PLANT SOIL. 215: 57-64.

Mauromicale G., Licandro P. 2002. Salinity and temperature effects on germination, emergence and seedling growth of globe artichoke. AGRONOMIE 22: 443-450.

Mayer A.M., Poljakoff-Mayber A. 1989. The germination of seeds. Pergamon Press, Oxford, 270 p.

Meloni D.A., Oliva M.A., Ruiz H.A., Martinez C.A. 2001. Contribution of proline and inorganic solutes to osmotic adjustment in cotton under salt stress. J. PLANT NUTR. 24: 599-612.

Munns R. 2002. Comparative physiology of salt and water stress. PLANT, CELL ENVIRON. 25: 239-250.

Parida A.K., Das A.B. 2005. Salt tolerance and salinity effects on plants: a review. ECOTOXICOL. ENVIRON. SAF. 60: 324-349.

Pereira K.S.N. 2000. Tolerância varietal da goiabeira ŕ salinidade da água de irrigação durante a germinação e produção de mudas. Master's thesis, Universidade Federal da Paraiba, Brazil, 82 p.

Strogonov B.P. 1964. Physiological basis of salt tolerance of plants. Program

Scient. Transl., Jerusalem, 279 p.

Távora F.J.A.F., Ferreira R.G., Hernandez F.F.F. 2001. Crescimento e relações hídricas em plantas de goiabeira submetidas a estresse salino com NaCl. REVISTA BRASILEIRA DE FRUTICULTURA. 23(2): 441-446.

Zuazo V.H.D., Martínez-Raya A., Ruiz J.A., Tarifa D.F. 2004. Impact of salinity on macro- and micronutrient uptake in mango (*Mangifera indica* L. cv. Osten). SPAN. J. AGRIC. RES. 2(1): 121-133.

WPŁYW ZASOLENIA WODY NA ROZWÓJ SIEWEK CZTERECH ODMIAN GUAWY (*Psidium guajava* L.) W WARUNKACH PÓŁNOCNO-WSCHODNIEJ BRAZYLII

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STRESZCZENIE

W północno-wschodniej Brazylii występują problemy z zasoleniem wody i gleby. Badania miały na celu ustalić wpływ zasolenia wody do nawodnień na kiełkowanie i rozwój siewek czterech odmian guawy (*Psidium guajava* L.): ‘Pentecoste’, ‘Paluma’, ‘Surubim’ i ‘IPA B-38’. Badania przeprowadzono w układzie losowym, stosując wodę o pięciu stopniach zasolenia (przewodnictwa jonowego): 0,5; 1,5; 3,0; 4,5 i 6,0 dS m^{-1}. Zasolenie znacząco ograniczyło kiełkowanie nasion oraz wysokość siewek, średnicę pędu, powierzchnię liści i zawartość suchej masy w korzeniach, pędach i liściach wszystkich badanych odmian. Przy stosowaniu wody o przewodnictwie jonowym powyżej 4,5 dS m^{-1} wszystkie rośliny zamarły. Zawartość suchej masy była najwyższa w liściach a najniższa w pędach. Guawa jest bardziej wrażliwa na zasolenie podczas rozwoju siewek niż podczas kiełkowania. Jakość siewek nawadnianych wodą o przewodnictwie jonowym powyżej 1,5 dS m^{-1} nie kwalifikowała ich jako materiału do nasadzeń.

Słowa kluczowe: guawa, zasolenie wody, produkcja siewek