

WATER SALINITY AND INITIAL DEVELOPMENT OF YELLOW PASSION FRUIT

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ABSTRACT: Considering the lack of information on salt tolerance of passion fruit (*Passiflora edulis*) seedlings, a study was carried out to evaluate the effects of water salinity on the vigor and initial growth in a completely randomized design with 8 levels of electrical conductivity of irrigation water (EC_w), varying from 1.0 to 8.0 $dS\ m^{-1}$. Salinity delayed the germination process, but relative reduction was observed only above EC_w 4.43 $dS\ m^{-1}$. Seedling vigor and growth decreased with increasing salinity, however, water at 4 $dS\ m^{-1}$ resulted in 85% of vigor and seedlings with more than 50% growth in comparison to the lowest salinity treatment. Based on soil salinity, the passion fruit may be considered as 'moderately tolerant' to salinity during the initial phase.

Key words: *Passiflora edulis*, salinity tolerance, electrical conductivity

SALINIDADE DA ÁGUA E DESENVOLVIMENTO INICIAL DO MARACUJAZEIRO AMARELO

RESUMO: Considerando-se a inexistência de indicativos de tolerância do maracujazeiro (*Passiflora edulis*) à salinidade, estudaram-se, no delineamento inteiramente casualizado, os efeitos de oito níveis de condutividade elétrica da água de irrigação (CEa), variando de 1,0 a 8,0 $dS\ m^{-1}$, sobre o vigor e a formação de mudas de maracujazeiro amarelo. A salinidade retardou a germinação, mas só houve decréscimo relativo com CEa > 4,43 $dS\ m^{-1}$; o vigor de plântulas e o crescimento foram afetados com a salinidade, todavia, água de CE de 4 $dS\ m^{-1}$ proporcionou 85% de vigor e mudas com crescimento superior a 50% em relação ao menor nível estudado. Com base na salinidade do solo, o maracujá amarelo pode ser considerado 'moderadamente tolerante' na fase de muda.

Palavras-chave: *Passiflora edulis*, tolerância, condutividade elétrica

INTRODUCTION

Fruit cultivation under irrigated condition in northeastern Brazil has increased considerably during the last decades, mainly due to the excellent temperature and insolation conditions. The Brazilian Government, during next five years, expects to establish 100,000 to 150,000 ha per year of irrigated fruit crops, under the auspicious Program for Support and Development of Irrigated Fruit Cultivation in the Northeast - PADFIN (Brasil, 1998). In 1997, the irrigated area in the region was already close to 400,000 ha, with the potential for nearly 6 million ha (Bernardo, 1997). However, Chile, which has a total irrigated area of 220,000 ha, is the leader in global fruit export, with an annual exchange of about US\$ 1.4 billion (Brasil, 1998).

Due to the expected increase in irrigated area in the Northeast and scarcity of good quality water in the region, the use of marginal quality water, from the salinity/sodicity point of view, has become a necessity in any irrigation program. This, associated with inadequate soil-water-plant management and edaphoclimatic conditions, has promoted soil salinization, jeopardizing crop yields,

and even causing the abandonment of formerly productive areas. In 1983, there were already about 8.5 million ha affected by salinity and related problems in the region (Pereira, 1983).

The inhibition of crop growth under saline conditions is commonly caused by osmotic effect and/or due to excessive ion accumulation in the plant tissues, which may cause ionic toxicity and/or nutritional imbalance (Boursier & Lauchli, 1990). The extent to which each stress condition affects plant growth/development, however is dependent on various factors, including plant species, cultivar and phenological stage, soluble salt composition, stress intensity and its duration, and edaphoclimatic conditions (Cramer et al., 1994).

Each plant material has a salinity tolerance limit, above which the yield reduces linearly (Maas, 1984; Ayers & Westcot, 1991). This limit is called salinity threshold (ST). These authors classified the passion fruit as sensitive to salinity, crops with $ST < 1.3\ dS\ m^{-1}$. However, the precise ST value or rate of yield reduction as a function of salinity increase has not been mentioned. Based on the relationship between electrical conductivity of irrigation water (EC_w) and electrical conductivity of

saturation extract of soil (EC_{se}), as proposed by Ayers & Westcot (1991), for a leaching fraction between 0.15 and 0.20, the threshold value in terms of water salinity (EC_w) would be around 0.9 dS m^{-1} .

Because of the magnitude of salinity problems in Brazilian Northeast region, as well as the importance of passion fruit for the region (40% of national production), and the lack of information about threshold salinity indicators for passion fruit, the objective of this study was to evaluate the effects of irrigation water salinity on passion fruit seedling vigor and growth.

MATERIAL AND METHODS

The experiment was carried out from December 1999 to March 2000, in a greenhouse at the Department of Agricultural Engineering, Campus II - Federal University of Paraíba (UFPB), in Campina Grande, PB, Brazil (latitude: 7°15'18" S; longitude: 35°52'28" W; altitude: 550 m).

The effects of eight levels of electrical conductivity of irrigation water (EC_w) on the initial development of yellow passion fruit (*Passiflora edulis Sims. f. flavicarpa* Deg) until 77 days after sowing (DAS) were evaluated. Water salinity levels varied from 1 to 8 dS m^{-1} (N_1 to N_8 , respectively), and a randomized complete block design was used.

The substrate used was a mixture of three parts of soil + one part of earthworm humus on weight basis. The soil was a sandy-loam (0 - 0.2 m), non-saline and non-sodic Oxisol, pH 5.4, from Nova Floresta - PB, the most important passion fruit producing municipality in the State of Paraíba.

Plastic pots (0.25 m high and 0.1 m in diameter) were drilled at the bottom for drainage, and were filled with 1.9 kg of the substrate. At 0.015 m depth, 10 seeds were sown in each recipient. At 16 DAS, the first thinning was performed, when only the two most vigorous seedlings were left. At 32 DAS, the second thinning was done, leaving one plant per pot. Until 32 DAS, pots were kept inside plastic trays, randomly distributed, and the water drained from six replications from each treatment was collected. After 32 DAS, the drainage water was collected from each pot separately, by coupling a collector pot at the bottom of each one.

Irrigation waters were prepared by adding NaCl, $CaCl_2 \cdot 2H_2O$ and $MgCl_2 \cdot 6H_2O$ to the tap water, in a way to obtain the specific EC_w for each treatment, keeping Na:Ca:Mg proportion as 7:2:1, the proportion valid for most irrigation waters in northeastern Brazil (Medeiros, 1992).

Pots were irrigated every other day, and the volume applied intended to supply the evapotranspiration requirements and provide a leaching of about 40%. The evapotranspiration or water consumption was determined by the difference between the volume applied and the volume drained.

Starting at 46 DAS, 10 mL of solution containing 4,5 g L^{-1} of soluble fertilizer (19:19:19) was applied every other day to each pot. The fertilizer solution contained also Fe, Mn, B, Zn, Cu and Mo, at 1000, 500, 200, 150, 110 and 70 mg kg^{-1} , respectively. Substrate samples were collected at 32 and 77 DAS to evaluate the saturation extract salinity according to method suggested by EMBRAPA (1997).

The seed vigor was evaluated by determining the germination percentage (GP), using 12 repetitions, at 11 and 16 DAS; and seedling vigor was evaluated using 2 replications, by means of shoot dry matter (DMS) and root (DMR). The evaluations of initial development of passion fruit were performed at 32 DAS, using 2 replications, and at 77 DAS, using 4 repetitions. Besides the DMS and DMR, these evaluations included: number of leaves (NL), and plant height (PH). At 77 DAS, the evaluation also included stem diameter at the root-shoot junction (SD) and leaf area (LA) estimated on the basis of previously established relationship between the weight of leaf discs of known area and the weight of the whole leaf.

Mineral composition of leaves and roots (Na, Ca, Mg and K content) was measured at 77 DAS using the method described by Malavolta et al. (1997); Na and K were quantified by flame photometry and Ca and Mg by atomic absorption spectrophotometry. The relative water consumption was also evaluated up to 32 DAS and from 33 to 77 DAS.

Statistical analyses to explain salinity effects included analysis of variance (Ferreira, 1996) and linear, quadratic and piece meal regression analysis.

RESULTS AND DISCUSSION

Seed vigor

Irrigation water salinity affected ($P < 0.01$) germination percentage (GP), quadratically in both periods (11 and 16 DAS) (Figure 1A). A lengthening of the germination period was observed, mainly above N_5 level. At 11 DAS, GP decreased abruptly with increasing EC_w . In relation to N_1 , the decrease in germination was 41.2% for N_5 and 90.6% for N_8 . At 16 DAS, the relative decrease in GP occurred only for EC_w values higher than 4.43 dS m^{-1} .

The most important salinity effect was the extension of the germination period, 5 days on average, since the relative decrease due to the highest EC_w level (N_8), at 16 DAS (39.6%), was similar to that at the N_5 level, at 11 DAS.

Further, in high salinity treatments (N_7 and N_8), seed germination was observed up to 24 DAS, although it was not taken in to consideration. Since more than 80% of germination occurring at the lowest salinity level was observed with EC_w 6.7 dS m^{-1} , the salinity tolerance of yellow passion fruit is quite evident at this stage.

Excessive amounts of soluble salts in the soil cause a decrease in osmotic potential and consequently, a decrease in the water potential gradient between soil

and seed. This makes difficult water absorption by the seed (Pizarro, 1985). Depending on the saline stress intensity, it may cause delay of the germination period, as observed in this study up to EC_w 4.43 $dS\ m^{-1}$, or inhibition of the germination process. Moreover, the excessive absorption of ions such as Na and Cl causes a decrease in respiration and in the activity of some enzymes involved in germination (Azimov, 1973), limiting the availability of energy for the cell division process and embryonic axis development.

Initial seedling development

Seedling development (16 DAS) decreased linearly with increasing irrigation water salinity. Figure 1B presents the regression equations (significant at 0.01 level of probability) obtained when relating DMS and DMR production to EC_w . Evaluation of seedling development shows a higher salinity effect on roots, DMS decreased 3.90% per unit increase of EC_w in relation to N_1 (100%), while DMR decreased 5.33% on average. Similar effects have been observed in other studies on different crops, for example: Marinho et al. (1998) in pineapple; Souza (1999) in melon and watermelon, although some authors (Maas & Hoffman, 1977; Shannon, 1997) have referred that salinity affected root system less than aerial parts.

Two factors have to be taken in account while studying plant tolerance to salinity: the salinity threshold (ST), level at which deleterious effects over plant growth/development commence, and rate of decrease, when salinity levels are above ST values.

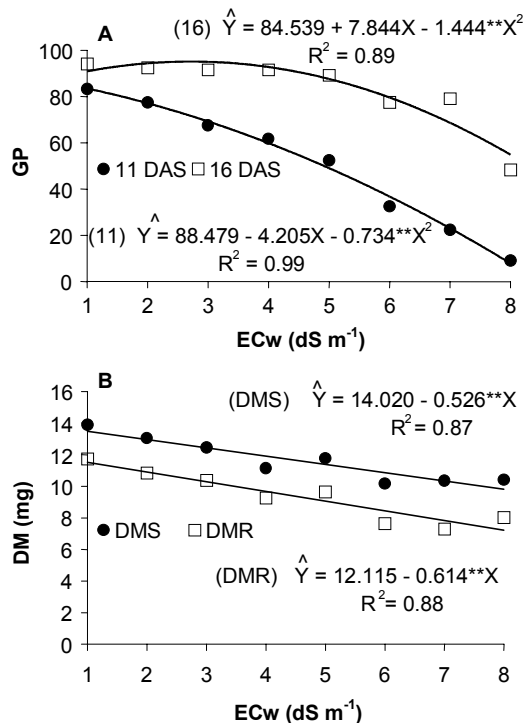


Figure 1 - Germination percentage (GP) at 11 and 16 days after sowing - DAS (A) and dry matter of shoot (DMS) and root (DMR) at 16 DAS (B) as a function of water salinity (EC_w). $^1EC_w = 1, 2, \dots, 8$ refer to salinity levels N_1, N_2, \dots, N_8 , respectively.

In this study, although the EC_w restricted seedling growth starting at the lowest salinity level (1.0 $dS\ m^{-1}$), the decrease rate observed was quite small (Figure 1B). Thus, at high salinity level, 8 $dS\ m^{-1}$ e.g., 72.7% of DMS and 63% of DMR were obtained, in relation to N_1 level. These results show the tolerance to salinity of yellow passion fruit during seedling emergence phase, mainly when salinity level is lower than 4 $dS\ m^{-1}$. At this level, the relative accumulation of plant matter was above 85%, in relation to N_1 . A possible explanation may be that as salinity extended the germination period, the majority of the seeds, at the highest salinity levels studied, germinated between 11 and 16 DAS (Figure 1A), partially justifying the lower DMS and DMR at 16 DAS for these treatments.

Several studies show the deleterious effects of salinity over the vigor of other crops (Souza, 1999; Viana, et al., 2001; and others). The effects are of physio-chemical nature: physical, since the salinity decreases osmotic potential of soil solution, which makes water absorption by roots more difficult; and chemical due to toxic effects, which may occur by direct action of specific ion, or by nutritional disorder (Pizarro, 1985). In this study, the more intense effect was physical because no toxicity effects or abnormalities were observed.

Seedling development

Seedling growth was affected by irrigation water salinity at both evaluation dates (32 and 77 DAS), mainly in the highest level (Figures 2 and 3).

At 32 DAS, there was a decrease in the number of leaves only at EC_w above 4.71 $dS\ m^{-1}$, when compared to N_1 . According to regression equation $\hat{Y} = 5.241 + 0.289 EC_w - 0.051^{**} EC_w^2$ ($R^2 = 0.91$), the relative reduction at the highest EC_w level (N_8) was only 22%. Nevertheless, at 77 DAS the effects were intensified and NL decreased linearly (Figure 2), accumulating a relative reduction of about 50% at N_8 , more than two times higher than that of 32 DAS at the same EC_w level.

Leaf area reduction due to salinity increase occurred mostly due to change in leaf size, instead of number of leaves (Figure 2), as observed by Rhoades & Loveday (1990). NL decreased 7.19% with per unit increase of EC_w above N_1 , while LA decreased nearly 10.53%. Morphologic adaptations, like the reduction of leaf size and number, are common when plants are under water and saline stress as a way to reduce water loss by transpiration (Shannon, 1997).

During seedling formation, until 32 DAS, the fruit tolerance to salinity was good (Figure 3). Even though the linear decreases occurred starting from N_1 during this period, these were relatively small. For unit increase of EC_w , relative decreases of 7.0, 8.1, and 7.6% were observed for PH, DMS and DMR respectively, based on N_1 (Figure 3). Hence, seedlings showed more than 75% of relative growth when irrigation water was of 4 $dS\ m^{-1}$, considered as of "severe restriction" for most crops by Ayers & Westcot (1991).

At 77 DAS, salinity effects were more intense, causing more problems to seedling growth; at EC_w of 2 $dS m^{-1}$, the relative reductions in PH, DMS and DMR (based on N_1) were 24.8, 20.2 and 19.6% respectively (Figure 3). These values were similar to the ones obtained with water of 4 $dS m^{-1}$, at 32 DAS (21.0, 24.3 and 22.8% respectively). At 32 DAS, as well as at 77 DAS, there was a parallelism among curves (Figure 3), indicating that salinity effects on root system and aerial parts of plant were similar.

Salinity also reduced stem diameter at 77 DAS ($\hat{Y} = 0.393 - 0.031^{**} EC_w$, $R^2 = 0.92$); however, the reduction was less severe compared to decreases

observed in PH, DMS and DMR. At 8 $dS m^{-1}$, stem diameter was approximately 41% of the diameter at N_1 .

Comparing the relative reduction caused by water salinity at 77 DAS, NL and diameter were the variables less affected, while more harmful effects were observed, in ascending order, on LA, DMS, DMR and PH.

The evidences that salinity and/or sodicity affect different metabolic processes in plants, as CO_2 assimilation, protein synthesis, respiration, water relations, enzymatic reactions and phytohormones conversion have been known for a long time (Menguel & Kirkby, 1987; Shannon, 1997). These effects cause, among other problems, reduced energy availability to sustain the plant growth at satisfactory levels (Munns & Termaat, 1986).

The intensification of salinity effects with plant age may be clearly observed by the piece meal regression analysis for the DMS data as a function of EC_{se} at 32 and 77 DAS (Figure 4). Limiting EC_{se} values (salinity threshold - ST) above which a decrease in DMS occurred, were 5.61 and 2.73 $dS m^{-1}$, at 32 and 77 DAS respectively, while relative decrease rates above these limits were similar (7.78 and 7.44%, for 32 and 77 DAS respectively), proving that the salinity effects were more drastic at 77 DAS.

In addition to salt tolerance differences among species and cultivars, differences may also exist within the same genotype group according to growth stages (Shannon, 1997).

Although salinity effects were found to intensify with plant age in this study, the results were better than expected, since Maas (1984) classified passion fruit as sensitive to salinity. Based only on ST values (77 DAS), yellow passion fruit may be classified as moderately sensitive during the seedling stage (ST between 1.3 and 3.0 $dS m^{-1}$). Nevertheless, if additional criteria of the same author considered, the crop is classified as moderately tolerant, because for $EC_{se} = 4 dS m^{-1}$ DMS was approximately 90%.

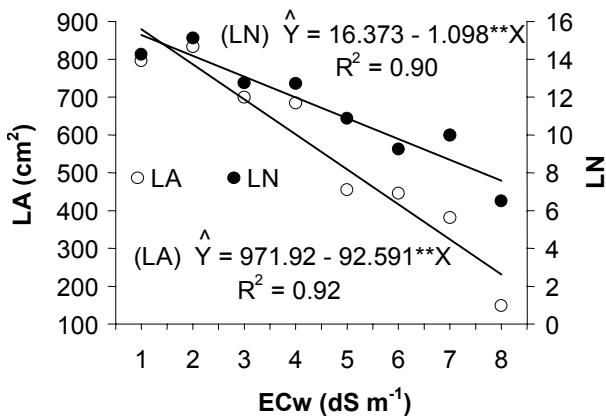


Figure 2 - Number of leaves (NL) and leaf area (LA) at 77 days after sowing as a function of irrigation water salinity (EC_w).

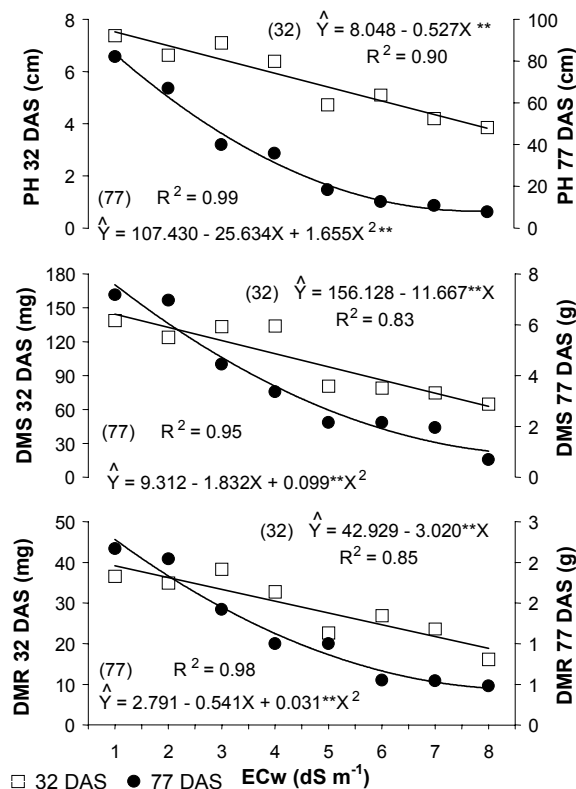


Figure 3 - Plant height (PH), dry matter of shoot and root (DMS and DMR) at 32 and 77 days after sowing (DAS) as a function of irrigation water salinity (EC_w).

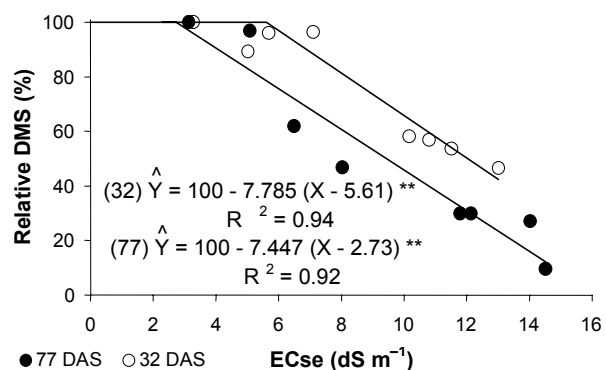


Figure 4 - Dry matter of shoot (DMS) at 32 e 77 days after sowing (DAS) as a function of electrical conductivity of saturation extract of soil (EC_{se}).

Water consumption

Soluble salt concentration in the root zone reduces the water flux from soil to plant and to atmosphere due to osmotic effects (Rhoades & Loveday, 1990), reducing plant transpiration and metabolism.

In this study, the osmotic effects were responsible for the reduced plant water consumption between 33 and 77 DAS with increasing salinity levels (Figure 5A). The reduction of the evapotranspiration during the period followed a quadratic trend, similar to the discussion for PH, DMS and DMR (77 DAS), so that the water consumption by plants at N_8 was equivalent to nearly 39% that of N_1 , indicating that salinity stress induces water stress, with consequent growth reduction. There is a direct relationship between evapotranspiration and plant growth (Doorenbos & Kassam, 1994). Maximum evapotranspiration, as well as maximum growth, occur when water is supplied. On the other hand, if there is water restriction, growth is reduced as observed here with increasing EC_w .

Considering that during the study the substrate was kept close to its maximum water retention capacity (field capacity) by frequent irrigations, the applied volumes of water in irrigation promoted frequent leaching, with no visible toxicity symptoms. The osmotic effect was probably the main cause for reduction of plant growth with increase in water/soil salinity.

No differences (<10%) were found among saline treatments in relation to relative water consumption up to 32 DAS (Figure 5A). The germination period was 16 days, therefore, the transpiration by seedlings during the first days after germination was relatively smaller

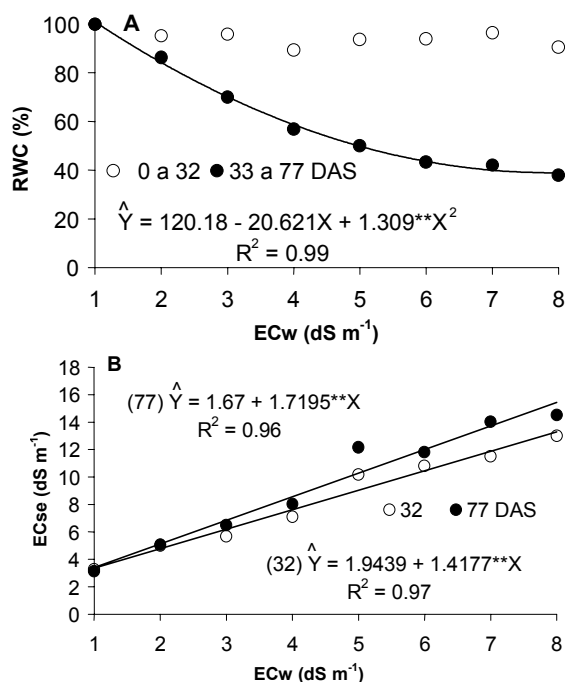


Figure 5 - Relative water consumption (RWC) accumulated for 0 - 32 and 33 - 77 days after sowing DAS (A); electrical conductivity of saturation extract of soil at 32 and 77 DAS (B) as a function of irrigation water salinity (EC_w).

compared to soil surface evaporation. No substantial decrease in water consumption was observed during that period among the treatments.

Although the leaching fraction (LF) equivalent was tentatively kept around 0.4 in all treatments, for first 32 DAS the observed LF (0.43) was slightly higher than the projected value and for 33 to 77 DAS, slightly lower (0.34) but during 77 days leaching amounted 39% on average.

From the first to the second period, there was a small increase in soil salinity (Figure 5B) except for N_1 , probably due to a decrease in LF. Despite the high LF, the resulting EC_{se} values for the respective EC_w treatments were higher than expected for steady-state condition (Ayers & Westcot, 1991), mainly for the treatments with lower EC_w values, where relatively higher salt concentrations occurred. Ayers & Westcot (1991), when estimating EC_{se} at a specific LF, considered a 40:30:20:10 water extraction model in the root zone, probably not valid for this study due to limited volume of soil.

Mineral composition of leaf and root

Higher accumulation of Na, K, Ca and Mg was found in yellow passion fruit leaves in comparison to the roots 77 DAS (Figure 6). Na content in leaves, as well as in roots, was directly related to water salinity. Inversely, K amounts in leaves and roots, and Ca and Mg contents in leaves decreased with increasing salinity levels, following a quadratic trend for K and Mg, and a linear for Ca. No significant relationship was observed between EC_w and contents of Ca and Mg in roots.

In saline environments where Na is predominant in relation to K, plant potassium nutrition may be restrained (Schroeder et al., 1994). This suggests that the absorption mechanism for both cations is the same. Similarly, in general, Na ions cause disturbances in Ca nutrition and this nutrient has an important role in controlling the selective permeability of the plasmalema (Cramer et al., 1988).

Nutritional disturbances caused by Na were verified. At the lowest salinity level, Na and Ca amounts in yellow passion fruit leaves were almost equivalent (27.54 and $31.8\ g\ kg^{-1}$) - Figure 6. However, for each unit increase in EC_w above N_1 there was a $5.56\ g\ kg^{-1}$ increase in Na and at the same time, a $1.95\ g\ kg^{-1}$ decrease in Ca. Therefore at higher levels of water salinity there were wide differences between Na and Ca contents.

K absorption was more drastically reduced, even at low salinity levels. In relation to N_1 , the percentage decreases were 41.1, 56.8, 65.3, 70.8, 74.6, 77.4 and 79.6 for N_2 to N_8 treatments, respectively. For Mg, these values were 9.8, 17.9, 24.7, 29.9, 33.5, 35.6 and 36.2%, respectively.

The decrease in K, Ca and Mg contents and corresponding increase in Na concentration in plants suggest that the plasmalema lost part of its selective ion

absorption capacity. Probably, Na displaced Ca from the plasmatic membrane to intercellular spaces, reducing selective permeability of root thereby allowing an increase in Na absorption in detriment to K, Ca and Mg, as reported by Lacan & Durand (1995).

The unit increase in EC_w caused an increase of 53.9 and 142 % in $Na/(Ca+Mg)$ and Na/K ratios in leaves, respectively, in relation to N_1 (Figure 7A). As a result, there was reduction in plant growth, decrease in DMS, increase in Na concentration (Figure 7B) and decrease in K, Ca and Mg contents in the plant (Figure 7C).

Although Na increased with increasing salinity, no visual toxicity symptoms were detected. Plants were probably able to find a reasonable adjustment, directing the excess Na to the vacuole, a mechanism for salinity tolerance described by Poljakoff-Mayber & Lerner (1993). Yet, the nutritional disorder caused by Na contributed to

reduction of plant growth with salinity, due to the essentiality of Ca, Mg and K to plants.

Maintenance of adequate K amounts in plants is essential for growth (Wignarajah, 1995) as K activates more than 50 enzymes, some of them involved in phosphorylation reactions, carbohydrate and protein synthesis and respiration, being also essential for transport of carbohydrates and distribution to the various plant organs. Mg is vital to the photosynthetic process, especially because it constitutes 2.7% by weight, the chlorophyll molecule and activate various enzymes. Ca, which has another important function of maintaining selective permeability of plasma membrane.

Among the interrelated factors that influence plant's ability to tolerate saline conditions, are the sensitivity of the genotype to show Ca deficiency induced by Na, and the ability to maintain adequate K levels while growing under conditions of high concentration of Na in soil (Grieve & Fujiyama, 1987).

The selective ionic absorption mechanism gives the plant the capacity to discriminate between similar elements like Na and K. It is an important characteristic in the adaptation process to salinity as observed by Shannon & Noble (1995) in subterranean clover varieties (*Trifolium subterraneum* L.), which showed, under saline conditions,

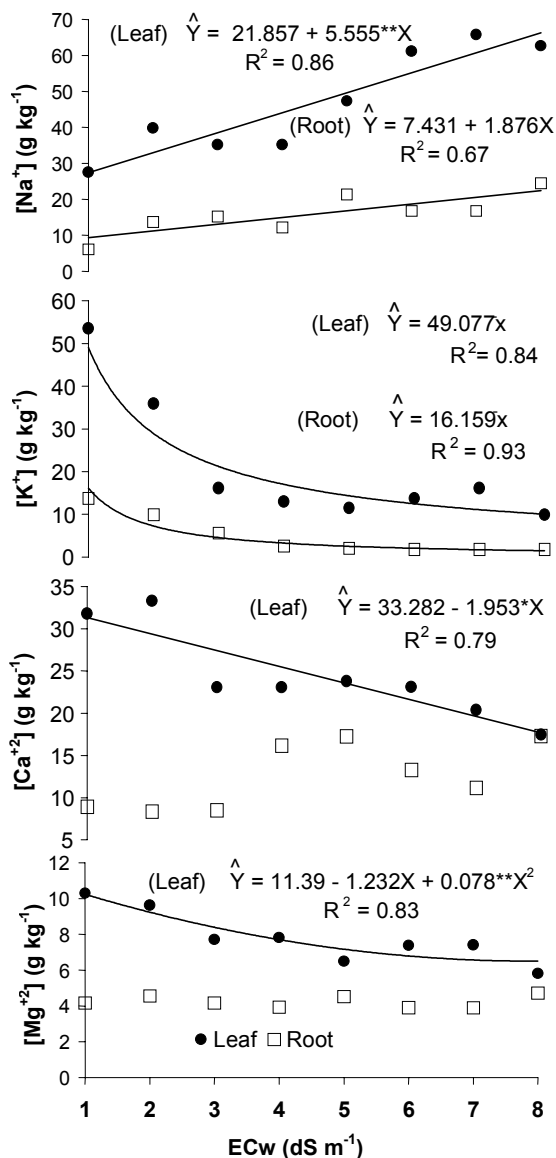


Figure 6 - Contents of Na, K, Ca and Mg in passion fruit leaves and roots 77 days after sowing (DAS), as a function of irrigation water salinity (EC_w).

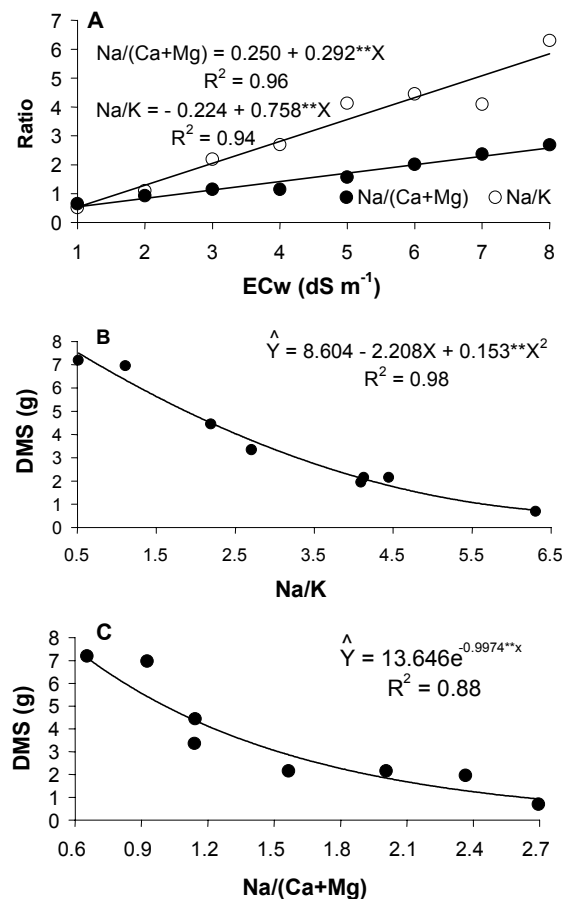


Figure 7 - Na/K and $Na/(Ca+Mg)$ ratio in plant leaf as a function of water salinity (EC_w) and dry matter of shoot (DMS) 77 days after sowing.

low Na concentration and satisfactory K levels in leaves. Similarly, low Na/K ratio in grains and leaves of salt tolerant plants have been observed (Ashraf & O'Leary, 1996); therefore the ability to maintain Na/K ratio less than 1.0 has been considered as a characteristic of salt tolerant plants (Bottacin et al., 1984). Passion fruit seedling were able to keep this index up to EC_w 1.6 dS m⁻¹ (Figure 7A).

Regarding the relative decrease of DMS as a function of EC_{se} , if water of $EC_w < 4.0$ dS m⁻¹ is adequately managed to maintain $EC_{se} < 8$ dS m⁻¹, it may be used to produce yellow passion fruit seedlings with a maximum growth reduction of 50%. In addition, there is growth recovery later, in the field, mainly if planting is performed during the rainy season or if irrigation water used is of low to moderate salinity, as reported by Costa et al. (1986) for coconut palm.

CONCLUSIONS

Salinity effects intensified with plant age, and EC_{se} threshold values for passion fruit seedlings were 5.61 and 2.73 dS m⁻¹ at 32 and 77 DAS, respectively and a mean decrease of 7.6% per unit increase of EC_{se} is observed above this level.

The increase in Na/K and Na/(Ca+Mg) ratios in the plant caused by salinity is a limiting factor to plant growth.

Yellow passion fruit is tolerant to salinity during the germination stage and moderately tolerant during seedling phase.

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