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## Growth of cape gooseberry (*Physalis peruviana* L.) plants affected by salinity

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### Summary

A greenhouse experiment was conducted to assess the effect of salt stress on the growth of the cape gooseberry. Sixty-seven-day-old cape gooseberry plants were surveyed in perlite pot cultures salinized with varying concentrations of NaCl, i.e. 0 (control), 30, 60, 90 and 120 mM for 75 days. The growth indices: leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), unit leaf rate (ULR = NAR), leaf area ratio (LAR), leaf weight ratio (LWR), and specific leaf area (SLA), were calculated. Increasing levels of NaCl (60 to 120 mM) in the growth medium caused a reduction in the leaf growth parameters: LAI, ULR, LWR and SLA. The reduction of leaf area expansion per unit of plant biomass (LAR) was primarily caused by a decrease in the SLA, which played an important role in determining the RGR of salt stressed plants. Concentrations of 30 mM NaCl stimulated the growth parameters: CGR, RGR, ULR and LAI, suggesting that this response is associated with adaptative morphological and physiological mechanisms to salt stress, such as osmotic adjustments. The curves of CGR, ULR, LAR and SLA at 55 days after transplanting showed a reflection point from which salt effect begins to act more severely. The cape gooseberry can be classified as a moderately salt-tolerant species.

### Introduction

For most plant species, salinity decreases growth rate. A rise in salinity is often associated with irrigation and can, therefore, cause a decrease in yield (FLOWERS, 2004; TESTER and DAVENPORT, 2003). This is particularly important, as despite its relatively small area of about 15% of cultivated land in the world, irrigated land is estimated to produce nearly one-third of the world's total food (MUNNS, 2002; MUNNS and TESTER, 2008). In Colombia, the soils susceptible to salinity cover an area of 82.596 km<sup>2</sup>, of which 71.587 km<sup>2</sup> are in dry areas, around 90.39% (MALAGÓN et al., 1998).

Growth inhibition due to soil salinity is caused by low external water potentials, ion toxicity and ion imbalance (MUNNS, 1993). The degree to which each of these factors affect growth depends on the plant ecotype and environmental conditions (BAYUELO-JIMÉNEZ et al., 2003). Modifications of these parameters highly affect plant gaseous exchange and related metabolic processes (ALI-DINAR et al., 1999; HSIAO, 1973). Due to growth reduction in leaves and roots, the salts in soil solution decrease stomatal conductance and, consequently, photosynthesis (MUNNS, 1993). In most studies of salinity, a single harvest date has been used to correlate growth with the physiological effect of salinity (BAYUELO-JIMÉNEZ et al., 2003). The results from such studies can be misleading when comparing salinity treatments because the initial size of the plant can influence the size or rate of growth at harvest, which is when the factors which are taken into account in growth analysis studies are measured (HUNT, 1990). Growth analysis provides considerable insight into the functioning of a plant and its dependence on genotype and environment (LAMBERS et al., 1998). In the cape gooseberry, the first results of growth analysis in the plant's response to environmental conditions, such

as altitude (FISCHER, 1995) and salinity (ULLOA et al., 2006), were reported in Colombia.

The cape gooseberry is not only an important source of vitamins A and C for the Colombian highland farmers, but has also become the second most important export fruit (FISCHER et al., 2007). Although salinized soils (CE > 4 dS m<sup>-1</sup>) are commonly found in various zones where the cape gooseberry is cultivated (FLÓREZ et al., 2008a), little is known about the plant's growth response. For this reason, the objective of this study was to determine the effects of salinity on vegetative growth parameters of the cape gooseberry.

### Materials and methods

#### Plant material and management

Between April and July 2007, the experiments were carried out in the laboratories and greenhouse of the Faculty for Agriculture and Horticulture at Humboldt-Universität zu Berlin, using *P. peruviana* 'Colombia' ecotype seeds germinated in blond peat substrate on March 28. The seedlings were transplanted in polyhouses 20 days after sowing. After 45 days, 340 young plants were transplanted in black plastic pots (2 l) containing perlite as a substrate, where they grew over a period of 75 days. The plants were not pruned but staked with a polypropylene fiber. Pots were placed in double rows on elevated greenhouse tables. Plant rows were 0.5 m apart, and the space between plants within a row was 0.35 m resulting in a plant density of 5.7 plants/m<sup>2</sup>. Before starting the experiment, plants were supplied with a commercially formulated complete fertilizer. The climatic conditions in the greenhouse during the experiment were 23°C mean air temperature and 60.2% mean relative humidity (RH).

#### Plant nutrition

A nutrient solution for the adult cape gooseberry plants was prepared dissolving 0.2 g Kristalon™ (19-6-20-3 + micronutrients) per liter of water. The electrical conductivity (EC) of the nutrient solution was 1.4 dS m<sup>-1</sup> with an average pH of 5.2. The application was made with a Dosatron, which applied a concentration of 0.5%, with two applications per day lasting three minutes each.

#### Plant treatments

Five treatments of 0, 30, 60, 90 or 120 mM NaCl were studied over 75 days. Each plot consisted of 68 plants. Four samplings were made at 45, 55, 65 and 75 days after transplanting (dat). The salt concentrations were applied to the plants every two days using a 500 mL beaker.

#### Measurements

Environmental conditions (air temperature and RH) were recorded daily during the entire experiment for 12 weeks. The EC of the irrigation water was measured twice a week using a pH conductivimeter, the Hanna Instruments HI 9811 and averaged 0.70 (non-saline control), 3.94 (30 mM NaCl), 6.36 (60 mM NaCl), 9.62

(90 mM NaCl), and 12.53 dS m<sup>-1</sup> (120 mM NaCl) over the course of the experiment. The pH was recorded and averaged at 7.9, 7.96, 8.06, 8.11 and 8.12, respectively.

### Growth parameters

Three randomly selected plants were taken at days 45, 55, 65 and 75 to measure plant height, number of leaves, totally expanded leaf area, and dry matter (DM) of roots, leaves and stem. Samples were dried at 70 °C for 48 hours. Taking into account that the evaluations were carried out during a short period of the vegetative growth phase, the changes in growth obtained from dry weight (DW) and leaf area analysis were fitted to an exponential model. The equation used was:  $W = ae^{bT}$ , where  $W$  is the total DW, coefficient  $a$  is the value of  $W$  or  $\log_e W$  and corresponds to initial DW when the growth rate  $T = 0$  and coefficient  $b$  is the rate of increase of  $W$  or  $\log_e W$  (HUNT, 1990) (Tab. 1).

Tab. 1: Growth parameters used in the evaluation

| Parameter | Description                               | Formulae                          | Unit                                 |
|-----------|---|-----------------------------------|--------------------------------------|
| LAI       | Leaf Area Index                           | LA/PA                             | Non-dimensional                      |
| CGR       | Crop Growth Rate                          | $1/PA * dW/dt$<br>$= (LAI * ULR)$ | g cm <sup>-2</sup> day <sup>-1</sup> |
| RGR       | Relative Growth Rate                      | $1/W * dW/dt$<br>$= (ULR * LAR)$  | g g <sup>-1</sup> day <sup>-1</sup>  |
| ULR (NAR) | Unit Leaf Rate =<br>Net Assimilation Rate | $1/LA * dW/dt$                    | g cm <sup>-2</sup> day <sup>-1</sup> |
| LWR       | Leaf Weight Ratio                         | LW/W                              | Non-dimensional                      |
| LAR       | Leaf Area Ratio                           | LA/W<br>$= (SLA * LWR)$           | cm <sup>2</sup> g <sup>-1</sup>      |
| SLA       | Specific Leaf Area                        | LA/LW                             | cm <sup>2</sup> g <sup>-1</sup>      |

LA = leaf area; PA = area occupied by plant; W = total dry weight (root DW + shoot DW); LW = leaf DW; dW = differential of weight; dt = differential of time; shoot DW includes DW of leaves, stems, flowers and fruits.

### Statistical analysis

The experiment involved a completely randomized design and was repeated three times. The data were statistically analysed by analysis of variance using SAS software (SAS 9.1); the mean values among treatments were grouped and compared using Tukey's Range Tests at  $p < 0.05$ .

## Results and discussion

### Leaf area index

The LAI is defined as the one sided green leaf area per unit ground area in broadleaf canopies (HUNT, 1990). The LAI curves increased in all treatments with time and, in the first 45 days, did not present significant differences between the evaluated treatments (Fig. 1). At day 75, the LAI of 30 mM NaCl treated plants was the highest, but, in plants exposed to 120 mM NaCl, it was the lowest.

The lower LAI increase of plants, which received 60 and higher mM NaCl, was due to salt effect, since leaf area expansion is a sensitive parameter of salt stress in plants, which is responsible for a decrease in leaf growth (WALKER and BERNAL, 2008). Reduction in leaf growth rate has been related to a reduction in cell turgor, cell wall rheological properties and a reduction in photosynthetic rate (MUNNS, 1993). Salinization causes an abrupt fall in the leaf water potential, which is not immediately counterbalanced

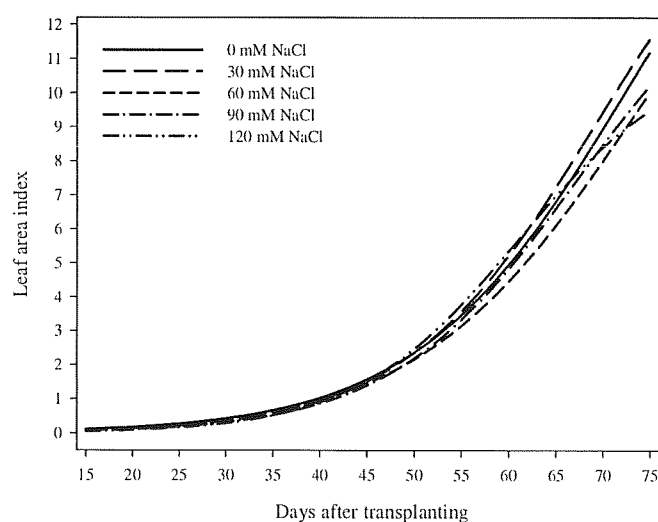


Fig. 1: Leaf area index of cape gooseberry plants subjected to different NaCl concentrations.

by the slower decrease in leaf osmotic potential (CUARTERO and FERNANDEZ-MUÑOZ, 1999). At relatively low salinities, this can result in a transient reduction in turgor and leaf growth rate (YEO et al., 1991).

During long term exposure to salt, leaf expansion, probably, depends on the abilities of a plant to avoid excessive concentration of ions in the transpiring tissues and to produce new leaves at a faster rate than the old ones (MUNNS, 2002). Also, Munns stated that salt injury is due to Na<sup>+</sup> and/or Cl<sup>-</sup> accumulating in transpiring leaves at excessive levels, exceeding the ability of the cells to compartmentalize these ions in the vacuole. In our study, salt-specific effects included burning of leaf margins, reduced leaf area and death and abscission of older leaves.

In pepper subjected to high salinity, LYCOKOUFIS et al. (2005) supposed that growth restriction predominantly was caused by a reduced stomatal conductance, while after a long-term exposure to salinity, growth may also be suppressed due to inhibition of photosynthesis at the chloroplast level. This effect was attributed by CRAMER et al. (2001) to a decrease of leaf cellular expansion, whereas ALI-DINAR et al. (1999) and EBERT et al. (1999) stated that leaf area was reduced as a consequence of physiological disorders triggered by salt stress, accumulation of Na<sup>+</sup> and Cl<sup>-</sup> in different plant tissues, as well as by reduction of net photosynthesis rate and pigment contents in the leaf tissue.

Sodium can facilitate the accumulation of nitrites in plant tissue that, in turn, causes toxic effects and slow assimilation of nitrogen (NAVARRO and NAVARRO, 2000) affecting leaf area growth. On the other hand, cape gooseberry plants could have had decreased leaf area expansion as a water saving measure (DODD and DAVIES, 2004), taking into account that salt treated plants absorb less water than untreated ones (MARSCHNER, 2002).

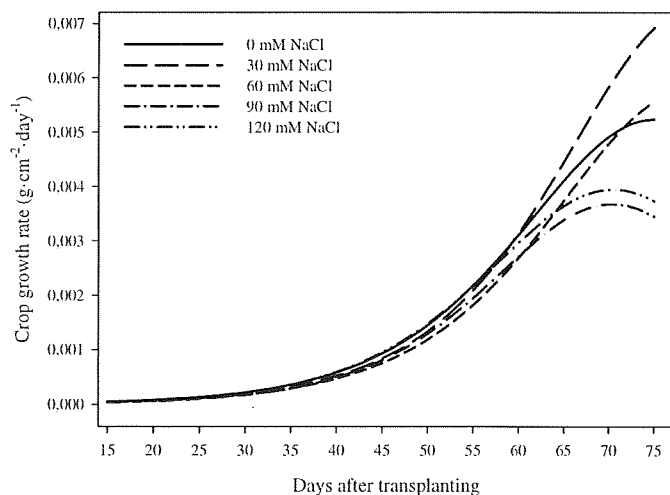
### Crop growth rate

The CGR is measured by harvesting plants at frequent intervals and calculating the increase in dry weight rate, per unit of land area, from one harvest to the next (HUNT, 1990). The CGR followed a sigmoid curve for plants exposed to all treatments, without presenting significant differences between treatments during the first 65 days (Fig. 2). The highest CGR of 6.8 mg cm<sup>-2</sup> day<sup>-1</sup> appeared at day 75 and corresponded to plants in the 30 mM NaCl treatment, followed

by the plants exposed to 60 mM NaCl with  $5.4 \text{ mg cm}^{-2} \text{ day}^{-1}$ . Plants irrigated with concentrations of 120 mM NaCl reduced their CGR by 39% on average compared to the control ( $5.2 \text{ mg cm}^{-2} \text{ day}^{-1}$ ).

The CGR is a function of the ULR and the LAI (HUNT, 1990). Therefore, factors affecting each of these parameters indirectly affect the CGR. In our conditions, the CGR presented a high and positive correlation ( $r=0.98$ ) with the LAI and was less dependent on the ULR. Crop growth rate is slow early in the growth of the crop because of the incomplete cover and the low percentage of received sunlight. A rapid increase in the CGR occurs as the crop develops, leaf area expands, and less light penetrates through the crop to the soil surface (BOONJUNG and FUKAI, 1996.).

The maximum CGR generally coincided with the flowering differentiation stage (approximately at day 55) and then decreased as the plant matured due to the cessation of vegetative growth and the loss of mature leaves. At day 55, it was evident that the distribution of assimilates might be more process-oriented rather than related to the differentiation of flowering, this was evidenced in the appearance of the first flower buds in the plants (MIRANDA, 2010).



**Fig. 2:** Crop growth rate of cape gooseberry plants subjected to different NaCl concentrations.

Concentrations of 30 mM NaCl apparently had a beneficial effect on cape gooseberry plants. Apparently, these moderate levels of salinity could be beneficial for the crop and usually reduce excessive vegetative vigor (SAVVAS and LENZ, 2000). BENNETT and KHUSH (2003) stated that growth of dicotyledonous halophytes is frequently stimulated by salt, MARSCHNER (2002) also reported beneficial effects of sodium on the growth of nonhalophytes (glycophytes). It appears that the growth response at moderate salinities may be largely the consequence of an increased uptake of solutes that are required to induce cell expansion, since this maintains the pressure potential in plant tissues (KHAN et al., 2000).

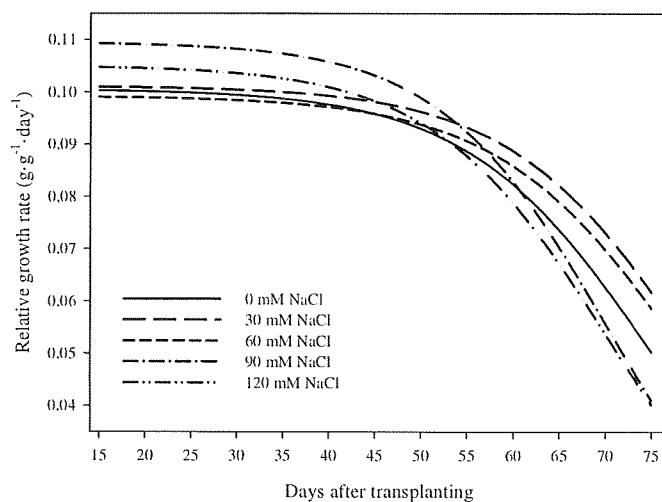
In general, plant species can be classified into four groups (A to D), based on the differences in their growth response to sodium (MARSCHNER, 2002). According to the response of the cape gooseberry, when treated with 30 mM NaCl, with increased DW rates of different plant parts and the whole plant (MIRANDA, 2010), compared to unsalinized controls, this species can be classified in group B due to the increased crop growth rates in response to sodium.

Under saline conditions, this species accumulates sodium in the shoots (MIRANDA, 2010), where it is utilized in the vacuoles of leaf cells for osmotic adjustment (FLOWERS and LÄUCHLI, 1983).

Due to this fact, the cape gooseberry has been classified as having moderate tolerance to salinity, comparable to other Solanaceae fruit species, such as the lulo (EBERT et al., 1999; FLÓREZ et al., 2008b) and the tomato (MAAS, 1986).

### Relative growth rate

The RGR is the increase in plant DW per unit of weight already present (HUNT, 1990). The RGR decreased with plant age for all treatments (Fig. 3). The mean values of the RGR were between 0.080 and  $0.092 \text{ g g}^{-1} \text{ day}^{-1}$ , meaning, these rates of the cape gooseberry, according to BRESINSKY et al. (2008) are between those of herbaceous plants ( $0.15 \text{ g g}^{-1} \text{ day}^{-1}$ ) and season-green trees ( $0.02 \text{ g g}^{-1} \text{ day}^{-1}$ ). No statistical differences between the treatments were observed.



**Fig. 3:** Relative growth rate of cape gooseberry plants subjected to different NaCl concentrations.

Nevertheless, the highest RGR tended to occur in plants that were exposed to the highest NaCl concentrations until day 55, later these values diminished mostly to the end of the experiment. The intermediate concentrations, 30 and 60 mM, were those that in the end supported the highest values followed by those of the control, and the lowest RGR corresponded to the concentration of 120 mM NaCl (Fig. 3).

Traditionally, models have shown that, when salts accumulate in the root zone, the osmotic potential decreases, leading to reduced water uptake and subsequently reduced growth above the crop tolerance level of soil salinity (MAAS, 1986). Further explanation of this behavior might be that reduction in vegetative growth under saline conditions is a primary adaptation to the restriction in water availability due to the low osmotic potential that prevails in the external medium (PASTERNAK, 1987; SONNEVELD, 2000), and also due to limitations derived from the nutritional imbalance (GRATTAN and GRIEVE, 1999).

The RGR is a function of the ULR ( $r=0.52$ ), which is an index of the photosynthetic-assimilatory capacity of the plant per unit leaf area, and the LAR ( $r=0.93$ ), which is an index of the leafiness of the plant (HUNT, 1990). Similar to the RGR, the LAR presented with a tendency to decrease for 0 to 90 mM NaCl treatments (Fig. 5), contrary to the behavior of the ULR, thus we can conclude that, in the case of the cape gooseberry, the LAR, but not the ULR, is highly related to the RGR and, also, coincides well with results obtained by CRAMER et al. (1994) in maize. Because the LAR is a measure of balance between the potential photosynthetic capacity and respiratory

potential cost, it is possible that, besides the reduction in growth, presumably caused by diminishing water uptake due to a reduced transpiration as a result of increased salinity (i.e. the osmotic effect), the RGR can also be affected by an increased respiration (KARLBERG et al., 2006; SHALHEVET, 1994).

Our result is contrary to the one of BAYUELO-JIMÉNEZ et al. (2003) who found in various *Phaseolus* species that the URL of salt stressed plants is highly correlated with the RGR, but not with the LAR. These authors suggested that the declining CGR with an increase in salinity depended on lower rates of photosynthesis that were accompanied by a lower URL.

### Unit leaf rate

The dry matter accumulation rate of the whole plant per unit of leaf area is termed the unit leaf rate or net assimilation rate at any instant during crop growth and is a measure of the average efficiency of the leaves of plants or in a crop stand (HUNT, 1990; LAMBERS et al., 1998). Except for the highest salt concentration, the URL of the plants increased up to the last third of the evaluation time, then decreased (Fig. 4). The ULR presented with a tendency to increase for plants held at 60 mM NaCl with  $0.00051 \text{ g cm}^{-2} \text{ day}^{-1}$  on average and  $0.00052 \text{ g cm}^{-2} \text{ day}^{-1}$  for control plants until day 55.

Compared to these treatments, the curve of plants kept at 30 mM NaCl presented a point of inflection only at day 70. Plants exposed to 90 mM enhanced the ULR (11%) slightly from the beginning until day 55, but showed an abrupt reduction (41%) for the period between days 55 and 75. The unit leaf rate of plants treated at 120 mM NaCl decreased sharply (from  $0.0009$  up to  $0.0004 \text{ g cm}^{-2} \text{ day}^{-1}$ ), which represents a reduction of 55% during the entire experiment.

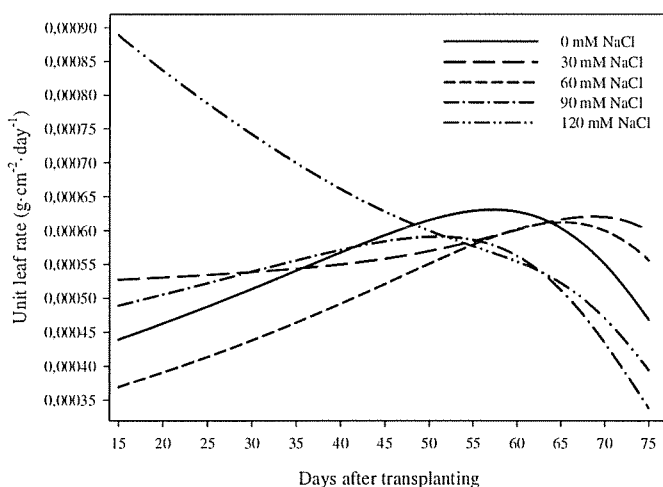


Fig. 4: Unit leaf rate of cape gooseberry plants subjected to different NaCl concentrations.

The ULR of cape gooseberry control plants in greenhouse conditions (mean air temperature  $23.0^{\circ}\text{C}$ ) in Berlin was about 100 times higher than those of FISCHER (1995) found at 2,690 m above sea level in field conditions in Tunja (Boyaca, Colombia), where mean air temperature was only  $12.5^{\circ}\text{C}$ .

The strong and early decline in the ULR of the two highest NaCl concentrations, presumably indicates that this rate was affected by decreasing photosynthetic efficiency, supposedly associated with a high respiratory rate (KARLBERG, 2006). The decrease of the ULR with plant age may also be partially due to the older average leaf age and resulting lower photosynthetic efficiency. This is manifested in decreases in the production of photoassimilates that becomes

insufficient for maintaining continuous growth; this could explain the sharp abruptions in the ULR index in recent assessments. In general, as plants grow, more and more leaves are fully or partially shaded; thus, the ULR decreases during the growth evaluation.

In agreement with our results, some authors have claimed that there was a relation between the ULR reduction and growth inhibition for the plants as a result of salt stress (ALARCON et al., 1994; WAHID et al., 1999). ULLOA et al. (2004) observed in *Physalis* plants subjected to 120 mM NaCl a decrease in the ULR of 51%. Also in the cucumber, NaCl stress decreased the ULR between 8-13% (CHEN et al., 1999). In the pepper, salinities between 3.5 and 5.5  $\text{dS m}^{-1}$  reduced the NAR by 30% compared with non-salinized plants (VILLA-CASTORENA et al., 2003).

We share the opinion of MUNNS et al. (1995) that the saline conditions accelerated the ageing of mature leaves because the continued transportation of salts inside the transpiring leaves for long periods of time might result in high concentrations of  $\text{Na}^{+}$  and  $\text{Cl}^{-}$  (MIRANDA, 2010), leading them to final abscission. Some authors suggest that the URL (or NAR) reduction could be a good physiological marker for salt tolerance (AZEVEDO and TABOSA, 2000).

### Leaf area ratio

Generally, the LAR reduced constantly starting from the initiation of the experiment in all treatments, except in plants which were treated with 120 mM NaCl (Fig. 5). In this treatment, the LAR increased (from 119 to  $154 \text{ cm}^2 \text{ g}^{-1}$ ) during the first 50 days and diminished abruptly starting with day 55, reaching a decrease of 34% compared to the maximum attained value. In the 30 mM NaCl treatment, the LAR decrease was slight (15%) until day 55, and then fell sharply (45%) in comparison to the first evaluation.

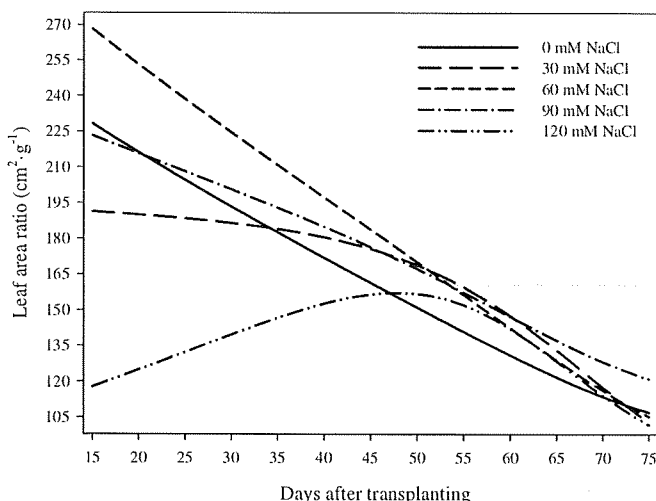


Fig. 5: Leaf area ratio of cape gooseberry plants subjected to different NaCl concentrations.

The LAR is the amount of leaf area per unit total plant mass and a function of the SLA and the LWR (LAMBERS et al., 1998) and has been recently classified as the most important determination of growth (BRESINSKY et al., 2008). Also, the LAR is characterized by HUNT (1990) as a measure of the balance of payments between income and expenditure because it deals with the potentially photosynthesizing and potentially respiring components of the plant.

In salinized plants, the LAR was reduced by effects from both DM allocation (LWR) and specific leaf area (SLA), but the latter relation was more significant ( $r=0.98$ ). Decreasing LAR values indicate that

salinity mainly affected leaf elongation and, hence, the development of photosynthetic surface area (CURTIS and LÄUCHLI, 1986). After the initial effect, the differences in the LAR between control and salinized plants were not statistically significant, possibly reflecting plant adaptation to stress and coinciding with results obtained by TALEISNIK et al. (1997).

Salinity-induced reductions of the LAR in 60 mM and 90 NaCl treatments indicate that leaf thickness increased with NaCl salinity due to increased diameter of palisade and spongy parenchyma (BOSABALIDIS and KOFIDIS, 2002). These authors stated that the degree of such succulence increases proportionally to the increasing concentration and duration of salinization.

Most plants have developed morphological and physiological mechanisms, which allow them to adapt and survive. These mechanisms are mainly comprised of a reduction of the leaf size, leaf rolling, dense leaf pubescence, among others (BOSABALIDIS and KOFIDIS 2002). The development of succulence in response to salinity is a common observation in some dicotyledonous (FLOWERS et al., 1986). An increase in the water content of a plant such as this might mitigate against an excessive ion concentration and an increase in succulence together with the increase in ion concentration may be indicative of successful compartmentalization of ions within the vacuole (FLOWERS et al., 1991). Additionally, BURSLEM et al. (1996) stated that increases in leaf thickness are associated with an increase in the ratio of mesophyll area available for the absorption of CO<sub>2</sub> per unit leaf area, and, hence, the efficiency of water use under conditions with a deficit of soil water.

#### Leaf weight ratio

The LWR is the fraction of the total plant biomass allocated to the leaves (LAMBERS et al., 1998). In all treatments, the LWR decreased with the period of exposure to salinity, until days 65-70 (Fig. 6). 90 mM and 120 mM NaCl decreased the LWR from 1.04 to 0.43 and from 0.80 to 0.38, respectively. The lowest LWR corresponded to plants exposed to minor salt stress (30 mM NaCl), and the control plants, with a reduction of 58% and 41% during the evaluation period, respectively.

The decreasing values of the LWR during the evaluation time are associated with an increasing distribution of the DM to other plant structures other than the leaves as plants grow (DEMÜRAL et al., 2005), as confirmed by the findings of MIRANDA (2010). In 60 and

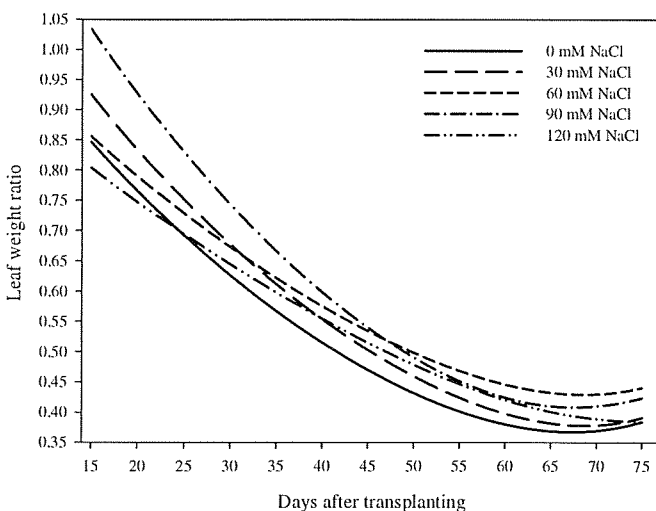


Fig. 6: Leaf weight ratio of cape gooseberry plants subjected to different NaCl concentrations.

more mM NaCl treated plants, there was very little growth, which, interestingly, had a higher LWR than plants of low and non-salt treatments. Thus, the LWR in salinized *Physalis* plants did not serve as an indicator of salinity altered leaf expansion and allocated the DM to the leaf tissue, as described by CURTIS and LÄUCHLI (1986).

#### Specific leaf area

The SLA is a measure of density or relative thinness, because it measures leaf areas in relation to the DW of leaves (HUNT, 1990). The SLA increased for plants from the beginning of the evaluation, being highest in plants of 30 mM NaCl (371 cm<sup>2</sup> g<sup>-1</sup>) treatment at day 55, while all treatments presented their reflection point, except the 60 mM NaCl treatment (at day 45) (Fig. 7). By day 55, in the 90, 120 and 0 mM NaCl treatments, an SLA of 335, 340 and 320 cm<sup>2</sup> g<sup>-1</sup>, respectively, was measured.

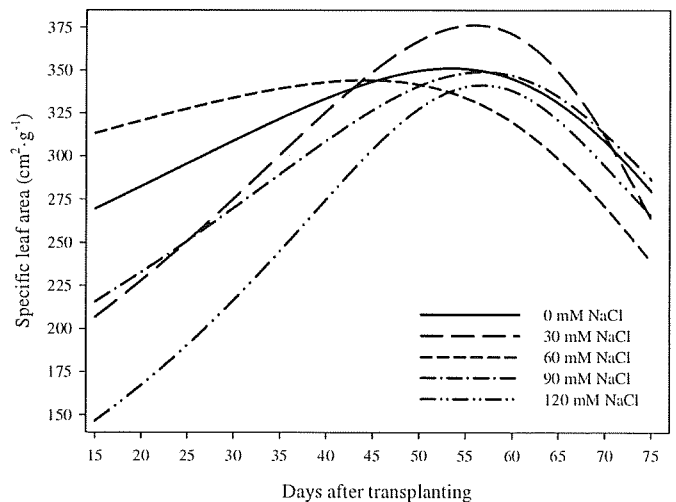


Fig. 7: Specific leaf area of cape gooseberry plants subjected to different NaCl concentrations.

The SLA is, for simplicity, often assumed to be constant (KARLBERG et al., 2006); however, in our study this response cannot be confirmed in any treatment. An increase in the SLA for plants from the beginning of the evaluation, was also observed by other authors (GARY et al., 1993; MARCELIS et al., 1998).

With increasing salinity, the SLA has been shown to decrease (BRUGNOLI and BÖRKMAN, 1992), but this reaction occurred in our study, only after passing day 55. This behavior indicates that before the inflection point (day 55) of the curves, plants were more dependent on their leaf area rather than leaf weight, and growth was affected more by reduced leaf area expansion (BAYUELO-JIMÉNEZ et al., 2003) which proves the low LAI (Fig. 1) in this phase of plant growth. Falling SLA values from day 55 are in agreement with the LAR, confirmed by the high correlation ( $r=0.98$ ) between these two growth indices.

Lower values of the SLA tend to correspond with relatively high investments in leaf defences and long leaf lifespan (CORNELISEN et al., 2003). KATERJI et al. (1998) and KARLBERG et al. (2006) claimed that reductions in the SLA might indicate that the energy cost for the plant required for the formation of the assimilatory surface increases considerably due to severe reductions in net photosynthesis because of the effect of salinity or osmotic adjustment, which is an energy consumptive process. Moreover, the decreasing SLA may indicate an alteration in the structure of the leaf or the increased concentration of minerals such as Na, Cl and other nutrients (PEREZ et al., 2004;

MIRANDA, 2010 ). Also BAYUELO-JIMÉNEZ et al. (2003) suggested that the reduction of the SLA in salt stressed plants, probably, reflects an overloading of the leaves by inorganic and organic solutes, which allows osmotic adjustment but reduces the efficiency for gaining carbon.

### Conclusions

From the present study, we conclude that salinity has a significant impact on the growth of the cape gooseberry in soilless cultures. Sodium chloride treatments reduced the growth of plants, however the magnitude of responses varied with the salt dosage applied and duration of salt stress. High concentrations of salt confirmed that leaf area development was a sensitive parameter of the cape gooseberry to this type of stress, reducing the LAI, the ULR, the LWR, and the SLA. The reduced leaf area expansion per unit of plant biomass (LAR) was primarily caused by a decrease in the SLA and played an important role in determining the RGR of salt stressed plants. The growth parameters CGR, RGR, ULR and LAI were stimulated by moderate salinity stress (30 mM NaCl), suggesting that this response is possibly associated with the development of morphological and physiological mechanisms, mainly osmotic adjustments to maintain the pressure potential in plant tissue. The cape gooseberry can be considered as moderately tolerant to salinity conditions.

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