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Emergence and vegetative development of melon in function of the soil salinity

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Abstract

Soil salinity is one of the main factors limiting the development and global agricultural productivity. Melon (*Cucumis melo* L.) is mainly produced in arid and semi-arid regions around the world, favoring the accumulation of soluble salts in the soil. Therefore, this study aimed to evaluate the emergence and vegetative development of melon genotype under different levels of soil salinity. The assessments were performed based on the exchangeable sodium percentage (ESP) at 0, 20, 25, 30 and 35%. The emergence was affected around 30 percentage points, by comparing the control and the highest dose (35%). The emergence speed and the emergence speed index parameters were also affected in a similar way, as well as the length and dry matter of the shoot. The growth of the plants was also affected by the saline stress, being superior in the control (0%) in relation to the treatments with NaCl. The leaf area increased between weeks 4 and 7 after the planting and was slightly superior in the control in relation to the plants submitted to saline stress (20, 25, 30 and 35% of exchangeable sodium). The melon is more sensible to the saline stress in the seedling emergence than in the vegetative development over time. The development of melon seedlings is mainly affected in exchangeable sodium values superior to 20%. The analyzed hybrid is sensible to the saline stress even in 20% of exchangeable sodium.

Keywords: *Cucumis melo* L.; biomass; growth; salt stress; sodium.
Abbreviations: ES_Emergence speed; ESI_Emergence speed index; ESP_exchangeable sodium percentage; LA_Leaf area; WAP_weeks after planting.

Introduction

The soil salinity is one of the main limiting factors of the agriculture production, reaching approximately 20% of cultivated land areas worldwide (Gupta and Huang, 2014). The salinization process may be classified as primary or secondary, due to the natural deposition as weathering and rain or by anthropic action, respectively (Herbert et al., 2015). In general, the main effects of the salinity in the soil characteristics are related to the dispersion of particles, increase of the density, reduction of the hydric potential and pH changes (Singh et al., 2016).

In addition to decreasing the water availability, the salt excess may cause toxicity in plants due to the ion absorption (Flowers et al., 2015). According to Parihar et al. (2015), the detrimental salinity effects, are observed at the whole plant and affects all the major processes such as germination, growth, photosynthesis, water relation, nutrient imbalance, yield and others. However, plants are more sensible to the salinity during the emergence and vegetative development phases, whereas the tolerance to the saline stress during such phases may be directly related to the tolerance in the productive phase (Läuchli and Grattan, 2007).

Soil salinity is a prevalent environmental hazard in arid and semiarid regions around the world (Allbed and Kumar, 2013). These areas are primarily characterized by the dry and hot weather, elevated rates of evapotranspiration and low rainfall index, favoring the accumulation of salts in the soil. In this context, melon (*Cucumis melo* L.) is mainly produced in these areas around the world and is cited as moderately sensible to the saline stress (Tedeschi et al., 2011). However, Sarabi et al. (2017) evaluated the impact of saline stress on physiological and biochemical characteristics in different melon genotypes and observed a considerable salinity effects on the parameters measured with significant genotypic variability among the studied plants.

The salinity effects in melon are most often evaluated with the use of saline water. Rouphael et al. (2012) evaluated melon plants cultivated in salinized hydroponic solution and among the results, they observed reductions in shoot biomass and fruit yield. Huang et al. (2012) observed a yield reduced in melon (cv. Huanghemi) in function of saline irrigation.

Considering the salinization process, it's important to emphasize that Na^+ and Cl^- ions are among the main accumulates in the soil and are considered the most prejudicial to the vegetal metabolism (Tavakkoli et al., 2011). In this context, the exchangeable sodium percentage (ESP) proposed by Richards (1954) can be a good parameter to evaluate the salinity effects in melon. According to Horneck et al. (2007), as ESP increases, soil structure decreases, the infiltration rate of water into soil and the rate of water movement through soil may be reduced and the plants can show a symptons such a leaf burn, scorch and dead tissue along the outside edges of leaves by the high concentrations of sodium.

Few studies have evaluated the salinity effects in melon by the ESP. Also there may be variations not only among the genotypes, the temporal exposure to stress, environmental conditions and management. Thus, the aim of this work was to evaluate the emergence and vegetative development of a melon genotype under different soil salinity levels by the exchangeable sodium percentage (ESP).

Results and discussion

Emergence of melon under soil salinity

The effect of Na was driven through decrease in the emergence percentage (EP), emergence speed (ES) and emergence speed index (ESI) of melon with increasing in ESP.

The emergence values obtained in the control (0 ESP) was 97%, while in 20 ESP it was 95% approximately. Similar values (close to 90%) were also observed between the 25 and 30 ESP treatments. In the 35 ESP treatment, there was a material emergence fall, with an approximate value of 70% (Fig. 1).

In the emergence speed (ES) assessment, the seedlings emerged around 5 days after seeding (DAS) in the control treatment (0 ESP) and approximately 6, 7, 8 and 11 days in the 20, 25, 30 and 35 ESP treatments, respectively (Fig. 2A).

In the control treatment (0 ESP), the emergence speed index (ESI) was close to 10 seedlings day^{-1}, and such amounts reduced to approximately 7, 6, 5 and 3 in the 20, 25, 30 and 35 ESP treatments, respectively (Fig. 2B).

Pinheiro et al. (2016) aiming assessing the effects of salt stress in melon seeds, observed reductions on germination particularly from the osmotic potential of -0.2 MPa. However, Liu et al. (2016) affirms the sodic salts have migration capacity and are concentrated primarily in the soil surface, generating higher resistance and acting as a physical barrier which may lead to a weak establishment of seedling emergence (even those germinated).

The reduction in the soil osmotic potential by the excess of salts is another important factor connected to the seedling emergence, since it jeopardizes the water absorption by the seeds and reduces the use of reserves for the embryo growth and stretching of the young tissues (Wahid et al., 2011).

Seedling development of melon under soil salinity

The length and the dry matter of the shoot were also reduced in a similar manner, with the increase of the ESP of the soil (Fig. 3). In contrary with the data observed for the emergence, the reduction in these parameters was more stressed from 20 ESP.

Decreases in growth, biomass accumulation and water potential of shoots were some of the apparent responses to salinity, as observed by Bonacina et al. (2017) in *Melissa officinalis* L. plants. The difference of the osmotic potential among the soil and de plant tissues reduces the oxygen diffusion and affects plant physiology at cellular levels through osmotic and ionic adjustments that result in reduced emergence and biomass production (Nawaz et al., 2010).

The results observed in the emergence corroborate the results observed by Farhoudi et al. (2011) in muskmelon plants under saline stress conditions. Said authors directly associated the smallest development of the seedlings with the longest germination time and seedling establishment.

Growth of melon plants under soil salinity

The growth of melon plants was superior in the control (0 ESP) from the first week after planting (WAP) in relation to the treatments with NaCl. By the end of the experiment, the difference in the height of the plants between the control and the treatments with NaCl was of 20 cm, approximately (Fig. 4).

Among the treatments with NaCl (20, 25, 30 and 35 ESP), no significant differences were observed in the plants growth over time, which was of 60 cm approximately in the seventh WAP (Fig. 3).

These results differ from the results observed in the seedling emergence data, in which more stressed differences in the treatments with NaCl were observed (Fig. 1).

Due to the fact that they are related to the excessive absorption of ions, the salinity toxic effects are less related to the seedling emergence, since they pertain to the secondary responses of more developed plants and with a higher time of exposure to the saline stress. These responses include, primarily, the ionic homeostasis, elimination of toxic radicals and more efficient transportation of water (Hasegawa et al., 2011).

In addition to the effects in the osmotic potential of the soil and toxics over the plants, the excess of salts may cause nutritional disturbances (Hasanuzzaman et al., 2013).

The Na^+ and Cl^- ions are among the main accumulates in the soil and are considered the most prejudicial to the vegetal metabolism (Tavakkoli et al., 2011). In this context some macronutrients, as nitrogen (N), are affected by the excess of Na^+ and Cl^- mainly in the capture, absorption and mobilization via xylem (Chen et al., 2010).

On the other hand, micronutrients such as copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) are, in general, affected due to the alteration in the soil pH caused by the salts (Calvo-Polanco et al., 2014).

For all treatments, it was observed that the leaf area (LA) was increased between weeks 4 and 7 after the planting (Fig. 5).

In many species, the reduction of the leaf development is a primary effect of the saline stress, which is partially recovered after some time by means of the tolerance mechanisms (Munns et al., 2006). However, the LA of the control plants (0 ESP) was slightly superior in relation to the plants submitted to saline stress (20, 25, 30 and 35 ESP) (Fig. 5).

The reduction of the leaf area due to the saline stress may be related to an anticipated senescence process, mainly of

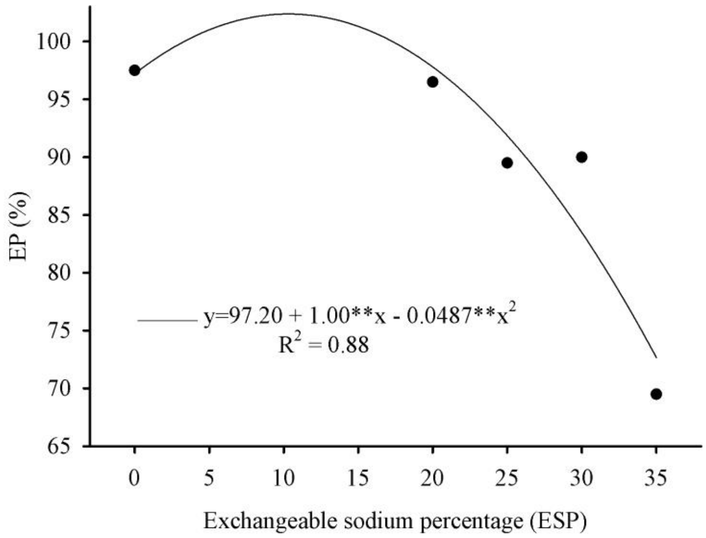

Fig 1. Emergence percentage (EP) of melon seedlings submitted to saline stress. **: significant to 1% by the t test

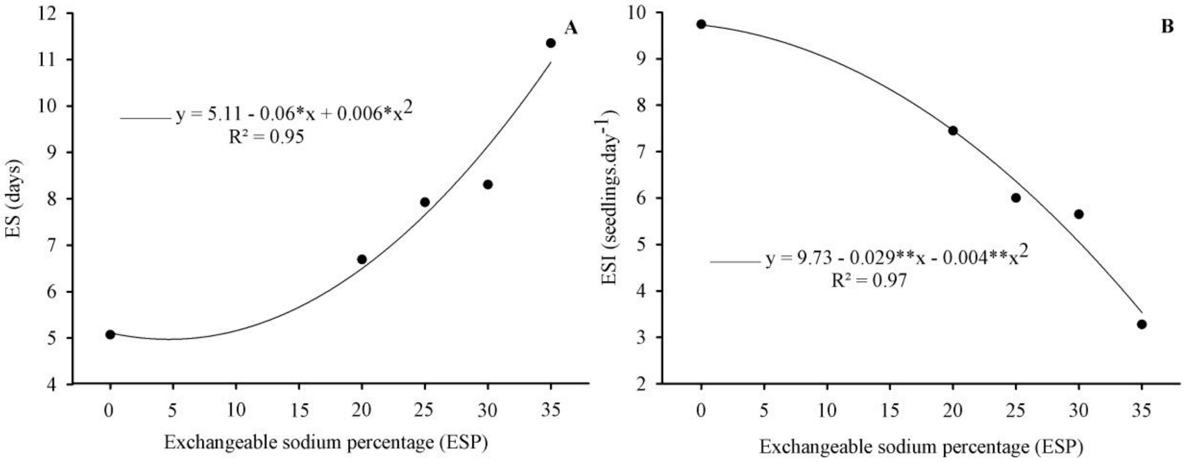

Fig 2. Emergence speed (ES) (A) and emergence speed index (ESI) (B) of melon seedlings submitted to saline stress. *, **: significant to 5 and 1% by the t test

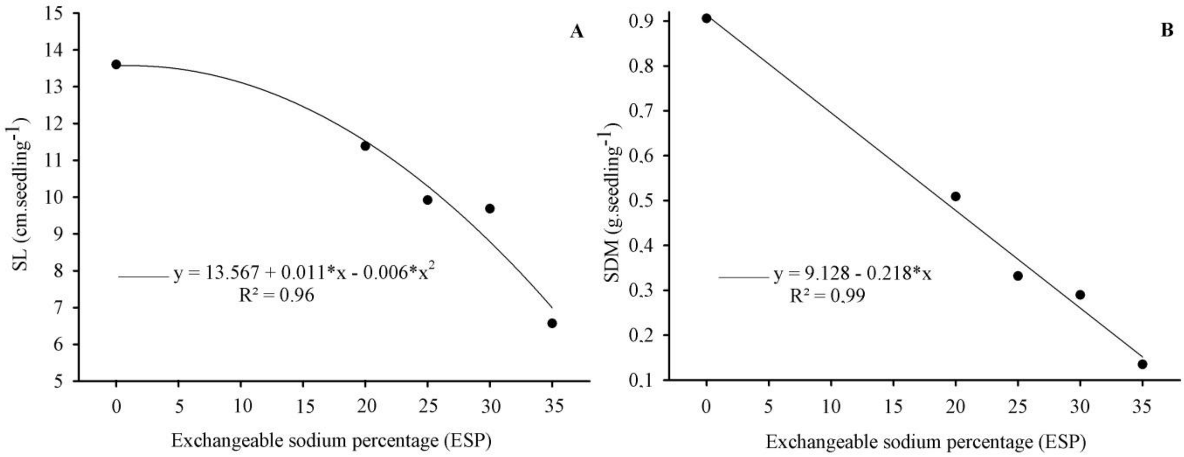

Fig 3. Shoot length (SL) (A) and shoot dry matter (SDM) (B) of melon seedlings submitted to saline stress. *: significant to 5% by the t test

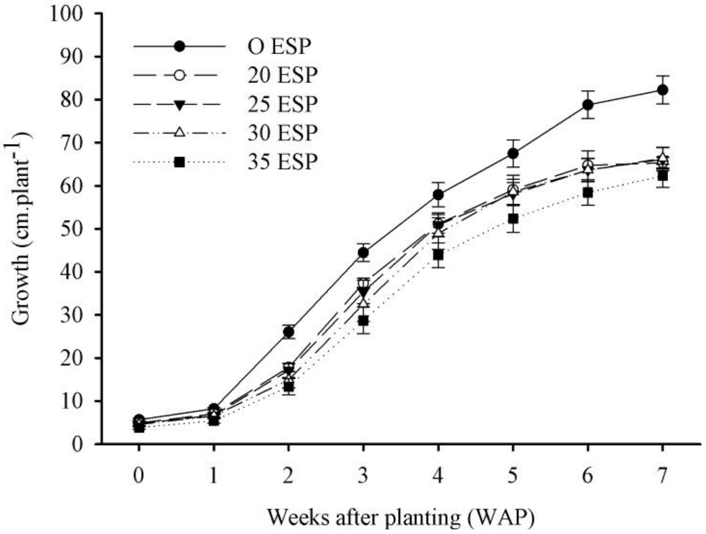

Fig 4. Growth of melon plants submitted to the saline stress. Bars: Standard error

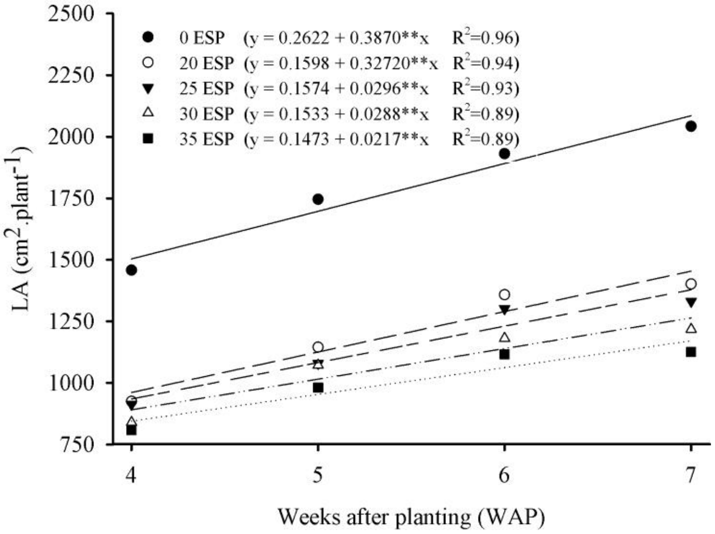

Fig 5. Leaf area (LA) of melon plants submitted to the saline stress. **: significant to 1% by the t test

the inferior leaves (Kahlaoui et al., 2011). In addition, the cell dehydration, the reduction in the cell divisions, the changes in the intracellular pH and the extensibility, conductivity and turgor of the cell walls are other important components of the leaf development process that may be affected by the excess of salt (Läuchli and Grattan, 2007).

The observed reductions in the leaf area can be associated the reduction of the active photosynthetic area. The increase in salinity may cause increase in water use efficiency and intrinsic water use efficiency and reduces the carboxylation efficiency (Oliveira et al., 2017).

Thus, a minor photosynthetic area results in the reduction of the photoassimilate offer and, consequently, affects the growth, development and production of plants submitted to the saline stress (Hasanuzzaman et al., 2013).

The liming is also an important factor to be considered in the assessment of the growth and of the area leaf. The calcium (Ca) has a fundamental role in the permeability and infiltration of soil water and is directly involved in the structural and functional integrity of the cells and membranes, regulating the transportation and selectivity of ions in plants (Lazof and Bernstein, 1999).

According to Wang et al. (2014), the presence of Ca^{2+} ions in sodic soils may improve a series of chemical and physical processes limited by the excess of Na^+, as cation-exchange capacity. Thus, the liming generates a supplementation of Ca^{2+}, decreasing the Na:Ca relation and minimizing the effects of the NaCl excess.

It is worth to highlight that, despite of the toxic effects in the cell, the Na^+ may also perform an important role by means of an intracellular influx in the initial moments of the saline stress, acting as an indicator of the adaptation to the salinity (Ismail et al., 2014).

However, this positive contribution of Na^+ is only effective is there is a cytoplasmic extrusion capacity and/or compartmentalization in the vacuoles, in order to avoid the effects that may lead to the cell death (Läuchli and Grattan, 2007).

These strategies are commonly observed in different species, but must be followed by other adaptive responses, once they may result in the dehydration of the cells due to the reduction of the osmotic potential caused by the accumulation of Na^+ (Ji et al., 2013; Ismail et al., 2014).

It is important to highlight that different methods of saline stress induction, such as the use of saline water and excessive manure, may difficult the comparison among studies (Läuchli and Grattan, 2007). Besides, the effects of the saline stress depend on factors such as the species, cultivar, phenological stage, types of salts, intensity and duration of the stress, in addition to the associated soil and weather conditions.

In summary, the observed results indicate less tolerance of the melon plants to the saline stress in the seedling emergence phase. This fact is probably related not only to the mentioned tolerance mechanisms, but also to a minor capacity of the newly emergence seedlings to activate them.

The activation of said mechanisms seems to result in a better development of the most developed plants, even in a limited manner and in more elevated ESP values.

Materials and Methods

Location and plant material

The study was conducted in an experimental area of the Plant Science Department of the Universidade Federal de Viçosa (UFV), in the State of Minas Gerais, Brazil between January and May, 2015. Diplomata F_1 (Agristar Brasil Ltda.) seeds of yellow hybrid melon (*Cucumis melo* var. *inodorus*) were used for all assessments.

Soil analysis and salinity incubation

The soil was collected from fields in Coimbra, Minas Gerais, Brazil, and classified according to the Soil Taxonomy as an Oxisol udox distric. The soil was collected from the top layer (0–20 cm), air-dried and sieved to <2 mm prior to characterization. The soil had the following soil physical and chemical properties: clay 24%, silte 17%, sand 59%, pH (H_2O) 5.8, Ca and Mg and 2.3, 1.4 and $cmol_c\ dm^{-3}$, respectively; K and Na 98 and 7 mg dm^{-3}.

In order to increase exchangeable sodium percentage (ESP) in soil, a linear equation $y = 0.545 + 0.016x$ was obtained in preliminary tests, where y represents ESP (%) and x doses of NaCl. Then, doses of 1239; 1558; 1876 and 2194 mg dm^{-3} NaCl were incubated in the soil to obtain 20, 25, 30 and 35% of ESP, respectively.

According to Richards (1954), a sodic soil has an ESP superior to 15% and it is calculated by the following the Eq. 1:

$$\mathrm{ESP} = \mathrm{Na} \times (\mathrm{Ca} + \mathrm{Mg} + \mathrm{K} + \mathrm{Na} + \mathrm{H} + \mathrm{Al})^{-1} \times 100 \qquad (1)$$

The corresponding doses of NaCl to reach 20, 25, 30 and 35 of ESP were applied in 8 dm^3 soil, homogenized, put into the trays and incubated for 10 days. A control (0 ESP), without NaCl addition, was also used.

Emergence of melon under soil salinity

Then, 50 seeds of melon (*Cucumis melo* var. inodorus) were sown in equidistance points, at 1 cm depth in each tray. Trays were watered by weight with distilled water to hold the water content at 80% of field capacity.

The seedling emergence was expressed in percentage of normal seedlings (Brasil, 2009). The emergence speed index (ESI) and the emergence speed (ES) were calculated with the use of the formulae proposed by Maguire (1962) and Edmond and Drapala (1958), respectively.

Seedling development of melon under soil salinity

After the emergence evaluation, it was performed the measurement of the shoot of the normal seedlings with the aid of a ruler and the results were expressed in cm $seedling^{-1}$. The samples were dried in greenhouse of forced air circulation at 70 ºC until weight stabilization. Then, the shoot dry matter was determined, and the results were expressed in g $seedling^{-1}$.

Liming, fertilizing, irrigation and vegetative development of melon under soil salinity

For the vegetative development in green house trial, lime ($CaCO_3$:$MgCO_3$ at Ca:Mg ratio of 4:1) was applied to soil aiming the percent base saturation of 80%. Soil was wetted to 80% of the field capacity and incubated into plastic bags for 20 days. Samples were air-dried and passed through a sieve (2 mm) for the pot trial experiment.

The corresponding doses of NaCl to reach 20, 25, 30 and 35 of ESP were applied in 9 dm^3 soil, homogenized into the plastic bags and incubated for 10 days before potting. A control without NaCl application was included. Then, the samples were potting and phosphorus was applied to the soil at rate of 350 mg dm^{-3} before planting.

Single seedlings of melon (*Cucumis melo* var. inodorus) with two or three fully expanded leaves were transferred to the pots. Plants were supported with a polyethylene string tied to a wire string at 10 cm and 2 m of height, and conducted in a haul. Liquid basal nutrients N, K, S, B, Cu, Fe, Mn, Mo and Zn were applied at 10, 20 and 30 days after planting at rate of (mg dm^{-3}) 200; 200; 40; 0.81; 1.33; 1.55; 3.66; 0.15 and 4.0, respectively.

Pots were watered by a dripping system with real output of 1.03 L h^{-1}, 7 mca pressure and Christiansen's uniformity coefficient (CUC) of 96.1. The irrigation management was based on the crop evapotranspiration (ETc). The melon hydric demand was determined with the adjustment coefficients in relation to the reference evapotranspiration (ETo). The irrigation liquid blade was calculated by the hydric balance, considering the entrance of the water by irrigation and its output.

The ETc was estimated by the equations 2 and 3 proposed by Allen et al. (1998), Allen & Pereira (2009) and Delazari et al. (2016), in which: ETc = crop evapotranspiration (mm d^{-1}); ETo = reference evapotranspiration (mm d^{-1}); Kc = crop coefficient; Kcb = basal crop coefficient; Ke = soil evaporation coefficient; Ks = stress coefficient:

$$\mathrm{ETc} = \mathrm{ETo} \times \mathrm{Kc} \qquad (2)$$

$$\mathrm{Kc} = (\mathrm{Kcb} \times \mathrm{Ks}) + \mathrm{Ke} \qquad (3)$$

It was used Kcb initial, intermediary and final values of 0.15; 0.75 and 0.50, respectively (Allen et al., 1998).

The plant growth was assessed between the first and the seventh week after planting (WAP). Plant height was measured from the soil surface to the apical bud, using a measuring tape. The results were expressed in cm $plant^{-1}$.

Leaf area of melon under soil salinity

The leaf area (LA) of the plants was determined using the maximum length and width measurements of the melon leaves. Between the fourth and seventh WAP, when the effects of the treatments were visually observed, the leaves of several growth stages were harvested and measured with the support of a millimetric ruler.

The LA was then determined with the aid of the LAI-3100 (LI-COR). The model that correlated with the measurements (L and W) and the LA was a first order linear equation ($y = 1.201 + 0.813x$). The results were expressed in cm^2 $plant^{-1}$.

The seedling emergence experiment was conducted in randomized block design (RBD) with 5 treatments (0, 20, 25, 30 and 35 ESP) and 4 replications. Each experimental unit was composed of 50 seeds. The data were submitted to the variance analysis. The averages were adjusted to regression equations. The regression coefficients were assessed by the t test at 1 and 5% of probability.

Experimental design and statistical analyses

The vegetative development experiment was conducted in completely randomized design (CRD) with 5 treatments (0, 20, 25, 30 and 35% of exchangeable sodium percentage (ESP)) and 10 replications. Each experimental unit was composed of one plant.

The data were submitted to the variance analysis. The averages of the leaf area were adjusted to regression equations. The regression coefficients were assessed by the t test at 1 and 5% of probability. The plant growth data were submitted to the variance analysis and represented by average ± standard deviation.

Conclusion

The initial phase of the melon growth is more sensible to the salinity, with the commitment of the emergence and development of the seedlings. The development of newly emerged melon seedlings is mainly affected in ESP values superior to 20%. The salinity affects the vegetative development of the melon over time, however, in a less severe manner than the initial development. The assessed melon hybrid is, in general, sensible to the saline stress, even in lower exchangeable sodium percentages (ESP), such as 20%.

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