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Will increasing temperature and CO_2 affect pumpkin early development in Brazilian semi-arid?

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ABSTRACT

With rising levels of CO_2 in atmosphere, understanding possible impacts on development and growth of plants becomes increasingly important. The aim of this study was to evaluate interaction between different temperatures and CO_2 levels in germination and early development of seedlings of different species of pumpkin. Seeds of *Cucurbita pepo* cultivars 'Caserta' and 'Redonda', and *Cucurbita maxima* 'Coroa' were sown in trays of 36 cells and held in growth chambers with different combinations of levels of CO_2 and day/night temperatures. The experimental design was completely randomized in a 2 X 3 factorial scheme with two levels of CO_2 concentration (360 and 550ppm) and three day/night temperatures (26/20, 29/26 and 32/26°C), with four replicates of 18 seedlings for each treatment. CO_2 levels used caused different effects among cultivars for most variables, but a significant change in physiological behavior of seedlings with increasing CO_2 concentration was not observed. Increase in temperature led to physiological changes in both seeds and seedlings. The predicted conditions of increasing concentration of atmospheric CO_2 and temperature are damaging to production of pumpkin seedlings

Keywords: Cucurbitaceae, Germination, Climate change

Aumento de CO_2 e temperatura afetará o crescimento inicial de abóbora no Semiárido brasileiro?

RESUMO

Com o aumento dos níveis de CO_2 na atmosfera, a compreensão dos possíveis impactos no desenvolvimento e crescimento das plantas torna-se cada vez mais importante. O objetivo deste estudo foi avaliar a interação entre diferentes temperaturas e níveis de CO_2 na germinação e desenvolvimento inicial de mudas de diferentes espécies de abóboras. Sementes de abóbora (*Cucurbita pepo*) cv. Caserta e Redonda, e moranga (*Cucurbita maxima*) cv. Coroa foram semeadas em bandejas de 36 células e mantidas em câmaras de crescimento, com diferentes combinações de concentrações de CO_2 e temperaturas dia / noite. O delineamento experimental foi inteiramente casualizado, em esquema fatorial 2 x 3 com dois níveis de concentração de CO_2 (360 e 550 ppm) e três variações de temperaturas dias / noite (26/20, 29/26 e 32/26 ° C), com quatro repetições de 18 mudas. Os níveis de CO_2 usados causaram efeitos diferentes entre cultivares para a maioria das variáveis, mas não foram observadas mudanças significativas no comportamento fisiológico de mudas. O aumento da temperatura levou a mudanças fisiológicas em sementes e mudas. As condições previstas de aumento da concentração de CO_2 e temperatura atmosféricos são prejudiciais à produção de mudas de abóbora e moranga

Palavras-chave: Curcubitácea, Germinação, Mudanças climáticas

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Introduction

Pumpkins (*Cucurbita* spp.) stand out among the curcubitaceae of socioeconomic and food importance in different regions of Brazil. The Northeast region of Brazil, where they are widely cultivated, has high variability of marketed and consumed pumpkins and squash cultivars (RESENDE; BORGES;GONÇALVES, 2013).

Data from the 4th and 5th IPCC reports showed that semi-arid northeastern region is one of the Brazilian regions most likely to be affected by climate (PARRY et al., 2007; STOKER et al., 2013). Reinforcing this statement, researchers at National Institute for Space Research - INPE have developed regional models for future scenarios, with higher spatial resolution. Such models indicated temperature may increase by the end of the century, from 1.5 to 2.5 ° C at B2 scenario, and 3.0 to 5.5 ° C at A2 scenario (MARENGO, 2014).

Carbon dioxide concentration ([CO_2]) has shown a significant increase in recent years due to increasing use of fossil fuels, deforestation, and organic residues of urban and rural activities . and, today [CO_2] is about 35% higher than it was 150 years ago (ANGELOTTI; SÁ; MELO, 2009). Increases in the greenhouse gases concentration has been correlated to global warming. Greenhouse effect is essential for sustaining life on earth, however, anthropogenic activities have caused an excessive increase of certain gases in atmosphere (COLLINS et al., 2007).

Rising atmospheric [CO_2] has the potential to positively impact C3 food crop production by directly stimulating photosynthetic carbon gain, which leads to increased crop biomass and yield (BISHOP; LEAKEY; AINSWORTH, 2014). However, there is little direct evidence that the relative CO_2 stimulation of C3 crops productivity is greater at higher temperatures, because the optimum temperature for C3 crop photosynthesis is not always the same as the optimum temperature for C3 crop yield (HATFIELD et al. 2011), and higher temperatures can have a more negative impact on reproductive processes than on photosynthesis (WELCH et al. 2010).

Plants interact with their physical environment through exchange of energy (GUZMAN; MOLINA, 2015). During plants development, physical changes in their environment may occur. Temperatures vary with the succession of seasons and over any 24-h period, low night temperatures alternate with higher daylight temperatures. Even within a single day, a sudden chill may occur when clouds screen the sun's heat. These temperature changes have a considerable impact on cell physiology (RUELLAND; ZACHOWSKI, 2010). Exposure to elevated temperatures can cause morphological, anatomical, physiological, and, ultimately, biochemical changes in plant tissues and, as a consequence, can affect growth and development of different plant organs. These temperature fluctuations can cause drastic reductions in commercial yield of vegetables (MORETTI et al., 2010). Also, temperature is one of the main factors which determine distribution of plant species in different ecosystems in the world. Thus, plant species establishment of is directly dependent on factors such as the minimum, average and maximum temperatures (PROBERT, 1993; SCHLENKER; ROBERTS, 2009).

Germination is the first essential stage in crop and food production. Temperature and water potential are the primary environmental factors that control germination and seedling early environment in all species, and affect the rate and final percentage germination as well as growth and establishment speed of young plants (DURR et al., 2015).

Experiments on seed and seedling responses to increasing [CO_2] and temperature are rare, and there is no comprehensive review of these early plant life history stages, although this critical phase often suffers the highest mortality (PARMESAN; HANLEY, 2015).

Thus, the objective of this study was to evaluate interaction between different temperatures and atmospheric [CO_2], corresponding to simulations of future climate scenarios on pumpkins *Cucurbita pepo* L. 'Caserta' and 'Redonda' and *Cucurbita maxima* Duchesne 'Coroa' seedling emergence and early development.e possíveis soluções e último parágrafo do objetivo.

Material and Methods

This study was carried out at Embrapa Semi-arid, located in Petrolina, Pernambuco State, Brazil, from February to September, 2011, using *Cucurbita pepo* L. 'Caserta' and 'Redonda' and *Cucurbita maxima* Duchesne 'Coroa' seeds. The experimental design was completely randomized in a 2 X 3 factorial scheme with two atmospheric [CO_2] (360 and 550ppm) and three day/night temperatures (26/20, 29/26 e 32/26°C), based on current and future climate scenarios (STOKER et al., 2013).

Seeds were sown manually in polyethylene trays with 36 cells containing commercial substrate (130% retention capacity, pH 5,8) using four replicates of 18 plants per treatment. Trays were placed in plastic containers containing water so that it ascended by capillarity and, in addition, water was sprayed onto the substrate when it was below field capacity.

Trays were kept in two growth chambers with a 12h photoperiod. The air inside the chamber was supplemented with 360 ppm CO_2 (chamber 1) simulating current atmospheric concentration, and 550 ppm CO_2 (chamber 2), simulating concentration in future scenario. CO_2 sources used were pressure cylinders with 99.8% CO_2 and 58.3 kg F.cm^{-2}. The conditions inside both growth chambers were monitored automatically. The experiment was divided into three different stages, so that the day/night temperatures (26/20, 29/26 e 32/26°C) in each chamber was reset at every three months.

Seedling emergence counts were performed daily during 8 days. After this period, percentage of emergence (E%) was calculated, considering only normal seedlings (BRASIL, 2009). In addition, kinetic variables were also calculated such as mean emergence time- MET (LABOURIAU, 1962); average emergence speed – AES (KOTOWSKI, 1926) and emergence speed index- ESI (MAGUIRE , 1962).

At 8 days after sowing, 10 plants per replicate, totalling 40 plants per treatment, were measured and evaluated for seedlings shoot and root length (SL, RL respectively), fresh weight (SFW, RFW respectively) and dry weight (SDW, RDW respectively) according to Nakagawa (1999).

All data were subjected to ANOVA by using SISVAR program (FERREIRA, 2011). When significant differences occurred, mean separation for relative values was performed by using Tukey multiple range test at 5% probability.

Results and Discussion

Each pumpkin cultivar showed different response to [CO_2] and temperature combinations. There was significant interaction among factors evaluated in E%, MET and AES of 'Redonda' seeds. Concerning other variables and cultivars assessed, seeds and seedlings showed independent responses to [CO_2] and temperature.

'Redonda' seedlings showed a lower E% when exposed to 550 ppm CO_2 and 29/23 °C day/night temperatures. On the other hand, interaction between 26/20°C day/night temperatures and 360 ppm CO_2 contributed to significant decrease in MET (Figure 1a). There was a reduction of 'Coroa' seedlings E% as temperature increased for both [CO_2] (Figure 1b). 'Caserta' seedlings E% was not influenced by temperature, however, the highest [CO_2] (550 ppm) promoted higher E% in all temperatures (Figure 1c).

All cultivars showed lower MET and higher AES at 26/20°C than at other temperatures (Figure 1d-i). 'Redonda' seedlings showed lower MET and higher AES at 360 ppm CO_2 (Figure 1d and g, respectively), while 'Coroa' and 'Caserta' showed no significant influence of [CO_2] regarding speed of germination process (Figure 1e-f and h-i, respectively).

The 29/23 °C day/night temperature decreased ESI for 'Redonda' seedlings (Figure 1j) and increasing day/night temperatures inhibited ESI for 'Coroa' and 'Caserta' seedlings (Figure 1k-l).

For all studied cultivars, increase in temperature led to significant reduction of shoot and root lengths (Figure 2). Root length of all cultivars did not change in different [CO_2](Figure 2d-e). However, 'Caserta' seedlings showed higher length when subjected to 550ppm [CO_2] at 26/20 ° C day/night temperature (Figure 2c).

Regarding shoot and root fresh weights, both were reduced with the increase in day/night temperature for all cultivars (Figure 3a-f). Shoot fresh weight of 'Redonda' seedlings were higher when exposed to 360 ppm [CO_2](Figure 3a). 'Caserta' and 'Coroa' seedlings showed no differences in fresh weight of shoots with different [CO_2] (Figure 3b-c). Only for 'Coroa', 550 ppm [CO_2] combined with 26/20 ° C day/night temperature led to higher root fresh weight comparing to other temperature/CO2 combinations (Figure 3e).

Increasing temperatures inhibited shoot and root length in eight days seedlings of all pumpkins studied. Little or no [CO_2] effect was observed in seedlings growth (Figure 3).

Climate changes appears to be more intense in Brazilian semiarid region where, according to IPCC report and INPE climate modelling, temperature increase can be up to 5°C on a worst scenario case (MARENGO, 2014).

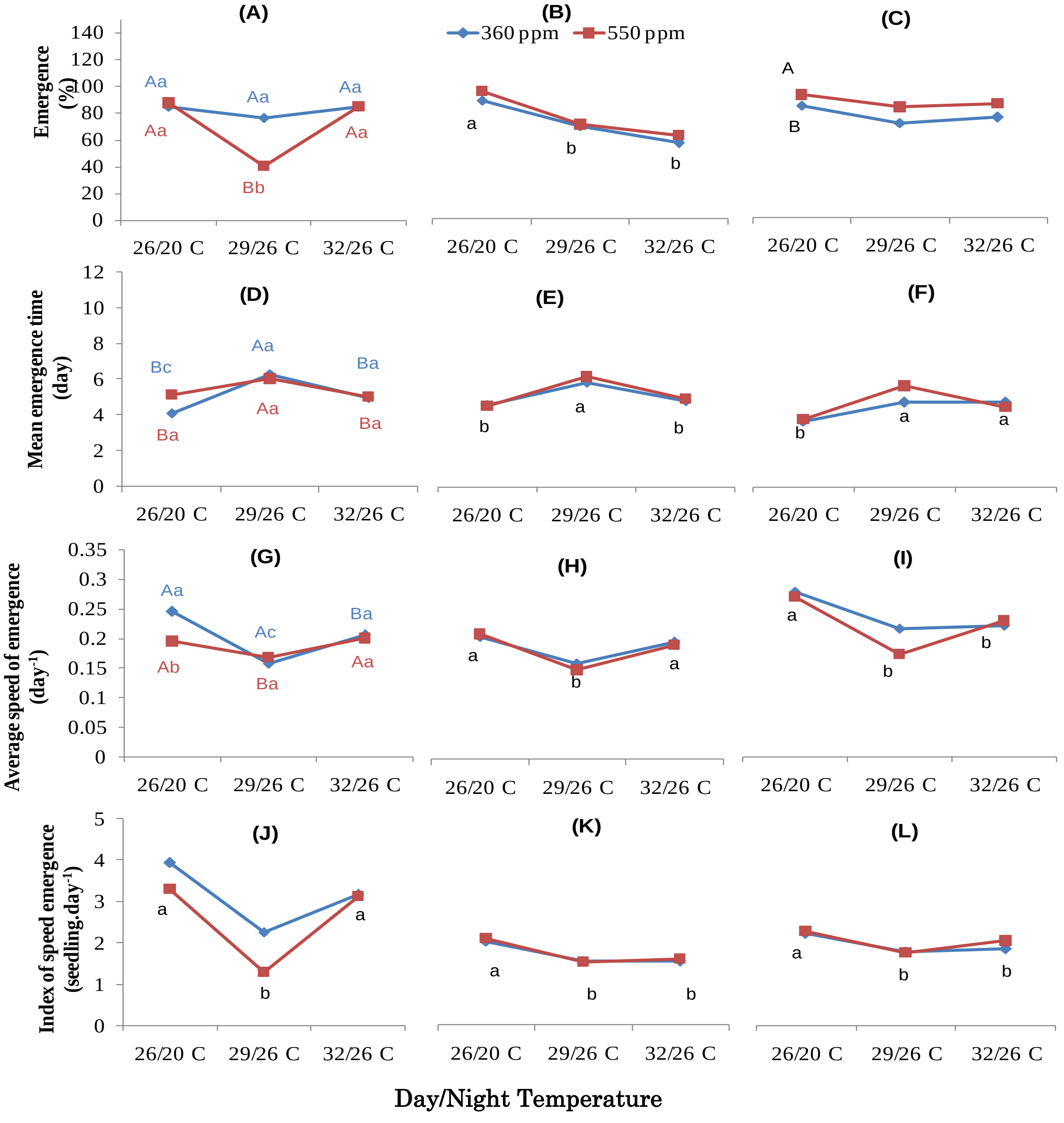
During plant development, high temperatures can affect photosynthesis, respiration, aqueous relations and membrane stability as well as levels of plant hormones, primary and secondary metabolites. Seed germination can be reduced or even inhibited by high temperatures, depending on the species and stress level (BEWLEY et al., 2013).

Vegetable species may have their production cycles affected (MORETTI et al., 2010). Carrot and lettuce seeds have lower germination when subjected to temperatures above 30°C (NASCIMENTO; PEREIRA, 2002). In carrots, high temperatures, 35 40°C, can not only delay or inhibit seed germination, but also compromise seedling establishment in the field (PEREIRA; NASCIMENTO, 2002). Temperatures at or above 30°C also prevented growth of seedlings of marigold (KOEFENDER et al., 2009). Furthermore, different cultivars of radish, showed lower root length when seedlings were subjected to elevated temperatures, above 35°C (STEINER et al., 2009).

In Cucurbitaceae family, increasing [CO_2] and temperature favored growth and accumulation of assimilates, benefiting the production of seedlings of watermelon cultivars (SILVA et al., 2015). However, high temperatures, close to 30°C and above, affected germination and seedling growth of pumpkin species and cultivars studied in this work (Figures 1, 2). This may affect all production cycle of these species in warmer future climate.

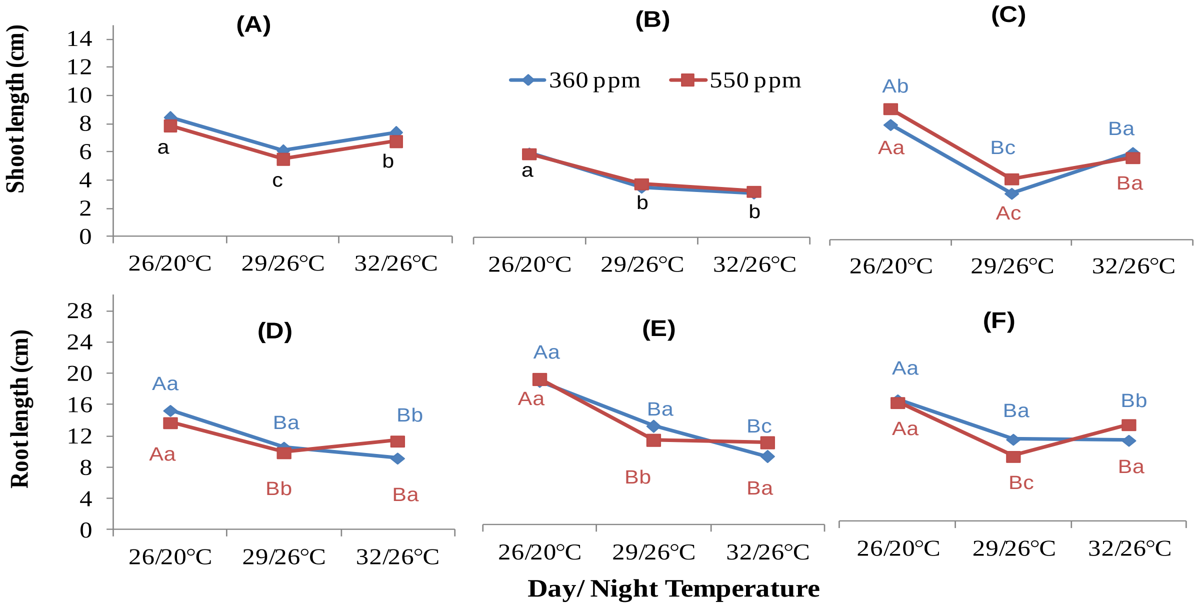
Atmospheric CO_2 is an essential substrate for photosynthesis. High [CO_2] stimulates the photosynthesis leading to an increased assimilation of carbon (C), thereby enhancing plant growth (CAPORN, 1989). Although the effect of CO_2 in photosynthesis is well known, the available literature is quite controversial about the effects of CO_2 on the initial stages of seedling growth. An increased rate of lettuce seedling emergence has been observed in an enriched environment with CO_2 (ITO, 1989). On the other hand, lettuce seedlings, under controlled [CO_2], showed reduction of fresh weight (CAPORN, 1989). Plants grown in pots, cut flowers, vegetables and forest species respond to increased [CO_2] through the addition of dry weight, plant height, number of leaves and side shoots (MORTENSEN, 1987). In pumpkin and squash seeds and seedlings studied in this paper it is likely that the atmospheric CO_2 increase does not affect germination and early growth (Figures 1, 2).

Figure 1-Percentage of emergence (A-C), mean emergence time (D-F), average speed of emergence (G-I) and emergence speed index (J-L) of seeds of Cucurbita pepo cv. Redonda (A, D, G, J) and Caserta (C, F, I, L) and Cucurbita maxima cv. Coroa (B, E,H, K) submitted to different day/night temperatures (26/20, 29/23 and 32/26 °C) and atmospheric CO_2 concentrations (360 and 550ppm).



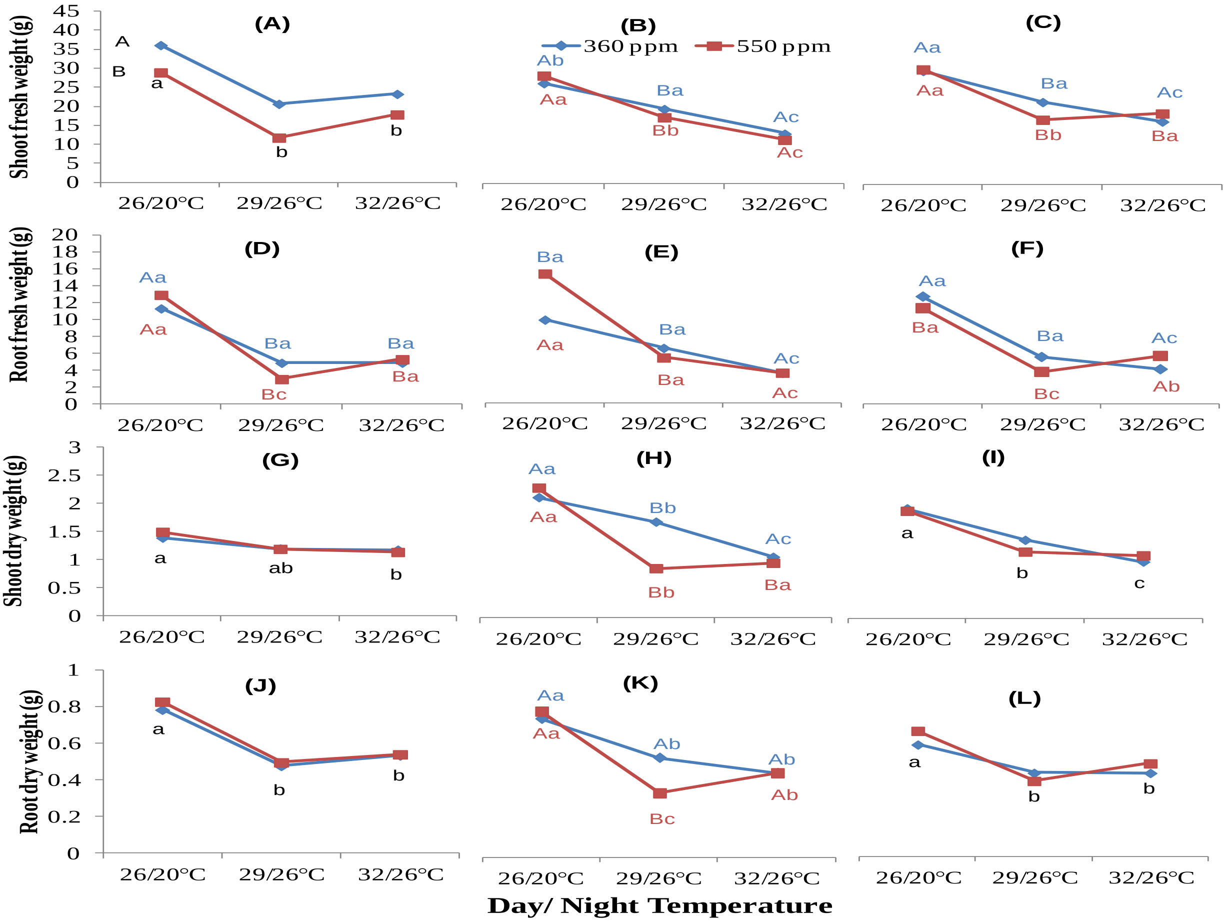
The different capital letters for [CO_2] and lowercase letters for temperatures differ by Tukey test at 5% probability

Figure 2- Length of shoot (A-C) and root (D-F) of seedlings of squash (*Cucurbita pepo*) cv. Redonda (A, D) and Caserta (C, F) and pumpkin (*Cucurbita maxima*) cv. Coroa (B, E) submitted to different day/night temperatures (26/20, 29/23 and 32/26 ° C) and atmospheric [CO_2] (360 and 550ppm). The different capital letters for [CO_2] and lowercase letters for temperatures differ by Tukey test at 5% probability.



The different capital letters for [CO_2] and lowercase letters for temperatures differ by Tukey test at 5% probability

Figure 3-Fresh weight of shoots (A-C) and roots (D-F), dry weight of shoots (G-I) and roots (J-L) of seedlings of squash (*Cucurbita pepo*) cv. Redonda (A, D, G, J) and Caserta (C, F, I, L) and pumpkin (*Cucurbita maxima*) cv. Coroa (B, E,H, K)submitted to different day/night temperatures (26/20, 29/23 and 32/26 ° C) and atmospheric CO_2 concentrations (360 and 550ppm).



The different capital letters for [CO_2] and lowercase letters for temperatures differ by Tukey test at 5% probability

Conclusions

Future climate increase in temperature may compromise seedling emergence and early growth of the squash and pumpkin cultivars studied. The cultivars accessed were more sensitive to temperature increase than to increased [CO_2].
Emergence and early growth of seedlings of *Cucurbita pepo* 'Redonda' and 'Caserta' and *Cucurbita maxima* 'Coroa', generally were not affected by [CO_2].

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