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Development and bloom in hybrids of wild passion fruit cultivated in different types of pots and shading levels

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ABSTRACT: Ornamental hybrids of passion flowers are thoroughly diffused in many countries and used in the decoration of houses and gardens. However, the cultivation of ornamental passion fruits practically unexploited in Brazil. This study aimed at evaluating the growth and blooming of F_1 hybrids of *Passiflora* L. (*P. sublanceolata* J.M. MacDougal [ex *P. palmeri* var. *sublanceolata* Killip] vs. *P. foetida* var. *foetida* L.) cultivated in ceramic and concrete pots under different shading levels. The vegetative and flower evaluations were carried out weekly, in clonal cuttings 60 days after rooting. The height, leaf length and width, the number of internodes and leaves and stem diameter were evaluated using a randomized complete design in a factorial scheme which corresponded to two genotypes, two types of pot, three shading levels (25 %, 50 %, 75 %) and seven weeks of evaluation, with four replications. For the variable number of flowers, the same experimental design was adopted. However, the number of evaluations was modified for three periods, but this was not considered for the flower diameter and leaf area. The shading levels of 25 % and 50 % were the most favorable to the growth in height, whereas hybrid genotypes under 25 % shade had greater increase in the number of leaves, internodes and stem diameter, showing tolerance to moderate shade. The higher values for length, width and leaf area were observed at 75 % shade. The greatest number of flowers was verified at 25 % shadow in concrete pots. As for the types of pot, the ceramic ones were more favorable to the growth of hybrid plants during the first weeks of acclimatization to the treatments, and the concrete ones were more propitious to blooming. Thus, the use of hybrid plants in concrete pots for the ornamentation of internal environments is recommended, if they are well illuminated.

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Keywords: passion flower, ornamental hybrids, interspecific hybridizations, light intensity, morphological characteristics

Introduction

The cultivation and commercialization of ornamental plants are activities which have been ongoing for a long time. As ornamental plants, *Passiflora* L. stands out due to their size, format, exuberance, diversity and the combination of colors of their flowers and leaves. Since the XVII century there has been the ornamental cultivation of these species in Europe, using *P. caerulea* L. and *P. incarnata* L. (Peixoto, 2005). In 1819 the Englishman Thomas Milne succeeded in obtaining the first *Passiflora* hybrid, through the cross of *P. racemosa* Brot with *P. caerulea*, and, since then, more than 685 interspecific hybrids for ornamental purposes have already been produced and registered (Vanderplank et al., 2003; Ulmer and MacDougal, 2004; King, 2007; Abreu, 2009).

A basic factor for plant development and flower production is the radiation of the sun, which can be characterized by its quality, duration and intensity. The photoperiod acts mainly in the change from the vegetative to the reproductive state, which could be determining for some species in the definition of their blossom-time (Hopkins, 1999). Mattana et al. (2010) observed that chemical composition of the leaf essential oil was influenced by intensities of light in *Pothomorphe umbellate* (L.) Miquel

The species of the *Passiflora* genus are widely distributed in tropical and subtropical regions (Vanderplank, 2000; Ulmer and MacDougal, 2004) where the solar radiation is high, but where there are also huge areas of humid and shaded tropical forests. In order to aim at creating a new product for the ornamental plant market, destined for interior decoration, the hypothesis that different shading levels and pots for cultivation interfere in the development of *Passiflora* hybrids was tested. For this purpose growth and bloom variables were analyzed.

Materials and Methods

The experiment was conducted at Ilhéus (39°10′ W, 14°39′; S, 78 m), state of Bahia, Brazil. Two genotypes were evaluated, HD13-133 and HD13-141F_1 hybrids, obtained from the cross of *P. sublanceolata* (Killip) J.M. MacDougal [ex *P. palmeri* var. *sublanceolata* Killip] vs. *P. foetida* var. *foetida* L. at the greenhouse of the Bankof Active Germplasm (BAG-Passifloras).

Hybrids were propagated by cuttings that were removed from the intermediary part of the branches, prepared and standardized with four nodes and four leaves reduced to the half their area. After being selected in bevel, their basal extremities were immersed in talc (inert powder) with synthetic auxin (indole-3 butyric acid – IBA) at a concentration of 2 g kg^{-1}. Cuttings were put in black 1.5 L polyethylene bags, containing washed sand. During the rooting period, cuttings were kept in a greenhouse and irrigated twice a day. After rooting, cuttings were transferred to 45 L ceramic or concrete pots, filled with samples of an Oxisol, previously installed in artificial shading obtained with black plastic type screens. Screens were fixed in wood frames measuring 5 × 5 × 2 m^3 for each light level, under field conditions (www.passifloras.org). Plants were tutored in frames, made of bamboo or wire, nearly 1.0 m in height. Daily watering, fertilizing every 90 days with 3.9 g urea; 34.29 g monoammonium phosphate (MAP) and 14.97 g KCl, and micronutrients and urea (23.3 g L^{-1}) were applied every 15 days.

The structures propitiated the incidence of 25 %, 50 % and 75 % global radiation right under the screen. The data of the photosynthetically active radiation (PAR), temperature and relative humidity, in each environment, measured to the level of the superior extremity of the plants between 8h00 and 18h00 (Figure 1), were obtained with a visible-light-radiation sensor connected to a Data Logger climatological station. The data corresponding to the climatic variables, global radiation, average temperature, relative air humidity (RH) and precipitation data, of the months corresponding to the experiment and collection of the morphologic data times, were supplied by the UESC Micrometeorological Station located near the experiment installations (Table 1).

Evaluations were carried out between Nov. 2007 and Jan. 2008, in clonal cutting, 60 days after rooting. The following growth variables were evaluated for seven weeks after the hybrid clones had been installed in the experiment: (i) plant height: measuring the length of the stem of the biggest branch, using a tape measure, from the point of connection of the root and stem up to its superior extremity; (ii) length and width of the three biggest leaves; (iii) internodes and leaf number from the same branch used for measurement of the plant height; (iv) stem diameter to the level of the second node of only one branch; (v) leaf area, 109 days after the application of the treatments, using leaf area measurer. For the blossom variable, the number of flowers was registered, daily, for 30 days from the 10th day of blooming, from 8h00 to 10h00. The flower diameter was obtained in the same period.

A randomized complete design was used in a factorial (2 × 2 × 3 × 7) scheme, corresponding to two genotypes, two types of pots, three shade levels and seven weeks of evaluation, with four replications. The same design was adopted for the number of flowers, three periods (each period corresponding to the average of ten consecutive days of counting). The time factor was not considered for the flower diameter and leaf area; for this reason we used different pots for the measured. Thus were employed four-way analysis of variance

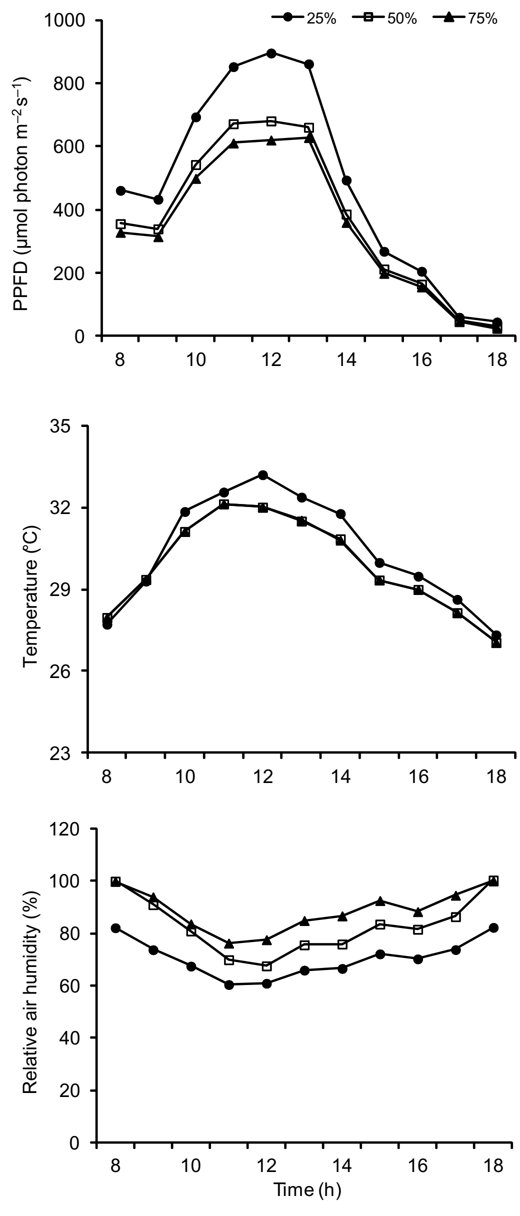

Figure 1 – Day course of the photosynthetically active radiation (PAR), temperature and relative humidity, of each shaded environment, measured at the level of the superior extremity of the plants between 8h00 and 18h00.

Table 1 – Climatic variables during the experimental period.

Month/year	Global radiation	Average temperature	Relative air humidity	Precipitation
	W m^{-2}	°C	%	mm
Nov. 2007	188764.3	23.7	84.8	401.8
Dec. 2007	246965.4	23.5	87.8	251.8
Jan. 2008	353862.4	26.3	80.9	200.2

model: (2 × 2 × 3 × 3) corresponding to the number of flowers, (2 × 2 × 3) corresponding to flower diameter and leaf area and (2 × 2 × 3 × 7) corresponding the other variables. For statistical analysis, the ANOVA, comparison of averages using the Tukey test ($p \leq 0.05$) and regression analysis between the analyzed variables was performed using the SAS 6 and Genes (Cruz, 2006) software programs.

Results

There was an effect ($p \leq 0.05$) for genotypes, types of pots, shading, sampling periods and simple interaction Genotype × Shading and Genotype × Type of pots for all characteristics evaluated, except for leaf width and length where did not interaction Genotype × Type of pots ($p > 0.01$). There was no effect of the pot types for leaf length and width during the evaluation period.

The HD13-133 genotype cultivated in ceramic or concrete pots presented high values in height under 25 % shading (Figure 2A and Figure 2B) respectively. The hybrid HD13-141 also presented more increase in height when cultivated ceramic pots under 25 % shading (Figure 2D).

As for the internode number, the two genotypes presented similar performance to that one observed for the plant height variable. The HD13-133 genotype presented great internodes number when cultivated in ceramic or concrete pots under 25 % shading (Figure 3A and 3B) respectively. The HD13-141 genotype presented a higher internode number in ceramic pots under 25 % shading (Figure 3C).

The HD13-133 hybrid presents higher number of leaves 25 % shading, for both types of pots (Figure 4A and 4B). The HD13-141 presented higher response for leaves number when cultivated in ceramic pots under 25 % shading (Figure 4C).

The stem diameter decreased with increasing shading level for the two genotypes. The HD13-133 hybrid had similar values for the shading levels for both types of pots (Figure 5A and B). For the HD13-141 hybrid a greater increase was verified in the stem diameter under 25 % shading when cultivated in concrete pots (Figure 5D).

The most shaded environment promoted greater increases in the leaf length and width for the HD13-133 hybrid genotypes (Figure 6). Therefore, an effect was observed regarding genotypes, types of pots and shading levels, as well as the interaction among them for the

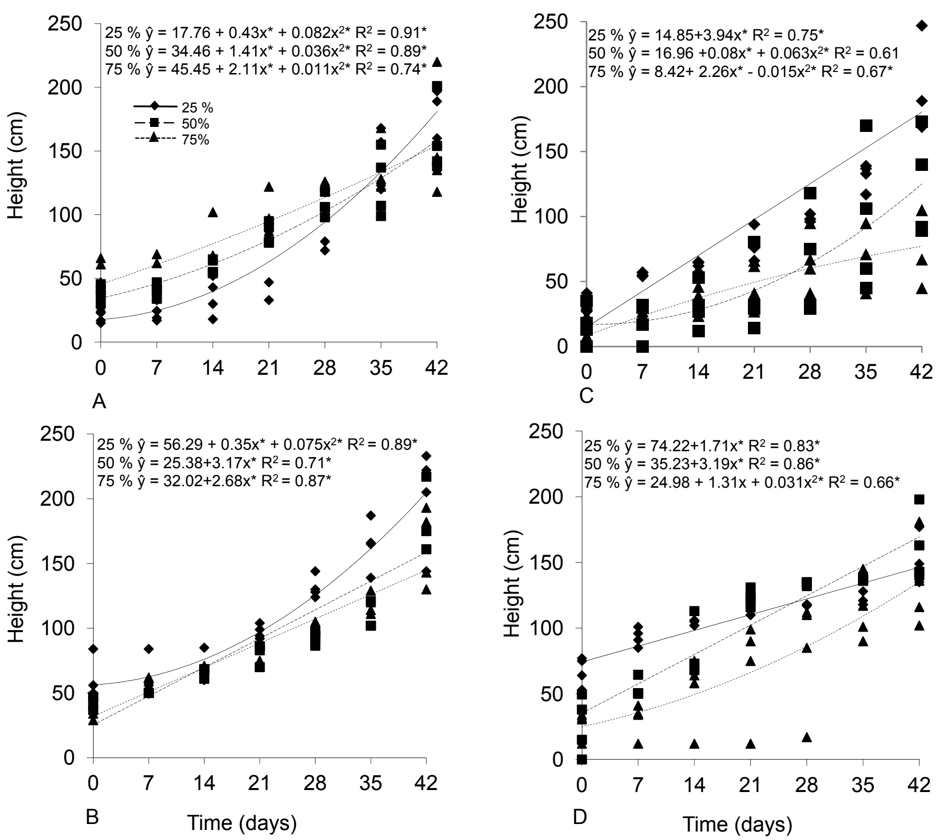

Figure 2 – Growth in height of the longest branch of clonal cuttings of *Passiflora* L. hybrids, submitted to three shading levels, for 42 days, from 60 days after the rooting of the cuttings from stems. A-B) HD13-133 Hybrids; A) Cultivation in ceramic pots; B) Cultivation in concrete pots. C-D) HD13-141 Hybrids; C) Cultivation in ceramic pots; D) Cultivation in concrete pots. *Significant to 5 % probability by the F test.

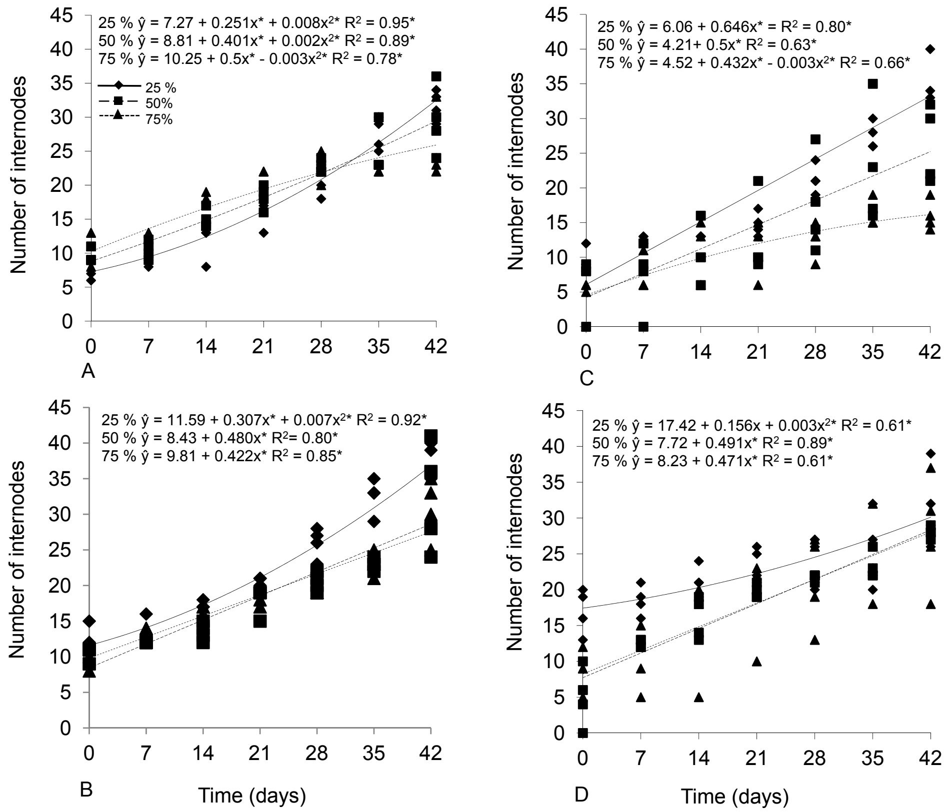

Figure 3 – Number of internodes of the longest branch of clonal cuttings of *Passiflora* L. hybrids, submitted to three shading levels, for 42 days, from 60 days after the rooting of the cuttings from stem. A-B) HD13-133 Hybrids; A) Cultivation in ceramic pots; B) Cultivation in concrete pots. C-D) HD13-141 Hybrids; C) Cultivation in ceramic pots; D) Cultivation in concrete pots. *Significant to 5 % probability by the F test.

Table 2 – Mean leaf area inHD13-133 and HD13-144 *Passiflora* L. hybrids submitted to three irradiance levels and cultivated in different types of pots after 109 days of exposure to the treatments.

Genotype	Shading	Ceramic pot	Concrete pot
		Leaf area (cm^2) ± standard error	
	%		
	25	57.47 ± 4.08 Ba	57.66 ± 0.72 Ab
HD13-133	50	60.68 ± 1.61 Ba	70.99 ± 4.79 Aab
	75	64.26 ± 2.05 Ba	77.64 ± 5.60 Aa
	25	44.70 ± 7.09 Bb	71.92 ± 2.08 Ab
HD13-141	50	70.55 ± 2.16 Ba	76.87 ± 3.02 Aab
	75	80.02 ± 8.26 Ba	88.33 ± 5.32 Aa

Averages followed by the same letters did not differ (Tukey test, $p \leq 0.05$). Capital letters refer to the type of pot effect (within row) and small letters to the shading effect (within column).

leaf area (Table 2). Leaf area increased with increasing shading levels for the two hybrids cultivated in ceramic and concrete pots. The greatest average values for leaf area were found for the two hybrid genotypes cultivated in concrete pots under 75 % of shading (Table 2).

There was no effect of the types of pots and shading levels on the diameter of the flower. Differences were detected only in relation to the genotypes, with the HD13-141 presenting a greater diameter (64.7 mm) than that of HD13-133 (63.0 mm).

The mean data for number of flowers are shown in Table 3. Effect ($p \leq 0.05$) of the genotypes, pot types, shading and sampling periods, as well as the interaction of these factors, was verified. Flower number was higher when shading levels were decreased during the evaluation period, for the two hybrid genotypes cultivated in the different types of pots. The greatest average values were observed for the hybrid HD13-133 cultivated in concrete pots under 25 % shading, in the last week of evaluation (Table 3).

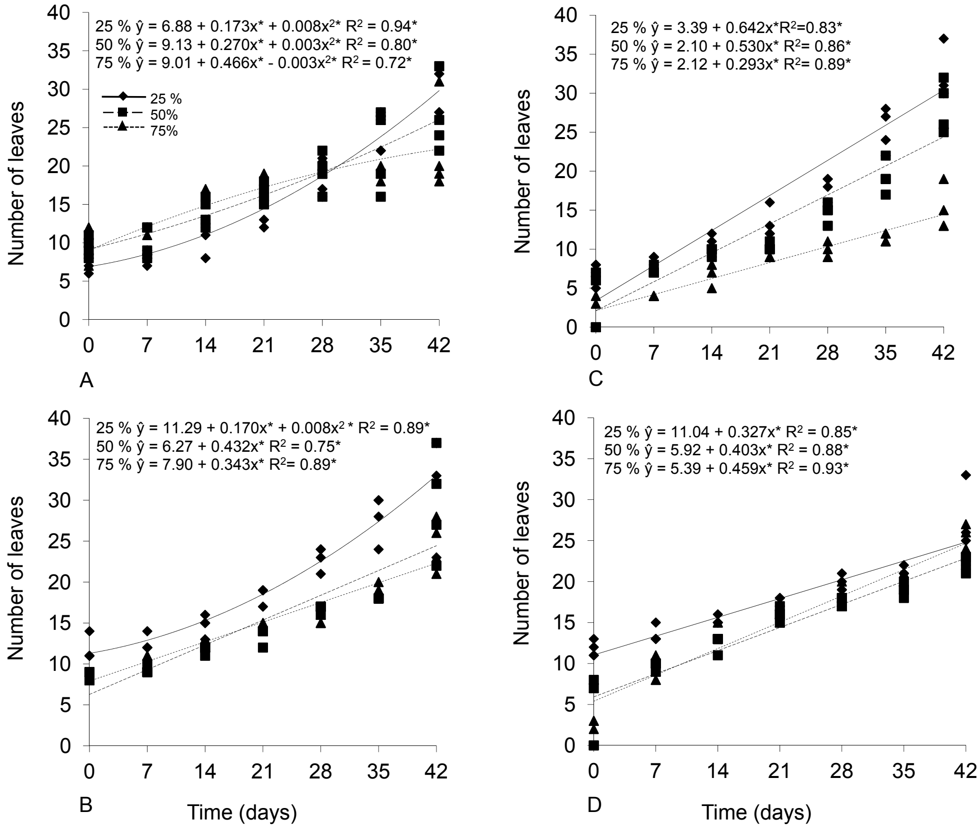

Figure 4 – Number of leaves of the longest branch of clonal cuttings of *Passiflora* L. hybrids, submitted to three shading levels, for 42 days, from 60 days after the rooting of the cuttings from stem. A-B) HD13-133 Hybrids; A) Cultivation in ceramic pots; B) Cultivation in concrete pots. C-D) HD13-141 Hybrids; C) Cultivation in ceramic pots; D) Cultivation in concrete pots. *Significant to 5 % probability by the F test.

Table 3 – Mean number of flowers in *Passiflora* L. hybrid genotypes submitted to three shading levels cultivated in ceramic and concrete pots 30 days after exposure to the treatments.

Genotype	Shading	Ceramic pot			Concrete pot		
		Time (days) ± standard error					
		10	20	30	10	20	30
	%						
HD13-133	25	2.42 ± 0.43 Ab	3.14 ± 0.40 Aab	3.79 ± 0.60 Aa	2.94 ± 0.53 Ac	3.97 ± 0.29 Ab	7.50 ± 0.21 Aa
	50	1.13 ± 0.10 Bb	2.13 ± 0.17 Bab	3.06 ± 0.13 Aa	1.39 ± 0.49 Bb	3.20 ± 0.19 Aa	3.03 ± 0.43 Ba
	75	0.64 ± 0.26 Bb	1.76 ± 0.21 Ba	2.08 ± 0.08 Ba	0.26 ± 0.19 Cb	1.63 ± 0.23 Ba	2.19 ± 0.12 Ba
HD13-141	25	1.18 ± 0.32 Ab	2.98 ± 0.17 Aa	2.84 ± 0.34 Aa	2.19 ± 0.48 Ab	3.97 ± 0.36 Aa	2.91 ± 0.28 Ab
	50	1.01 ± 0.48 Ab	2.74 ± 0.06 Aa	2.75 ± 0.21 Aa	0.90 ± 0.09 Bb	3.01 ± 0.21 Aa	2.85 ± 0.10 Aa
	75	0.08 ± 0.08 Bb	1.03 ± 0.13 Ba	1.33 ± 0.17 Ba	0.04 ± 0.04 Ba	0.71 ± 0.07 Ba	0.64 ± 0.19 Ba

Averages followed for the same letters did not differ (Tukey test, $p \leq 0.05$). Capital letters refer to the shading effect (within row) and small letters to the time effect (within column).

Discussion

The irradiance of the environment in which the plants grow is of fundamental importance, because the adaptation of the plants to this environment depends on the adjustment of their photosynthetic apparatus, so that the light is used in a possibly more efficient way (Lima Júnior et al., 2006). High irradiance may reduce the productivity of tropical plants, as in *Minquartia guianensis* Aubl. (Dias and Marenco, 2007). Then, it is interesting to know how hybrids genotypes of *Passiflora* respond at shading environment and cultivated in types of pots that are the more common in the market. The responses of the plants can be observed in the growth variables, as height of plant, stem diameter and leave number, and are used for making inferences about the tolerance to shading levels (Almeida et al., 2005).

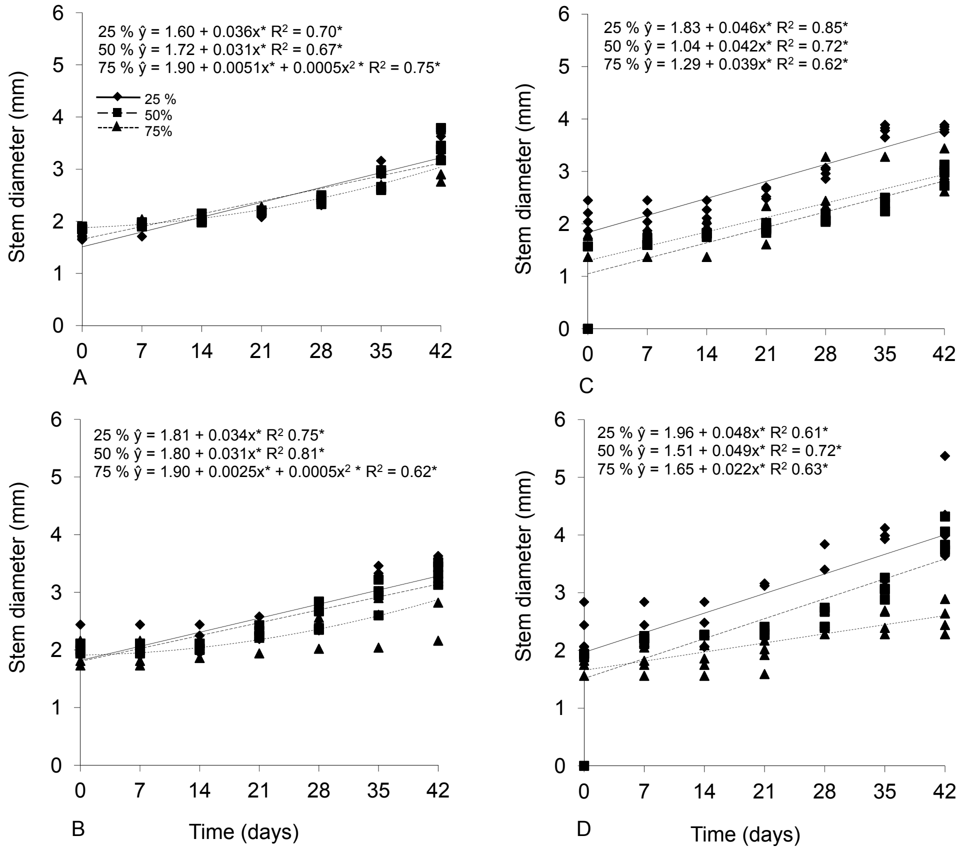

Figure 5 – Stem diameter to the level of the second node of clonal cuttings of *Passiflora* L. hybrids, submitted to three shading levels, for 42 days, from 60 days after the rooting of the cuttings from stem. A-B) HD13-133 Hybrids; A) Cultivation in ceramic pots; B) Cultivation in concrete pots. C-D) HD13-141 Hybrids; C) Cultivation in ceramic pots; D) Cultivation in concrete pots. *Significant to 5 % probability by the F test.

Generally, the condition of 75 % shading was unfavorable to the growth of the plants, while the greatest irradiances, obtained with 25 and 50 % shading, favored the development of the hybrid genotypes of *Passiflora*, promoting greater growth in height in moderate shade. Taking into account the effect of the interactions Genotype × Type of pot and Genotype × Shading, the genotypes presented different responses to each shading level and type of pot for almost all evaluated characteristics, and HD13-133 was superior in relation to plant height, internode number and number of flowers when cultivated in ceramic pot under 25 % shading.

The responses of the hybrid genotypes, in relation to the plant height, varied according to the shading level. The height is a good characteristic to evaluate the response of the plant to the light, because the species have different response patterns, related to their capacity to adapt to the variations in the light intensity (Zanella et al., 2006). Although in this study greater heights had occurred in more illuminated environments, passion fruit plants under different shading levels presented greater growths in height in environments with 80 % shading (Zanella et al., 2006). Similarly, in the ornamental pineapple *Tapeinochilos ananassae* (Hassk.) K. Schum. the lowest luminosity was obtained with 82 % shading, promoted higher stem height (Meleiro and Graziano, 2007).

Low tolerance to high shading levels was furthermore evidenced in this study by the smallest development of the plants under low irradiance conditions (Felfili et al., 1999). Thus, the reduced growth observed for the most shaded environment suggested that condition is limiting for their development. In the present study, the hybrid presented greater height under lower levels of shading and they also presented greater internode numbers under the same conditions. The internodes numbers reflect the growth of the plants in height, and the ratio (plant height/number of internodes) characterizes the average length of the internodes (Lécolier et al., 2009). In field studies with three species of *Passiflora,* 147 days after sowing, a higher number of internodes was verified in relation to the main branch for *P. gibertii* N.E. Brown when compared to *P. edulis* f. *flavicarpa* O. Deg. and *P. cincinnata* Mast. (Silva et al., 2006).

In *Passiflora* hybrids*,* the increase of the number of leaves was proportional to the increase in the irradiance. Similar to this, a lower number of leaves for seedlings was verified in *P. edulis* Sims, cultivated under 70 % shade (Silva et al., 2006). In *Sclerolobium paniculatum* seedlings cultivated in full sun and 50 % shading result-

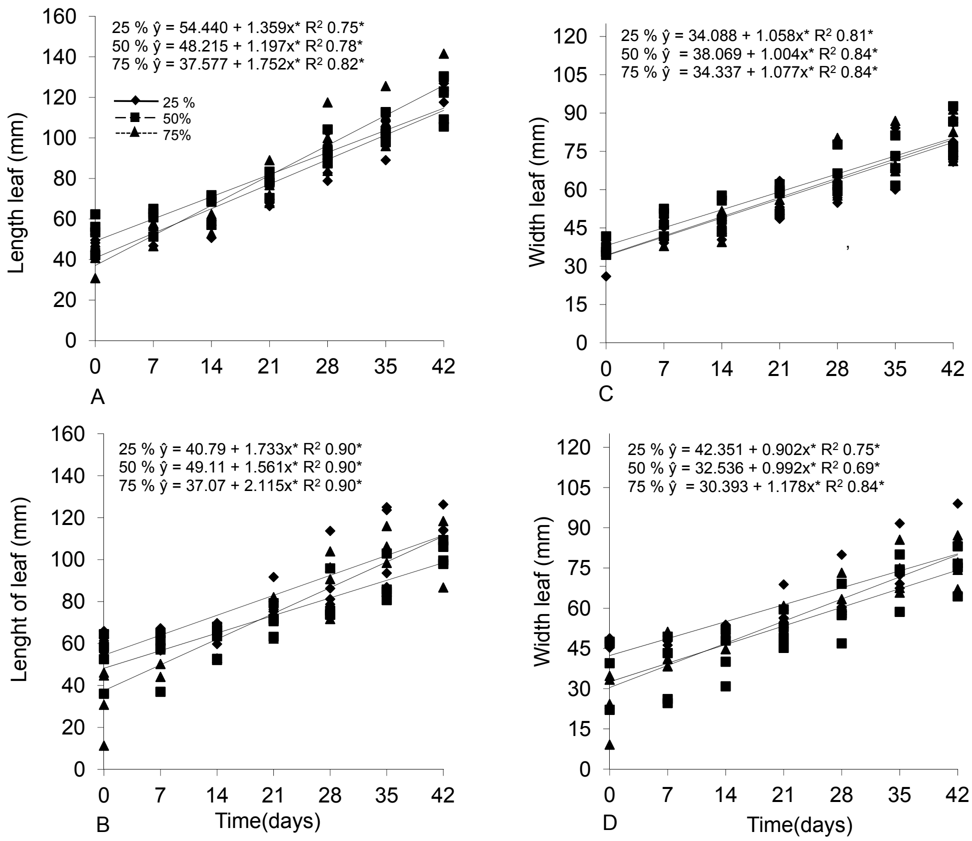

Figure 6 – Length and width of the three longest leaves of clonal cuttings of *Passiflora* L. hybrids, submitted to three shading levels, for 42 days, from 60 days after the rooting of the cuttings from stem. A, C) HD13-133 Hybrids; B, D) HD13-141 Hybrids. *Significant to 5 % probability by the F test.

ed in a higher number of leaves (Felfili et al., 1999). The genotype can also be an important factor in determining the number of leaves in plants. Under field conditions, *P. gibertii* presented higher numbers of leaves in relation to *P. cincinnata* and *P. edulis* f. *flavicarpa* under the same conditions (Vasconcelos et al., 2005).

In this study a higher increase for the stem diameter in conditions of higher light (25 % shading) intensity was shown. Similar results obtained in the arboreal species *Pseudopiptadenia psilostachya*, with higher values for the stem diameter at levels of 30 and 50 % shading (Fonseca et al., 2006). The growth in diameter depends on the exchange activity which, in turn, is stimulated by carbohydrates produced by the photosynthesis and hormones translocated from the apical areas (Paiva et al., 2003). Although higher values have been verified for the stem diameter under 25 % shading, the difference between this and the other shading levels was of little significance.

The leaf area is a characteristic which allows one to analyze the shade tolerance of different species, since it is directly correlated with the photosynthesizing surface area (Lima Júnior et al., 2006). In the present study, the elevation of the shading resulted in the greater leaf area. Similar to the results found in this study, passion fruit seedlings presented higher values for leaf area when submitted to the highest shading levels (Silva et al., 2006). There is the need to enlarge the photosynthesizing surface to maximize the light absorption, searching for a better use of the low irradiance intensities (Almeida et al., 2005). However, there was reduction in the leaf area in passion fruit under low light intensity conditions (Kluge, 1998). The determination of the leaf area is important in the establishment of physiologic processes related to growth and development, including transpiration intensity, liquid assimilatory rates, leaf area index (Franco and Dillenburgl, 2007).

Leaf length and width presented higher growth in low irradiance conditions, under 75 % shade. Expansion of the leaf under low luminosity is frequently reported in other species, and indicates the way the plant compensates for the decrease in light, taking better advantage of this resource with the increase in surface (Franco and Dillenburgl, 2007).

The 25 % shade conditions favored not only the growth but also the bloom of the hybrid genotypes, and a greater number of flowers occurred in conditions of higher irradiance which decreased gradually with the increase in the shading. The decrease in the number of flowers due to intense shading can be related to the reduction of the photosynthesis rate (Cavichioli et al., 2006). These results reinforced the studies that showed lower production on the part of the passion fruit plant with the decrease in the levels of solar radiation, and flowers were not observed under intense shading (Menzel and Simpson, 1988). In *Dimocarpus longan* Lour., floral induction has been done with potassium chlorate (Potchanasin et al., 2009; Sringarm et al., 2009a) but shade prevented floral induction in this species despite the treatment (Sringarm et al., 2009b).

Yellow passion flower presented greater numbers of flowers in environments without shade and with artificial light (Cavichioli et al., 2006). Among the climatic factors, the photoperiod performs an important function in the yellow passion fruit blossom, since this species only bloom when submitted to 12 or more hours of light (Watson and Bowers, 1965). In the hybrid genotypes, the beginning of the blossom occurred first in the less shaded environment, demonstrating the importance of light in that process, because increases in irradiance are one of the factors that can induce blooming (Soares et al., 2009).

Although the difference among the types of pots used was small, cultivation in ceramic pots proved to be more favorable to the growth of the hybrids. This can be attributed to the claylike constitution of the ceramic, which possesses a high capacity of water adsorption, making nutrients more available to the plants, an essential condition for growth. Studies developed in the passion fruit, under protected conditions, showed that hydric stress affects plant growth appreciably (Menzel et al., 1986). Soil moisture should be adapted for each situation of cultivation. For the passion fruit, maintaining the soil close to the field capacity, principally in the blooming period (Menzel et al., 1986). According to the authors, the water content of the passion fruit should correspond to matrix potential values close to -0.06 MPa, for sandy soils, and superior to -0.02 MPa, for soils from medium to claylike texture. It was determined that the water potential of the soil for the passion fruit plant should not be inferior to -0.02 MPa during the flower differentiation period (Souza et al., 2006).

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