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Germination and seedling growth of ornamental species of *Passiflora* under artificial shade

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ABSTRACT. *Passiflora morifolia*, *P. suberosa litoralis*, and *P. palmeri* var. *sublanceolata* are three wild species with ornamental potential that occur in Brazil. These species were evaluated with the purpose of determining the effects of different shade levels on seedling emergence and initial growth. Treatment with 50% shade resulted in the highest percentage of seedling emergence and the highest emergence speed index for all three species. The 50% shade level was the best condition for growth of *P. morifolia* and *P. palmeri* var. *sublanceolata* seedlings because in this condition, they presented higher growth in relation to control and the other treatments. However, *P. suberosa litoralis* can be considered a sun species because it grew better in full sunlight and 25% shade, but its growth was stunted at 75% shade. Increased leaf area and specific leaf area were due to changes in leaf dimension and shape in response to an increase in shade levels. These observations related to the initial growth reflect the development and adaptation of adult plants to heterogeneous environments. Therefore, *P. morifolia* and *P. palmeri* var. *sublanceolata* seedlings adapted better to moderate shade conditions, and *P. suberosa litoralis* seedlings should be cultivated in full sunlight.

Keywords: Passifloraceae, passion flowers, emergence speed index, development, irradiance.

Germinação e crescimento inicial de espécies ornamentais de *Passiflora* sob sombreamento artificial

RESUMO. *Passiflora morifolia*, *P. suberosa litoralis* e *P. palmeri* var. *sublanceolata* são espécies silvestres com potencial ornamental, que ocorrem no Brasil. Foram avaliadas com o objetivo de verificar os efeitos de diferentes níveis de sombreamento na germinação e no crescimento inicial de plântulas. O tratamento com 50% de sombreamento apresentou os maiores valores de percentagem de germinação e de índice de velocidade de emergência para as três espécies. Esse tratamento foi o mais indicado para a formação de plântulas de *P. morifolia* e *P. palmeri* var. *sublanceolata*, pois nessa condição elas apresentaram maior crescimento em altura e incremento de biomassa. Por outro lado, *P. suberosa litoralis* apresentou maior incremento de biomassa a pleno sol e a 25% de sombreamento, com redução a 75% de sombreamento. O incremento da área foliar e da área foliar específica foi devido às alterações na dimensão e na forma das folhas em resposta ao sombreamento. Essas observações demonstram que o crescimento inicial de plântulas reflete o desenvolvimento e a adaptação de plantas adultas à ambientes heterogêneos. Por fim, plântulas de *P. morifolia* e *P. palmeri* var. *sublanceolata* mostraram-se mais adaptadas às condições de sombra moderada ao passo que plântulas de *P. suberosa litoralis* podem ser cultivadas à pleno sol.

Palavras-chave: Passifloraceae, flor-da-paixão, índice de velocidade de emergência, desenvolvimento, irradiância.

Introduction

The *Passiflora* L. genus originates in South America and has its greatest geographical distribution in the Central-North area of Brazil (MELETTI; MAIA, 1999). The species are cultivated for their edible fruits, medicinal properties and, more recently, ornamental characteristics (ABREU et al., 2009). The use of passion flowers as ornamental plants has existed since the 15th century (VANDERPLANK, 2000) and currently continues in European and North American countries in the hybrid seedling market. Its beautiful and exotic flowers and leaves increase the ornamental value of the plant, making passion flowers a prosperous product in the ornamental plant agribusiness.

Some other features place the passion flower on the list of ornamental plants: the peculiar characteristics of the flowers, the capacity for flowering all year round, and the abundance of blooms and exuberant foliage (ULMER; MACDOUGAL, 2004). However, this potential is practically unexplored in the Brazilian plant market (ABREU et al., 2009).

Passiflora hybrids with ornamental potential have been cultivated for this purpose in various countries in the northern hemisphere, where the climate does not favour the breeding of tropical species. Brazil, however, has not yet made use of the wide genetic variability present in the country. The edaphoclimatic conditions in Brazil and the large number of species could potentiate a practically unexploited market. Thus, through competent programs of mass diffusion, the passion flower can be introduced into the Brazilian tropical ornamental plant market. Exportation, especially in Europe, which has cultivated ornamental passion flowers for years, could be a new source of income for the country (ABREU et al., 2009).

The propagation of *Passiflora* is done mainly through seeds at the commercial level, although it may also be done through grafting and cutting (DELANOY et al., 2006; LEONEL; PEDROSO, 2005). In order to obtain plants with the desired standards of quality, it is essential to understand the viable methods of propagation. The formation of seedlings in greenhouses is a very common practice in the cultivation of *P. Edulis* (ZANELLA et al., 2006) and may be employed in the production of seedlings of species with ornamental value (GUISELINI et al., 2004). Many growth variables have been used to evaluate the behaviour of seedlings in relation to shade, such as height and stem diameter, which are used frequently. The ability to grow quickly in height when shaded is an important adaptation mechanism when species are deprived of their full complement of sunlight (BJÖRKMAN, 1981; VERDIAL et al., 2000; ZANELLA et al., 2006). The production of dry matter, the leaf area, and the relationship between the biomass of the shoot and root portions are also used. Leaf area is a feature that is used to analyze the shade tolerance of different species because it correlates directly with the photosynthetic surface area (FARIAS et al., 1997; MATOS et al., 2009; MENZEL; SIMPSON, 1988). However, studies about the seedling growth of ornamental *Passiflora* species concerning the quantity of light absorbed are rare, which makes it difficult to specifically understand the plant's growth and development.

The *Passiflora* wild species are germplasms of interest because they can be used as a source of genes to improve traits in the cultivated species, and, for this purpose, attempts have been made to obtain ornamental hybrids (ABREU et al., 2009; SOUZA et al., 2003). The main objective of this study was to evaluate the effects of different shade levels on seed germination and the initial growth of selected seedlings of wild *Passiflora* species with ornamental potential. Such factors may efficiently subsidize the production of seedlings, indicating which levels of shade are most adequate to optimize cultivation.

Material and methods

The experiment was conducted in Ilhéus, Bahia State, Brazil (39°13'59" W, 14°45'15" S). The three species under study, *P. morifolia* Mast., *P. suberosa litoralis* (Kunth) K. Porter-Utley, and *P. palmeri* var. *sublanceolata* Killip, have been cultivated at UESC's Active Germoplasm Bank. *P. morifolia* occurs widely in Guatemala, Mexico, Venezuela, Bolivia, Colombia, Brazil, Ecuador, Peru, Paraguay, and Argentina. This species has beautiful white flowers with a purplish corona, which gives it, together with its intermediate plant size, favourable characteristics for growing in pots for indoor decoration (MILWARD-DE-AZEVEDO; BAUMGRATZ, 2004; VANDERPLANK, 2000). *P. suberosa litoralis* occurs in almost all of Central and South America, Hawaii, New Guinea, Fiji, and Samoa (VANDERPLANK, 2000). Lobed leaves of *P. suberosa litoralis* are examples of the wide variety of shapes, sizes and shades of green leaves in the genus. Many passion flower species have ornamental value only as a function of foliage (ABREU et al., 2009). *P. palmeri* var. *sublanceolata* is an ornamental tropical species; it is an herbaceous climber of medium size with beautiful flowers with pink and white petals and a purple corona. It is already being used as a parent in interspecific crosses to obtain hybrids for ornamental plants in the USA and Europe, as in the hybrids *P.* 'Aurora' and *P.* 'Pink Jewel' (ULMER; MACDOUGAL, 2004).

Sowing was performed in ten polyethylene bags per treatment, with a capacity of 2 L, with washed sand and matured manure in a 1:1 ratio used as substrate. Ten seeds per bag were sown at a depth of approximately 1.5 cm. At 46 days after emergence, a selection was performed to leave only the most vigorous seedling per plastic bag. After sowing, irrigation was performed daily by a micro-sprinkler system.

Artificial shade was obtained with black plastic screens fixed in wooden frames with dimensions of 5 x 5 x 2 m, under field conditions, which allowed for the reduction of 25% (light shade), 50% (partial shade), and 75% (full shade) of global radiation, along with a control treatment under full sun. The

PPFD, temperature, and relative air humidity values (Figure 1), measured at the upper extremity of seedlings between 8h and 18h, were obtained with a quantum sensor S-LIA-M003 connected to a climatologic station Hobo Micro Station Data Logger (Onset, EUA).

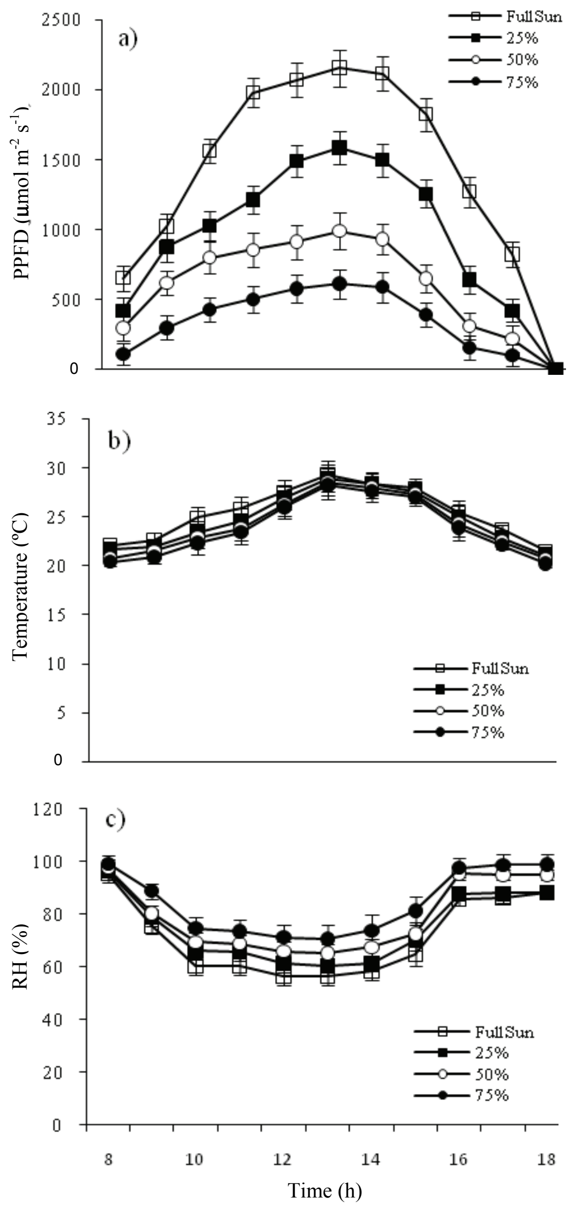

Figure 1. Daily changes in (a) photosynthetic photon flux density (PPFD), (b) temperature, and (c) relative air humidity (RH) in the full sunlight and shaded environments.

Seedling emergence was evaluated from the eighth day after sowing at regular intervals of two days, until the seedling emergence rate proved to be constant at approximately 90 days after sowing, considering the percentage of seedlings emerged with open cotiledonary leaves. The emergence speed index (ESI) was determined using the procedures described by Edmond and Drapala (1958), where counts of the seedlings were performed at regular intervals of five days, starting at the beginning of emergence until stabilization, according the following formula:

$$ESI = \frac{(N_1.G_1)+(N_2.G_2)+...+(N_n.G_n)}{G_1+G_2+...+G_n}$$

where:

N is the number of sowing days at each count, and *G* is the number of emerged seedlings in each counting.

The initial seedling growth evaluations were performed 46, 60, 74, and 88 days after the emergence, using ten seedlings per treatment. Evaluations were made by measuring the height of the seedlings from the collar to the apex extremity, with the help of a measuring tape and the stem's diameter at the level of the 2nd knot, obtained with the help of a digital pachymeter.

At 94 days after the emergence, five plants per treatment were randomly collected and used to determine the leaf area (LA), ratio shoot/root (S/R), the specific leaf area (SLA), and the leaf area ratio (LAR). Root (RDW), stem (SDW), leaf (LDW), and total (TDW) dry weight were obtained after drying at 70°C until a constant mass was reached. Leaf area was estimated using an automatic Leaf Area Meter LI-3100 (Li-Cor, USA). The S/R ratio was calculated as the quotient between shoot (SDW ± LDW) and RDW. The SLA and LAR were estimated as the quotients between individual mean values of LA and LDW and between total LA and LDW per seedling, respectively (BENINCASA, 1988).

The experiment was conducted with a completely randomized design, using a 4 x 3 factorial arrangement with four light levels (full sunlight and 25, 50, and 75% shade) and three *Passiflora* species, with ten replicates for evaluations of seed germination and initial growth (height and stem diameter) and five replicates for analysis of dry weight, using one seedling per experimental unit. The results were subjected to a variance analysis (ANOVA) followed by Tukey's mean comparison test ($p < 0.05$) and regression analysis ($p < 0.05$ and $p < 0.01$) (STORCK et al., 2006). All statistical procedures were performed using the software Statistica 6.0 (STATSOFT Inc., 2007).

Results and discussion

Germination

The seedling emergence for the three species studied started eight days after sowing. Seedling emergence concluded after 65 days after sowing for *P. morifolia* and *P. suberosa litoralis* and 90 days after sowing for *P. palmeri* var. *sublanceolata*. Seedling emergence and ESI percentage averages differed ($p < 0.05$) between shade levels for the three species (Table 1). *P. morifolia* presented higher percentages of seedling emergence at shade levels of 50 and 75% (49.3 and 44%, respectively). In the same conditions, the lowest ESI values were found (10.83 and 11.27 days), indicating that there was faster initial development of these seedlings under dense shade treatment. However, *P. palmeri* var. *sublanceolata* species presented low percentage rates of seedling emergence in all treatments, of which the highest value was 26.6 at 50% of shade. In the same treatment, this species presented the lowest ESI value, which indicates a higher rate of growth for recently emerged seedlings under moderate shade conditions. In contrast, differences in seedling emergence rates for *P. suberosa litoralis* were not found between shade levels of 50 and 75%, while the lowest ESIs occurred at 50 and 75% of shade (15.4 and 18.7 days, respectively).

Some reports about the seedling emergence of *Passiflora* raise concern over a slow and irregular period of emergence (ALEXANDRE et al., 2004; DELANOY et al., 2006; PASSOS et al., 2004). The treatment using 50% shade presented with the best percentage of seedling emergence and of emergence speed index for all three species studied (Table 1). The low values of observed seedling emergence suggested that the conditions were not fully satisfactory for the germination of seeds of the three wild species of *Passiflora*. Other abiotic factors also affect the germination process, such as temperature and relative humidity (PINHEIRO; BORGHETTI, 2003; SOCOLOWSKI et al., 2010). Some species require light for germination at near optimum temperatures, and some species are indifferent to light under these conditions (BENÍTEZ-RODRÍGUES et al., 2004). However, no difference in temperature was observed between the four light availability levels (Figure 1). The higher relative humidity observed in the more shaded conditions, together with the reduction of irradiance, may have benefited the germination rates by creating a micro-climate that is favourable for seedling emergence.

Studies of the germinative behaviour of *P. molissima* and *P. tricuspis* have shown germination rates close to 27 and 57%, respectively, confirming the low germination for wild *Passiflora* species (DELANOY et al., 2006). In contrast, *P. edulis*, the purple passion fruit, an already domesticated species, presents a seedling emergence capacity of approximately 90% (MELETTI; MAIA, 1999). *Passiflora* seeds demonstrate dormancy due to the impermeability of the integument (MORLEY-BUNKER, 1980; DELANOY et al., 2006). However, nothing is known about the mechanisms of physiological or physical dormancy in the species studied; rather, it is suspected that dormancy exists.

Seedling growth

The estimated regressions (Table 2) showed that the growth of the three species studied was influenced by shade treatments. There was an increase in the height of seedlings with the increase of shade starting from 60 days after emergence, especially at levels of 50 and 75%, which presented the highest average values for the three species (Figure 2a, b and c). In contrast, the increase in the diameter of the stems was proportional to the decrease in the shade for the three species, with the highest average values occurring in full sun and 25% shade (Figure 2d, e and f). Moreover, the relation between shade and the increase in the diameter of the stems became more intense starting at 74 days after emergence.

The low height values of seedlings that grew under full sun indicate that this condition limits these species' initial development (Figure 2a, b and c). In contrast, the increase in height of shaded plants is considered to be a typical morphogenetic response (MATOS et al., 2009). Similarly, shade induced more growth in height in *P. edulis* f. *flavicarpa* plants (ZANELLA et al., 2006). Apical dominance tends to increase when plants are submitted to high shade levels, due to a decrease in the production of photoassimilates and the highest level of auxin at the stem apex bud (VANNESTE; FRIML, 2009; WOODWARD; BARTEL, 2005).

Table 1. Seedling emergence (%) and emergency speed index (ESI) of *P. morifolia*, *P. suberosa litoralis*, and *P. palmeri* var. *sublanceolata*, under different shade conditions.

Shade	*P. morifolia*		*P. suberosa litoralis*		*P. palmeri* var. *sublanceolata*	
	%	ESI	%	ESI	%	ESI
Full Sun	28.0 ± 0.1^{Ab}	15.8 ± 0.2^{Ca}	26.7 ± 0.2^{Ab}	24.1 ± 0.3^{Ba}	2.7 ± 0.8^{Bc}	30.9 ± 0.2^{Aa}
25%	29.3 ± 0.2^{Ab}	16.0 ± 0.1^{Ba}	32.0 ± 0.4^{Aab}	20.6 ± 0.2^{Aa}	6.7 ± 0.5^{Bb}	21.5 ± 0.3^{Ab}
50%	49.3 ± 0.2^{Aa}	10.8 ± 0.2^{Bb}	42.7 ± 0.1^{Aa}	15.4 ± 0.2^{Ab}	26.7 ± 0.5^{Ba}	18.2 ± 0.1^{Ab}
75%	44.0 ± 0.05^{Aa}	11.3 ± 0.3^{Cb}	41.3 ± 0.2^{Aa}	18.7 ± 0.4^{Bb}	12.0 ± 0.3^{Bb}	31.2 ± 0.4^{Aa}

Note: means of ten replicates ± S.E. Means comparison were done using Tukey's test ($p < 0.05$). For each variable lower case letters indicate comparisons between treatments and capital case between species.

The increase in stem diameter is directly related to the exchange activity, which depends on photosynthetic products, such as carbohydrates and hormones, from the apical bud (PAIVA et al., 2003). *P. edulis* f. *flavicarpa* seedlings cultivated under 70% shade seemed very etiolated, with wide internode intervals and a small number of leaves, when compared to seedlings grown under full sunlight (SILVA et al., 2006). This fact was also seen in more prominent shade (75%), where a light etiolation in *P. morifolia*, *P. suberosa litoralis*, and *P. palmeri* var. *sublanceolata* seedlings occurred (Figure 2d, e and f).

At 94 days of exposure, differences ($p < 0.05$) were observed between treatments for RDW, SDW, LDW, and TDW (Table 3). The highest RDW values occurred at 50% shade for *P. morifolia* and *P. palmeri* var. *sublanceolata* and at full sunlight for *P. suberosa litoralis*. A difference in SDW between shade levels for *P. suberosa litoralis* and *P. palmeri* var. *sublanceolata* was not observed. However, for *P. morifolia*, the highest SDW values, observed in the treatment with 50% shade, differed in relation to the other levels of shade. A decrease in the shade level had a diminishing effect on LDW for *P. suberosa litoralis*, while for *P. morifolia* and *P. palmeri* var. *sublanceolata* the LDW value increased along with a decrease in the light intensity. As a result of the increment of shade, there was a reduction of TDW for *P. suberosa litoralis*, while for *P. morifolia* and *P. palmeri* var. *sublanceolata*, higher TDW values occurred at 50% shade (Table 3).

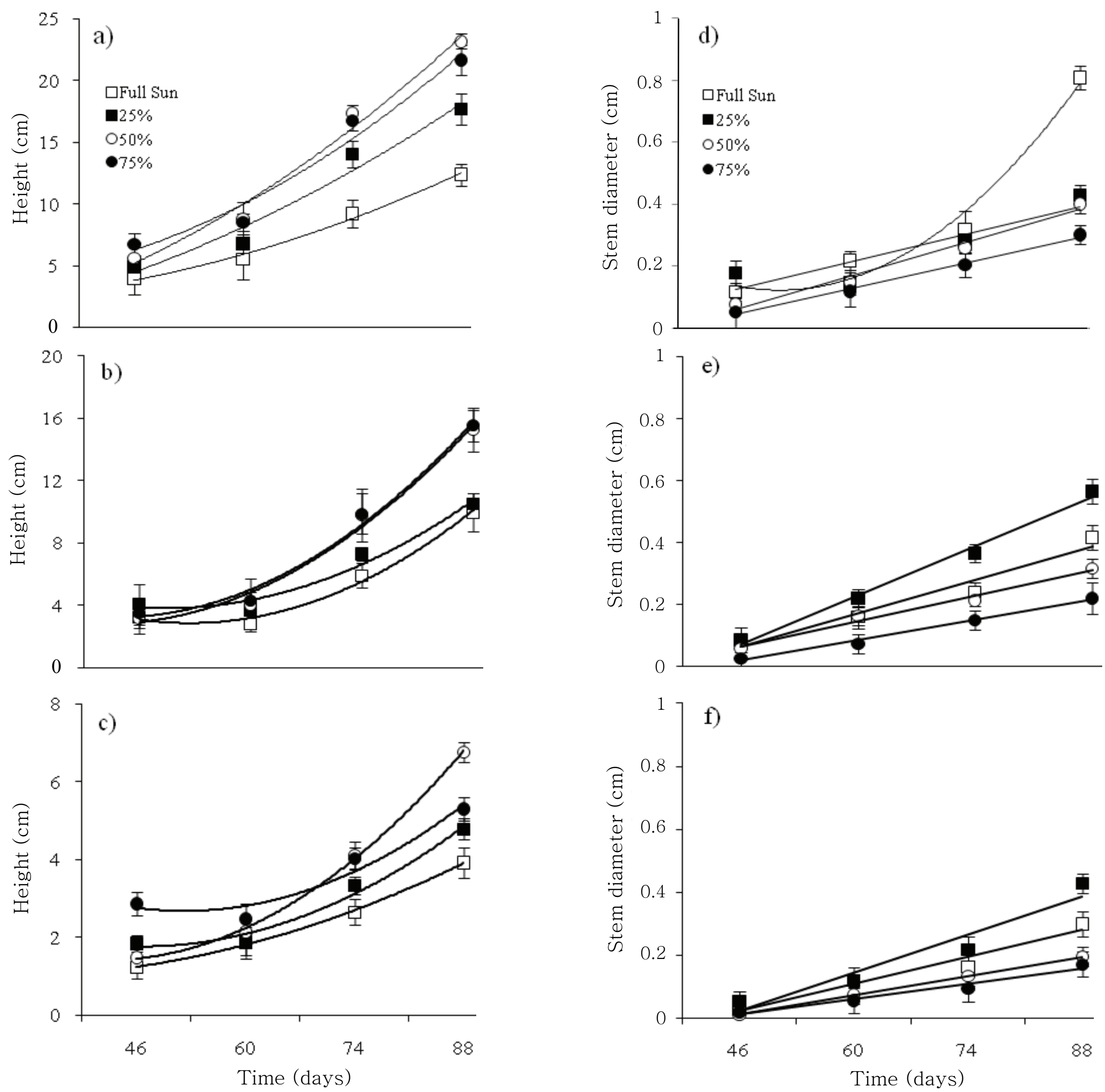

Figure 2. Height (a-c) and stem diameter (d-f) of *P. morifolia* (a, d), *P. suberosa litoralis* (b, e), and *P. palmeri* var. *sublanceolata* (c, f) seedlings under different shade conditions, at 46, 60, 74, and 88 days after emergence. Points are means of ten replications (± S.E).

Table 2. Regressions for the relationship between shade levels and time (days) to height and stem diameter.

Species	Shade	Height	Stem Diameter
P. morifolia	Full Sun	$\hat{y} = 0.40x^2 \pm 0.87x \pm 2.56, r^2 = 0.99^{**}$	$\hat{y} = 0.09x^2 - 0.27x \pm 0.31, r^2 = 0.97^{**}$
	25%	$\hat{y} = 0.44x^2 \pm 2.32x \pm 1.72, r^2 = 0.96^{*}$	$\hat{y} = 0.09x \pm 0.04, r^2 = 0.81^{*}$
	50%	$\hat{y} = 0.66x^2 \pm 2.82x \pm 1.73, r^2 = 0.98^{**}$	$\hat{y} = 0.11x - 0.05, r^2 = 0.98^{**}$
	75%	$\hat{y} = 0.79x^2 \pm 1.34x \pm 4.15, r^2 = 0.96^{*}$	$\hat{y} = 0.08x - 0.04, r^2 = 0.99^{**}$
P. suberosa litoralis	Full Sun	$\hat{y} = 1.11x^2 - 3.23x \pm 5.21, r^2 = 0.98^{**}$	$\hat{y} = 0.10x - 0.04, r^2 = 0.95^{*}$
	25%	$\hat{y} = 0.91x^2 - 2.24x \pm 5.21, r^2 = 0.96^{*}$	$\hat{y} = 0.16x - 0.09, r^2 = 0.99^{**}$
	50%	$\hat{y} = 1.15x^2 - 1.53x \pm 3.29, r^2 = 0.98^{**}$	$\hat{y} = 0.08x - 0.02, r^2 = 0.98^{**}$
	75%	$\hat{y} = 1.21x^2 - 1.89x \pm 3.96, r^2 = 0.98^{**}$	$\hat{y} = 0.06x - 0.05, r^2 = 0.99^{**}$
P. palmeri var. *sublanceolata*	Full Sun	$\hat{y} = 0.16x^2 \pm 0.08x \pm 0.99, r^2 = 0.99^{**}$	$\hat{y} = 0.08x - 0.06, r^2 = 0.96^{*}$
	25%	$\hat{y} = 0.35x^2 - 0.73x \pm 2.14, r^2 = 0.98^{**}$	$\hat{y} = 0.12x - 0.09, r^2 = 0.93^{*}$
	50%	$\hat{y} = 0.49x^2 - 0.70x \pm 1.65, r^2 = 0.99^{**}$	$\hat{y} = 0.06x - 0.05, r^2 = 0.99^{**}$
	75%	$\hat{y} = 0.42x^2 - 1.19x \pm 3.54, r^2 = 0.95^{*}$	$\hat{y} = 0.05x - 0.04, r^2 = 0.96^{*}$

Note: (*) and (**) represent significant difference at $p < 0.05$ and $p < 0.01$, respectively, by the *F*-test.

Table 3. Root (RDW, g), stem (SDW, g), leaf (LDW, g), and total dry weight (TDW, g) of *P. morifolia*, *P. suberosa litoralis*, and *P. palmeri* var. *sublanceolata* seedlings under different shade conditions until 94 days after emergence.

Species	Shade	RDW	SDW	LDW	TDW
P. morifolia	Full Sun	1.84 ± 0.1^{Bd}	1.52 ± 0.1^{Ab}	2.33 ± 0.08^{Bc}	5.69 ± 0.2^{Bd}
	25%	2.57 ± 0.05^{Ab}	1.77 ± 0.1^{Ab}	3.04 ± 0.08^{Ab}	7.38 ± 0.1^{Ab}
	50%	3.04 ± 0.07^{Aa}	2.17 ± 0.03^{Aa}	3.82 ± 0.1^{Aa}	9.03 ± 0.2^{Aa}
	75%	2.27 ± 0.04^{Ac}	1.75 ± 0.09^{Ab}	2.55 ± 0.1^{Ac}	6.57 ± 0.2^{Ac}
P. suberosa litoralis	Full Sun	2.74 ± 0.2^{Aa}	1.58 ± 0.1^{Aa}	2.96 ± 0.1^{Aa}	7.28 ± 0.2^{Aa}
	25%	2.72 ± 0.2^{Aa}	1.49 ± 0.2^{Aa}	2.32 ± 0.2^{Bab}	6.53 ± 0.3^{Ba}
	50%	2.04 ± 0.1^{Bab}	1.28 ± 0.1^{Ba}	2.39 ± 0.3^{Bab}	5.71 ± 0.1^{Ba}
	75%	1.8 ± 0.2^{Bb}	1.16 ± 0.1^{Ba}	1.89 ± 0.1^{Bb}	4.85 ± 0.4^{Ba}
P. palmeri var. *sublanceolata*	Full Sun	1.25 ± 0.1^{Cb}	0.97 ± 0.1^{Ba}	1.62 ± 0.1^{Cb}	3.84 ± 0.1^{Cb}
	25%	1.96 ± 0.1^{Ba}	1.18 ± 0.07^{Ba}	2.18 ± 0.2^{Bab}	5.33 ± 0.2^{Ca}
	50%	2.08 ± 0.1^{Ba}	1.25 ± 0.03^{Ba}	2.53 ± 0.2^{Ba}	5.86 ± 0.2^{Ba}
	75%	1.55 ± 0.07^{Bb}	1.02 ± 0.06^{Ba}	1.84 ± 0.1^{Bb}	4.41 ± 0.1^{Bb}

Note: Means of five replicates ± S.E. Means comparison were done using Tukey's test ($p < 0.05$). For each variable lower case letters indicate comparisons between treatments and capital case comparisons between species.

A study of the development of *P. edulis* f. *flavicarpa* seedlings showed the highest values of RDW in plants grown in full sunlight (SILVA et al., 2006). The same study showed that in 30% shade, there was an increase in SDW in *P. edulis* f. *flavicarpa* seedlings, while the lowest values were found in full sunlight and 70% shade. Low RDW values in *P. suberosa litoralis* that grow in environments with more intense shade may have occurred due to the decrease in the amount of auxin that was carried by roots in shaded plants, resulting in the decrease in the formation of roots (MORELLI; RUBERTI, 2000; VANNESTE; FRIML, 2009).

The highest LDW values for *P. suberosa litoralis* seedlings in full sunlight may have occurred due to an increase in foliar thickness that normally occurs under high amounts of light (SCALON et al., 2001). A similar result was found by Silva et al. (2006), who observed a decrease in the production of leaf biomass in *P. edulis* f. *flavicarpa* accompanying an increase in the shade level. The low light intensity for passion flowers caused branch etiolation and reduced the aerial part dry biomass (CLAUSSEN, 1996; KLUGE, 1998); these data corroborate those obtained in this experiment for *P. suberosa litoralis*. Moreover, the *P. morifolia* and *P. palmeri* var. *sublanceolata* TDW values are similar to those observed for *P. edulis* f. *flavicarpa*, where the accumulation of TDW in plants in full sunlight was lower than that obtained from shade treatments (ZANELLA et al., 2006).

An effect ($p < 0.05$) of shade levels on LA, SLA, and LAR was found for the three species studied, whose highest averages were observed at 50 and 75% shade (Table 4). *P. morifolia* and *P. palmeri* var. *sublanceolata* presented maximum values of LA, SLA, and LAR in 75% shade, while for *P. suberosa litoralis*, maximum values for these parameters occurred in 50% shade. The S/R value did not differ between shade levels (Table 4).

The increase in LA and SLA is caused by changes in leaf dimensions and shape as a response to increasing shade levels. The expansion of the leaf under low irradiance is frequently reported and indicates the way that the plant compensates for the decrease in light, making better use of this resource by increasing the surface area (CAMPOS; UCHIDA, 2002). Increased SLA may improve light harvesting per unit of resources invested in construction of photosynthetic tissues (LUSK et al., 2008); it represents an adaptive mechanism, demonstrating the most efficient utilization of photoassimilates, as a larger photosynthetic area is produced per unit of accumulated dry matter (CHAVES et al., 2008; DAMATTA, 2004).

Table 4. Leaf area (LA, cm^2), specific leaf area (SLA, cm^2 g^{-1}), leaf area ratio (LAR, cm^2 g^{-1}), and ratio shoot $root^{-1}$ (S/R) of *P. morifolia*, *P. suberosa litoralis*, and *P. palmeri* var. *sublanceolata* seedlings under different shade conditions until 94 days after emergence.

Species	Shade	LA	SLA	LAR	S/R
P. morifolia	Full Sun	137.97 ± 4.6^{Ac}	36.41 ± 2.2^{Ad}	15.33 ± 0.8^{Ad}	1.96 ± 0.1^{Aa}
	25%	185.01 ± 8.0^{Ab}	61.27 ± 4.1^{Ac}	25.09 ± 1.3^{Ac}	1.87 ± 0.1^{Aa}
	50%	256.55 ± 11.5^{Aa}	101.53 ± 6.5^{Ab}	39.22 ± 2.2^{Ab}	1.89 ± 0.1^{Aa}
	75%	292.42 ± 9.8^{Aa}	126.12 ± 6.5^{Aa}	51.66 ± 2.6^{Aa}	2.12 ± 0.1^{Aa}
P. suberosa litoralis	Full Sun	83.51 ± 5.2^{Bbc}	28.35 ± 1.9^{Ab}	11.48 ± 0.7^{Ab}	1.69 ± 0.1^{Aa}
	25%	76.31 ± 5.0^{Bc}	33.39 ± 2.7^{Bb}	11.85 ± 1.2^{Bb}	1.43 ± 0.1^{Aa}
	50%	129.49 ± 7.0^{Ba}	53.42 ± 6.2^{Ba}	22.64 ± 1.0^{Ba}	1.85 ± 0.2^{Aa}
	75%	100.51 ± 5.6^{Bb}	57.18 ± 2.0^{Ba}	20.91 ± 1.2^{Ba}	1.75 ± 0.2^{Ba}
P. palmeri var. *sublanceolata*	Full Sun	34.1 ± 2.4^{Cb}	13.83 ± 1.6^{Bb}	5.89 ± 0.6^{Bb}	1.82 ± 0.1^{Aa}
	25%	42.29 ± 2.5^{Cb}	19.93 ± 2.1^{Cb}	8.04 ± 0.7^{Bb}	1.75 ± 0.2^{Aa}
	50%	61.24 ± 2.7^{Ca}	34.06 ± 3.3^{Ca}	13.91 ± 0.6^{Ca}	1.87 ± 0.1^{Aa}
	75%	61.32 ± 3.7^{Ca}	38.3 ± 3.3^{Ca}	16.04 ± 1.2^{Ba}	2.14 ± 0.2^{Aa}

Note: Means of five replicates ± S.E. Means comparison were done using Tukey's test ($p < 0.05$). For each variable lower case letters indicate comparisons between treatments and capital case comparisons between species.

Therefore, the low LAR values observed in passion flowers at full sunlight may have benefited these plants, decreasing the exposure of plant tissues to the sun and reducing water loss and self-shade (MATOS et al., 2009). An increase in the S/R ratio was found with an increase in shade for *P. edulis* f. *flavicarpa* (SILVA et al., 2006). Shading favored the growth of the aerial part; however, the values obtained at full sunlight revealed a balance in the production of dry weight for both parts (Table 2). Low S/R values in plants from environments with higher light indicate that the biomass was distributed more to the roots than to photosynthesizing organs, allowing higher absorption of water and nutrients, a strategy that guarantees higher rates of photosynthesis and transpiration in these environments.

Conclusion

The shade treatments were most effective for seedling emergence of *P. morifolia*, *P. suberosa litoralis* and *P. palmeri* var. *sublanceolata*. Moreover, it can be indicated for the formation of *P. morifolia* and *P. palmeri* var. *sublanceolata* seedlings because in these conditions, the shade-tolerant species presented higher vegetative growth in relation to the other treatments. *P. suberosa litoralis* was revealed to be a sun-tolerant species, as it grew and developed better under full sunlight. The functional meaning of these morphological characteristics and structural adjustments were related to differential development under the imposed shade conditions, at a whole plant level. The development of these species in each environment was best demonstrated by growth rates and biomass accumulation because environment interferes in the production of biomass. Notwithstanding, relevant importance should be given to the adoption of handling techniques. These results may be useful for selecting sun and shade-tolerant species for landscaping projects, and they provide support for introducing the cultivation of *Passiflora* into the Brazilian tropical ornamental plant market. *P. suberosa litoralis* can be used as ornamental plants in outdoor gardens, green live fencing or pergola green cover, whereas *P. morifolia* and *P. palmeri* var. *sublanceolata* can be better used as indoor vase plants in shaded environments.

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