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Full Length Research Paper

Alternative substrates for production of *Heliconia psittacorum* L. seedlings under shade and open field conditions

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This study aimed to evaluate the effect of different substrates and environmental conditions on seedling production of heliconia (*Heliconia psittacorum* L.) in Northeastern Brazil. A completely randomized blocks design with treatments distributed in a factorial arrangement (6 x 2) referring to substrate compositions and environmental condition to produce seedlings (open field and net-house) was used, with four replications. The following substrates were tested: (i) soil + sand + bovine manure (SSB); (ii) soil + sand + goat manure (SSG); (iii) decomposed buriti stem (*Mauritia vinifera,* Mart.) (DBS); (iv) Carnauba (*Copernicia prunifera*) industry residual + carbonized rice husks (CRR); (v) semi-decomposed residual of carnauba industry (RCI) and (vi) soil. Both substrate and environmental conditions affect seedling formation of heliconia. Decomposed buriti stem and semi-decomposed residual of carnauba industry could be used as substrate for high quality heliconia seedlings. Net-house is necessary for *Heliconia* seedlings production.

Key words: *Heliconia psittacorum* L., tropical flower, growing media, industry waste, net-house.

INTRODUCTION

Heliconia (*Heliconia psittacorum* L.) is a tropical ornamental flower species native to the tropical America and commonly found in Central and South America (Kepler and Mau, 1996). Among the tropical ornamental flowers, *Heliconia* have presented higher growth in the international market due to its exuberance, color and format, detaching that *Heliconia* has been commercialized in European and American markets as cut flowers, potted plants and in interior landscape (Santos et al., 2009). *Heliconia* has been commonly propagated by rhizome or micropropagation (Rocha et al., 2009), but the adequate substrate is not a consensus in the international literature and the use of industry residuals for substrate composition aiming seedling production of *Heliconia* have been poorly studied. The most used substrate on floriculture around the world is peat moss which availability is uncertain in the future, thus motivating the floriculture industry to look for alternative components in commercial potting substrates (Bachman and Metzger, 2008). Additionally, because peat-based commercial potting substrates have low ion exchange capacities, there is concern about the environmental impact of leachates containing high concentrations of chemical fertilizers. A thorough understanding of the characteristics of growing media, which greatly affect plant growth, is essential to improve the re-use of bio-

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Abbreviations: SSB, Soil sand bovine; **SSG,** soil sand goat; **DBS,** decomposed buriti stem; **CRR,** carnauba; **DWS,** dry weight of shoot; **DWR,** dry weight of root + rhizome; **TPT,** time to produce tillers; **NSR,** number of sprouts per rhizome; **TNL,** total number of new leaves.

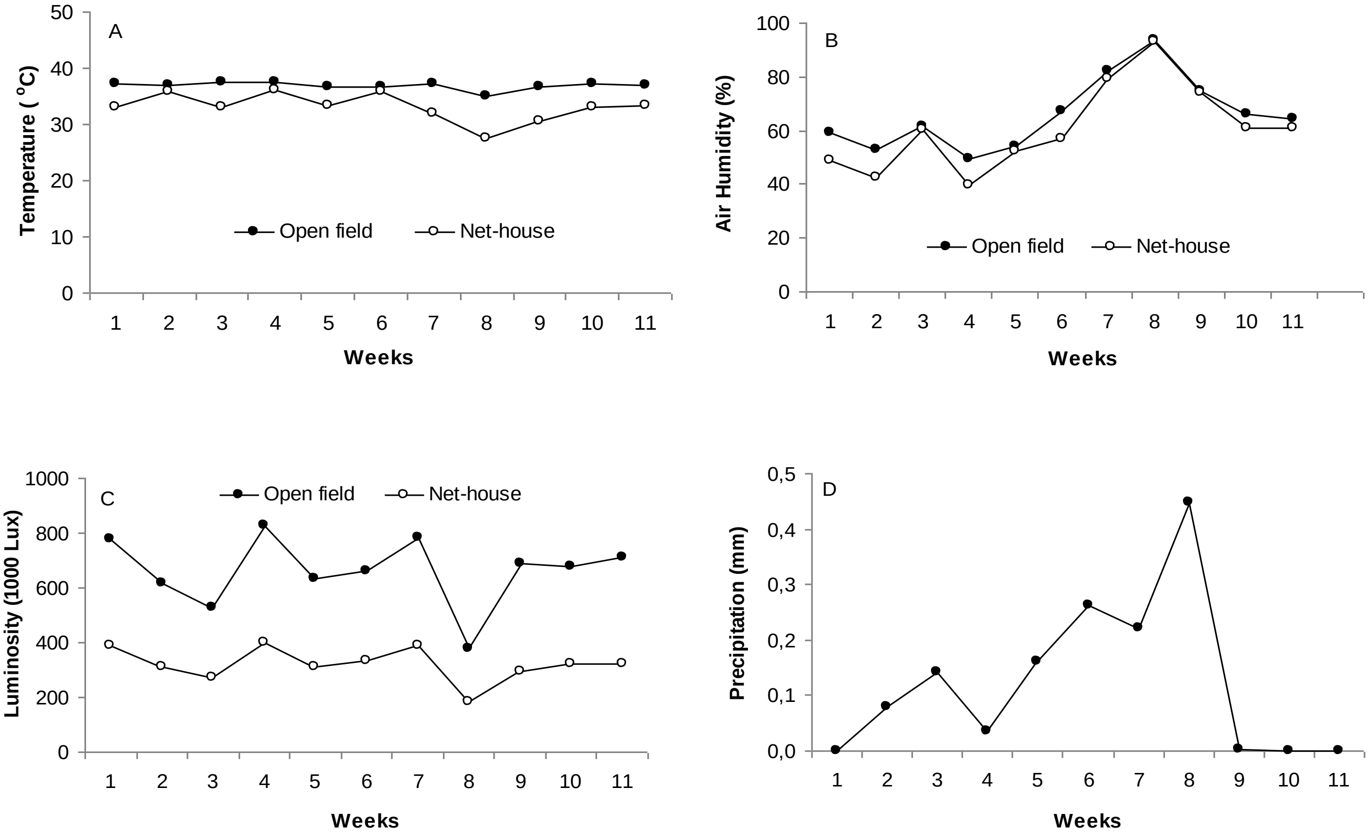

Figure 1. Average week values of temperature (A), air humidity (B), luminosity (C) and precipitation (D) from November 2009 to January 2010 in Bom Jesus, Piaui State, Brazil.

solids as a peat substitution in container cultivation.

This way, lots of studies have being developed focusing on factors that limit the use of compost as a substrate (salinity, pH or physical properties) and its tolerable quality as a growing media, detaching components such as alternative composts (Grigatti et al., 2007), biosolids (Papafotiou et al., 2004), coconut fiber and pine bark (Cavalcante et al., 2008), composting sugar-cane bagasse (Catunda et al., 2008) and the use of products such as carbonized rice husks (Kennedy et al., 2005) and manure (Turhan et al., 2007). Specifically for heliconias, Konnerup et al. (2009) studied treatment of domestic wastewater and Santos et al. (2004, 2006) evaluated different substrates with cabonized rice husks, humus and coconut fiber. Another important factor to produce high quality seedlings is the use of net-houses for protection against the direct incidence of sun rays and rain (Röber and Schacht, 2008). Heliconia is a tropical flower and the huge majority of its species are shade-intolerant during field cultivation (Santos et al., 2009), but for seedling production, many research work have been developed especially about acclimatization (Santos et al., 2004; Rodrigues et al., 2005; Rocha et al., 2009) using shading nets aiming to improve the quality of *Heliconia* seedling. In addition, these research works were developed in different ecological environments which results are specific for each region. Hence, this study was aimed to evaluate the effect of different substrates and environmental conditions on seedling production of *H. psittacorum* L. in Northeastern Brazil.

MATERIALS AND METHODS

Plant material and growth conditions

H. psittacorum L. plants propagated by rhizome were used in this study. The experiment was carried out from November 2009 to January 2010 at the Horticulture Sector of Federal University of Piaui, Piaui State, Brazil, under a Cwa climate with an average precipitation of 1400 mm.year^{-1}. During the execution of the experiment, the climatic data were collected from a meteorological station installed in the Horticulture sector and inside the net-house, which is presented in Figure 1.

Treatments and experimental design

The experimental design was randomized blocks with treatments distributed in a factorial arrangement (6 x 2) referring to substrate compositions; (i) soil + sand + bovine manure (SSB); (ii) soil + sand + goat manure (SSG); (iii) decomposed buriti stem (*Mauritia*

Table 1. Physical characteristics of the substrates studied in Brazil.

Substrate	WD (kg m^{-3})	DD (kg m^{-3})	RWC (%)	AE (%)	TP (%)
SSB	1327.89	1128.71	34.16	21.29	55.45
SSG	1360.80	1142.49	35.85	18.38	54.23
DBS	453.64	100.35	42.04	52.14	94.18
CRR	633.70	250.66	39.63	47.54	87.17
RCI	528.33	173.10	42.99	47.34	90.33
Soil	1648.23	1253.88	49.08	1.35	50.42

SSB = soil + sand + bovine manure, at a 1:1:1 in volume; SSG= soil + sand + goat manure, at a 1:1:1 in volume; DBS = decomposed buriti stem (*Mauritia vinifera,* Mart.); CRR = carnauba (*C. prunifera*) industry residual + carbonized rice husks); RCI= semi-decomposed residual of carnauba (*C. prunifera*) industry; soil=red oxisoil; WD = wet density; DD=dry density; RWC = retention water capacity; AE = aeration space; TP = total porosity.

Table 2. Chemical characteristics of the substrates studied in Brazil.

Substrate	pH (1:5)	EC(mS cm^{-1})	N (mg L^{-1})	P(mg L^{-1})	K (mg L^{-1})	Ca (mg L^{-1})	Mg (mg L^{-1})
SSB	7.7	0.43	0.15	0.80	2.00	1.63	0.30
SSG	8.9	0.89	0.08	0.75	3.00	0.43	0.27
DBS	6.8	0.31	1.98	0.75	22.67	2.13	0.93
CRR	5.1	0.56	1.74	0.74	5.33	0.90	0.73
RCI	6.0	0.10	1.56	0.69	2.00	0.73	0.60
Soil	6.7	0.34	0.27	4.83	2.67	0.73	0.30

SSB = soil + sand + bovine manure, at a 1:1:1 in volume; SSG= soil + sand + goat manure, at a 1:1:1 in volume; DBS = decomposed buriti stem (*Mauritia vinifera,* Mart.); CRR = carnauba (*C. prunifera*) industry residual + carbonized rice husks); RCI= semi-decomposed residual of carnauba (*C. prunifera*) industry; soil=red oxisoil; EC = electrical conductivity.

vinifera, Mart.) (DBS); (iv) Carnauba (*Copernicia prunifera*) industry residual + carbonized rice husks (CRR); (v) semi-decomposed residual of carnauba industry and (vi) soil and environmental condition to produce seedlings (open field and net-house under 50% of luminosity) with four replications of three plants each. The substrates studied were, as follows: (i) SSB at a 1:1:1 in volume); (ii) SSG at a 1:1:1 in volume; (iii) (DBS; (iv) CRR; (v) RCI; and (vi) soil (red oxisoil). The decomposed buriti stem was obtained in swamps of Bom Jesus County, naturally decomposed, while carnauba residual was obtained from an industry in Picos County, Piaui State, Brazil. The treatments under 50% of shade were conducted in a net-house of 40 m^2, 4m width, 10 m length and 3 m high. Water supply was done manually according to plant requirement and the substrates were kept as close as possible to field quantities, been daily (once a day) applied after root time; 90 mL/pot of water direct on soil.

Determination of the main physical-chemical characteristics of the substrates

Physical and chemical characteristics of each substrate studied are shown in Tables 1 and 2, respectively.

Physical characteristics were determined by the methods proposed by De Boodt and Verdonck (1972) and Wilson (1983) which included: (i) wet and dry densities; (ii) retention water capacity: water volume between 10 and 100 hPa tensions; (iii) aeration space: difference between total porosity and the volume of water retained under a 10 hPa tension; (iv) total porosity: percentage of air compared to the total volume. Chemical characteristics included pH, electrical conductivity. N, P, K, Ca and Mg were determined according to recommendations of Malavolta et al. (1997). A suspension of 5 g fresh sample and 50 ml distilled water was stirred for 30 min, at 25°C then filtered and used for measuring pH and electrical conductivity.

Variables analyzed

The variables were recorded at the end of the experiment, and are described as follows: (i) time to produce tillers (in days); (ii) plant height (in cm), measured with a millimeter rule; (iii) number of sprouts per rhizome; (iv) total number of new leaves; (v) dry weight of shoot (DWS) and root + rhizome (DWR): plants of each substrate were placed at the laboratory, dried under 70°C during 72 h and each weight was determined in a Sartorious® brand precision balance (0.01 precision) and expressed in g.plant^{-1}.

Statistical analyses

Statistical analyses included analysis of variance (ANOVA) and mean separation of all dependent variables studied using Tukey's test and correlation analysis between substrate characteristics and the dependent variables studied. Assistat program was used and terms were considered significant at $P \leq 0.01$ (Silva and Azevedo, 2006).

RESULTS AND DISCUSSION

Significant interactions between environmental condition

Table 3. Average time to produce tillers (TPT), plant height (PH), number of sprouts per rhizome (NSR), total number of new leaves (TNL) and dry weight of shoot (DWS) and root + rhizome (DWR) of *Heliconia* seedlings as a function of substrate and environmental condition to produce seedlings.

Parameter	TPT (cm)	PH (cm)	NSR (cm)	TNL (g plant^{-1})	DWS (g plant^{-1})	DWR (g plant^{-1})
Environmental condition (E) ("F" value)	0.56 ns	26.24 **	59.12 **	59.57**	13.94 **	26.87 **
Net-house	20.60 a	28.19 a	2.44 a	3.10 a	2.16 a	2.44 a
Open Field	18.38 a	15.32 b	0.75 b	1.27 b	0.98 b	0.98 b
SMD	6.02	5.10	0.45	0.49	0.64	0.57
Substrate (S) ("F" value)	4.87**	7.75 **	5.94 **	7.04 **	1.16 ns	2.78 *
SSB	31.83 a	19.84 a	2.06 a	2.31a	1.45 a	1.75 ab
SSG	23.88 ab	25.17 a	1.56 a	2.13 a	1.38 a	1.52 ab
DBS	15.94 bc	30.31 a	1.88 a	2.75a	1.87 a	1.77 ab
CRR	18.06 abc	23.08 a	1.50 ab	2.56 a	1.58 a	2.19 a
RCI	19.38 abc	26.38 a	2.19 a	2.69 a	2.17 a	2.32 a
Soil	7.88 c	5.78 b	0.38 b	0.69 b	0.96 a	0.71 b
SMD	15.45	13.09	1.14	1.24	1.65	1.47
Interaction E x S	3.33 *	1.75 ns	2.84 *	2.89 *	0.74 ns	1.49 ns
V. C. (%)	52.69	40.02	47.71	37.61	70.00	57.21

SSB = soil + sand + bovine manure, at a 1:1:1 in volume; SSG= soil + sand + goat manure, at a 1:1:1 in volume; DBS = decomposed buriti stem (*Mauritia vinifera,* Mart.); CRR = carnauba (*C. prunifera*) industry residual + carbonized rice husks); RCI= semi-decomposed residual of carnauba (*C. prunifera*) industry; soil=red oxisoil; * and **= significant at 5% and 1%, respectively; ns = non significant; averages followed by same letter, in the column, do not differ by the test of Turkey (P≤ 0.01); SMD = significant minimum difference; V.C.= variation coefficient.

to produce *Heliconia* seedlings and substrate were registered for time to produce tillers (TPT), number of sprouts per rhizome (NSR) and total number of new leaves (TNL) (Table 3), which shows that these factors are interdependent and substrate effect depends on environmental condition to produce seedlings of *Heliconia*.

Effects of substrate on growth development

As it can be seen in Table 3, the substrate used for production of *heliconia* seedlings had statistical influence on almost all variables studied, except for DWS. Independently of the variable studied, soil used as substrate for *Heliconia* seedlings production produced the lowest average (Table 3). Plant height (Table 3) presented a remarkable difference of nearly 80% between the lower and the higher averages obtained by soil and DBS respectively. Additionally, Barbosa et al. (1999), in a study using expanded clay as substrate and Terra et al. (2011) also studying different substrates, observed close relation between plant height and aeration space of the substrate used; the results are in agreement with those of this study. This result shows that higher total porosity (r=0.60, $P \leq 0.01$) and aeration space (r=0.81, $P \leq 0.01$) of the substrate, led to higher plant height. In comparison to other studies about seedling production of *heliconia*, plant height obtained for DBS and RCI were remarkably above 20.09 cm reported by Santos et al. (2004) using carbonized rice husks + commercial substrate (proportion 1:1 in volume) and 32.27cm registered by Santos et al. (2006) using carbonized rice husks + humus (proportion 1:1 in volume) as substrate. Following the tendency of the other variables studied, total number of new leaves showed the lowest average for soil, while DBS and RCI promoted the higher ones (Table 3). Number of new leaves presented a positive correlation (r=0.95, $P \leq 0.01$) with plant height, showing that both variables were affected by the same way by the treatments.

Accordingly, the number of new leaves was also positively correlated with nitrogen (r=0.88, $P \leq 0.01$) and magnesium (r=0.87, $P \leq 0.01$) contents of the substrate, and the results agree with the findings of Castro et al. (2007) who studied the importance of macronutrients for *heliconia*. According to Marschner (2005), nitrogen acts as a ligand, the reduced N participates readily in H-bonding with other nucleophiles, notably deoxyribonucleic acid (DNA) and protein helices, while magnesium roles include a long list of enzymatic reactions which require or are promoted by Mg^{2+} and it is the central atom of the chlorophyll. DWR presented a significant difference of almost 70%, between soil and RCI substrates, respectively; lower and the higher averages (Table 3).

Accordingly, it was important to detach the high influence of the substrate physical characteristics on root growth and development as previously reported by Ribeiro et al. (2007) which is in agreement with the results of this study because substrates with higher DWR also presented both higher total porosity and aeration space

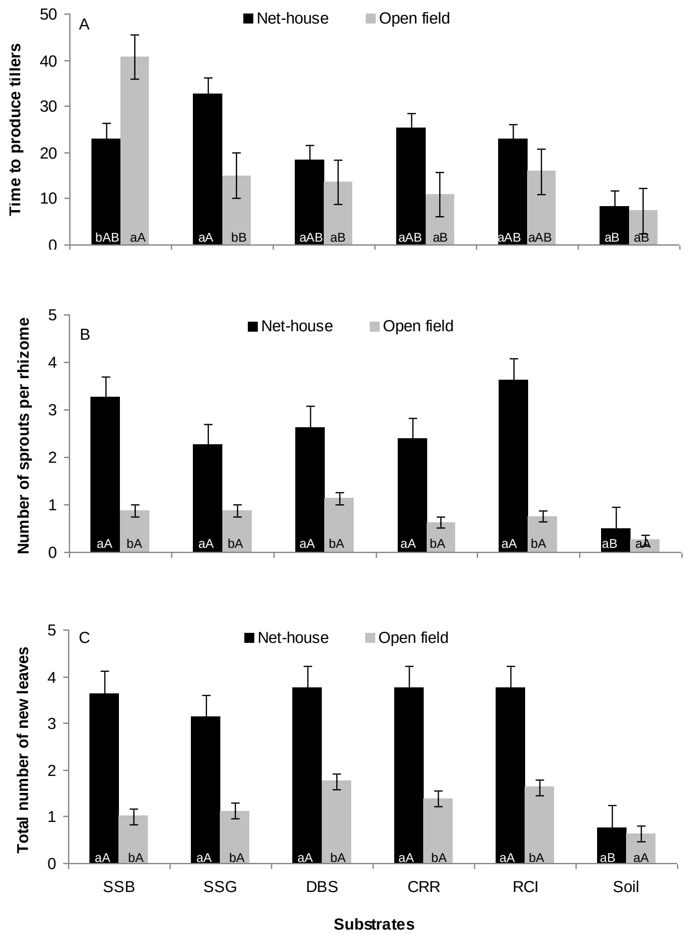

Figure 2. A, Average time to produce tillers; B, number of sprouts per rhizome; C, total number of new leaves of *heliconia* seedlings as a function of substrate and environmental condition to produce seedlings. Small letters compare environmental condition to produce seedlings and capital letters compare substrates. The error bars represent the standard error of the mean of quadruplicates.

(Table 1) with correlation coefficients of 0.81 ($P \leq 0.01$) and 0.71 ($P \leq 0.01$), respectively. Strojny et al. (1998) reported that a basic condition for root growth and development is an adequate supply of oxygen because O_2 deficiency causes plant reaction and accumulation of deleterious compounds which reduce plant growth and development. Compared to Kämpf (2000) recommendations, DBS, CRR and RCI substrates had total porosity which fell within the 75 to 90% recommended range that is important to promote good growth and development of horticultural plants.

Effects of environmental conditions on growth development

Among all variables studied, only average time to produce tillers was not affected by the environmental condition to produce seedlings (Table 3) and, independently of all variable, all averages were higher for seedlings produced under net-house conditions. For average time to produce tillers, the substrate effect depended on environmental condition for seedlings production of *Heliconia*. This way, only SSB substrate promoted higher TPT under open field conditions (Figure 2). This could be caused by the high density and low total porosity of this substrate (Table 1); characteristics that allow the substrate to maintain more available water for long time (Fischer, 1996) that is important for *Heliconia* seedling production under open field conditions. NSR and TNL presented the same data distribution, that is, independent of the substrate studied, significant higher averages were registered under net-house conditions in relation to open field conditions (Figure 2). Under net-house conditions, TNL was positively correlated with nitrogen content of the substrate; that is, higher N content of the substrate, lead to higher TNL which could be explained by the high exigency of *heliconia* during seedling production phase (Castro et al., 2007). The functions of nitrogen on plant growth and development were properly described by Marschner (2005). TNL averages of Table 3 are remarkably lower than the values registered by Santos et al. (2004, 2006). DWS was influenced by environmental conditions for *Heliconia* seedlings production (Table 3) with superiority of nearly 55% for seedling under net-house conditions. In addition, Costa et al. (2009) studied heliconia genotypes under partial shade and concluded that *H. psittacorum* L. was classified as high performance under partial shade condition, which is in agreement with the study. In comparison to another Musaceae species, banana, Saleh (2005) investigated the growth of banana under shade conditions and concluded that shading with black saran is not recommended for banana plants, since it reduced irradiance level by about 76% than open field condition which in turn negatively affects the vegetative growth, leaf mineral content and yield of 'Williams' banana plants.

Conclusion

The results of our study indicate that: (i) both substrate and environmental conditions affect seedling formation of heliconia; (ii) DBS (*Mauritia vinifera,* Mart.) and semi-decomposed residual of carnauba (*C. prunifera*) industry could be used as substrate for high quality *heliconia* seedling production; and (iii) net-house is necessary for heliconia seedlings production.

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