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Influence of nursery conditions on germination and initial development of pejibaye (*Bactris gasipaes*)

Marcos S. Bernardes[1], Valter U. Cromberg[2], Lino R.R. Fúria[1] and Adriana N. Martins[1]
[1] Depto de Agricultura-ESALQ/USP, C.Postal 9 Piracicaba-SP, 13.418-900, Brazil.
[2] SARIMA Construtora SA, Piracicaba-SP, Brazil.

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Abstract: Pejibaye (*Bactris gasipaes)* seeds were germinated in trays covered with transparent plastic. Vermiculite or composted shredded pine leaves were used as substrate. The trays were kept in a glasshouse under natural light (treatment GL) or 60% shade (treatment GS), or in an open-side plastic greenhouse under natural light (treatment PL). The total emergence percentage and the emergence rate were significantly higher for treatment GS, 45.5% and 8.62 x 10^{-3} day^{-1} respectively, than for GL (17.5% and 5.41 x 10^{-3} day^{-1}) and PL (16.5% and 5.21 x 10^{-3} day^{-1}). There was no difference between substrates. Higher emergence percentage in treatment GS was caused by more adequate substrate temperature (16.5°C to 31.9°C). In treatment GL the substrate temperature varied between 17.7°C and 38.5°C, achieving the highest average (28°C) and the largest thermal amplitude (20.8°C). Temperature of treatment PL varied between 12.6°C and 27.6°C, with the lowest average (20.1°C). Visual observation suggested that shade may favours the initial development of seedlings. Substrate temperature might be regarded as a better indicative of environmental conditions for germination than the air temperature. Shade inside the glasshouse protected germination substrate from extreme temperatures.

Key words: *Bactris*, pejibaye, seed, germination, temperature, shade, substrate.

Production of palm hearts (*palmito)* are mainly obtained from natural occurring palms, particularly *Euterpe* sp., resulting in the progressive elimination of trees. This destructive harvesting is one of the primary factors limiting the expansion of palm heart production in Brazil and reducing biodiversity of natural neotropic forests. Brazil is still the main producer of palm hearts, with 88.4% of the world exports in 1988. The recent price increase makes domestication and cultivation of several palm species feasible, even in the State of São Paulo, Southeast of Brazil (Mora Urpi *et al.* 1991, Cromberg 1993).

One of these crops is the pejibaye (*Bactris gasipaes* H.B.K) Arecoideae. It is a domesticated palm (Clement 1988) that grows on low fertile soils in the humid Neotropics. The average temperature where it attains best growth ranges from 24°C to 28°C. The fruit usually contains one seed, with an edible endosperm, and occasionally two fused seeds. However, seedless fruits may also occur (Johannessen 1966, Almeyda and Martin 1980, Coates-Beckford and Chung 1987). Several authors agree that *B. gasipaes* is a fast-growing multipurpose tree with promising ecological and economical characteristics, and significant potential for both, agroforestry and monoculture (Clement 1986). The pejibaye can achieve palm heart yields two to six times higher than those of *Euterpe* palms, and despite its different characteristics, it is well accepted by consumers (Bovi *et al.* 1987).

Frequently, palm seeds appear unresponsive to apparently favourable germination conditions. This may be caused by mechanical constraints such as a thick testa or endocarp (Tomlinson 1990). Haan (1988) reported that the latent period of pejibaye seeds extends from

1.5 to 14 months after sowing, but the majority of seeds germinate within 3 months after the first germinated seeds are noticed. Bovi *et al.* (1987) observed that the presence of the pericarp contributes to the slow emergence rate of *palmito* palms (*Bactris* and *Euterpe*) seeds, constituting an extra mechanical constraint for imbibition and an suitable substrate for pathogenic microorganisms. Hence, they recommended the extraction of the pericarp for faster and more uniform germination. For pejibaye propagation which still depends on seeds, environmental conditions that control germination need to be better quantified.

For germination of palm seeds, Koebernick (1971) successfully used perlite, a material similar to vermiculite. Basu and Mukheijie (1972) also considered sand as a good substrate for this purpose. Mora Urpi (1979) reported successful germination of seeds packed in transparent polyethylene bags and maintained at a constant water content. However, Haan (1988) reported some difficulties in germinating pejibaye seeds by this method because the excessive humidity inside the bags favoured the development of pathogens. Preliminary observations in Jamaica indicate that the germination rate is slow and fungal growth occurs on seeds germinated in polyethylene bags (Coates-Beckford and Chung 1987). These authors obtained higher germination percentage (80.4% on average) with seeds receiving only one chemical treatment and germinated in a single layer on moist absorbent paper in plastic trays, covered with transparent polyethylene, than with seeds treated twice and germinated in bags (46.1% on average). They suggested that the second chemical treatment may have contributed to germination inhibition. Nevertheless, the germination in bags itself may have had some negative effects on the germination percentage. Villalobos and Herrera (1991) compared six different germination media: trays with sawdust or sand, polyethylene bags alone or with sawdust or sand, and seeds on their own between two polyethylene layers. They observed that germination occurred in all cases except in polyethylene bags with sawdust and on seeds between polyethylene layers. Failure to germinate was caused by high moisture content in these last two germination media.

Rees (1963) recommended that the substrate for germination of palm seeds has to be kept humid and the substrate temperature ranging from 26.5°C to 29.5°C, and never below 25.5°C. Villalobos and Herrera (1991), in two experiments, evaluated the effect of temperature on germination of pejibaye seeds in polyethylene bags. All treatments which included 40°C caused seed death. No differences in germination were detected between room temperature (daily average of approximately 22°C) and constant incubator temperature of 30°C. However, a significantly higher value of plumule length was found in the treatment with 30°C, compared to that with room temperature. Our preliminary tests carried out in Piracicaba (Brazil) to germinate pejibaye seeds in open-air conditions, failed mainly because of the low temperatures occurring from April until September. During this period the monthly averages of the minimum air temperature ranged from 9.7°C to 12.2°C.

Bovi *et al.* (1987) suggest 2 cm as the best depth for sowing *palmito* seeds in nurseries. For all germination systems, in polyethylene bags, seed beds or trays, Haan (1988) recommended that the seeds should be protected from the direct sun's light, with some kind of shade. Also, reported some benefits of shade during initial plant development in the field, in spite of a higher yield and earlier harvest in mature trees kept under full light conditions. Valverde *et al.* (1987) reported better growth of pejibaye *callus* cultivated *in vitro* under darkness than under full light, and suggested an inadequate photomorphogenesis effect of high light intensity over the apex. In contrast, Germek *et al.* (1981) observed slower growth of pejibaye trees under the moderate shadow of *Muntingia calabura* canopy, a shade tree used in *Euterpe edulis* cultivation.

Experiments under daily alternating conditions, resembling those which are naturally met in nurseries and in the field, are important to define appropriate management practices for the production of planting material (Bewley and Black 1994). This is particularly important for pejibaye, a crop scarcely studied.

This study focused on the emergence of pejibaye seeds germinated in trays and on the initial development of seedlings to evaluate the effect of temperature, shade and substrates, under different greenhouse conditions in order to optimize the production of planting materials.

MATERIAL AND METHODS

The experiment was carried out at the Department of Agriculture of ESALQ/USP, Piracicaba, State of São Paulo, Brazil (22°45'S, 47°40'W).

The pejibaye fruits were harvested during February 1992, at the INPA (Manaus/Brazil) germoplasm collection in a progeny from the Peruvian Amazon. Immediately after harvesting fruits were soaked in water for 24 hours. Then, the pericarp was extracted by hand maceration. Lightweight seeds which floated in water were discarded. The remaining seeds were air dried under shade for a few hours, packed in polyethylene bags, and air freighted to Piracicaba. The seeds did not receive any treatment to prevent infestations or infections.

Seeds were placed in multi-pot styrofoam trays with 100 cells of 2.5 x 2.5 x 10 cm. The seeds were individually sown in each cell to a depth approximately of 2 cm. Each tray had 50 cells with expanded vermiculite (Verm.) and 50 with composted shredded pine leaves (Comp.). No supplementary fertilizer was added to the substrate. During the experimental period a simple wood framework, 50 cm high and covered with polyethylene sheeting, was set over the trays to maintain high humidity. Trays were watered up to twice a day.

The germination occurred in a glasshouse or in a plastic polyethylene greenhouse, with both covers transmitting about 85% of sun's light. The former was equipped with forced-air ventilation and a manual mechanism for opening ridge and side panels, both to provide air exchange and internal temperature control to a range from 16°C to 35°C. The plastic greenhouse had large side openings so the internal temperature was similar to that of the open-air conditions.

The following three germination conditions were used, each one divided in two substrates:

-**GS**: inside the glasshouse (G), under a shade (S) provided by a black nylon netting transmitting 60% of the incident light;

-**GL**: inside the glasshouse (G), under natural light (L);

-**PL**: inside the plastic (P) greenhouse, under natural light (L).

The seeds were sown on April 24, 1992. The emergence counts were conducted weekly, starting on day of first seed emergence (53 days after sowing, DAS). The measurements ended 200 DAS when no additional seed emergence was noticed. Seeds were considered "emerged" when the cotyledonary extension organ was visible (Tomlinson 1990). The emergence percentage was calculated as the number of seeds emerged/the total number of seeds x 100. The emergence rate was calculated as the reciprocal of the time taken to complete emergence (Bewley and Black 1982).

The trays were distributed randomly among treatments, each tray representing one replication. The treatments were obtained from the factorial combination of three germination conditions (GS, GL and PL) and two substrates (Verm. and Comp.) with five replications. The effect of treatments on total emergence percentage and on emergence rate was evaluated using analysis of variance. The values of total emergence percentage and emergence rate were transformed to their arcsin and square root, respectively, to standardize the variances. Mean separation was calculated by the test of Tukey (Pimentel Gomes 1978). The data were analyzed with the package SANEST (Zonta and Machado 1985).

Microclimatic data were evaluated for some representative sample days. Air temperature and relative humidity inside of the trays' plastic cover were measured by thermohygrometer. Substrate temperature was measured with soil thermometers at 2 cm depth. The daily amplitude for the microclimatic parameters was calculated from the difference between maximum and minimum values.

After germination, all seedlings with the first bladed leaf emerged were removed from the trays, transplanted to black polyethylene bags (18 x 28 cm) with clay soil, and kept in the glasshouse. From each treatment, the seedlings were separated to grow in two different conditions: under natural light in the glasshouse and under an extra artificial shade provided by the same nylon netting used in the germination treatments. The number of days to reach the first eophyll fully expanded was evaluated. Visual observations were carried out to record further plant development and growth. At the end of February 1993, all the seedlings were planted in field. The results of this second experimental phase were not statistically analyzed.

RESULTS

Microclimate measurements: The daily time-course of the microclimatic parameters air temperature (Fig. 1), relative humidity (Fig. 2) and substrate temperature (Fig. 3) are shown for a typical day (85 DAS). The daily average values and amplitude, for the same microclimatic parameters, in the same period, are presented in Table 1. Since there were no differences between Verm. and Comp. in terms of substrate temperature, Table 1 shows only the average of both, for each germination condition.

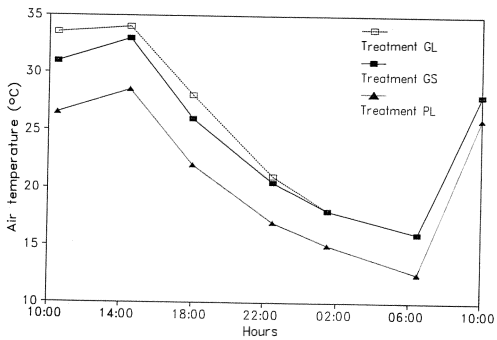

Fig. 1. Daily time-course of air temperature (°C) surrounding the germination trays of pejibaye seeds, inside a glasshouse under shade (GS) or without shade (GL), and inside a plastic greenhouse without shade (PL), during the period 18-19 July (85 DAS).

The air temperature in PL was lower than in the other two treatments, because it was located in an open greenhouse without efficient heat conservation. The air thermal amplitude was very similar in all treatments. Figure 1 shows that PL was cooler than GS and GL, throughout the day. Day air temperature was higher in GL than in GS, specially from 10 am to 6 pm, whereas the night temperature was the same in both treatments.

The relative humidity was slightly higher in PL than in GL and GS, which had similar values between each other. A treatment effect on the relative humidity was not evident (Figure 2).

The average substrate temperature markedly increase from treatment PL, to GS and to GL, respectively, in increments of approximately 4°C. Figure 3 shows that this difference is maintained throughout the day, although differ-

TABLE 1

Daily average and amplitude of microclimatic parameters observed inside of the trays for all treatments in the period 18-19 July (85 DAS)

	Microclimate Component		Treatment
	GS	GL	PL
Air temperature (°C)			
average	24.5	25.0	20.5
amplitude	17.0	18.0	16.0
Relative humidity (%)			
average	67.3	68.1	70.9
amplitude	46.0	46.0	46.0
Substrate temperature (°C)			
average	24.2	28.0	20.1
amplitude	15.4	20.8	15.0

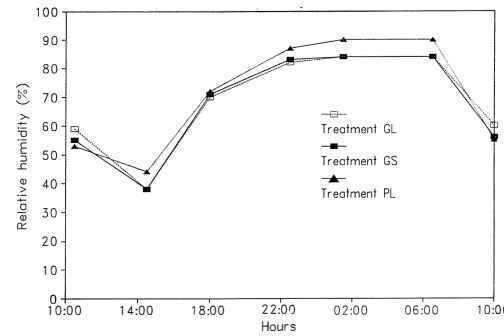

Fig. 2. Daily time-course of relative humidity (%) surrounding the germination trays of pejibaye seeds, inside a glasshouse under shade (GS) or without shade (GL), and inside a plastic greenhouse without shade (PL), during the period 18-19 July (85 DAS).

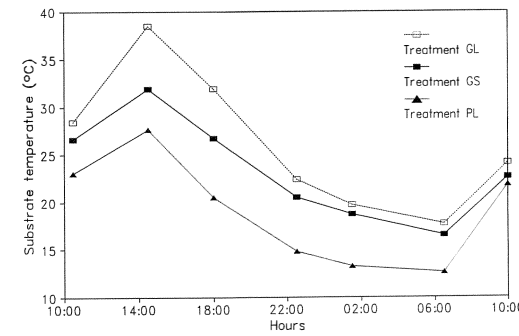

Fig. 3. Daily time-course of substrate temperature (°C) in the germination trays of pejibaye seeds, inside a glasshouse under shade (GS) or without shade (GL), and inside a plastic greenhouse without shade (PL), during the period 18-19 July (85 DAS).

ences are somewhat smaller at lower temperatures. The substrate thermal amplitude was 5.4°C and 5.8°C higher in treatment GL than in GS and PL, respectively. The substrate temperature varied from 17.7°C to 38.5°C in GL, from 16.5°C to 31.9°C in GS, and from 12.6°C to 27.6°C in PL.

Emergence measurements: The interaction between germination conditions and substrates was not significant. Furthermore, under all germination conditions differences between substrates were not significant. Table 2 shows the total emergence percentage and emergence rate for the three germination conditions. Both emergence attributes were significantly higher in GS ($P<0.001$) than in GL and PL. No significant difference was found between the latter.

The time course of accumulated emergence of pejibaye seeds is shown in Figure 4. In GS the total emergence percentage was achieved 116 DAS, whereas in GL and PL it was reached at 185 and 192 DAS, respectively. Figure 4 clearly shows the rapid emergence of seeds in GS, during the first 80 DAS, in contrast to other two treatments, where emergence took place throughout the experimental period.

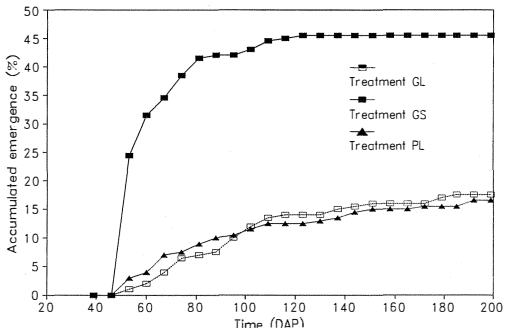

Fig. 4. Time course (in days after sowing, DAS) of accumulated emergence (%) of pejibaye seeds, inside a glasshouse under shade (GS) or without shade (GL), and inside a plastic greenhouse without shade (PL).

Initial development observations: Regardless of light treatment all seedlings survived transplantation to bags with soil. It was observed that transplanted seedlings grown under shade achieved the first fully expanded eophyll, on average, 42 days after transplanting, whereas the seedlings grown under natural light had the first expanded eophyll 56 days after transplanting. Moreover, plants grown under shade had darker green and larger leaves than the plants grown under natural light. By the end of February 1993, all the seedlings had 2 to 5 fully expanded leaves.

TABLE 2

Total emergence percentage and emergence rate,,of three germination treatments of pejibaye seeds

	Treatment	Total
Emergence (%)		
rate (day^{-1})		
GS	45.5 a	8.62×10^{-3} a
GL	17.5 b	5.41×10^{-3} b
PL	16.5 b	5.21×10^{-3} b

Values followed by the same letter in each column are not significantly different ($p<0.001$) according to Tukey's test.

DISCUSSION

The highest seed emergence was observed in the glasshouse under 60% shade (treatment GS), compared to that under natural light either in the glasshouse or in the open-side plastic greenhouse (treatments GL and PL). This suggests that the shade would be responsible for the better emergence in treatment GS. Perhaps shade itself affected seed emergence; however, it could not be demonstrated in the present study.

In treatment GS the substrate temperature fluctuated daily from 17°C to 32°C, an adequate range, according to previous study (Villalobos and Herrera 1991), resulting in a higher seed emergence than in the other treatments. In treatment GL the low emergence rate might be attributed to the effect of either high substrate temperature or large substrate thermal amplitude. The substrate temperature in treatment GL reached maximum values up to 40°C, and maintained values above 30°C from 11 am until 7 pm. These temperature were above the optimum range. Villalobos and Herrera (1991) observed that temperatures equal or above 40°C caused death of all pejibaye seeds, even when this temperature occurred only one day per week, alternating with 6 days of room tem-

perature. The large substrate thermal amplitude, with values around 20°C, was also inappropriate for seed germination (Rees 1963). Both, high temperature and large thermal amplitude of the substrate may cause rapid changes in seed water content during the day. This can be specially deleterious for recalcitrant seed (Bewley and Black 1994), as those of the pejibaye. The lowest substrate and air temperature, both with daily average of about 20°C, and night temperature below 15°C, were probably the main reasons for the lowest emergence percentage and rate, observed in PL.

Additionally, air temperature may not be a very accurate index to evaluate germination environment. Air temperature was very similar in both, GL and GS, but the emergence rate was different in these two treatments.

The emergence rate is of great value in characterizing seed response to temperature and environmental conditions, because it indexes the time needed to complete germination. This attribute is even more important for seeds with a short longevity as those of pejibaye palm, in which higher emergence rate may result in better seed usage.

Under the prevailing climatic conditions, the germination of pejibaye seeds must be carried out in nurseries to protect the seeds and seedlings from low temperatures. Greenhouses with open sides, like the one used in treatment PL, do not conserve sufficient heat to achieve the best germination conditions for pejibaye seed. This is especially important during late autumn, winter and early spring. Shade inside of glasshouses can provide an additional protection from high substrate temperatures and reduce their thermal amplitude, leading to better nursery conditions for germination of pejibaye seeds.

The initial development of pejibaye seedlings was better under shade than under the natural light in the glasshouse. This result might be attributed to the shade protection effect from high temperature and water stress. Moreover, the light environment under shade, with lower radiation intensity and modified spectral composition, might affect pejibaye growth and development.

Many species are known whose seeds germinate better under daily alternating conditions of light and temperature. The responses depend on the amplitude and frequency of the fluctuation (Bewley and Black 1994). Furthermore, the optimum temperature and the range of temperature at which germination can occur may be modified by several environmental factors. Additionally, light requirement of seeds for germination may change with seed age and temperature (Mayer and Poljakoff-Mayber 1975, Bewley and Black 1982). Therefore the absolute values obtained in this experiment must be analyzed within these possible interactions. Nevertheless, the above results suggest that the optimal substrate temperature for germinating pejibaye seeds vary from 20°C to 32°C.

Further studies are required to evaluate the light, humidity and temperature requirements for the germination and initial development of pejibaye seeds. Also, constant conditions must be compared to daily alternating regimes of light and temperature.

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RESUMEN

Semillas de pejibaye (*Bactris gasipaes*) fueron germinadas en bandejas con cubiertas plásticas transparentes. Dos tipos de sustrato (vermiculita y hojas de pino molidas y parcialmente humificadas), y tres tipos de cobertura (en un invernadero de vidrio con luz directa (GL), o 60% de sombra (GS) y bajo cubierta plástica con luz directa (PL) fueron estudiados. El tipo de sustrato no afectó significativamente el porcentaje o la tasa de germinación de las semillas de pejibaye. Los mayores porcentajes y tasas de germinación se observaron en el tratamiento GS (45.5% y 8.62 x 10^{-3} dia^{-1} respectivamente). En el tratamiento GL el porcentaje y la tasa de germinación fueron 17.5% y 5.41 x 10^{-3} dia^{-1}, y en el tratamiento PL 16.5% y 5.21 x 10^{-3} dia^{-1}, respectivamente. El mejor comportamiento del pejibaye en el tratamiento GS fue atribuido a una más adecuada temperatura de germinación. En el tratamiento GS las temperaturas del sustrato se mantuvieron entre 16.5°C y 31.9°C mientras que en el tratamiento GL alcanzaron valores más extremos (17.7°C y 38.5°C). En el tratamiento PL la temperatura del sustrato varió entre los 12.6°C y los 27.6°C. Observación visual sugire que el sombreo puede favorecer el desarollo inicial de las plántulas de pejibaye. Más que la temperatura del aire, la temperatura del substrato fue la principal determinante de la germinación del pejibaye. El sombreo protejió el sustrato de germinación de alcanzar temperaturas extremas.

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