Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9275
ISSN on-line: 1807-8621
Doi: 10.4025/actasciagron.v39i4.32786

# Germination and development of *Amburana cearensis* seedlings as influenced by seed weight, light and temperature

**João Paulo Nobre de Almeida[1*], Bruno Franca da Trindade Lessa[2], Charles Lobo Pinheiro[3], Fernanda Melo Gomes[3], Sebastião Medeiros Filho[3] and Cydianne Cavalcante Silva[1]**

*[1]Universidade Federal Rural do Semi-Árido, Cx. Postal 137, 59625-900, Mossoró, Rio Grande do Norte, Brazil. [2]Universidade Federal do Vale do São Francisco, Petrolina, Pernambuco, Brazil. [3]Universidade Federal do Ceará, Fortaleza, Ceara, Brazil. *Author for corresponde. E-mail: joaopaulonobre@yahoo.com.br*

**ABSTRACT.** The objective of this work was to study the seed germination and seedling growth of *A. cearensis* (Allemão) A. C. Sm. influenced by seed weight and under different temperature and light conditions. Seeds were individually weighed and divided into three weight classes (light, medium and heavy), and each was subjected to germination tests under two light conditions (presence or absence) and six temperature regimes (20, 25, 30, 35, 40, and 20-30°C). The experiment was established with a completely randomized design in a split-split plot arrangement with four replicates. We determined the first count, final germination percentage and germination speed index. To assess seedling growth, the length and dry mass of the epicotyl and root + hypocotyl axis were also determined. The data were subjected to Tukey's test ($p \leq 0.05$). The optimal conditions for seed germination occurred at a temperature of 30°C, with light and medium seeds showing greater vigour. Temperatures of 35 and 40°C were detrimental to the growth of the species, whereas the best conditions occurred with light and medium seeds at temperatures of 25 and 30°C in the presence of light.

**Keywords:** cumaru, abiotic factors, seed vigour.

## Germinação e desenvolvimento de plântulas de *Amburana cearensis* em função do peso da semente, luz e temperatura

**RESUMO.** O objetivo do trabalho foi estudar a germinação de sementes e o crescimento de plântulas de *Amburana cearensis* (Allemão) A. C. Sm. em função do peso das sementes sob diferentes condições de temperatura e luz. As sementes foram pesadas individualmente e separadas em três classes (leves, médias e pesadas), e cada uma foi submetida a testes de germinação em duas condições de luz (presença e ausência) e seis regimes de temperatura (20, 25, 30, 35, 40 e 20-30°C). O experimento foi inteiramente casualizado em parcela sub-subdividida com quatro repetições. Nós determinamos a primeira contagem, porcentagem final e o índice de velocidade de germinação. Para a avaliação do crescimento das plântulas, o comprimento e a massa seca do epicótilo e do eixo raiz/hipocótilo. As condições ótimas para a germinação das sementes ocorreram na temperatura de 30°C e com um maior vigor com sementes leves e médias. As temperaturas de 35 e 40°C foram prejudiciais ao crescimento da espécie, enquanto as melhores condições ocorreram com as sementes leves e médias nas temperaturas de 25 e 30°C e na presença de luz.

**Palavras-chave:** cumaru, fatores abióticos, vigor de sementes.

## Introduction

The predatory extraction suffered by some important plant species native to the Caatinga biome is putting them at risk of extinction. The survival of *Amburana cearensis* (Allemão) A. C. Sm., commonly known in Brazil as 'cumaru' or 'imburana-de-cheiro', is threatened, given that the simple removal of its bark (medicinal part) causes great damage to the plant (Canuto, Silveira, Bezerra, Leal, & Viana, 2008). It is necessary to preserve this species as, despite its unquestionable economic and social importance, due to logging and the wide use of ther parts of the plant in folk medicine, its predatory use continues to decimate large areas (Almeida et al., 2010). However, primary information about *A. cearensis*is limited and scattered, particularly regarding its propagation and ecology, which makes studies on the germination and seedling establishment of this species necessary to enable agronomic management including appropriate techniques for its proliferation.

The classification of seeds by weight is a strategy that can be used to standardize seedling emergence in the field and to obtain seedlings with similar sizes and/or greater vigour (Carvalho & Nakagawa, 2012). Seed weight is a key variable in the production process, as it is directly related to seed quality (Silva, Maia, &

Moraes, 2007). This is because heavier seeds were better nourished during their development and are therefore more vigorous due to well-formed embryos and larger amounts of reserves (Carvalho & Nakagawa, 2012).

Several studies have been conducted to assess the influence of seed weight on the germination and physiological quality of many plant species. However, studies are still quite scarce for forest species, with some species such *Hymenaea stigonocarpa*, *Tabebuia heptaphylla*, *A. cearensis* and *Enterolobium contortisiliquum* being citedamong them (Pereira, Giraldelli, Laura, & Souza, 2011; Ribeiro, Costa, Senna, & Caliman, 2012; Almeida, Pinheiro, Lessa, Gomes, & Medeiros Filho, 2014; Lessa, Almeida, Pinheiro, Gomes, & Medeiros Filho, 2015).

The ecological significance of the relationships among seed weight, light requirements and temperature fluctuation seems to be related to the need to avoid germination in deep soil, where it is difficult for small seeds to emerge (Thompson & Grime, 1983). In some species, the light requirement for seed germination is strongly influenced by the temperature range over which seeds can germinate, which is characteristic of each species (Bewley, Bradford, Hilhorst, & Nonogaki, 2013). Temperature directly influences the germination percentage, affecting both the water absorption rate and biochemical reactions (Amato et al., 2007). According to their response to the presence of light, seeds can be classified as positively photoblastic (benefited by light), negatively photoblastic (negatively affected by light) ornon-photoblastic or indifferent (Marcos Filho, 2015).

Some researchers have studied the temperature and type of light suitable for the seed germination of native species such as *Licania rigida* Benth. (Diniz, Moreira, Silva, & Medeiros Filho, 2008) and *Luetzelburgia auriculata* (Nogueira, Silva, Bezerra, & Medeiros Filho, 2012). Nevertheless, there is a lack of information regarding the direct effects of seed reserves and environmental factors on the germination process of forest species.

Thus, this work aimed at studying the germination and development of *A. Cearensis* seedlings from different seed weight classes under different temperature and light conditions.

## Material and methods

We randomly collected seeds of *A. cearensis* from the ripe fruit of 20 adult plants at the Experimental Farm Vale do Curu in Pentecoste, Ceará State, 110 km from Fortaleza. The harvested fruit were packed in polyethylene bags and sent to the Seed Analysis Laboratory at the Federal University of Ceará (UFC) in Fortaleza, Ceará State, where the seeds were extracted, manually processed and dried under shade conditions for six days. Thereafter, the seeds were packed in polyethylene bags and stored at ±12°C and 50% relative humidity.

Four hundred seeds were separated from the total seed sample and individually weighed using an analytical balance (0.0001 g) to classify the sample into three distinct classes based on their specific weight (Figure 1), defined as light (< 0.25 g), medium (0.25 - 0.35 g) and heavy (> 0.35 g). Thereafter, the seeds from the submitted sample were individually weighed and classified into their respective classes.

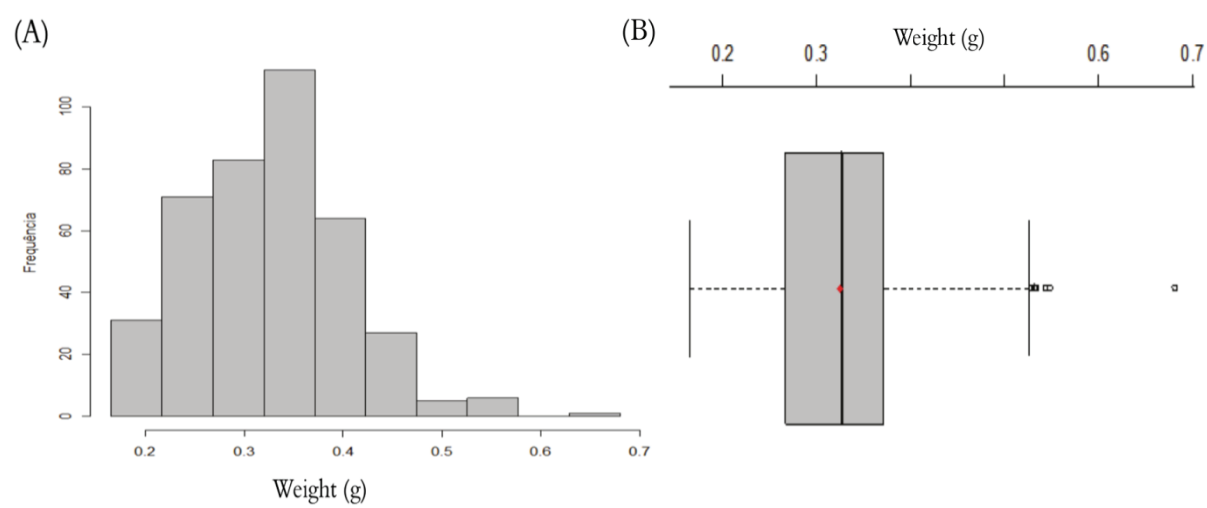


**Figure 1**. Frequency histogram (A) and box plots (B) for the weight distribution of a sample of 400 *Amburana cearensis* (Allemão) A.C. Sm. seeds.

The water content and weight of a thousand seeds from every class were determined based on the recommendations of the Rules for Seed Analysis (Brasil, 2009). Seed sterilization was performed by immersing all the seeds from every class in 5% sodium hypochlorite for 15 minutes and a 0.4% nystatin® solution to prevent fungal growth.

The effects of temperature, light and weight were studied using a completely randomized experiment witha split-split plot design, with temperature regimes applied to the whole plots (20, 25, 30, 35, 40, or 20-30°C) and light conditions applied to the subplots (presence or absence). The sub-subplots consisted of seed weight classes (light, medium and heavy) with four replicates, and every experimental unit was one paper roll containing 25 seeds.

Seeds from every weight class were placed in rolls of blotting paper moistened with distilled water (2.5 times the paper weight) to germinate. These rolls were packed in transparent plastic bags to reduce water loss in B.O.D. (Biochemical Oxigen Demand) incubators regulated at constant (20, 25, 30, 35, and 40°C) and alternating temperatures (20 - 30°C) with a photoperiod of 12 hours under two light conditions (presence or absence). The treatments under darkness included paper rolls with seeds wrapped in aluminium foil and black bags, and the first count was performed under green safe light.

Germination was assessed on a daily basis, and the substrate was moistened when necessary. The germinated seeds showed radicle protrusion equal to or greater than 2 mm. At the end of the test, we recorded the germination percentage (first and final count at 7 and 21 days, respectively) and the germination speed index (GSI), which was determined based on the daily counts of the number of germinated seedlings up to 21 days after sowing, based on Maguire (1962).

After 21 days, the length of normal seedlings was assessed by the portion above (epicotyl length - EPL) and below (root + hypocotyl axis - RHL) the cotyledon insertion; these results were expressed in cm.seedling$^{-1}$. After removing the cotyledons, the epicotyl and root + hypocotyl fractions of every experimental unit were dried in a forced air oven (at 80°C for 24 hours) to determine the epicotyl dry mass (EPDM) and root + hypocotyl dry mass (RHDM). Thereafter, the seedlings were weighed using an analytical balance with an accuracy of 0.0001 g; these results were expressed in g seedling$^{-1}$. Furthermore, the total length and dry biomass of the seedlings were determined by the following calculations: EPL + RHL and EPDM + RHDM, respectively.

These data were evaluated by the Shapiro-Wilk and Kolmogorov tests to assess their normality. Analysis of variance (ANOVA) and Tukey's test (5%) were then conducted for the normally distributed data. The Box-Cox transformation was used for the non-normal data, and the non-parametric Mann-Whitney test (5%) was conducted when the normal distribution assumption was not met. Assistat 7.6 beta software was used to perform the ANOVA and Tukey's test, whereas the normality and Mann-Whitney tests were performed using the Action 2.4 software.

## Results and discussion

Seeds from the three weight classes had a water content of approximately 9.4% (Table 1), regardless of their weight, showing that the classes did not influence the hygroscopic equilibrium between the seeds and the environment. A significant increase in the thousand-seed weight due to the increase in weight categories is also observed in Table 1, wherein a marked difference of more than 180 grams between heavy and light seeds stands out. This reveals that *A. cearensis* seeds have great weight variability, which is a critical factor in the perpetuation and survival of this species in highly competitive environments.

**Table 1.** Water content (WC) and thousand-seed weight (TSW) of Amburana cearensis (Allemão) A.C. Sm. seeds as influenced by weight classes.

| Weight Classes | WC | TSW |
|---|---|---|
| | ---- % ---- | --- g --- |
| Light | 9.4 | 221.4 c |
| Medium | 9.3 | 285.4 b |
| Heavy | 9.4 | 403.3 a |
| CV (%) | - | 1.85 |

Means followed by the same letter do not differ by Tukey's test at the 5% probability level.

There were significant differences within the isolated factors and their interactions for the germination and seedling growth variables (Table 2). The interaction between light and temperature as well as between weight and temperature were highly significant for the germination speed index. For the root + hypocotyl dry mass and the total dry mass, there was only an interaction between temperature and light, whereas for the root + hypocotyl length, there was an interaction between temperature and seed weight. In turn, the mutual influence of the three factors (temperature, light and weight) was critical to the epicotyl length and epicotyl dry mass. The germination percentage, first count and total length data did not meet the normal distribution assumption, even after the data transformation, unlike the length of the root + hypocotyl axis, which met the normality assumption after its transformation.

**Table 2.** Summary of ANOVA for germination speed index (GSI), epicotyl length (EPL), root + hypocotyl axis (RHL), epicotyl dry mass (EPDM), root + hypocotyl dry mass (RHDM) and total dry biomass (TDB) of *Amburana cearensis* (Allemão) A.C. Sm.

| FV | GL | GSI | EPL | RHL | EPDM | RHDM | TDB |
|---|---|---|---|---|---|---|---|
| | | Mean Square | | | | | |
| Temp. | 5 | 16.63** | 118.91** | 152.74** | $1.17x10^{-3}$** | $1.24x10^{-3}$** | $4.64x10^{-3}$** |
| error 1 | 18 | 0.32 | 0.70 | 0.56 | 0 | $10^{-5}$ | $2x10^{-5}$ |
| Light | 1 | 1.15 ns | 89.36** | 40.78** | $3x10^{-4}$** | $9.1x10^{-4}$** | $2.32x10^{-3}$** |
| T x L | 5 | 3.62** | 6.99** | 3.25 ns | $6x10^{-5}$** | $6x10^{-5}$** | $1.7x10^{-4}$** |
| error 2 | 18 | 0.26 | 0.88 | 1.72 | 0 | $10^{-5}$ | $2x10^{-5}$ |
| Weight | 2 | 41.33** | 18.01** | 19.35** | $5x10^{-5}$** | $10^{-5}$ ns | $10^{-4}$* |
| T x W | 10 | 2.17** | 5.76** | 4.21** | $2x10^{-5}$* | $10^{-5}$ ns | $4x10^{-5}$ ns |
| L x W | 2 | 0.57 ns | 0.42 ns | 0.23 ns | $10^{-5}$ ns | $10^{-5}$ ns | $3x10^{-5}$ ns |
| T x L x W | 10 | 0.45 ns | 0.26* | 0.5 ns | $10^{-6}$* | $10^{-6}$ ns | $10^{-5}$ ns |
| error 3 | 72 | 0.32 | 0.88 | 0.93 | $10^{-5}$ | $10^{-5}$ | $3x10^{-5}$ |
| Total | 143 | | | | | | |
| CV 1 | | 19.5 | 28.57 | 23.71 | 22.88 | 24.14 | 22.27 |
| CV 2 | | 17.63 | 32.1 | 41.56 | 23.25 | 23.98 | 22.46 |
| CV 3 | | 19.45 | 31.89 | 30.68 | 35.01 | 24.8 | 28.18 |

** $p < 0.01$; * $p < 0.05$; ns: not significant, based onthe F-test.

By analysing the germination behaviour of *A. cearensis* seeds, it is possible to see marked differences in the effects of environmental factors and seed reserves onthe first count and final germination percentage. Seed germination was observed both in the presence and absence of light (Figure 2A), which characterizes the seeds as neutrally photoblastic or insensitive to light. These results are similar, in part, to those reported by Lessa et al. (2015), who also found that the germination of *Enterolobium contortisiliquum* seeds occurs regardless of the light conditions.

Means followed by the same letter do not differ by the non-parametric Mann-Whitney test at a 5% probability level.

This insensitivity to light may be due to the quantity of phytochrome present in the seeds in the active form being insufficient to induce the germination process (Bewley et al., 2013). The search for knowledge about the effects of light on the ecological succession of forest species, such as *Luetzelburgia auriculata* (Nogueira et al., 2012), *Clitoria fairchildiana* (Alves et al., 2012), *Guazumaul mifolia, Dimorphand ramolli s*and *Anadenanthera colubrine* (Figliolia, Aguiar, & Silva, 2009), has been frequently reported in the literature.

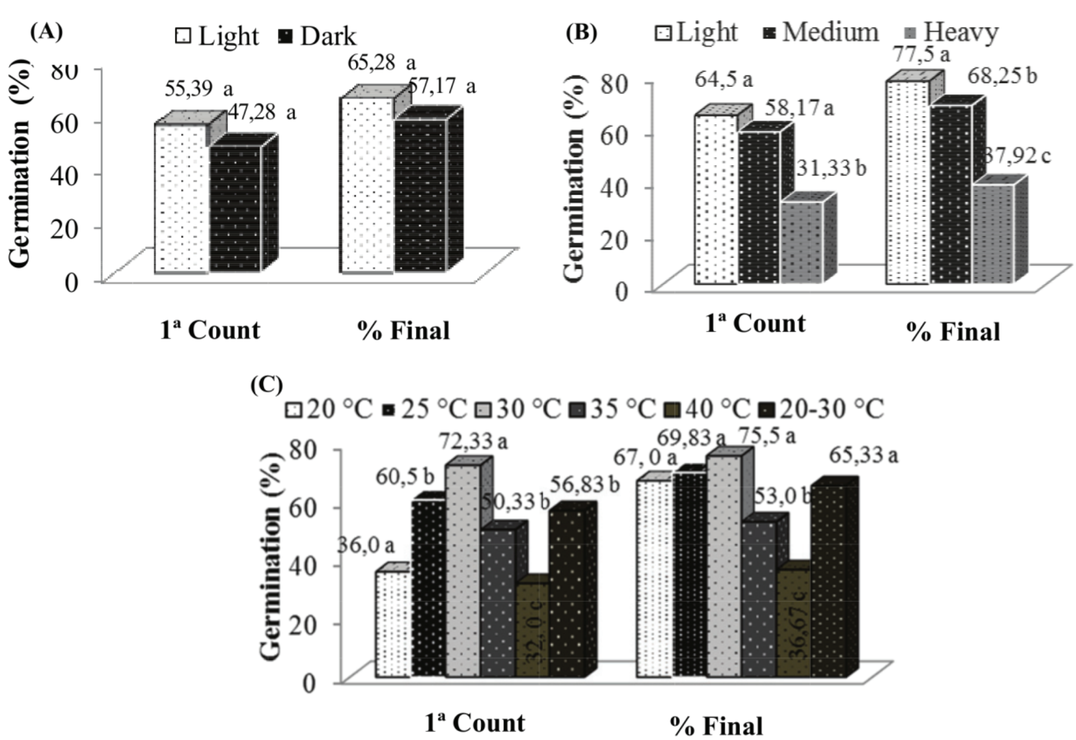


**Figure 2**. First count and final germination percentage (%) of *Amburana cearensis* (Allemão) A. C. Sm. seeds as influenced by light conditions (A), weight classes (B) and temperature regimes (C).

Regarding the temperature regimes (Figure 2C), evidence of the best temperature for germination of *A. cearensis* seeds was already noted in the first count, for which 30°C was ideal. As for the final germination percentage, the temperature range was increased, with 20, 25, 30 and 20-30°C being considered as appropriate for germination. In both tests, the temperature of 40°C was strongly detrimental. The simple fact that germination occur sunder more than one temperature regime characterizes, for many plant species, adaptation to natural temperature variation in the environment. These results corroborate, in part, those obtained by Guedes et al. (2010), who found 25, 30, and 20-30°C to be some of the most ideal temperatures for the final germination percentage of *A. cearensis* seeds. The temperature range of 20 to 30°C can be considered optimal for the seed germination of forest species (Diniz et al., 2008; Alves et al., 2012; Nogueira et al., 2012).

Significant differences in the first count and the final germination percentage can be further seenby evaluating the influence of seed weight on germination (Figure 2B). Seeds from the light and medium classes showed higher germination performance in the first count in relation to heavy seeds. Nevertheless, this characteristic changed in the final germination percentage, for which anincrease in seed weight adversely affected germination. In this case, light seeds are the best option to increase the germination of *A. cearensis*. These results differ from the reports of Carvalho and Nakagawa (2012), in which heavier seeds were noted to be the most well-nourished, being more vigorous due to the presence of well-formed embryos and larger amounts of reserves.

However, it is important to note that, in some circumstances, heavier seeds might not be the most vigorous. This may be due to factors such as temperature, water and nutrient supply, light intensity and photoperiod length, which may affect seed development and the accumulation of reserves, consequently affecting seed vigour (Carvalho & Nakagawa, 2012). On the other hand, studies demonstrating that light seeds exhibit better germination are scarce.

Taking into account that heavy seeds have a larger amount of reserves, it can be inferred that the various types of substances present in this weight class, as well as their quality, could be somehow detrimental to seed germination. Considering that *A. cearensis* seeds are highly allelopathic due to the coumarin compound, this substance might influence their germination process. Chemicals present in the extract of *A. cearensis* seeds have strong allelopathic potential, which can interfere with seed germination and the development of other plants in the same environment (Silva et al., 2006; Felix, Ono, & Araújo, 2010).

Barbosa (2003) makes reference to the fact that, so far, no inhibition of the germination of *A. cearensis* seeds has been reported and that coumarin might be present in low concentrations in mature seeds of this species, as the inhibition of germination can be related to increasing levels of this substance. Based on these studies, it can be assumed that heavy *A. cearensis* seeds (> 0.35 g) have large amounts of coumarin, which is likely to inhibit their germination, a fact that has not yet been proven in the literature. Hence, future studies should be directed at explaining this gap.

From an ecological point of view, regarding the dispersibility of this species, light seeds tend to travel longer distances than heavy seeds, the latter of which usually remain near the mother plant due to their weight and end up competing for nutrients and space. In terms of survival, it can also be inferred that this species may repel its dispersers by investing in a larger coumarin content in the heavy seeds.

Table 3 shows that the lowest GSI values were obtained at 20 and 40°C. This result was more evident in the absence of light at the temperature of 40°C (1.04), resulting in this being the only treatment for which the absence of light had a significant effect. This shows that under the different temperature regimes, *A. cearensis* seeds are insensitive to light, i.e., are neutrally photoblastic, except at a temperature of 40°C, at which they are preferably positively photoblastic. Certain temperature limits above or below the upper or lower limits of the optimal temperature range tend to decrease the germination speed, thus resulting in a disruption of membranes and leading to a reduction in the total germination (Carvalho & Nakagawa, 2013).

**Table 3**. Germination speed index (GSI) of *Amburana cearensis* (Allemão) A.C. Sm. seeds subjected to different temperatures in the presence or absence of light.

| GSI | | | | | | |
|---|---|---|---|---|---|---|
| | Temperatures | | | | | |
| Light | 20°C | 25°C | 30°C | 35°C | 40°C | 20-30°C |
| Presence | 2.22 aC | 3.00 aB | 4.12 aA | 3.30 aB | 2.74 Abc | 2.81 aBC |
| Absence | 2.26 aC | 3.41 aB | 4.39 aA | 3.09 aB | 1.04 bD | 2.94 aB |
| lsd for columnn = 0.4552 lsd for lines = 0.6383 | | | | | | |

Means followed by the same letter, upper case in the same row and lower case in the same column, do not differ by Tukey's test at a 5% probability level.

The highest germination index occurred at a temperature of 30°C, regardless of the presence of light, differing significantly from the other temperatures (Table 3). These results are similar to those obtained by Diniz et al. (2008), who studied the influence of light and temperature on the germination of *Licania rigida* Benth. seeds and found an interaction between these factors, with the highest germination speed index obtained at a temperature of 30°C in the absence of light.

By analysing the results shown in Table 4, it can be observed that light and medium seeds had higher germination speed indices at all temperatures except for 35°C, at which only light seeds differed from the other weight classes. However, the combination of a temperature of 30°C and light and medium seeds promoted the highest germination speed. Heavy seeds negatively influenced this speed, which can be clearly seen at 40°C. These results differ from the results reported in the literature, which indicate that heavy seeds are usually those with the highest germination speed. Lessa et al. (2015) found that heavy *Enterolobium contortisiliquum* seeds had a higher germination speed index.

**Table 4.** Germination speed index (GSI) of *Amburana cearensis* (Allemão) A.C. Sm. seeds of different weight classes under different temperature regimes.

| GSI | | | | | | |
|---|---|---|---|---|---|---|
| Classes | Temperatures | | | | | |
| Light | 2.63 aC | 3.85 aB | 4.99 aA | 4.38 aAB | 2.22 aC | 3.74 Ab |
| Edium | 2.19 abC | 3.32 aB | 5.27 aA | 3.14 bB | 2.77 aBC | 3.13 Ab |
| Heavy | 1.89 bA | 2.45 bA | 2.50 bA | 2.07 cA | 0.67 bB | 1.74 bA |
| lsd for column = 0.6714 lsd for lines = 0.8195 | | | | | | |

Means followed by the same letter, upper case in the same row and lower case in the same column, do not differ by Tukey's test at a 5% probability level.

A possible explanation for the negative influence of heavy seeds on the germination speed index is that the ratio between the surface and volume of a seed is reduced with an increase in seed size. This decreases the ability of a seed to obtain enough water to beginthe germination process (Harper & Benton, 1966), thus causing greater delays in germination and seedling establishment. Such findings may provide an appropriate weight class for the proliferation of this species to produce more homogeneous and vigorous seedlings, as light and medium *A. cearensis* seeds are likely to contribute the most to an increase in the propagation of the species.

The following results take into account the growth behaviour and dry biomass of *A. cearensis* seedlings. Temperatures of 40 and 35°C were highly detrimental to the establishment of the species, killing seedlings shortly after germination.

Regarding the total length of *A. Cearensis* seedlings, for the isolated factors, it can be seen from Figure 3 that the best growth occurred when the seeds were germinated in the presence of light (Figure 3A). The weight classes did not influence seedling development (Figure 3B), and the temperatures of 25 and 30°C were considered as ideal for seedling establishment (Figure 3C). With respect to the temperatures, the corresponding expected results were confirmed by Guedes et al. (2010), with 30°C being one of temperatures that promoted greater seedling length in *A. cearensis*. In regard to the fact that there was no influence of seed weight on shoot growth, Lessa et al. (2015) reported similar results in *Enterolobium contortisiliquum* seedlings.

Means followed by the same letter do not differ by the non-parametric Mann-Whitney test at a 5% probability level.

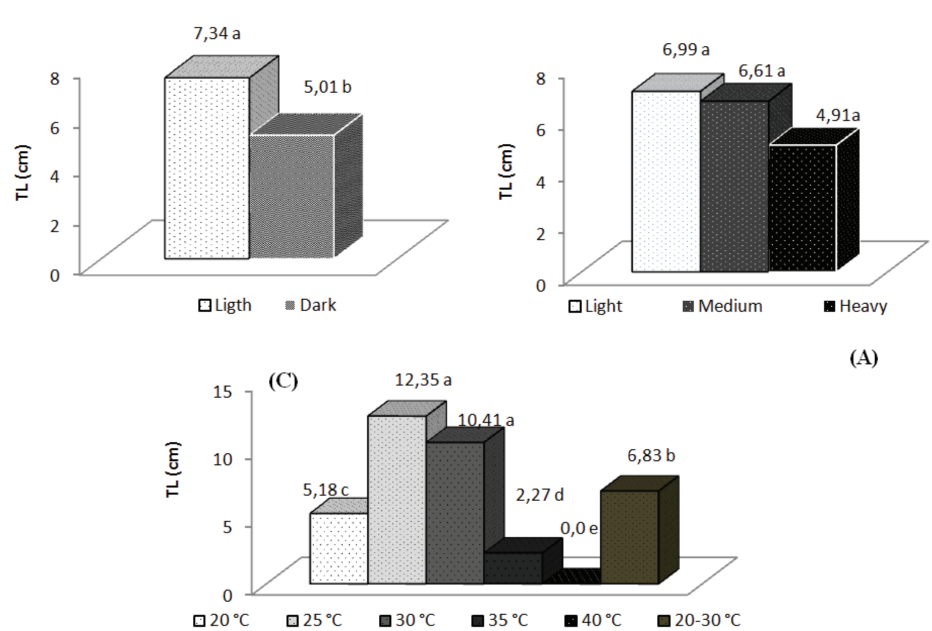


**Figure 3**. Total length (TL) of *Amburana cearensis* (Allemão) A.C. Sm. seedlings as influenced by light conditions (A), weight classes (B) and temperature regimes (C).

The light requirement of seeds is associated with different ecological groups: pioneer, secondary and climax (Figliolia & Piña-Rodrigues, 1995). *Amburana cearensis* is described in different ways in the literature, being included in more than one ecological group. This has been verified by Barbosa (2003), who describes that *A. cearensis* demonstrates shade tolerance, as it germinates under the forest canopy, and it later shows characteristics of pioneer species during the young plant stage.

Regarding the influence of different temperatures and seed weight on the root + hypocotyl length (Table 5), it can be seen that low (20°C) and high temperatures (35 and 40°C) were not critical in the differentiation among the weight classes. Temperatures of 25, 30, and 20-30°C were essential to the perception of such differences, for which light and medium seeds stood out as the best in terms of the promotion of increased root growth. The optimal temperature for germination and seedling growth is a prime factor that ensures the action of seed reserves in the establishment of the species, with the ideal temperature being responsible for increasing metabolism and the translocation of these reserves to the embryonic axis.

**Table 5.** Root + hypocotyl length (RHL) of *Amburana cearensis* (Allemão) A. C. Sm. seedlings as influenced by seed weight.

| RHL | | | | | | |
|---|---|---|---|---|---|---|
| Temperature | | | | | | |
| Classes | 20°C | 25°C | 30°C | 35°C | 40°C | 20-30°C |
| Light | 3.70 aC | 7.95 aA | 5.24 Ab | 0.81 aD | 0.00 aD | 3.66 aC |
| Mediu | 3.87 aC | 7.27 aA | 5.86 Ab | 0.66 aD | 0.00 aD | 3.28 aC |
| Heavy | 3.24 aB | 5.49 bA | 2.86 Bb | 0.88 aCD | 0.13 aD | 1.94 bBC |
| lsd for columns = 1.1606 lsd for lines = 1.314 | | | | | | |

Means followed by the same letter, upper case in the same row and lower case in the same column, do not differ by Tukey's test at a 5% probability level.

The process that led to this greater root growth is the result of favourable conditions for germination, which are associated with a complex sequence of biochemical reactions. In these reactions, reserve substances stored in the supporting tissue are broken down, transported and resynthesized in the embryonic axis. The higher the temperature, the faster and more efficient the germination, up to a certain limit (Carvalho & Nakagawa, 2012). Within these limits, the temperature of 25°C enabled the better translocation of reserves, with maximum efficiency, when light and medium seeds were used. A comparison between light and heavy seeds reveals an increase in root growth of more than 44 and 83.22% at temperatures of 25°C and 30°C, respectively.

It can be seen in Table 6 that the factor of light along with temperature showed unique responses in terms ofthe epicotyl length. This growth was certainly evidenced by the perception of light, withits presence being critical for growth. Along with the light factor, temperatures of 25 and 30°C led to increased epicotyl length, with increases of 20.89 and 38.98%, respectively, when compared to that in the absence of light. These results are similar to those reported by Alves et al. (2012), who found that the greatest *Clitoria fairchildiana* length occurred at a temperature of 30°C under a white light regime.

**Table 6.** Epicotyl length (EPL), epicotyl dry mass (EPDM), root + hypocotyl dry mass (RHDM) and total dry biomass (TDB) of *Amburana cearensis* (Allemão) A.C. Sm. as a function of temperature and light presence or absence.

| | Temperature | | | | | |
|---|---|---|---|---|---|---|
| Light | 20°C | 25°C | 30°C | 35°C | 40°C | 20-30°C |
| Presence | 2.06 aD | 5.96 aA | 6.56 aA | 3.10 aC | 0.16 aE | 4.36 aB |
| Absence | 1.08 bC | 4.93 bA | 4.42 bA | 0.00 bC | 0.00 aC | 2.47 bB |
| | | | EPDM (g) | | | |
| Presence | 0.006 aC | 0.017 aAB | 0.018 aA | 0.007 aC | 0.00 aD | 0.014 aB |
| Absence | 0.005 bD | 0.017 aA | 0.014 bB | 0.000 bE | 0,00 aE | 0.008 bC |
| | | | RHDM (g) | | | |
| Presence | 0.013 aC | 0.023 aA | 0.018 aB | 0.007 aD | 0.00 aE | 0.014 aC |
| Absence | 0.011 bBC | 0.015 bA | 0.011 bB | 0.000 bD | 0.00 aD | 0.008 bC |
| | | | TDB (g) | | | |
| Presence | 0.019 aC | 0.040 aA | 0.036 aA | 0.014 aC | 0.00 aE | 0.0284 aB |
| Absence | 0.015 aC | 0.033 bA | 0.025 bB | 0.000 bD | 0.00 aD | 0.0241 aB |

Means followed by the same letter, upper case in the same row and lower case in the same column, do not differ by Tukey's test at a 5% probability level. LSD for EPL, EPDM, RHDM and TDB in columns (0.8083, 0.0018, 0.0020, 0.0036, respectively) and lines (1.0957, 0.0025, 0.0029, 0.0052, respectively).

The temperatures of 30, 25, and 20-30°C (in this order) showed higher mean values of epicotyl dry mass, with the highest results obtained under light conditions, with the exception of 25°C, at which the mean values were not different (Table 6). For the root + hypocotyl dry mass, the greatest increase (53.33%) was observed in the presence of light at a temperature of 25°C.The total dry missal so responded similarly to epicotyl growth, for which the highest results were obtained at temperatures of 25 and 30°C (21.21 and 44%, respectively) when compared to seedlings under light limitation. One of these results is similar to those reported by Pacheco, Matos, Ferreira, and Feliciano (2007), where a constant temperature of 30°C resulted in a greater increase in the hypocotyl dry mass of *Apeibati bourbou* Aubl. seedlings.

The explanation for the shorter seedling length in the dark is the permanence of phytochrome A throughout seedling development, which inhibits etiolation, a phenomenon that only occurs in the presence of phytochrome B (Carvalho & Peres, 2013). Based on this response, it can be deduced that under low light conditions, such as under a very closed canopy, *A. cearensis* suffers strong competition for light, thus requiring a clearing for its growth and survival. Although *A. cearensis* is a species typically adaptable to semi-arid conditions and considering that there was no influence of light on germination, the results are quite enlightening. The presence of light was critical for seedling growth, enabling the normal development of seedling structures, thus indicating that this species might be classified as a pioneer in ecological succession.

Table 7 shows the influence of the factor of seed weight on EPL and EPDM, which showed a significant three-way interaction. Based on the results previously mentioned and described by the statistical breakdown of the temperature × light interaction (Table 6), which revealed the superiority of the combination of 30 or 25°C in the presence of light for these variables, it can be seen from Table 7 that seed weight is a key factor in the development of *A. cearensis* seedlings, affecting even seed photoblastism. The data showed that under the best combination of temperature and light (30 or 25°C in the presence of light) for EPL, seeds classified as light or medium produced more vigorous seedlings when compared to the heavy seeds. For EPDM, this behaviouroccurred again at 30°C, whereas at 25°C, there was no difference among the weight classes. These results are also similar to those reported by Almeida et al. (2014), who observed higher growth of *A. cearensis* seedlings by using light and medium seeds at a temperature of 30°C.

**Table 7**. Epicotyl length (EPL) and epicotyl dry mass (EPDM) means of *Amburana cearensis* (Allemão) A. C. Sm. seedlings for the three-way interaction of temperature × light × weight.

| | EPL (cm) | | | EPDM (g) | | |
|---|---|---|---|---|---|---|
| | Weight Classes | | | Weight Classes | | |
| Temp. x Light | Light | Medium | Heavy | Light | Medium | Heavy |
| 20°C x Light | 2.06 A | 2.16 A | 1.97 A | 0.006 A | 0.001 A | 0.007 A |
| 20°C x Dark | 0.99 A | 1.16 A | 1.08 A | 0.004 A | 0.006 A | 0.004 A |
| 25°C x Light | 7.01 A | 5.83 AB | 5.03 B | 0.018 A | 0.016 A | 0.016 A |
| 25°C x Dark | 5.88 A | 4.97 AB | 3.93 A | 0.019 A | 0.017 A | 0.015 A |
| 30°C x Light | 7.60 A | 7.49 A | 4.59 B | 0.018 AB | 0.020 A | 0.015 B |
| 30°C x Dark | 5.32 A | 5.93 A | 2.02 B | 0.014 AB | 0.018 A | 0.010 B |
| 35°C x Light | 3.94 A | 2.90 A | 2.88 A | 0.008 A | 0.006 A | 0.006 A |
| 35°C x Dark | 0.00 A | 0.00 A | 0.00 A | 0.000 A | 0.000 A | 0.000 A |
| 40°C x Light | 0.00 A | 0.00 A | 0.49 A | 0.000 A | 0.000 A | 0.000 A |
| 40°C x Dark | 0.00 A | 0.00 A | 0.00 A | 0.000 A | 0.000 A | 0.000 A |
| 20-30°C x Light | 5.11 A | 4.45 A | 3.53 A | 0.015 A | 0.015 A | 0.013 A |
| 20-30°C x Dark | 3.35 A | 2.52 A | 1.53 B | 0.010 A | 0.009 AB | 0.005 B |

Uppercase letters in the same rows do not differ by Tukey's test at a 5% probability of error. EPL: LSD = 1.5862. EPDM: LSD = 0.0053.

Overall, light and medium seeds promoted better development of *A. cearensis*, which may indicate that they have higher tolerance to adverse environmental conditions. In terms of the low performance obtained with heavy seeds, these seeds have been influenced since the germination stage, which also causes changes in seedling establishment. A possible explanation for the detrimental effect of heavy seeds on seedling development under optimal temperature and light conditions is most likely associated with higher coumarin levels.

Seed weight also did not influence seedling development under non-optimal temperatures (20, 35, and 40°C), with the exception of alternating temperatures (20 - 30°C) in the absence of light, which also shows the influence of weight on light perception. This reveals once more a superiority of light and medium seeds (Table 7), i.e., the seedlings obtained from heavy seeds under dark conditions do not exhibit good development rates.

Temperature modifies seedling growth according to the amount of reserves in the seeds, indicating changes in the type of phytochrome throughout the development of this species. This shows that environmental factors establish different behaviours in this species depending on the ambient temperature and the type of light. Both extrinsic factors affect responses in the plant according to the amount of reserves in the seeds. These results may provide ecological and agronomic information for a better understanding and the sustainable exploitation of this species, allowing it to be propagated more efficiently for reforestation and preservation purposes.

## Conclusion

The germination of *A. cearensis* shows neutral photoblastism, where seeds from light and medium classes have greater vigour, and light seeds have a higher final germination percentage.

The temperature of 30°C is the most suitable for germination, whereas 35 and 40°C are strongly detrimental to seedling growth.

Temperature and seed weight influence the perception of light for seedling development.

Seedlings obtained from light and medium seeds resulted in greater epicotyl growth and dry mass at temperatures of 25 and 30°C in the presence of light.

## References


Almeida, J. R. G. S., Guimarães, A. G. G., Siqueira, J. S., Santos, M. R. V., Lima, J. T., Nunes X. P., & Quintans, Júnior, L. J. (2010). *Amburana cearensis* – uma revisão química e farmacológica. *Scientia Plena*, *6*(11), 1-8.

Almeida, J. P. N., Pinheiro, C. L., Lessa, B. F. T. M, Gomes, F. M., & Medeiros Filho, S. (2014). Estresse hídrico e massa de sementes na germinação e crescimento de plântulas de *Amburana cearensis* (Allemão) A.C. Smith. *Revista Ciência Agronômica*, *45*(4), 777-787.

Alves, M. M., Alves, E. U., Bruno, R. L. A., Silva, K. R. G., Moura, S. S. S., Barrozo, L. M., & Araújo, L. R. (2012). Potencial fisiológico de sementes de *Clitoria fairchildiana* R. A. Howard. *Fabaceae* submetidas a diferentes regimes de luz e temperatura. *Ciência Rural*, *42*(12), 2199-2205.

Amato, A. L. P., Maia, F. C., Maia, M. S., Caetano, L. S., Simioni, S. B., Conto, L., & Bonini Filho, R. M. (2007). Estabelecimento de condições de luz e temperatura na germinação de sementes de amendoim forrageiro. *Revista Brasileira de Sementes*, *29*(3), 61-66.

Barbosa, D. C. A. (2003). Estratégias de germinação e crescimento de espécies lenhosas da caatinga com germinação rápida. In I. R. Leal, M. Tabarelli, & J. M. C. Silva (Eds.), *Ecologia e conservação da caatinga* (p. 625-656). Recife, PE: Universidade Federal de Pernambuco.

Bewley, J. D., Bradford, K. J., Hilhorst, H. W. M., & Nonogaki, H. (2013). *Seeds:* Physiology of development, germination and dormancy (3rd ed.). New York, US: Springer.

Brasil. (2009). Ministério da Agricultura, Pecuária e Abastecimento – Secretaria de Defesa Agropecuária. *Regras para análise de sementes*. Brasília, DF: Mapa/ACS.

Canuto, K. M., Silveira, E. R., Bezerra, A. M. E., Leal, L. K. A. M., & Viana, G. S. B. (2008). *Uso de Plantas Jovens de Amburana cearensis A. C. Smith: Alternativa para preservação e exploração econômica da espécie.* Petrolina, PE: Embrapa Semiárido.

Carvalho, N. M., & Nakagawa, J. (2012). *Sementes: ciência, tecnologia e produção* (5a ed.). Jaboticabal, SP: Funep.

Carvalho, R. F., & Peres, L. E. P. (2013). *Fotomorfogênese.* Retrieved from http://www.miniweb.com.br/ciencia/artigos/fotomorfogenese.pdf.

Diniz, F. O., Moreira, F. J. C., Silva, F. D. B., & Medeiros Filho, S. (2008). Influência da luz e temperatura na germinação de sementes de oiticica (*Licania rigida* Benth.). *Revista Ciência Agronômica*, *39*(3), 476-80.

Felix, R. A. Z., Ono, E. O., & Araújo, F. P. (2010). Efeitos alelopáticos de extratos de *Amburana cearensis* na germinação de sementes de rabanete e alface. *Cultivando o Saber*, *3*(1), 18-31.

Figliolia, M. B., Aguiar, I. B., & Silva, A. (2009). Germinação de sementes de três arbóreas brasileiras. *Revista do Instituto Florestal*, *21*(1), 107-115.

Figliolia, M. B., & Piña-Rodrigues, F. C. M. (1995). Considerações práticas sobre o teste de germinação. In *Manual técnico de sementes florestais* (p. 45-59). São Paulo, SP: Instituto florestal. (Série Registros, 14).

Guedes, R. S., Alves, E. U., Gonçalves, E. P., Braga Júnior, J. M., Viana, J. S., & Colares, P. N. Q. (2010). Substratos e temperaturas para testes de germinação e vigor de sementes de *Amburana cearensis* (Allemão) A.C. Smith. *Revista Árvore*, *34*(1), 57-64.

Harper, J. L., & Benton, R. A. (1966). The behaviour of seeds in soil: II. The germination of seeds on the surface of a water supplying substrate. *Journal of Ecology*, *54*(1), 151-166.

Lessa, B. F. T., Almeida, J. P. N., Pinheiro, C. L., Gomes, F. M., & Medeiros Filho, S. (2015). Germinación y crecimiento de plántulas de *Enterolobiumcontortisiliquum* enfuncióndel peso de lasemilla y las condiciones de temperatura y luz. *Agrociencia*, *49*(3), 315-327.

Maguire, J. D. (1962). Speed of germination-aid in selection and evaluation for seedling emergence and vigor. *Crop Science*, *2*(1), 176-177.

Marcos-Filho, J. (2015). *Fisiologia de sementes de plantas cultivadas* (2a ed.). Piracicaba, SP: Fealq.

Nogueira, F. C. B., Silva, J. W. L., Bezerra, A. M. E., & Medeiros Filho, S. (2012). Efeito da temperatura e luz na germinação de sementes de *Luetzelburgia auriculata* (Alemão) Ducke Fabaceae. *Acta Botanica Brasilica*, *26*(4), 772-778.

Pacheco, M. V., Matos, V. P., Ferreira, R. L. C., & Feliciano, A. L. P. (2007). Germinação de sementes de *Apeibati bourbou* Aubl. em função de diferentes substratos e temperaturas. *Scientia Forestalis*, *19*(73), 19-25.

Pereira, S. R., Giraldelli, G. R., Laura, V. A., & Souza, A. L. T. (2011). Tamanho de frutos e de sementes e sua influência na germinação de jatobá-do-cerrado (*Hymenaea stigonocarpa* var. *Stigonocarpa* Mart. ex Hayne, Leguminosae Caesalpinoideae. *Revista Brasileira de Sementes*, *33*(1), 141-148.

Ribeiro, C. A. D., Costa, M. P., Senna, D. S., & Caliman, J. P. (2012). Fatores que afetam a germinação das sementes e a biomassa de plântulas de *Tabebuia heptaphylla*. *Revista Floresta*, *42*(1), 161-168.

Silva, G. M., Maia, M. S., & Moraes, C. O. C. (2007). Influência do peso da semente sobre a germinação e o vigor de cevadilha vacariana (*Bromus auleticus* Trinius). *Revista Brasileira de Agrociência*, *13*(1), 123-126.

Silva, W. A., Nobre, A. P., Leites, A. P., Silva, M. S. C., Lucas, R. C., & Rodrigues, O. G. (2006). Efeito alelopático de extrato aquoso de *Amburana cearensis* A. Smith na germinação e crescimento de sementes de sorgo (*Sorghum bicolor* L*.). Agropecuária Científica no Semi-árido*, *2*(1), 48-54.

Thompson, K., & Grime, J. P. (1983). A comparative study of germination responses to diurnally fluctuating temperatures. *Journal of Applied Ecology*, *20*(1), 141-156.

*Received on July 18, 2016.*
*Accepted on October 17, 2016.*