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Biometric, ultrastructural, and seed germination analysis of *Etlingera elatior* (Jack) R.M. Smith

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Summary

Torch ginger is a tropical species of ornamental/landscape, medicinal, and gastronomic use in several countries. The ideal physiological conditions for its seed development are unknown, which precludes sexual reproduction for propagation of seedlings and genetic improvement of the species. Thus, the objective of this study was to understand the morphological and biometric traits of its fruits and seeds and to evaluate the effect of temperature on the germination, storage, emergence, and seedling growth of two cultivars of torch ginger to contribute to future research on the propagation of the species. The color of the fruits suffices to distinguish the cultivars, while the other biometric and ultrastructural traits are similar between cultivars. The seeds of the two cultivars showed a higher percentage of germination in the dark under a thermoperiod of 35°C for 16 h and 25°C for 8 h. The Red Torch cultivar tolerated storage for up to 30 days, while the Pink Torch seeds could be stored for up to 90 days. The emergence in substrate was greater under the thermoperiod of 35/25°C, being 30% and 20% for the Red and Pink Torch cultivars at 30 days of thermal induction, respectively, but greater seedling growth occurred at 30/25°C.

Keywords: Zingiberaceae, propagation, tropical floriculture, conservation, torch ginger.

Introduction

The torch ginger (*Etlingera elatior)* is a Southeast Asian species belonging to the Zingiberaceae family and has multiple uses (ISMAIL et al., 2019; YUNUS et al., 2021). Its gastronomic importance, where is it part of the diet in countries of origin and medicinal importance are widely reported (ISMAIL et al., 2019; LADIO and ACOSTA, 2019). Several studies have shown its potential as a natural antioxidant and antimicrobial agent (MARZLAN et al., 2022). This species is also used for ornamental purposes as cut flowers, but also in landscape settings. Its inflorescences arouse interest due to their beauty, color, and exotic shapes (YUNUS et al., 2021).

Even with its aesthetic, medicinal, and gastronomic appeal, the torch ginger still does not have well established agronomic recommendations (YUNUS et al., 2021). To propagate the species, the usual practice is to divide its clumps, but this method exposes the propagules to contamination by soil pathogens (MEKAPOGU et al., 2021). An alternative would be propagation via seeds, but even in its center of origin, the species has low fruit and seed formation and depends on the presence of pollinators that can promote cross-fertilization of flowers (KUNNATH et al., 2013). There are no indications about seed production outside the center of origin of the species. As the most important pollinators in the center of origin are not present in the Brazilian fauna (*Tetragonula iridipennis*, *Nectarinia asiatica*, and *N. zeylonica*, studying its sexual reproduction may contribute to the *ex situ* propagation of the species via seeds to maintain its genetic diversity and allow crosses between materials of agronomic interest (KUNNATH et al., 2013).

Knowledge of the germination process is key to enabling the sexual propagation of a species. *Etlingera elatior* is a species whose seeds, when stored, lose viability, thereby reducing their germinative potential (YEATS, 2013). Some information is available on other species of order Zingiberales, such as the use of growth regulators to increase the germination percentage of *Strelitzia reginae* seeds and the *in vitro* culture technique under different thermoperiods to increase the germination of *Zingiber spectabile* seeds (REIS et al., 2017; CARVALHO et al., 2020).

One of the abiotic factors that influences germination is temperature. Temperature determines the speed of germination and regulates dormancy levels, establishing which portion of the population will germinate in a given time (BATLLA and BENECH-ARNOLD, 2015). Temperature regulates both the speed of the enzymatic processes mobilizing reserves and the production of gibberellin, altering the hormonal balance with abscisic acid, favoring germination (LAMONT and PAUSAS, 2023). In addition to abiotic factors, we should also consider factors related to storage, which will affect seed longevity in addition to the germination and vigor of a given lot of seeds (DE VITIS et al., 2020).

The studies about the sexual propagation of tropical species are scarce, thus, it aimed to characterize fruits and seeds of *Etlingera elatior* and evaluate its germination process, aiming to determine the optimal conditions to maximize germination parameters and dormancy breaking, which will allow the sexual propagation of the species.

Materials and methods

Plant material

The fruits of the Red Torch and Pink Torch cultivars of torch ginger (*Etlingera elatior*) were harvested from three mother plants, planted in 2011, under a black shade net with 50% shading, in full production from February to March. The mother plants were commercially obtained and cultivated at the coordinates (21°14'43"S; 44°59'59"W), with an altitude of 919 m, in a climate characterized as tropical highland.

Characterization of fruits and seeds

The mean number of fruits per inflorescence was determined by counting only the stems with fruits in the field. Twenty fruits of each cultivar were taken to the Laboratory of the Floriculture and Landscaping Sector to determine the fresh weight and count the seeds per fruit.

For the biometric analyses, 20 fruits of each cultivar were analyzed in Ground Eye® equipment to calculate the maximum and minimum diameter, perimeter, and area.

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The seed mucilage was previously made by friction with hydrated lime, and the seeds were then washed under running water and dried in the shade before analysis. Eight replicates with 100 seeds each were weighed to estimate the 1000-seed weight and then placed in an oven at 105 °C for 24 h to determine the water content. The biometric data of the seeds were obtained with Ground Eye® equipment. The parameters analyzed were the maximum and minimum diameter, perimeter, and area of seeds.

Scanning electron microscopy

The seeds, fresh or processed, were left completely or sectioned to visualize their internal structures. Three washes were performed in sodium cacodylate for dehydration. The seeds were soaked in a graded acetone series (25, 50, 75, 90, and 100%) for approximately 10 minutes each, and the last concentration was applied three times. The samples were then placed in individual cages.

The material was taken to a critical-point dryer to complete the drying and then mounted in stubs. To complete this step, the samples were glued to the stubs using double-sided tape and then gold-coated with a sputter coater. After the gold sputtering, the samples were examined under a scanning electron microscope (Leo Evo 40) and electron micrographs were taken.

Germination of seeds under different temperature and light regimes

The first germination test was performed on the day of fruit collection and seed processing. These were placed in a germination box with two filter papers moistened with distilled water (2.5 times the weight of the paper) according to the Rules for Seed Analysis (Brasil, 2009). The seeds of the cultivars were placed in a biochemical oxygen demand (BOD) incubator with different temperature treatments chosen based on previous tests: 25 °C constant, 35 °C constant, and 35 °C/25 °C (16 h/8 h, respectively). The effect of the presence and absence of light on germination was also evaluated in combination with the different temperatures evaluated, where part of the germination boxes were covered with aluminum foil (absence of light) or remained uncovered (presence of light).

The experiment was conducted in a completely randomized design in a 3×2×2 factorial arrangement (three temperatures, two light conditions, and two cultivars). Four replicates were performed for each treatment, and each experimental plot consisted of a germination box with 15 seeds.

Germination at different seed storage times

Sterilized seeds were stored in the dark in brown paper bags at room temperature (25 °C) for up to 6 months (0, 30, 60, 90, 120, 150, and 180 days) to evaluate the effects of time on seed germination. At each of the evaluation times, six replicates of 25 seeds were placed in germination boxes (Gerbox®) containing two sheets of germination paper moistened with distilled water that amounted to 2.5 times the weight of the paper, according to the Rules for Seed Analysis (Brasil, 2009).

The seeds were placed to germinate in BOD incubators in the dark under an alternating temperature regime 35 °C/25 °C (16 h/8 h, respectively). After 60 days, the germination percentage (%) was evaluated after each storage period in each cultivar, making for a two-factor factorial arrangement (2×7) between cultivars and storage times.

Seed emergence in different substrates

The emergence test was performed on seeds stored for 6 months at 25 °C. The seeds of each cultivar were placed in pots containing three different substrates: commercial substrate (Topstrato HP), vermiculite, and a 1:1 mixture of substrate:vermiculite. The pots were moistened with distilled water to the maximum retention capacity and covered with a transparent plastic bag. The pots were placed in BOD incubators with different temperature treatments based on the first germination test: 35 °C or 30 °C for 16 h in the presence of light, followed by 25 °C for 8 h in the dark, simulating a full day. The parameters evaluated were emergence after 75 days, shoot length and root length. The experiment was conducted in a completely randomized design in a 2×3×2 factorial arrangement (two temperatures, three types of substrate, and two cultivars). Three replicates were performed for each treatment, and each experimental plot consisted of a pot with 20 seeds.

Thermal induction times in substrate

Sterilized seeds were placed in #8 plastic pots (0.2 L) with a mixture of commercial vegetable substrate Topstrato® and vermiculite (1:1), covered with plastic bags, and placed in the dark in BOD incubators. Again the alternating temperature regime of 35 °C for 16 h and 25 °C for 8 h was used. The pots were removed from the BOD incubators and taken to the growth room at 25 °C with a photoperiod of 16 h at the following times: 0, 1, 2, 4, 15, 30, 45, and 60 days after sowing. For each treatment, three replicates were performed, each pot constituting one replicate. The parameter evaluated was the percentage of seedlings (%) that had emerged 120 days after inoculation. There was a two-factor factorial arrangement (2×8), with split plots in time so that the cultivars were the plots and the thermal induction times were the subplots.

Statistical analysis

In all evaluations, the data were subjected to analysis of variance (ANOVA), and the means of the treatments were compared by the Scott-Knott test at 5% probability when significant ($p<0.05$) (Ferreira, 2019).

Results

The plants had many inflorescences/plant, but fruit development was not observed in all inflorescences. In the counting performed exclusively on the stems with fruits, there were an average of 13.5 fruits per inflorescence in the Red Torch and Pink Torch cultivars. They had a wide range of 4-23 and 3-40 fruits/inflorescence, respectively (Fig. 1 A and B). It is worth mentioning that this was the result of natural pollination on site.

Regarding the morphological and biometric traits evaluated, the fruits varied from one cultivar to the other but also within the same cultivar throughout the infructescence (Fig. 1A - F). The fruit shape was similar for both cultivars, but the color of the Red Torch fruits was dark red, and they had a hair layer. The aril that covered the seeds had a pinkish-red color and a sweet aroma. Conversely, the fruits of the Pink Torch cultivar were light green in color and presented aromatic arils of a whitish color (Fig. 1E - F). The biometric data for the fruits are shown in Tab. 1.

The seeds showed no visual differences that distinguished the cultivars (Fig. 1G - H). Both were usually dark brown and almost black when they began the desiccation process. The biometric data of the seeds are shown in Tab. 2.

In the ultrastructural analysis, it was not possible to distinguish the two cultivars. In the electron micrographs, the aril that covered the seeds was deposited in lamellae, with a longitudinal arrangement along the entire length of the seed (Fig. 2A). In the processed seed (Fig. 2B), the outer structure of the seed coat was observed, which formed small longitudinal grooves, similar to the aril.

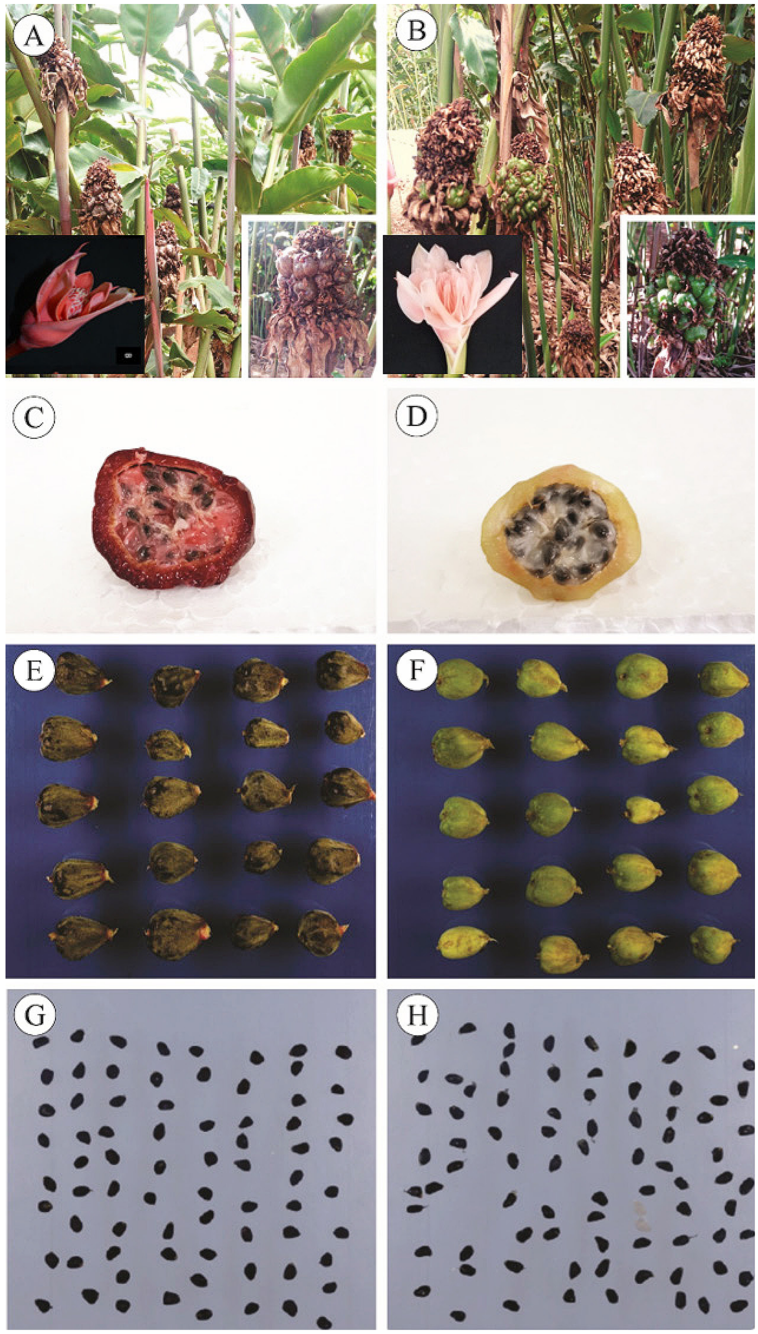

Fig. 1: Reproductive structures of torch ginger. Infructescence, fruits, and seeds of the cultivars Red Torch (A, C, E, and G) and Pink Torch (B, D, F, and H), respectively.

Tab. 1: Biometry of the fruits of the cultivars Red Torch and Pink Torch of *Etlingera elatior*.

Parameter	Cultivar	
	Red Torch	Pink Torch
Mean fruit weight (g)	8.96 (±3.31)	7.98 (±1.74)
Number of seeds/fruit	45.2 (±28.61)	75.3 (±21.37)
Mean area (cm²)	7.07 (±0.91)	7.15 (±1.62)
Maximum diameter (cm)	3.69 (±0.42)	3.62 (±0.53)
Minimum diameter (cm)	2.56 (±0.34)	2.45 (±0.26)
Perimeter (cm)	12.26 (±2.49)	12.18 (±1.56)

* Mean values followed by standard error

Tab. 2: Biometry of *Etlingera elatior* seeds of the Red Torch and Pink Torch cultivars.

Parameter	Cultivar	
	Red Torch	Pink Torch
1000-seed weight (g)	20.19	18.94
Water content (%)	10.91	12.72
Area* (mm²)	9.04 (±0.95)	9.13 (±1.02)
Maximum diameter* (cm)	0.45 (±0.33)	0.41 (±0.54)
Minimum diameter* (cm)	0.28 (±0.22)	0.26 (±0.24)
Perimeter* (cm)	1.23 (±0.14)	1.33 (±0.99)

* Mean values followed by standard error

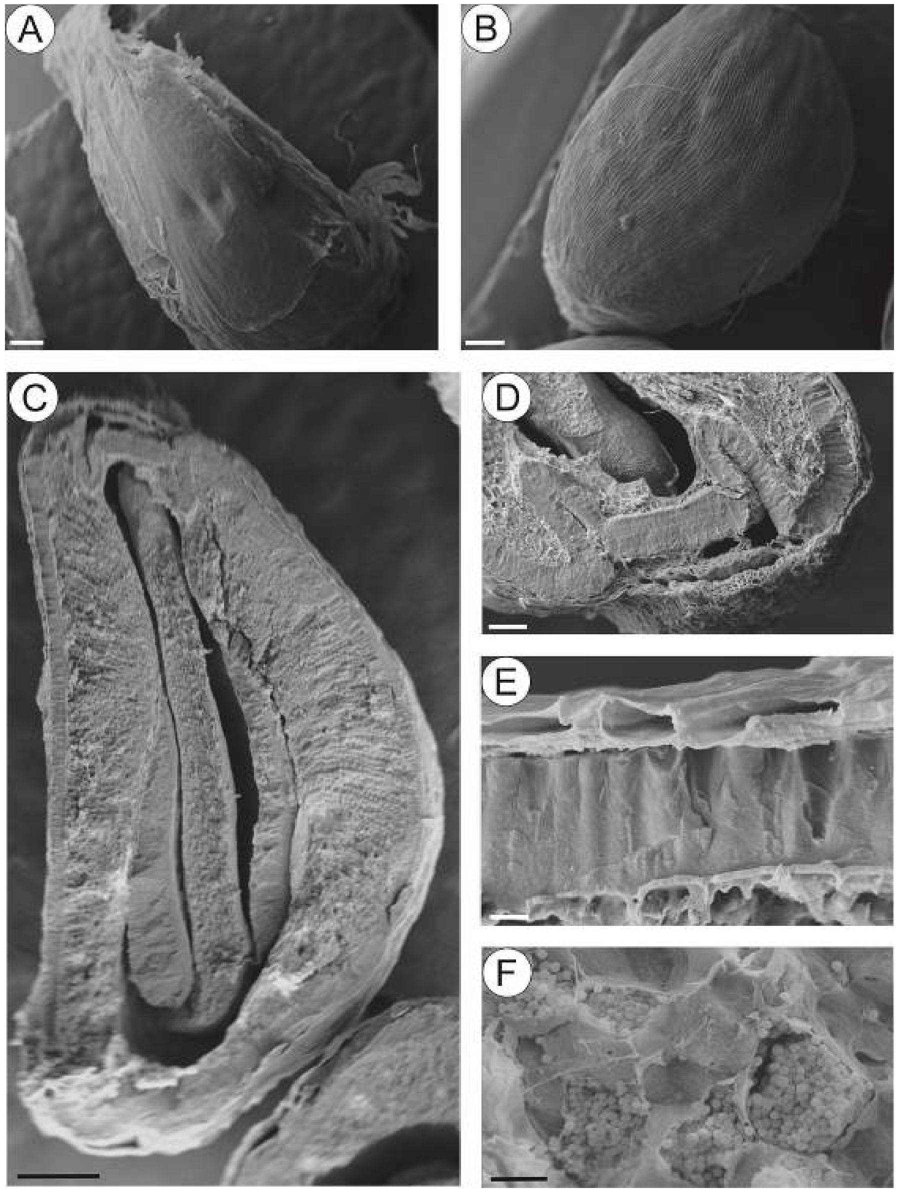

Fig. 2: Electron micrographs of *Etlingera elatior* seeds. A, Seed with aril. B, Seed without aryl. C, Seed in longitudinal section. D, Longitudinal section in the micropyle region. E, Detail of the seed coat layers. F, details of the perisperm cells, showing starch grains. Bar = 200 µm in A, B and C; 100 µm in D; 20 µm in E and F.

Regarding seed germination, the interaction between cultivars, light conditions, and temperature regime was not significant. The interaction between germination temperature and light conditions (Fig. 3A), alternating temperatures promoted a higher percentage of germination than constant temperatures, regardless of the light conditions. However, when comparing the presence and absence of light in the alternating temperature condition, there was a significant increase in the germination percentage of the seeds kept in the dark (62.22%) over those that received light (25.56%). Thus, the species could be classified as negatively photoblastic, given its higher germination rate in the absence of light in the best thermal condition.

Constant exposure to 35 °C resulted in the lowest germination percentages (~1%) (Fig. 3A). In the interaction between the two cultivars studied and the thermal regime (Fig. 3B), germination under alternating temperature was higher than under the other conditions in each cultivar. In addition, except for the condition of constant 35 °C, in which the means did not differ, the Red Torch cultivar showed higher germination percentages than the Pink Torch cultivar. Regarding seed storage (Fig. 3C), the interaction between cultivars and the storage time of the seeds was statistically significant. Again, these results indicate a physiological difference in the germination process of Red Torch vs. Pink Torch, even though they are the same species. Under the same storage times, the Red Torch cultivar had a higher percentage of germinated seeds than Pink Torch during the entire period evaluated.

The mean obtained with fresh seeds of torch ginger cv. Red Torch (0 days) indicates that their natural germination potential is maintained until up to 30 days of storage. After 60 days, there were no significant differences between the germination values obtained, which oscillated round 50% of the seeds, a decrease of more than 10% in the germination potential.

The initial germination of Pink Torch seeds was lower than that in the first analysis mentioned above. However, from 30 to 90 days of storage, the mean percentage of germinated seeds was higher, numerically matching the first evaluation performed with fresh

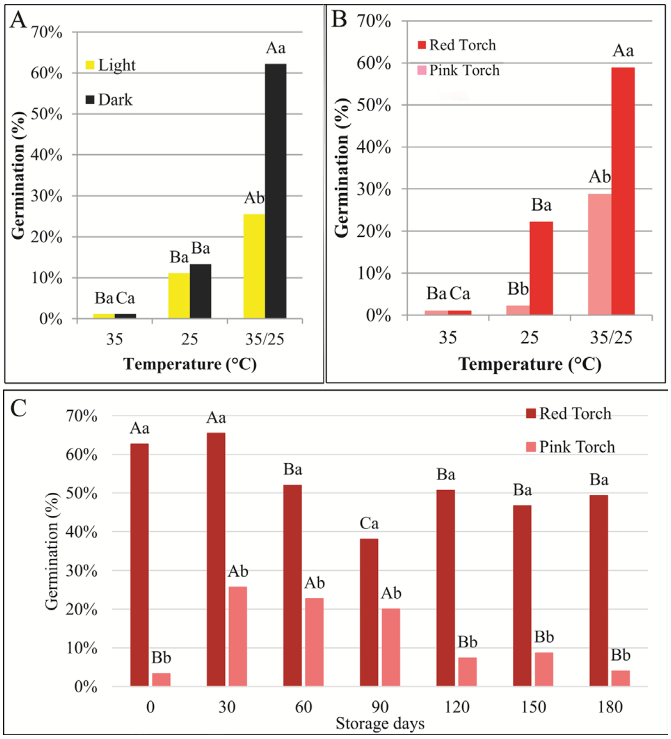

Fig. 3: Germination tests in seeds of torch ginger cv. Red Torch and Pink Torch. A, Statistical breakdown of the interaction between the temperature and light treatments. Columns with the same capital letters within the same light condition and lowercase letters within the same temperature treatment do not differ by the Scott-Knott test at 5% probability. B, Statistical breakdown of the interaction between the temperature treatment and cultivar. Columns with the same uppercase letters in each cultivar and lowercase letters in each temperature regime do not differ by the Scott-Knott test at 5% probability. C, Statistical breakdown of the interaction between storage time and cultivar. Columns with the same uppercase letters in each cultivar and lowercase letters in each storage time do not differ from each other by the Scott-Knott test at 5% probability.

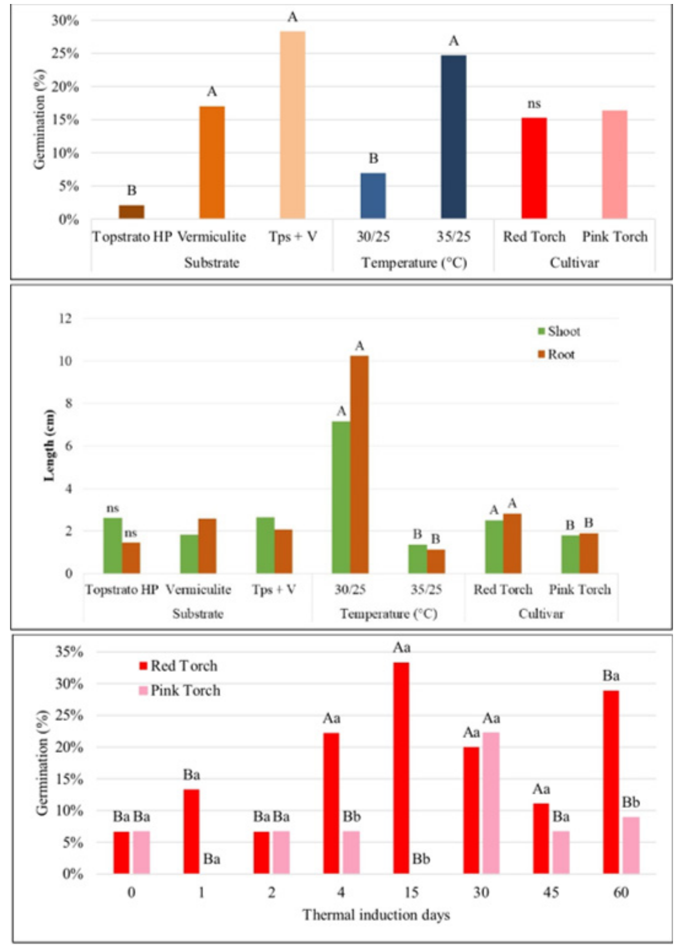

Fig. 4: Emergence and growth of seedlings of torch ginger cv. Red Torch and Pink Torch. A, Emergence percentage for the treatments with different substrates, temperature regimes and cultivars evaluated. Columns with the same letters for each of the sources of variation evaluated do not differ by the Scott-Knott test at 5% probability. B, Shoot and root length under the treatments evaluated. Columns with the same uppercase letters do not differ by the Scott-Knott test at 5% probability. C, Percentage of emergence under different thermoperiods. Means followed by the same uppercase letter for the same cultivar and means followed by the same lowercase letter for the same thermoperiod do not differ by the Scott-Knott test at 5% probability.

seeds. Finally, after 120 days of storage, there was a decrease in the germination potential of the seeds.

Regarding seedling emergence (Fig. 4A) from seeds stored for 60 days, the use of vermiculite and vermiculite + Topstrato HP provided the highest means, including higher than the commercial substrate. For both temperature regimes, there was greater emergence of seedlings with alternating 35/25 °C, similar to the previous germination test. Finally, when comparing the Red Torch and Pink Torch cultivars, there was no significant difference between them in the percentage of emergence. There was a decrease in the germination percentage of 43.61% and 12.5% for Red Torch and Pink Torch, respectively, when comparing the alternating temperature treatment of 35/25 °C of the first experiment with the results obtained in the second.

Although the thermal condition for the highest percentage of seedling emergence was 35/25 °C, the treatment at 30/25 °C showed significantly higher root and shoot growth (Fig. 4B). Of the substrates tested, vermiculite and vermiculite + Topstrato HP provided higher mean root length than Topstrato HP, whereas shoot length was similar between the three substrates. Regarding the cultivars evaluated, Red Torch seedlings had a higher mean root length than Pink Torch seedlings at 75 days after germination but did not differ statistically in shoot growth. However, it is possible that this difference between cultivars would decrease after longer periods of seedling establishment in the nursery.

The emergence percentages for the thermal induction treatments in the dark are shown in Fig. 4C. Thermal induction for 4, 15, 30, and 60 days had the highest mean values for the Red Torch cultivar, whereas for Pink Torch, the highest means occurred only at 30 days of thermal induction, both cultivars showing similar germination percentages at this induction time. The Red Torch cultivar had higher means at different induction times (1, 4, 15, and 60 days) than the Pink Torch cultivar. Fig. 5 shows the development of the germinated seed until the seedling emerged in the substrate.

Discussion

Low fruit production by *Etlingera elatior* under the edaphoclimatic conditions of its origin center has been reported. Only 24% of fruit formation is observed in flowers manually pollinated by cross-fertilization, and only 8% in naturally pollinated flowers (Kunnath

Fig. 5: Development of a seedling of torch ginger cv. Red Torch from the protrusion of the radicle to the formed seedling, usually lasting 15 days from germination to the formation of the second leaf in substrate. Bar: 2 cm.

et al., 2013). The species has gametic self-incompatibility, and its reproductive cycle includes three bird species, *Nectarinia Asiatica*, *Nectarinia zeylonica* and *Arachnothera longirostra*; and one stingless bee species, *Tetragonula irridipennis*, as the main pollinators (Kunnath et al., 2013; Yeats, 2013).

In Brazil, the reproductive biology of the species has not yet been studied. The main goal of such research would be increasing the production of fruits and seeds. Under local conditions, great seed production was found in the fruits collected, which indicates the presence of some highly efficient natural pollinators. The presence of possible pollinators visiting the flowers of Etlingera elatior, such as hummingbirds and bees, both native and exotic, was observed.

Data like these have not yet been reported in Brazil, but they corroborate the possibility of exploring the sexual reproduction of the species, especially because vegetative propagation should contribute to the lower fruiting of the inflorescences, given that clones from the same mother plant will be self-incompatible, and the species requires cross-pollination for fertilization (Kunnath et al., 2013).

In terms of seed ultrastructure, in the longitudinal section (Fig. 2C) the internal arrangement of the reserve tissues and the embryo was evident. The perisperm was the most abundant tissue, with cells that presented starch granules (Fig. 2F), though the endosperm usually stores protein reserves (Benedict et al., 2015). The embryo, elongated and with a slight curvature in the distal part, was lodged inside the seed, with no differentiated parts in its structure, typical of the subfamily Alpinoideae (Benedict et al., 2015).

In the detail of Fig. 2D, it is possible to observe the region of the micropylar collar, which consists of mesotesta cells folded over each other to form the micropyle and the operculum, apparently from the same origin, which are the site of the embryo's exit in the germination process (Khuat et al., 2022).

In addition to the mesotesta, the exotesta is visible in detail in Fig. 2E. The former, with sclerenchymatous characteristics, was probably a protective layer but also a barrier to the entry of water and gases into the embryo. In turn, the outer layer consisted of empty chambers arranged in a uniseriate manner in the highlighted area, but in the micropylar region, multiple layers were observed which could also act as a barrier to seed germination (Benedict et al., 2015; Khuat et al., 2022). The exotesta was also responsible for the shape of the seed, and its relief observed in Fig. 2B. Also, the biometric tests of seed size and mass generate data that can be used to standardize lots, enabling homogenization and improvement of seed vigor (Moura et al., 2010).

In the germination process, the temperature influences speed and uniformity, directly affecting the biochemical reactions that make up the entire process. Therefore, germination only occurs within certain temperature limits, which include a range or a single point where there will be maximum efficiency (Lamont and Pausas, 2023). We hypothesize that prolonged exposure to 35 °C was a determining factor for no germination.

Some species show germination reactions favorable to alternating temperature since they are similar to what happens in the natural environment of the torch ginger, for example, in which the daytime temperatures are higher and the nighttime temperatures are lower (Lamont and Pausas, 2023). These thermal fluctuations in the atmosphere can determine the rates of the gradual increase in seed coat permeability (Marcos-Filho, 2015).

Therefore, as the permeability of the sclerenchymatous mesotesta increases in the torch ginger seeds under alternating exposure to 35 and 25 °C, this favors the entry of water to overcome the possible physical dormancy imposed by the seed coat tissues. The impermeability of the seed coat is an important ecological factor for the perpetuation of some species because it allows the temporal separation of germination. It is influenced by environmental factors, such as water deficits and temperature, as well as by genetic traits (Ismail et al., 2019). However, achieving a certain germination rate at a certain temperature is not sufficient to define the existence of and the type of dormancy in the torch ginger seeds produced under local growth conditions. Tests involving other factors, such as gibberellin and inhibitors of abscisic acid, two important hormones of the germination process, are needed (Batlla and Benech-Arnold, 2015). If our above hypothesis is true, treatment with alternating temperatures may have contributed by weakening the seed coat rigidity at high temperatures but allowing the normal development of the embryo under milder temperatures.

More than 35% of the fresh Red Torch seeds and those stored for 30 days did not germinate. That percentage increased to more than 70% of the fresh seeds and seeds stored up to 90 days for Pink Torch. Several factors may be the cause of this phenomenon. Other physiological tests could be applied, such as the tetrazolium or electrical conductivity, to obtain more information about the germination potential of newly processed torch ginger seeds during the storage period (Marcos-Filho, 2015) and the physiological differences between the two cultivars.

Another possible biological factor responsible for the nongermination of some seeds could be a deeper dormancy level, inherent to this portion of the lot. Thus, even if the majority germinates, there would be internal and external signals responsible for coordinating the germination process for this seed extract that were not present, so they did not induce germination (Lamont and Pausas, 2023). The exogenous application of growth regulators, such as GA_3, could help break the deeper dormancy of seeds. Because gibberellins promote germination, they are responsible for coordinating the exit of the embryo from its quiescent state and the resumption of its development (Okabe et al., 2023). Other possible strategies are the application of other germination-promoting compounds, such as carbon nanotubes, which have been identified as germination accelerators in several species of agronomic interest (Korah et al., 2022).

In addition to compounds that can be applied to the seed, simpler techniques such as immersion in boiling water, incisions with blades, and mechanical impacts on the seed coat are also methods that can promote the breaking of dormancy (Lamont and Pausas, 2023). These techniques enable the overcoming of the physical dormancy imposed by the coat of some seeds, which prevents or restricts the entry of water into the embryo. Thus, it would be possible to promote faster rehydration, allowing germination (Carvalho et al., 2020).

Batlla and Benech-Arnold (2015) indicate that each cycle of alternating temperature works similarly to any product dose application. Thus, the exposure period would be the final dose to which the seeds were subjected. For the torch ginger cultivars tested, 30 days seems to be the ideal dose to achieve maximum germination of a seed lot, regardless of the cultivar, using only the temperature. It should also be noted that the decrease in germination percentage of the cultivars at 45 days of thermal induction could point to the acquisition of secondary dormancy mediated by temperature (Tiwari et al., 2016). The Pink Torch cultivar was more susceptible to this variation because it had a faster decrease in germination than the other, from 30 to 45 days versus 15 to 45 days. This cultivar appears to be more sensitive to or limited by the germination temperature, so it is possible that the ideal thermal conditions for each cultivar are different, and it is still necessary to determine other treatments that increase the percentage of Pink Torch germination.

Alternating temperature treatments are well-established techniques acting as mechanisms to break dormancy of seeds and promote germination in various species. Sampling conducted with over 400 native species from different habitats of the Tibetan Plateau obtained higher percentages of germination using alternating temperature cycles than constant temperatures, suggesting high applicability of the technique, even for non-related botanical families (Liu et al., 2013).

However, for ornamental species, there have been no reports of the use of alternating temperature to break dormancy or to induce germination. Tiwari et al. (2016) reviewed information on dormancy in the main genera of ornamental plants, such as *Asparagus* spp., *Brachiaria* spp., and *Rosa* spp., but among the recommendations for breaking dormancy, there are no references to the use of alternating temperatures, indicating a gap in the literature.

When comparing the two germination conditions, temporal and thermal induction, we observed that the maximum germination obtained in the first (65.4%) was higher than the maximum obtained in the second (50%). This is because the germination test indicates the maximum germination potential of a seed lot under favorable environmental conditions (Marcos-Filho 2015). On the other hand, the emergence test, as well as other vigor tests, such as electrical conductivity and accelerated aging, can provide information on the performance of the seeds in more adverse conditions resembling the reality of the field (Marcos-Filho, 2015; Santos et al., 2017). This variation is expected, given the change in optimal conditions of the germination test, which establishes the performance limit of the seed lot, and the emergence test, which imposes more restrictions on the physiological performance of the seed (Brasil, 2009).

Conclusion

The fruits and seeds of the cultivars used in this study do not differ biometrically, only in the external color of the fruits and in the pigmentation of the aril of the seeds. Biometric and ultrastructural information was generated to contribute to future studies on the reproductive biology of the species.

The best germination condition was an alternating temperature of 35/25 °C for 16/8 h, in the dark for both cultivars. The seeds can be stored for up to 30 days for the Red Torch cultivar and for up to 90 days for the Pink Torch cultivar, without a decrease in germination potential.

The substrates that provide greater emergence are pure vermiculite or a mixture of vermiculite and Topstrato HP 1:1. The seedling growths are higher at an alternating temperature of 30/25 °C for 16/8 h. The best thermal induction time in the substrate is 30 days, which allowed the highest emergence percentages in both cultivars.

Finally, among the two cultivars evaluated, Red Torch had a higher germination percentage and greater root growth under the development conditions tested than Pink Torch but did not differ in seedling emergence.

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Conflict of interest

No potential conflict of interest was reported by the authors.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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