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Germination and Vegetative Propagation of the Wild Species *Cuphea pulchra* Moric. (Lythraceae), a Potential Ornamental Crop

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Abstract: *Cuphea pulchra* Moric. is a species native to the Cerrado and Caatinga biomes that grows in environments with high temperatures and low rainfall and can be adapted as an ornamental plant for pots. Tests were carried out on *C. pulchra* seeds, as well as the cultivation of plants from both seeds and cuttings in a greenhouse. Seeds at different stages of maturity (green, almost ripe, and mature) were placed on agar and paper for germination tests. The cultivated plants were pruned as necessary. Two cutting tests were carried out according to the age of the donor plant. The flowering period was monitored. Germination was successful with the almost ripe seeds. Drastic pruning was able to produce compact plants in pots. Cutting tests had greater sprouting with younger donor plants. *Cuphea pulchra* stood out in terms of the length of the flowering period, which lasted up to ten months. Greenhouse cultivation produced viable plants for the ornamental plant market.

Keywords: successive pruning; drought tolerance; seed testing; cutting experiments

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1. Introduction

Every year, a large number of new species and cultivars are introduced to the market of ornamental plants by producers, especially pot plants, which are more attractive to consumers due to their lower relative cost, practicality, and greater durability [1].

The introduction of native species into urban landscaping and the pot plant market offers a vast field for the development of new research and studies in terms of cultivation, domestication, and propagation. This introduction has many advantages, whether by helping to conserve these species, popularizing them, or gaining knowledge of a flora that is still unknown to the wider population. Autochthonous species are adapted to local soil and climate conditions and are not dependent on the serial application of pesticides that exotic species commonly require [2].

A low number of native species are sold in flower shops and nurseries in Brazil, and the lack of research into their cultivation and propagation is the main reason for this lack of interest [3]. In addition to highlighting the lack of public policies, incentives, and interest, [4] points to other factors that complicate the success of native plants in ornamentation. These factors include the low level of technical knowledge about management and production, scarcity of research and funding, and uncertainties about the possibilities for use, all of which reinforce the preferential use of exotic species. Therefore, research into potential new native ornamental species, as well as knowledge about how they are propagated and managed, is of great importance in supporting the greater use of native species in the flower and ornamental plant market.

Cuphea has a wide range of species and is known for its ornamental potential [5], for use in landscaping, and as a pot plant. The genus already has eight species on the ornamental plant market.

Cuphea is characterized by representatives with a predominantly sub-shrubby habit, flowers arranged in racemes, an elongated, calcareous floral tube with lilac, white, yellow, pink, red, or purple petals, an ovary with a well-developed nectariferous gland at the base, and by its unique seed dispersal mechanism. This mechanism consists of exposing the placenta by breaking through the wall of the fruit and floral tube [6] (Figure 1D,E).

Figure 1. *Cuphea pulchra* Moricand (Lythraceae). (**A**) Flowering shrub on the outskirts of the city of Rio de Contas, state of Bahia, Brazil. (**B**) Detail of the terminal inflorescence. (**C**) Hummingbird visiting the flowers. (**D**) Fruit exposing placenta with almost ripe seeds. (**E**) Fruit exposing placenta with green seeds.

The *Cuphea* species with the most notable characteristics are those with showy and colorful flowers, with floral tubes measuring from 10 to 42 mm in length and intense coloration, which can vary from red, reddish-orange, and purplish red to yellow or green [7].

The development of vegetative propagation methods is a useful tool for the conservation of genetic resources and for the implementation of domestication programs. Propagation, by seeds and cuttings, is the most popular and economical method used with *Cuphea* species on the floriculture market [8]. In this context, the wild species *Cuphea pulchra* Moricand was selected as a good candidate for the ornamental plant market and for the study of germination behavior, propagation tests, seedling production, and adaptability for use as a potted plant, as the first steps towards the domestication of this species and its introduction as a new ornamental crop.

2. Materials and Methods

C. pulchra is represented by shrubs that can reach up to two meters in height in nature. It has flowers measuring 15–24 cm in length that are red-orange in color. The inflorescences present multiple flowers, concentrated at the apex of the branches, which are visited by hummingbirds, therefore bringing together characteristics of great ornamental appeal (Figure 1C). Furthermore, it originates from the Cerrado and Caatinga biomes in the northeast region of Brazil, growing in savannas, rocky fields, and Caatinga vegetation, in sandy-stony soils, where rainfall is low and temperatures are high, with long periods of drought and abundant sunshine, probably not requiring frequent watering.

2.1. Seed Collection

Seeds from different populations of *C. pulchra* were collected in August 2021, in the municipality of Rio de Contas, Chapada Diamantina, Bahia, in locations with the geographic coordinates 13°35′18–33″ S and 41°49–57′2–48″ W, at altitudes of about 1000–1300 m above sea level. The annual mean precipitation is around 520 mm, and the mean annual temperature is 22.3 °C. The seeds were kept in paper bags and stored at room temperature (at an average temperature of 20 °C) for 3 weeks until the germination tests began. Before starting the experiments, the seeds were sterilized with a solution of 1% sodium hypochlorite

(NaClO) for one minute. The collected seeds were at different stages of maturation and were classified into three categories for the germination experiment: mature, almost ripe, and green (Figure 1D,E).

2.2. Germination

The germination experiment was carried out from October to November of 2021. The number of seeds for each stage of maturity was determined by the number of seeds available in each category. Seeds from the three maturation categories were germinated in Petri dishes (9 cm) with pure agar (1%) [9] or filter paper (Table 1). Only the green seed category had enough seeds to test the effect of pretreatment with a growth regulator, Promalin (Giberellin [GA4+7]+ N-[phenylmethyl] [-1H-purine 6 amine] [6-benzyladenine]) solution. Promalin is known to stimulate better germination performance in some Cerrado species [10], such as *Passiflora setacea*, *P. alata*, and *P. cincinnata* [11,12], whose germination performance with the use of Promalin has been differentiated, as well as in several fruit crops [13]. The substrate for seed germination was agar and two layers of filter paper (Table 1).

Table 1. Categories and treatments performed for seed germination of *Cuphea pulchra* Moricand (Lythraceae).

Categories	Stages of Maturity	No. Dishes	No. Seeds/ Dishes	Pre-Treatment	Germin. Substrate
1	Ripe	3	5	-	Agar
2	Almost ripe	3	30	-	Agar
3	Green	4	51	-	Agar
4	Green	4	50	Promalin	Agar
5	Green	4	50	-	Filter paper

The Petri dishes were incubated at alternating temperatures: 30 °C (8 h light)/20 °C (16 h dark) (EL 202/4G, Eletrolab). The seeds were considered germinated when there was a radicle protrusion within the seed coat associated with its positive geotropic curvature [14]. Observations were made at intervals of 24 h. The germinated seeds were counted on a plate until there were no germinated seeds for seven days. The seeds that did not germinate were opened with a scalpel for the evaluation of viability. The seeds that were dark brown and/or covered with fungi were considered unviable. The hard seeds were cut and incubated in a 2, 3, 5-triphenyl tetrazolium chloride solution (0.5%) for 24 h to evaluate viability. The germinated seeds were monitored until the formation of seedlings, to be classified morphologically according to [15].

2.3. Greenhouse Growth

2.3.1. Cultivation of Plants from Germinated Seeds and Pruning

The seedlings produced by the germination experiments (N = 136), between 1 and 2 cm (15 to 29 days after the end of the germination experiments), were transplanted into plastic bags (10 × 14 cm) with two types of substrate (Figure 2): substrate 1 (3 parts underground red latosol, 1 part washed medium sand, 1 part tanned cattle manure, 4 kg of NPK fertilizer (4-14-8) and 4 kg of dolomitic limestone) and substrate 2 (4 commercial substrates, Terral brand, for pots (turf, manure, simple superphosphate and limestone), 1 part washed medium sand and 1 part vermiculite). The seedlings were placed in a greenhouse with artificial ventilation and sprinkler irrigation (2.1 mm/m^2 once a day at 9 am) for 12 weeks. Then, the plants were transplanted into plastic pots (17 × 21 cm) and moved to a screened vegetation house with irrigation activated twice a day for 5 min.

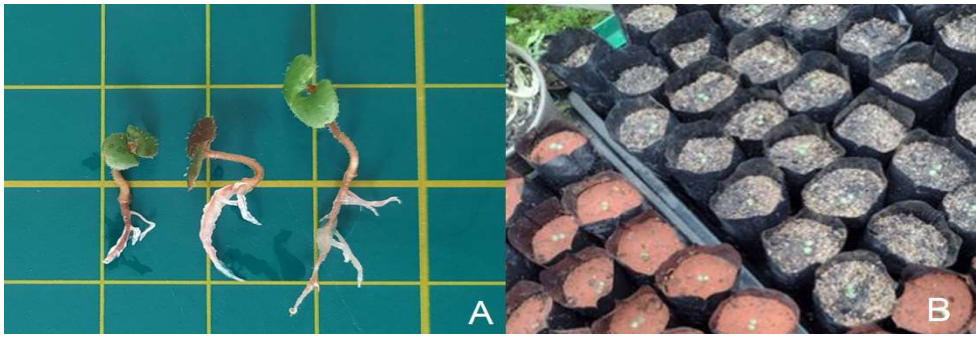

Figure 2. (**A**). *Cuphea pulchra* seedling type: phanero-epigeal-foliaceous seedling. (**B**). Seedlings in planted in red latosol (left) and commercial garden soil (right).

Pruning treatments were carried out to avoid excessive vertical growth, stimulate lateral branching, and structure the desired architecture for the potted plant. Twenty-eight plants were maintained as controls without pruning. The pruning regime (Table 2) consisted of apical pruning with removal of three to four pairs of leaves from the apex of the plant and drastic pruning, preserving only one to two branches at the base. For five and a half months, the height and diameter of the plants were measured every 40 days before pruning with a tape measure and a caliper, respectively. The individuals that had undergone apical pruning were not measured on the third and fourth measurements.

Table 2. Pruning regime carried out on plants of *Cuphea pulchra* Moricand (Lythraceae) growing in the greenhouse.

Weeks after Planting	Type of Pruning	Number of Individuals
15	Apical	10
26	Drastic	7
40	Drastic	19
63	Drastic	26
-	-	28 (control)

2.3.2. Cultivation from Cuttings

Cultivation was also carried out through cuttings from plants in natural vegetation and plants grown in a greenhouse. The cuttings were taken from adult plants (ADP) with woody stems, from the same natural vegetation from which the seeds were collected, and from juvenile plants (JDP) produced from germinated seeds in the laboratory and grown in the greenhouse, as presented in Table 3. The cuttings were taken from the apical and median portion of the stem from bezel cuts initiated in the region before a node, keeping a pair of leaves, and subsequently sealed with paraffin.

Table 3. Propagative material of *Cuphea pulchra* Moricand (Lythraceae) acquired for vegetative propagation tests. ADP = adult donor plants; JDP = juvenile donor plants.

Origin of Cuttings	Date of Acquisition	Age of Donor Plant (Stem Diameter)	Collected Cuttings and Sizes	Number of Cuttings
ADP collected in the field	August 2022	5–8 years (2.5–4 cm)	apical and median portions of ~27 cm	40
JDP cuttings collected in a greenhouse	November 2022	1 year (~0.5 cm)	apical and median portions of ~14 cm	21

For shipping to the laboratory in Brasilia, Federal District, the cuttings from Bahia were wrapped in damp newspaper, placed in a plastic bag, and sent by express mail. At the laboratory, the ends were once again cut into bevels, sealed, and the cuttings were placed in the substrates four days after collection. The cuttings collected from individuals grown in the greenhouse were used immediately after removal from the donor plant.

All cuttings were disinfected by immersing 2 cm of the basal parts in a 0.5% sodium hypochlorite solution for 10 min and then washing them with running water for 5 min. Three treatments were applied to test cultivation through cuttings: a control group without treatment, and immersion in an Indole-3-Butyric Acid (IBA) solution at two different concentrations (1000 and 3000 mg/L) for seven seconds each (Table 4).

Table 4. Treatments applied for cultivation of *Cuphea pulchra* Moricand (Lythraceae) through cuttings in a greenhouse.

Origin	IBA Concentration 1000 mg/L	IBA Concentration 3000 mg/L	Control
ADP cuttings	13	13	14
JDP cuttings	7	7	7

All cuttings were placed in plastic bags (10 × 14 cm) with a substrate of 70% washed medium sand and 30% commercial substrate, Terral brand (containing turf, manure, simple superphosphate, and limestone). The material was kept in a screened greenhouse with irrigation programmed 6 times a day, every 4 h, lasting 3 min each time (1.83 MM). Humidity was maintained at 70 to 100%, and the maximum and minimum day-night temperatures were 30 ± 1 and 25 ± 1 °C, respectively. Data records and evaluations were collected for the parameters of presence of rooting and number of days for leaf sprouting.

2.3.3. Field Capacity Testing, Chemical and Physical Analysis of Soils

Field capacity testing was carried out to determine how much water each type of soil can retain. For the test, 100 mL of each soil was placed in funnels covered internally with filter paper. The funnels were positioned to be supported by graduated cylinders, and 100 mL of water was added. After one hour, the amount of water retained in the soil and the amount collected by the test tube were checked.

To compare the two substrates used to grow the plants, samples of 250 g of each soil were sent to the company Terra Análises para Agropecuária Ltda., in Goiânia, Brazil. (https://www.laboratorioterra.com.br/, accessed on 12 September 2023) for chemical and physical analysis. None of the substrates had been previously fertilized. The elements analyzed were phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), aluminum (Al), hydrogen (H), pH, cation exchange capacity, base saturation, organic matter, and soil particle size.

2.4. Statistical Analysis

The statistical tests were carried out using the free software R, version 4.1.0 (2021). The logistic regression test was used to compare the germination percentage of the treatments, carried out using [16]. As there was no germination in the category of green seeds pretreated with Promalin, it was disregarded. ANOVA was used to compare the average germination time.

To assess the proportion of plant mortality in relation to the type of soil (red latosol or commercial garden soil), a t-test was carried out on the difference in the proportion of surviving plants 120 days after planting the seeds.

To assess plant height and diameter in relation to the type of soil (red latosol or commercial garden soil), a t-test was carried out on the difference in height and diameter observed at three different times: 40, 80, and 120 days after planting the seeds.

To evaluate the sprouting results obtained in the cutting experiments, the hourly time series of temperature and relative humidity (RH) from two periods were checked. The

data were obtained during the interval from the 1st to the 2nd cutting tests and during the 2nd cutting test (the interval between the 1st and the 2nd cuttings lasted from 15 October 2022 to 15 November 2022, and the 2nd cutting lasted from 16 November 2022 to 31 December 2022).

3. Results and Discussion

3.1. Seed Germination and Seedling Types

C. pulchra seeds are illustrated with the funiculus and micropyle oriented at the proximal end and the chalaza at the distal end of the seed (Figure 3). The seeds measure 2.1–3 × 2–2.9 mm and are oboval to suborbicular with obtuse margins [17]. As in all species of the genus, the seed coat has two layers of thick-walled sclerenchymatous cells, and the cells of the exotesta have internal hairs in the epidermal cells of the seed coat. These hairs swell upon contact with water and evaginate from the cell to cover the entire seed with helical mucilaginous threads [18].

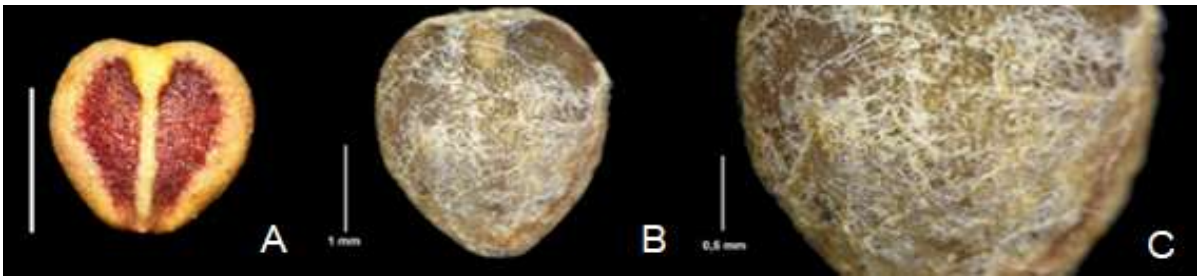

Figure 3. *Cuphea pulchra* seeds. (**A**). Mature seed. (**B**). Seed soaked in water after the protrusion of the mucilaginous hairs before germination. (**C**). Detail of seed with mucilaginous hairs.

A high percentage of *C. pulchra* seeds were empty: 93 ± 9 of those that were ripe, 30 ± 7% of those that were almost ripe and 65 ± 8% of those that were green. This is relevant information to guide collection actions, so the percentage of seeds without germination potential must be considered when calculating the total number of collected seeds that will be needed for cultivation.

The seeds that were at the full stage of maturity did not germinate, while the green or almost ripe seeds germinated easily within a week of testing and lasted for two weeks. The germination and vigor of *Cuphea* mature seeds are generally low, and some studies indicate that the mucilaginous threads of the exotesta act as a barrier to the movement of oxygen, making germination slower [19].

Although *Cuphea* species are known to present dormancy [20,21] as a strategy to avoid germination in the dry season, delaying this process until the rainy season [22,23], this research showed that the green and almost ripe seeds of *C. pulchra* had non-dormant seeds and were able to germinate at alternating temperatures and photoperiods (Figure 4, Table 5). The highest percentage of germination occurred in the almost ripe seeds and there was no germination in the mature seeds category. As most of the mature seeds were without embryos, it was not possible to conclude that the seeds in this category were dormant. The seeds of *C. pulchra* presented phanero-epigeal-foliaceous seedlings [15] (Figure 2).

The germination pattern of seeds from the two maturation categories and those that germinated in different substrates was similar (Figure 4), except for seeds treated with Promalin, whose germination did not occur. However, for those seeds, fungi were observed in the Petri dish. Phytotoxins isolated from various genera of fungi showed an inhibitory effect on seed germination and root growth of parasitic plant species in experiments using germination inducers [24], which could be a possible cause of inhibition of germination of the *C. pulchra* seeds treated with Promalin.

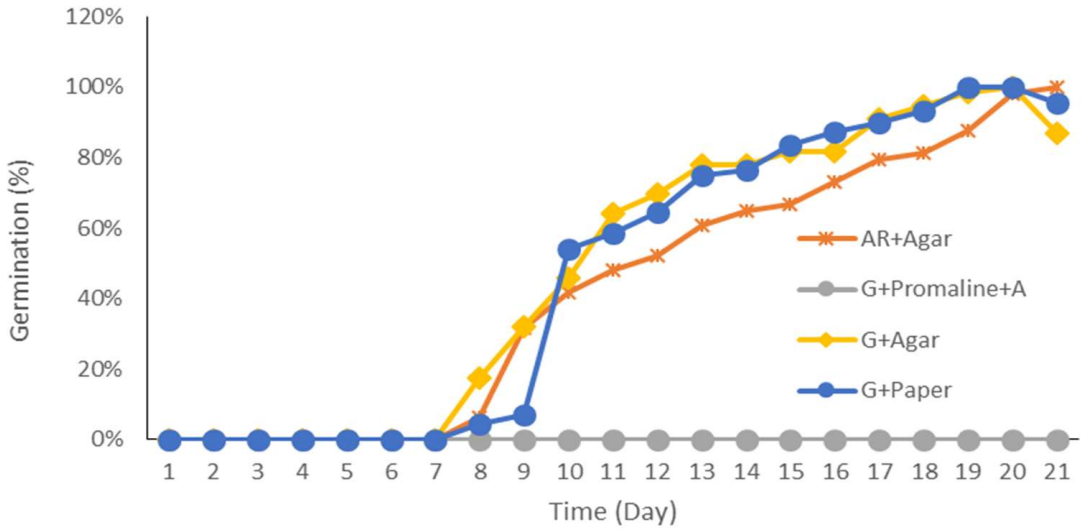

Figure 4. The time distribution (percentage) of cumulative germination in *Cuphea pulchra*. All experiments were conducted at alternating temperatures of 30 °C (8 h light)/20 °C (16 h dark). Seeds from two stages of maturation were used: almost ripe (AR) and green (G). Two pre-treatments were used: control (no treatment) and Promalin. The seeds were germinated in agar (A) or filter paper (Paper).

Table 5. *Cuphea pulchra* germination (%) according to the stage of maturation, pre-treatment, and germination substrate.

Stages Maturity	Pre-Treatment	Subst.	No. Seeds with Germination Potential	Germin. (%)	Germin. Time (h) *	Variance in Germination Time
Ripe	-	Agar	1	0% ^{a}	-	-
Almost ripe	-	Agar	63	77 ± 5 ^{a}	290 ^{d}	10592 ^{f}
Green	-	Filter paper	88	74 ± 8 ^{a}	266 ^{d}	4799 ^{e}
Green	-	Agar	68	68 ± 21 ^{a}	256 ^{d}	6262 $^{e\,f}$
Green	Promalin	Agar	56	0 ± 0 $^{b\,c}$	-	-

Different letters indicate significant differences. F* = 8.653 com p = 0.0099.

The seeds began to germinate a week after the experiment started (Figure 4). Almost all ripe seeds germinated in agar (77 ± 5%) had a higher germination percentage than the green seeds germinated on paper (74 ± 8%) and on agar (68 ± 21%), but there was no significant difference between them (Table 5). The green seeds germinated faster than the almost ripe seeds, but this difference was not significant (Table 5).

The variance in germination time was slightly greater in the almost ripe seeds when compared to the green seeds (Table 5). The tetrazolium test revealed that most seeds from all maturity stages, treatments, and substrates that did not germinate were without viability.

3.2. Plant Development in the Screened Greenhouse

3.2.1. Cutting Tests

The cutting experiments were conducted with cuttings taken from 5 to 8-year-old adult donor plants (ADP) and 1-year-old juvenile donor plants (JDP) (Table 3). The ADP and JDP cuttings were planted four days after being harvested and on the same day, respectively.

In the first cutting experiment, carried out with ADP cuttings, almost all the cuttings treated with IBA and the control cuttings dried out 53 days after the experiment was set

up. The percentage of individuals that sprouted leaves and persisted was 5%: one control cutting and one treated with AIB at 1000 mg/l. The temperature and relative humidity were monitored after the end of the first cutting test and every hour for 30 days.

The age of the mother plant proved to be an important factor for the cuttings' behavior in cultivation. In the JDP test, the rate of sprouting and root development was considerably higher than in the ADP test. Added to this is the difference in the planting time after collection, with immediate planting and the more favorable temperature and humidity conditions in the JDP test. The effect of maturation and aging of donor plants has been reported to influence the performance of rooted cuttings, such that a general decline in the rooting capacity and quality of nursery-grown plants is observed, as well as a reduction in survival, associated with donor plants that have reached a state of reproductive maturity [25].

The second cutting experiment was set up with JDP cuttings and, after planting the cuttings, the temperature and relative humidity were monitored every hour for 45 days.

At the end of the second cutting test, at 70 days, four control cuttings and four cuttings treated with AIB at 1000 mg/l had sprouted leaves and developed roots. This represented 38% of the cuttings with persistent sprouting, which did not dry out during the cutting test.

In between tests, of the 762 records, 8.5% had temperatures higher than 32 °C. The highest temperature was 39.9 °C and the lowest 10.1 °C. As for relative humidity, 34% of the records were lower than 70%, and the average relative humidity for the period was 76%.

In the second cutting test of the 1104 records, 3.4% had temperatures higher than 32 °C. The highest temperature was 37.8 °C and the lowest 14.5 °C. As for relative humidity, 32% of the records were lower than 70%, and the average relative humidity for the period was 79%.

C. pulchra showed tolerant behavior to high temperatures, similar to the conditions in the Caatinga and Cerrado environments, where wild populations live, in full sun. Under greenhouse growing conditions, the plants did not stunt despite lower light levels. The optimum temperature range for cultivation was from 20–30 °C, with faster development and greater production. Although the plants come from dry environments, they grew well at 77% relative humidity.

For *C. pulchra* cuttings, young, less lignified plants are more suitable for collecting branches, indicating that the age of the plant interferes with this type of approach, already evidenced in other cutting experiments with other species, where cuttings taken from juvenile individuals exhibited significantly higher rooting percentages than those taken from adult individuals [13,26]. Other conditions for the greater success of the second cuttings may have been the speed with which the cuttings were planted; unlike in the first test, with cuttings received from Bahia, in the second test, the cuttings were immediately planted. These results guide sustainable exploration efforts for this species, with the cultivation of seedlings from young plants kept in a nursery being a better strategy than field collection. This approach speeds up and makes the seedling production process cheaper, eliminating the need for collection.

3.2.2. Development Monitoring

The plants from seed germination had measurements taken every 40 days with n = 4 different times (t_0 = 40 days, t_1 = 80 days, t_2 = 120 days, and t_3 = 160 days). Three t-tests were applied to compare the average height of the plants grown in the two different substrates. According to the 95% confidence interval, there is 95% confidence that the true average height difference at 40 days is between 2.57 cm and 5.57 cm; at 80 days it is between 5.59 cm and 11.42 cm; and at 120 days between 4 cm and 18.21 cm. The average height of the plants in red latosol was greater compared to the plants in commercial garden soil. Thus, the differences in average plant height in the different substrates were statistically significant (Table 6).

Table 6. Results of three *t*-tests comparing the difference in average height.

Treatment	Height Difference between Substrates (cm)	CI 95% Height Difference	t-Statistic (g.lib)	*p*-Value	*p*-Value (Bonferroni)
40 days	−4.07 (*)	[−5.57; −2;57]	−5.3764 (104.21)	<0.0000	0
80 days	−8.51 (*)	[−11.42; −5;59]	−5.5771 (116.55)	<0.0000	0
120 days	−11.11 (*)	[−18.21; −4;00]	−3.3781 (12.995)	0.004949	0.01487

(*) Significant *t*-test at 5% level.

The average diameter difference was also compared using three *t*-tests. The tests showed that the differences in the average diameter of the plants grown in the different substrates were statistically significant. The red latosol, on average, provides the largest plant diameter.

The period in which there was the greatest difference in average height and diameter development between the plants grown in the different substrates was 120 days. In red latosol, the average height was 37.44 cm, and the average diameter was 2.99 mm. In commercial garden soil, the average height was 36.91 cm, and the average diameter was 2.92 mm (Table 7).

Table 7. Results of the three *t*-tests comparing the difference in average diameter.

Treatment	Diameter Difference between Substrates (cm)	CI 95% Diameter Difference	t-Statistic (g.lib)	*p*-Value	*p*-Value (Bonferroni)
40 days	−0.29 (*)	[−0.36; −0.21]	−7.6653 (94.08)	<0.0000	0
80 days	−0.48 (*)	[−0.66; −0,30]	−5.3122 (114.74)	<0.0000	0
120 days	−0.60 (*)	[−1.03; −0.17]	−2.9682 (14.74)	0.009951	0.29853

(*) Significant *t*-test at 5% level.

When comparing all the parameters analyzed for the two substrates, the commercial garden soil brought greater benefits to the *C. pulchra* plants compared to the red latosol. Despite the better development, there was a low proportion of surviving plants in red latosol. A difference test of proportion was carried out on surviving plants at 120 days of cultivation.

A high mortality rate was observed for plants from seed germination grown in red latosol, with the number of individuals decreasing over time, with one surviving at 160 days (Table 8; Figure 5). This may have occurred because latosol has low fertility, acidity, and high aluminum content, which, when in excess, is toxic to plants [27].

The difference test for the proportion of surviving plants in the two types of substrates (Table 9) showed that there was a high proportion of plant mortality in red latosol at 120 days. A priori, the proportion of surviving plants in the commercial garden soil was significantly higher than the proportion of surviving plants in the red latosol. The test was significant, and the Agresti–Caffo 95% CI indicates a 95% confidence that the true difference in survival rate at 120 days is between 47.70% and 75.41%. In other words, a *C. pulchra* plant grown in commercial garden soil is expected to have between 47.70% and 75.41% more probability of survival at 120 days of cultivation.

Table 8. Mortality of *Cuphea pulchra* Moricand individuals grown in a greenhouse over 160 days, categorized by substrates.

N° of Plants	40 Days		80 Days		120 Days		160 Days	
	Red Latosol	Commercial Soil	Red Latosol	Commercial Soil	Red Latosol	Commercial Soil	Red Latosol	Commercial Soil
122	55	67	-	-	-	-	-	-
120	-	-	53	67	-	-	-	-
67	-	-	-	-	11	57	-	-
52	-	-	-	-	-	-	1	51

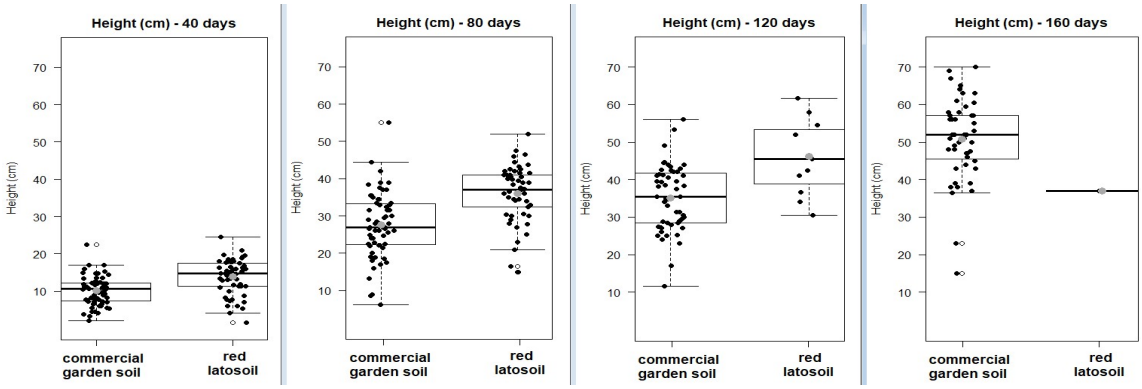

Figure 5. Boxplot of the height of plants that survived in commercial garden soil and red latosol at 40, 80, 120, and 160 days.

Table 9. Difference test for the proportion of surviving plants at 120 days. Substrate 1—red latosol; substrate 2—commercial garden soil.

Comparison	Survival Difference	Z_0	*p*-Value	CI 95% Agrestti–Caffo
Substrate 1 and 2	0.6358 (*)	7.0229	<0.0000	[0.4770; 0.7541]

(*) Test was significant at 5% level.

3.3. Substrate Analysis

A field capacity test was performed to determine water retention for each soil type. The commercial garden soil showed a retention of 28 mL, while the red latosol showed a retention of 20 mL, indicating a lower water retention capacity, which may have been one of the causes of the high mortality of plants in this substrate.

The physical and chemical analyses of the substrates (Table 10) indicated that, in terms of pH, the red latosol presented high acidity, indicative of the presence of exchangeable aluminum; a high amount of Ca, which can cause chlorosis; a high percentage of base saturation, which can be harmful to plants. When considering the bases alone, the levels of Ca, Mg, and K did not fit into the ideal range. Furthermore, there was a high content of P, the excess of which can reduce the availability of copper, iron, and zinc, reducing productivity [28]. The commercial garden soil had medium acidity and adequate levels of Ca, Mg, P, being more suitable for the cultivation of *C. pulchra*.

Table 10. Physical and chemical composition of soils used in the cultivation of *C. pulchra* in the greenhouse.

Nutrients	Red Latosol	Commercial Garden Soil
pH ($CaCl_2$)	4.7 un.	5.0 un.
Ca	8 cmolc/dm^3	5.7 cmolc/dm^3
Mg	1 cmolc/dm^3	1.3 cmolc/dm^3
Ca/Mg	8	4.4
Al	0.0	0.0
H + Al	1.6 cmolc/dm^3	3.6 cmolc/dm^3
K	0.532 cmolc/dm^3	0.317 cmolc/dm^3
CEC	11.13 cmolc/dm^3	10.92 cmolc/dm^3
V%	86%	67%
Ca/CEC	72.1%	52.3%
Mg/CEC	9%	11.9%
K/CEC	4.8%	2.9%
H+Al/CEC	14.4%	33%
P (Mehlich I)	80 mg/dm^3	18 mg/dm^3
MOS	23 g/kg	27 g/kg
Clay	23%	23%
Silt	6%	6%
Sand	71%	Sand
Fine sand	19%	25%
Coarse sand	81%	75%

After achieving the desired structure, the final substrate was applied, a mixture composed of 25% tile or brick shards, 25% pine bark, and 50% fertilized topsoil. The shards ensure good drainage and aeration of the substrate, while the topsoil helps retain water and assists in plant nutrition. The pine bark prevents soil compaction and provides acidity to the substrate, which is important for plants that thrive in more acidified soils, as is the case with *C. pulchra* [8].

3.4. Flowering

The occurrence of flowering in *C. pulchra* plants was recorded after 15 weeks of cultivation in red latosol and 23 weeks of cultivation in commercial garden soil, and it started in all pots synchronously, without fertilizer application. The duration of the flowering period was recorded weekly, and the flowering stage was considered from the beginning of the formation of flower buds and the end of flowering, until the flowers were bright and fresh. The flowering period varied from 12 to 44 weeks (Table 11), and flowering was vigorous and dense throughout the flowering period (Figure 6).

Table 11. Flowering period of *Cuphea pulchra* Moricand (Lythraceae) plants grown in the greenhouse, counted in weeks.

Start of Flowering	No. of the Pots	Duration of Flowering
ten months after planting	16	37 weeks
twelve months after planting	17	12 weeks
twelve months after planting	58	22 weeks
nine months after planting	13	44 weeks
nine months after planting	19	36 weeks
nine months after planting	40	36 weeks
eleven months after planting	4	13 weeks
eleven months after planting	22	27 weeks
eleven months after planting	50	18 weeks

Figure 6. *Cuphea pulchra* with vigorous flowering in the greenhouse.

In addition to the morphological attributes, aspects of the physiology of the species are suitable for the use of the species as a pot plant, such as the durability of the flowers, maintenance of consistency, and color.

3.5. Pruning

The pruning strategy was used to reduce the typical height of *C. pulchra* individuals (Figures 1A and 7B,C), which in nature can reach up to 2 m in height. Apical pruning was not efficient in generating compact and branched plants, desirable characteristics in floriculture for potted plants (Figure 7A). One of the causes may have been the time of 15 weeks after planting, expected to carry out the first apical pruning, which perhaps should have been performed much earlier.

Figure 7. *Cuphea pulchra* Moricand (Lythraceae) plants grown in the greenhouse. (**A**) Plants that underwent late apical pruning. (**B**,**C**) Control plants grown inside (**B**) and outside (**C**) the greenhouse. (**D**–**F**) Plants five months after management by drastic pruning of branches, showing an increase in basal branching and miniaturization of the plant.

The plants adapted well to growing in pots and to the drastic pruning regime aimed at increasing branching, compaction, and miniaturization of the plants, which resulted in a small and densely branched structure. After 17 months, the plants remained alive in small pots with a low soil volume (Figure 7D–F). The miniaturization of plants did not prevent the formation of terminal and multi-flowered inflorescences. The plants flowered between 15 and 52 weeks after planting and kept their flowers fresh for up to 10 months.

3.6. Could C. pulchra Be Another Invasive Plant?

It is known that ornamental horticulture constitutes an important route for the introduction of exotic species to different regions [29], and studies increasingly suggest that climate change may favor the invasion of many ornamental species [30]. Although *C. pulchra* is a species that, if cultivated, could escape cultivation and spread to new areas, this does not appear to be a threat. It is a species whose geographic distribution is confined to areas that reflect the species' adaptation to environmental regimes, specific conditions characterized by prolonged drought conditions and sandy-stony soils found in the savannah, the Caatinga, and rocky fields. Therefore, this species has a low free-transport capacity in natural environments.

As with many new crops, some obstacles must be overcome before a wild plant can become an important industrial crop. A good measure for *Cuphea* would be selection studies for improvements in targeting varieties that retain the seeds in the fruit.

The production of *C. pulchra* for ornamental purposes had greater viability in the commercial garden soil, with a low mortality rate and good development, even though the flowering of plants in that soil occurred 8 weeks after those grown in red latosol. Growing in pots proved to be advantageous for the species, which adapted well to the regime of drastic pruning. Indeed, pruning produced satisfactory results by promoting branching, shaping the plants, and generating many shoots in the region of the nodes, thus developing the desired architecture for cultivation as an ornamental plant. *C. pulchra* stood out in terms of the length of the flowering period, which lasted up to ten months, producing flowers of remarkable beauty. The beauty, viability, and hardiness of *C. pulchra* indicate that this species has great potential to be incorporated into the ornamental flowering plant market.

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