








Articles

Thermotherapy on seed quality of *Myracrodruon urundeuva*

Termoterapia na qualidade de sementes de *Myracrodruon urundeuva*

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ABSTRACT

The low quality of seeds and irrational exploitation have contributed to the endangerment of several forest species, such as aroeira-do-sertão (*Myracrodruon urundeuva* Allemão). Since no agrochemicals are registered for the treatment of forest tree seeds, the use of alternative methods is essential. One such method is thermotherapy, which is effective in controlling seed-borne pathogens. This study aimed to evaluate the effectiveness of thermotherapy on the sanitary and physiological quality of aroeira-do-sertão seeds. Seeds were collected from matrices trees in the municipality of Sousa, Paraíba (Brazil), and subjected to the following treatments: dicarboximide fungicide; moist heat at 40°C and 50°C for 5, 10, 15, and 20 minutes; and a control group. The sanitary and physiological qualities of the treated seeds were assessed. The experimental design was completely randomized in a 3×10 factorial scheme (matrices trees × ten treatments). The thermal treatment at 50°C proved to be a promising disease management strategy for *M. urundeuva* seeds, effectively controlling *Alternaria* sp. Thermotherapy at 50°C for 5 minutes did not impair the physiological quality of aroeira seeds and can be considered a sustainable alternative for producing high-vigor seedlings.

Keywords: Aroeira-do-sertão; Seed pathology; Thermal treatment

RESUMO

A baixa qualidade das sementes e a exploração irracional contribuem para a extinção de algumas espécies florestais, como a aroeira-do-sertão (*Myracrodruon urundeuva* Allemão). Por não existir registro de agrotóxicos para o tratamento de sementes de espécies florestais o uso de métodos alternativos é essencial, a exemplo da termoterapia, método eficiente no controle de agentes patogênicos em sementes. Assim, a pesquisa teve como objetivo determinar a eficiência da termoterapia sobre a qualidade sanitária e fisiológica de sementes de aroeira-do-sertão. As sementes foram coletadas de três árvores matrizes no município de Sousa-PB e submetidas aos tratamentos: fungicida dicarboximida, à 40 e 50°C por 5, 10, 15 e 20 minutos de imersão e a testemunha. Avaliou-se a qualidade sanitária e fisiológica das sementes tratadas. O experimento foi em delineamento experimental inteiramente ao acaso, em esquema fatorial 3×10 (3 matrizes por 10 tratamentos). O tratamento térmico a 50°C mostrou-se promissor como estratégia de manejo de doenças em sementes de *M. urundeuva*, sendo eficiente no controle de *Alternaria* sp. A termoterapia a 50°C por 5 minutos não compromete a qualidade fisiológica das sementes de aroeira e pode ser utilizada como alternativa sustentável para a produção de mudas de alto vigor.

Palavras-chave: Aroeira-do-sertão; Patologia de sementes; Tratamento térmico

1 INTRODUCTION

Commonly known as "aroeira" or "aroeira-do-sertão," *Myracrodruon urundeuva* is a species of the Anacardiaceae family. Among native species, it stands out for its wide distribution in the Caatinga biome (Freitas *et al.*, 2022). In traditional medicine, several pharmacological properties have been attributed to this species (Souza *et al.*, 2022).

Maintaining the biological diversity of the Caatinga is particularly challenging, as it is one of the least conserved biomes in Brazil and faces ongoing environmental degradation (Buarque; Santos, 2023). In this context, *M. urundeuva* emerges as a promising species for reforestation, offering social, economic, and environmental benefits (Araújo *et al.*, 2018). Its management is essential, and there is a growing demand for its seeds to restore forests and regenerate degraded areas (Parisi *et al.*, 2019).

Seeds can carry pathogenic agents that affect germination and seedling establishment, making the use of healthy seeds crucial to prevent the spread of these pathogens (Saldanha *et al.*, 2020). Studies indicate that chemical, physical, and biological control methods can be applied. Among them, thermoherapy has proven particularly effective, as it eliminates infections without harming the environment (Nobrega; Nascimento, 2020).

Thermotherapy is a physical method that is easy to apply, requiring only a heat source, which may be dry or moist. To optimize its efficacy, it is essential to determine the appropriate temperature and exposure duration for each species (Meganes *et al.*, 2020). In moist heat treatment, water acts as the heat conductor, placing the seeds in direct contact with it and thereby enhancing pathogen eradication (Boucher *et al.*, 2013).

From this perspective, this study aimed to evaluate the effects of thermotherapy on the sanitary and physiological quality of *Myracrodruon urundeuva* seeds, with a view toward seedling production for reforestation purposes.

2 MATERIALS AND METHODS

The experiment was conducted at the Phytopathology Laboratory (LAFIT) of the Center for Agricultural Sciences (CCA) at the Federal University of Paraíba (UFPB), Campus II – Areia, Paraíba.

Seeds were collected from *Myracrodruon urundeuva* mother trees located in the municipality of Sousa, Paraíba (06°45'33" S, 38°13'41" W, at an altitude of 225 m). Three mother trees were selected based on the presence of abundant inflorescences, well-developed canopies, and healthy phytosanitary appearance. Fruits were harvested using a pruning pole. After collection, the diaspores were taken to the Phytopathology Laboratory, where the seeds were extracted by gently shaking the fruits manually, using a 40 cm medium-grit sand sieve.

Seed disinfestation was performed using a 1% sodium hypochlorite solution for 3 minutes, followed by triple rinsing with sterilized distilled water (SDW). Thermal treatment consisted of immersing the seeds in SDW preheated to predetermined temperatures, where they remained submerged. Seeds were placed in perforated fine-mesh bags and immersed in a water bath under the following treatments: T1 – Control; T2 – Dicarboximide fungicide (240 g/100 kg of seeds); T3 – 40°C for 5 minutes; T4 – 40°C for 10 minutes; T5 – 40°C for 15 minutes; T6 – 40°C for 20 minutes; T7 – 50°C for 5 minutes; T8 – 50°C for 10 minutes; T9 – 50°C for 15 minutes; and T10 – 50°C for 20 minutes.

After treatment, seeds were incubated in 9-cm diameter Petri dishes containing a double layer of sterilized filter paper moistened with SDW. The plates were maintained for seven days at $25 \pm 2^\circ\text{C}$ under a 12-hour photoperiod. Fungal identification was conducted using an optical microscope and specialized literature (Seifert *et al.*, 2011), and results were expressed as the percentage of fungal occurrence.

For the germination test, seeds were disinfested in a 1% sodium hypochlorite solution for 3 minutes, followed by triple rinsing with sterilized distilled water (SDW), and then subjected to the previously described treatments. The seeds were placed in a *Biochemical Oxygen Demand* (B.O.D.) chamber at 25°C under a 12-hour photoperiod.

The test consisted of four replicates of 25 seeds each, using *Germitest*[®] paper roll substrate moistened with SDW in an amount equivalent to 2.5 times the dry weight of the paper. Results were expressed as the percentage of normal seedlings (Brasil, 2009).

For the germination speed index, daily counts were performed from the emergence of the first seedling until the 10th day, when the seedling count stabilized (Pacheco *et al.*, 2006). The index was calculated using the equation proposed by Maguire (1962).

The percentage of dead seeds included those that, by the end of the germination test, remained moist, had a soft appearance, or were infected by microorganisms, showing purulent secretions. Hard seeds were defined as those that had not absorbed water and remained firm (Brasil, 2009). Seeds that produced any part of a seedling but did not develop normally were classified as abnormal seedlings.

At the end of the germination test, the length of normal seedlings from each replicate was measured using a ruler graduated in centimeters, and results were expressed as the average seedling length in centimeters.

Seedling dry mass was determined by placing normal seedlings from each replicate in Kraft paper bags and drying them in an oven at 65°C for 48 hours. The dried material was weighed on an analytical balance with a precision of 0.001 g, and results were expressed in grams per seedling.

The experimental design was completely randomized in a 3×10 factorial arrangement, with three matrices and ten treatments. The seed health test comprised ten replicates of ten seeds per treatment, while the germination test involved four replicates of 25 seeds per treatment.

Statistical analysis was performed using R[®] software (R Core Team, 2019). Data were subjected to analysis of variance, and treatment means were compared using the Scott-Knott test at a 5% significance level. Fungal incidence data were previously transformed using the expression $(\sqrt{x + 1})$, as described by Bartlett (1947).

3 RESULTS AND DISCUSSIONS

Table 1 presents the incidence of storage fungi associated with *Myracrodruon urundeuva* seeds, namely: *Aspergillus niger*, *Aspergillus* sp., and *Penicillium* sp.

With regard to the incidence of *A. niger*, seeds treated with fungicide showed the lowest incidence values, significantly differing from all other treatments (Table 1).

For *Aspergillus* sp., no significant interaction was observed between the factors evaluated; however, significant isolated effects were noted for both treatments and mother trees. Mother Tree 1 exhibited the lowest incidence, along with the chemical treatment, when compared to the other treatments (Table 1).

In the case of *Penicillium* sp., no significant differences among treatments were observed for Mother Tree 1 (Table 1). In contrast, for Mother Tree 2, thermal treatments at 50°C for both immersion times significantly increased fungal incidence compared to the other treatments. A similar trend was observed in Mother Tree 3 for the treatment at 40°C for 20 minutes and at 50°C for all immersion times.

High temperatures can damage both internal and external seed tissues, facilitating the entry of storage fungi, particularly *Aspergillus* and *Penicillium*, which are known to cause seed deterioration when present (Saldanha *et al.*, 2020).

Table 1 – Incidence of storage fungi in *Myracrodruon urundeuva* seeds treated with moist heat thermotherapy

Treatments	Matriz 1	Matriz 2	Matriz 3	Mean
<i>Aspergillus niger</i> (%)				
T1: Control	58,0 bB	63,0 aB	79,0 aA	66,7
T2: Fungicide	8,0 cA	6,0 bA	5,0 bA	6,3
T3: 40°C/5 min.	65,0 bA	58,0 aA	71,0 aA	64,7
T4: 40°C/10 min.	87,0 aA	71,0 aB	60,0 aB	72,7
T5: 40°C/15 min.	81,0 aA	67,0 aA	75,0 aA	74,3
T6: 40°C/20 min.	60,0 bA	72,0 aA	73,0 aA	68,3
T7: 50°C/5 min.	61,0 bA	67,0 aA	75,0 aA	67,7
T8: 50°C/10 min.	68,0 bA	72,0 aA	78,0 aA	72,7
T9: 5°C/15 min.	70,0 bA	78,0 aA	72,0 aA	73,3
T10: 50 °C/20 min.	77,0 aA	67,0 aA	71,0 aA	71,7
Mean	63,5	62,1	65,9	
CV (%)	10,19			
<i>Aspergillus</i> sp. (%)				
T1: Control	35,0	39,0	55,0	43,0 a
T2: Fungicide	2,0	6,0	3,0	3,7 b
T3: 40°C/5 min.	42,0	50,0	52,0	48,0 a
T4: 40°C/10 min.	48,0	41,0	51,0	46,7 a
T5: 40°C/15 min.	45,0	47,0	51,0	47,7 a
T6: 40°C/20 min.	35,0	50,0	47,0	44,0 a
T7: 50°C/5 min.	34,0	45,0	38,0	39,0 a
T8: 50°C/10 min.	43,0	52,0	58,0	51,0 a
T9: 50°C/15 min.	42,0	59,0	44,0	48,3 a
T10: 50°C/20 min.	46,0	58,0	50,0	51,3 a
Mean	37,2 B	44,7 A	44,9 A	
CV (%)	17,72			
<i>Penicillium</i> sp. (%)				
T1: Control	2,0 aA	1,0 bA	2,0 bA	1,7
T2: Fungicide	0,0 aA	1,0 bA	0,0 bA	0,3
T3: 40°C/5 min.	2,0 aA	0,0 bA	0,0 bA	0,7
T4: 40°C/10 min.	1,0 aA	2,0 bA	2,0 bA	1,7
T5: 40°C/15 min.	1,0 aA	0,0 bA	2,0 bA	1,0
T6: 40°C/20 min.	0,0 aA	2,0 bA	6,0 aA	2,7
T7: 50°C/5 min.	0,0 aB	1,0 bB	9,0 aA	3,3
T8: 50°C/10 min.	5,0 aA	9,0 aA	4,0 aA	6,0
T9: 50°C/15 min.	0,0 aB	10,0 aA	2,0 bB	4,0
T10: 50°C/20 min.	0,0 aA	1,0 bA	0,0 bA	0,3
Mean	1,1	2,7	2,7	
CV (%)	19,41			

Source: Authors (2025)

In where: Means followed by the same lowercase letter in columns and uppercase letter in rows do not differ significantly according to the Scott-Knott test ($p \leq 0.05$); Data transformed using $\sqrt{x + 1}$; CV: Coefficient of variation; T1: Control (sterilized distilled water – SDW); T2: Captan (240 g per 100 kg of seeds).

With regard to the incidence *Alternaria* sp., no significant interaction was observed between the factors studied. However, an isolated treatment effect was detected, where thermotherapy at both 40°C and 50°C for all immersion times significantly reduced pathogen incidence compared to the control (Table 2).

The high incidence of storage fungi observed in this study may have inhibited the development of other fungal species typically associated with infection during earlier stages of the plant's life cycle. *Alternaria* spp. species are known to impair the physiological quality of seeds due to their predominantly seed-borne transmission. These pathogens can negatively affect seedling development and, in more severe cases, cause seed rot. (Soomro *et al.*, 2020).

Regarding the incidence of *Rhizopus* sp., thermal treatments starting at 40 °C for 15 minutes in Mother Tree 1 and 40°C for 20 minutes in Mother Tree 3 resulted in significantly higher values compared to the other treatments. In contrast, for Mother Tree 2, only the fungicide treatment proved effective when compared to the remaining treatments (Table 2).

Rhizopus sp. is capable of infecting both stored and non-stored seeds, and its main symptoms include seed rot and seed coat discoloration (Santos *et al.*, 2021).

For *Botrytis* sp., none of the thermal treatments were effective (Table 2). However, exposure to 50°C for 15 minutes in Mother Tree 1 and 40°C for 5 minutes in Mother Tree 3 favored pathogen development, with values significantly higher than those observed under other treatments. Seeds infected with *Botrytis* sp. typically show impaired performance due to the appearance of foliar spots on forest tree seedlings. These spots are whitish, initially isolated, and lack superficial sporulation. *Botrytis* is a saprophytic genus that colonizes dead tissues but can also reproduce and spread in healthy tissues (Marcuzzo; Riscarolli, 2018).

Table 2 – Fungal incidence in *Myracrodruon urundeuva* seeds treated with moist heat thermotherapy

Treatments	Matriz 1	Matriz 2	Matriz 3	Mean
<i>Alternaria</i> sp. (%)				
T1: Control	2,0	2,0	2,0	2,0 a
T2: Fungicide	0,0	0,0	0,0	0,0 b
T3: 40°C/5 min.	1,0	0,0	0,0	0,3 b
T4: 40°C/10 min.	0,0	0,0	0,0	0,0 b
T5: 40°C/15 min.	0,0	1,0	0,0	0,3 b
T6: 40°C/20 min.	0,0	0,0	0,0	0,0 b
T7: 50°C/5 min.	0,0	0,0	0,0	0,0 b
T8: 50°C/10 min.	0,0	0,0	0,0	0,0 b
T9: 50°C/15 min.	0,0	0,0	0,0	0,0 b
T10: 50°C/20 min.	0,0	0,0	0,0	0,0 b
Mean	0,3 A	0,3 A	0,2 A	
CV (%)	7,98			
<i>Rhizopus</i> sp. (%)				
T1: Control	5,0 bB	36,0 aA	35,0 bA	25,3
T2: Fungicide	1,0 bA	3,0 bA	4,0 cA	2,7
T3: 40°C/5 min.	12,0 bB	49,0 aA	44,0 bA	35,0
T4: 40°C/10 min.	9,0 bB	49,0 aA	35,0 bA	31,0
T5: 40°C/15 min.	29,0 aB	52,0 aA	32,0 bB	37,7
T6: 40°C/20 min.	37,0 aA	50,0 aA	55,0 aA	47,3
T7: 50°C/5 min.	27,0 aB	54,0 aA	59,0 aA	46,7
T8: 50°C/10 min.	23,0 aB	49,0 aA	50,0 aA	40,7
T9: 50°C/15 min.	25,0 aC	40,0 aB	59,0 aA	41,3
T10: 50°C/20 min.	25,0 aA	40,0 aA	40,0 bA	35,0
Mean	19,3	42,2	41,3	
CV (%)	19,98			
<i>Botrytis</i> sp. (%)				
T1: Control	0,0 bA	0,0 aA	3,0 bA	1,0
T2: Fungicide	0,0 bA	0,0 aA	0,0 bA	0,0
T3: 40°C/5 min.	0,0 bB	0,0 aB	12,0 aA	4,0
T4: 40°C/10 min.	0,0 bA	0,0 aA	4,0 bA	1,3
T5: 40°C/15 min.	0,0 bA	0,0 aA	1,0 bA	0,3
T6: 40°C/20 min.	0,0 bA	0,0 aA	4,0 bA	1,3
T7: 50°C/5 min.	0,0 bA	0,0 aA	1,0 bA	0,3
T8: 50°C/10 min.	0,0 bA	0,0 aA	3,0 bA	1,0
T9: 50°C/15 min.	9,0 aA	0,0 aB	2,0 bB	3,7
T10: 50°C/20 min.	2,0 bA	6,0 aA	2,0 bA	3,3
Mean	1,1	0,6	3,2	
CV (%)	18,13			

Source: Authors (2025)

In where: Means followed by the same lowercase letter in columns and uppercase letter in rows do not differ significantly according to the Scott-Knott test ($p \leq 0.05$); Data transformed using $\sqrt{x + 1}$; CV: Coefficient of variation; T1: Control (sterilized distilled water – SDW); T2: Captan (240 g per 100 kg of seeds).

For germination percentage (G) and percentage of dead seeds (DS), no significant interaction was observed between the evaluated factors, but a significant isolated effect was found for mother trees. Mother Tree 1 exhibited the highest germination percentage and, consequently, the lowest seed mortality (Table 3). Guedes *et al.* (2011), when evaluating optimal temperatures for *Myracrodruon urundeuva*, reported germination rates below 60%, highlighting the physiological variability of the species, as seed production is closely linked to environmental conditions.

The application of high temperatures during thermotherapy—such as treatments at 50°C—may have caused denaturation of external tissues and even deterioration of reserve tissues, impairing embryo nutrition and leading to seed death in Mother Trees 2 and 3 (Cardoso *et al.*, 2020; Nunes *et al.*, 2025).

With regard to the germination speed index (GSI), a significant interaction was observed between the factors studied (Table 3). In Mother Tree 1, the highest GSI values were recorded at 40°C for 5, 10, and 15 minutes and at 50°C for 5, 10, and 20 minutes; however, these did not differ statistically from the control. A similar pattern was observed in Mother Tree 2 at 50°C for 5, 10, and 15 minutes, which differed significantly from the other treatments. In Mother Tree 3, no statistically significant differences were observed among treatments.

The GSI values recorded in this study were higher than those reported in previous research. This superiority is likely due to seeds exposure to water at elevated temperatures, which rapidly increased their moisture content, stimulated respiration, and consequently enhanced the germination rate (Silva *et al.*, 2021).

Overall, thermotherapy did not compromise seed viability, suggesting that this species may possess inherent resistance to oxidative stress or contains significant levels of antioxidants that mitigated the negative effects of the heat treatment (Lamichaney *et al.*, 2021).

Table 3 – Germination (G), germination speed index (GSI), and percentage of dead seeds (DS) of *Myracrodruon urundeuva* seeds subjected to moist heat thermotherapy

Treatments	Matriz 1	Matriz 2	Matriz 3	Mean
G (%)				
T1: Control	66	48	48	54,0 a
T2: Fungicide	60	63	55	59,3 a
T3: 40°C/5 min.	63	54	49	55,3 a
T4: 40°C/10 min.	65	54	54	57,7 a
T5: 40°C/15 min.	70	45	48	54,3 a
T6: 40°C/20 min.	50	44	49	47,7 a
T7: 50°C/5 min.	60	63	62	61,7 a
T8: 50°C/10 min.	64	60	52	58,7 a
T9: 50°C/15 min.	54	66	51	57,0 a
T10: 50°C/20 min.	69	48	53	56,7 a
Mean	62,1 A	54,5 B	52,1 B	
CV (%)	18,51			
GSI				
T1: Control	24,4 aA	16,5 bB	16,5 aB	19,1
T2: Fungicide	20,0 bA	19,4 bA	16,1 aA	18,5
T3: 40°C/5 min.	22,8 aA	18,1 bB	16,5 aB	19,1
T4: 40°C/10 min.	24,4 aA	17,6 bB	19,8 aB	20,6
T5: 40°C/15 min.	25,7 aA	16,0 bB	16,5 aB	19,4
T6: 40°C/20 min.	17,8 bA	13,9 bA	16,5 aA	16,1
T7: 50°C/5 min.	22,3 aA	23,1 aA	21,4 aA	22,3
T8: 50°C/10 min.	22,5 aA	21,3 aA	18,8 aA	20,9
T9: 50°C/15 min.	18,5 bA	23,7 aA	18,0 aA	20,1
T10: 50°C/20 min.	24,9 aA	16,7 bB	19,0 aB	20,2
Mean	22,3	18,6	17,9	
CV (%)	18,58			
DS (%)				
T1: Control	8,5	13,0	13,0	11,5 a
T2: Fungicide	11,0	9,3	11,3	10,5 a
T3: 40°C/5 min.	9,3	11,5	12,8	11,2 a
T4: 40°C/10 min.	8,8	11,5	11,5	10,6 a
T5: 40°C/15 min.	7,5	13,8	13,0	11,4 a
T6: 40°C/20 min.	12,5	14,0	12,8	13,1 a
T7: 50°C/5 min.	10,0	9,3	9,5	9,6 a
T8: 50°C/10 min.	9,0	10,0	12,0	10,3 a
T9: 50°C/15 min.	11,5	8,5	12,3	10,8 a
T10: 50°C/20 min.	7,8	13,0	11,8	10,9 a
Mean	9,6 B	11,4 A	12,0 A	
CV (%)	23,94			

Source: Authors (2025)

In where: Means followed by the same lowercase letter in columns and uppercase letter in rows do not differ significantly according to the Scott-Knott test ($p \leq 0.05$); Data transformed using $\sqrt{x + 1}$; CV: Coefficient of variation; T1: Control (sterilized distilled water – SDW); T2: Captan (240 g per 100 kg of seeds).

With regard to shoot length (SL) and root length (RL), a significant interaction between the studied factors was also observed (Table 4). Heat treatments at 40 and 50°C for all immersion times promoted an increase in SL in Mother Tree 1 compared to the control. A similar response was observed in Mother Tree 2 at 40°C for 5 and 15 minutes. In Mother Tree 3, increased SL was recorded at 40°C for 10, 15, and 20 minutes, and at 50°C for 20 minutes; however, these did not differ statistically from the control.

For root length (RL) in Mother Tree 1, all thermal treatments—except for 40°C for 10 minutes—produced superior results compared to the control. A similar pattern was observed in Mother Tree 2 at 40°C for 5, 10, and 15 minutes and at 50°C for 10 and 15 minutes, with statistically significant differences from the other treatments. In Mother Tree 3, the same trend was noted at 40°C for 10 and 20 minutes and at 50°C for 5 and 15 minutes of immersion.

The low mortality rate and the increase in shoot and root length may be related to seed vigor. When seeds are well nourished during maturation, they tend to exhibit greater tolerance to temperature variability, due to higher reserves and increased levels of antioxidant compounds (Vieira *et al.*, 2019).

Shoot and root lengths are closely linked to the seed's reserves. The greater the reserves, the faster the metabolic processes, promoting quicker and more uniform emergence of the primary root and a higher growth rate (Pádua *et al.*, 2010).

For shoot dry mass (SDM), no significant interaction was found; however, isolated effects of treatments and plants were observed (Table 5). Mother Tree 1 exhibited the highest SDM content. Nevertheless, exposure to 50°C from 10 minutes onward impaired seedling development, resulting in lower values compared to other treatments.

Table 4 – Shoot length (SL) and root length (RL) of *Myracrodruon urundeuva* seedlings subjected to thermotherapy via moist heat

Treatments	Matriz 1	Matriz 2	Matriz 3	Mean
SL (cm. seedling ⁻¹)				
T1: Control	1,39 cB	2,07 bA	2,18 aA	1,88
T2: Fungicide	2,65 aA	2,17 bB	1,74 bC	2,19
T3: 40°C/5 min.	2,47 aA	2,64 aA	1,86 bB	2,32
T4: 40°C/10 min.	2,46 aA	2,29 bA	2,20 aA	2,32
T5: 40°C/15 min.	2,32 aA	2,39 aA	2,24 aA	2,32
T6: 40°C/20 min.	2,25 aA	2,24 bA	2,23 aA	2,24
T7: 50°C/5 min.	2,30 aA	2,20 bA	1,87 bB	2,12
T8: 50°C/10 min.	2,25 aA	2,15 bA	1,68 bB	2,03
T9: 50°C/15 min.	1,91 bB	2,19 bA	1,69 bB	1,93
T10: 50°C/20 min.	2,02 bA	1,50 cB	2,04 aA	1,85
Mean	2,20	2,18	1,97	
CV (%)	23,22			
RL (cm. seedling ⁻¹)				
T1: Control	0,91 bB	1,98 cA	2,36 bA	1,75
T2: Fungicide	1,98 aB	1,20 dC	2,65 bA	1,94
T3: 40°C/5 min.	2,52 aB	3,20 aA	2,08 bB	2,60
T4: 40°C/10 min.	1,40 bB	2,50 bA	2,94 aA	2,28
T5: 40°C/15 min.	2,51 aB	3,35 aA	2,62 bB	2,83
T6: 40°C/20 min.	2,56 aB	2,14 cB	3,05 aA	2,58
T7: 50°C/5 min.	2,79 aA	1,48 dB	2,98 aA	2,42
T8: 50°C/10 min.	2,36 aA	2,55 bA	2,49 bA	2,47
T9: 50°C/15 min.	2,47 aB	2,49 bB	3,21 aA	2,72
T10: 50°C/20 min.	2,73 aA	1,93 cB	2,28 bB	2,31
Mean	2,22	2,28	2,67	
CV (%)	34,56			

Source: Authors (2025)

In where: Means followed by the same lowercase letter in columns and uppercase letter in rows do not differ significantly according to the Scott-Knott test ($p \leq 0.05$); Data transformed using $\sqrt{x + 1}$; CV: Coefficient of variation; T1: Control (sterilized distilled water – SDW); T2: Captan (240 g per 100 kg of seeds).

Table 5 - Shoot dry mass (SDM) and root dry mass (RDM) of *Myracrodruon urundeuva* seedlings subjected to thermotherapy via moist heat

Treatments	Matriz 1	Matriz 2	Matriz 3	Mean
SDM (g. seedling ⁻¹)				
T1: Control	0,0112	0,0094	0,0104	0,0103 a
T2: Fungicide	0,0119	0,0102	0,0110	0,0110 a
T3: 40°C/5 min.	0,0114	0,0088	0,0107	0,0103 a
T4: 40°C/10 min.	0,0120	0,0098	0,0100	0,0106 a
T5: 40°C/15 min.	0,0124	0,0095	0,0102	0,0107 a
T6: 40°C/20 min.	0,0113	0,0092	0,0122	0,0109 a
T7: 50°C/5 min.	0,0105	0,0082	0,0111	0,0099 a
T8: 50°C/10 min.	0,0108	0,0081	0,0079	0,0089 b
T9: 50°C/15 min.	0,0078	0,0092	0,0082	0,0084 b
T10: 50°C/20 min.	0,0109	0,0082	0,0086	0,0092 b
Mean	0,0110 A	0,0091 C	0,0100 B	
CV (%)	16,18			
RDM (g. seedling ⁻¹)				
T1: Control	0,0008 cC	0,0014 bB	0,0031 aA	0,0018
T2: Fungicide	0,0020 aA	0,0014 bC	0,0034 aA	0,0023
T3: 40°C/5 min.	0,0021 aB	0,0023 aB	0,0030 aA	0,0025
T4: 40°C/10 min.	0,0015 bC	0,0025 aB	0,0036 aA	0,0025
T5: 40°C/15 min.	0,0022 aB	0,0025 aB	0,0034 aA	0,0027
T6: 40°C/20 min.	0,0021 aB	0,0018 bB	0,0036 aA	0,0025
T7: 50°C/5 min.	0,0022 aA	0,0019 bA	0,0023 bA	0,0021
T8: 50°C/10 min.	0,0022 aA	0,0024 aA	0,0021 bA	0,0022
T9: 50°C/15 min.	0,0018 aB	0,0027 aA	0,0021 bB	0,0022
T10: 50°C/20 min.	0,0021 aA	0,0023 aA	0,0016 cB	0,0020
Mean	0,0019	0,0021	0,0028	
CV (%)	16,08			

Source: Authors (2025)

In where: Means followed by the same lowercase letter in columns and uppercase letter in rows do not differ significantly according to the Scott-Knott test ($p \leq 0.05$); Data transformed using $\sqrt{x + 1}$; CV: Coefficient of variation; T1: Control (sterilized distilled water – SDW); T2: Captan (240 g per 100 kg of seeds).

For root dry mass (RDM) in Mother Tree 1, heat treatments at 40 and 50°C for all immersion durations resulted in the best outcomes compared to the control (Table 5). A similar response was observed in Mother Tree 2 at 40°C for 5, 10, and 15 minutes, and at 50°C from 10 minutes onward. In Mother Tree 3, the 40°C treatment—regardless of exposure time—led to a higher RDM, although the results did not differ statistically from the control.

Dry mass accumulation is directly influenced by the phenotypic and environmental characteristics of the mother plant. During the early stages of seedling development, growth and dry matter accumulation are slower, with shoot development playing a more decisive role in dry mass accumulation (Santos *et al.*, 2018).

The *aroeira* plants responded differently to thermal treatments. Mother Tree 1 outperformed Mother Trees 2 and 3, demonstrating greater resilience to the applied conditions. This performance was likely influenced by the higher seed vigor, as evidenced by larger seedlings and greater dry mass production. Therefore, seeds of this species with low vigor may have their physiological quality compromised when exposed to temperatures above 50°C.

5 CONCLUSIONS

Thermal treatment at 50°C proved to be a promising strategy for managing seed-borne diseases in *Myracrodruon urundeuva*, effectively controlling *Alternaria* sp.

Thermotherapy at 50°C for 5 minutes does not compromise the physiological quality of *aroeira* seeds and may serve as a sustainable alternative for the production of high-vigor seedlings.

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