Universidade Federal do Paraná
Setor de Ciências Agrárias
Pós-graduação em Engenharia Florestal
Revista Floresta

BIOACTIVE COMPOUNDS IN DIASPORES OF *Astronium urundeuva* (M.Allemão) Engl. FOR QUALITY MAINTENANCE DURING STORAGE

Ritielly Laiany Carvalho Senigalia[1*], Maria de Fátima Barbosa Coelho[2], Dagma Kratz[3], Elisangela Clarete Camili[4], Edila Cristina de Souza[5], Francival Cardoso Felix[6]

[1*]Universidade Federal de Mato Grosso, Programa de Pós-Graduação em Agricultura Tropical, Cuiabá, Mato Grosso, Brasil - ritiellycarvalho@gmail.com
[2]Universidade Federal de Mato Grosso, Programa de Pós-Graduação em Agricultura Tropical, Cuiabá, Mato Grosso, Brasil - e-mail: coelhomfstrela@gmail.com- coelhomfstrela@gmail.com
[3]Universidade Federal do Paraná, Programa de Pós-Graduação em Engenharia Florestal, Curitiba, Paraná, Brasil - kratzdagma@gmail.com
[4]Universidade Federal de Mato Grosso, Programa de Pós-Graduação em Agricultura Tropical, Cuiabá, Mato Grosso, Brasil - eccamili@hotmail.com
[5]Universidade Federal de Mato Grosso, Departamento de Estatística, Cuiabá, Mato Grosso, Brasil - edilacr@yahoo.com.br
[6]Universidade Federal do Paraná, Programa de Pós-Graduação em Engenharia Florestal, Curitiba, Paraná, Brasil - francival007@gmail.com

Received for publication: 03/03/2022 – Accepted for publication: 23/01/2023

Resumo

Compostos bioativos em diásporos de Astronium urundeuva (M.Allemão) Engl. para manutenção da qualidade durante o armazenamento. O sucesso da produção e comercialização de sementes depende de condições ideais para o armazenamento. Algumas espécies florestais apresentam problemas de conservação de sementes devido à alta incidência de fungos que reduzem a qualidade fisiológica. Assim, objetivou-se avaliar a efetividade da aplicação de compostos bioativos em diásporos de *Astronium urundeuva* (M.Allemão) Engl. (Anacardiaceae) para manutenção da qualidade fisiológica e redução da incidência de fungos durante o armazenamento. Para isso, organizou-se dois ensaios fatoriais: (i) aplicação de quatro óleos essenciais (canela, cravo, laranja e melaleuca) em cinco concentrações (0,00; 1,25; 2,50; 3,75 e 5,0 mL.kg^{-1}); e (ii) cinco extratos vegetais (cravo, canela, quina, alho e capim-limão) em cinco concentrações (0%, 25%, 50%, 75% e 100%). Os diásporos foram avaliados aos 0, 30, 60, 90, 120, 150 e 180 dias quanto à germinação, vigor de sementes e incidência fúngica. Os óleos essenciais de cravo (4,6 mL.kg^{-1}) e melaleuca (3,7 mL.kg^{-1}), e os extratos vegetais de cravo (71%) e capim-limão (73%) podem ser aplicados para manutenção da qualidade fisiológica e redução da incidência de fungos durante o armazenamento de diásporos de *A. urundeuva*. Além destes, os óleos essenciais de canela (3,8 mL.kg^{-1}) e laranja (4,0 mL.kg^{-1}), e os extratos vegetais de canela (72%) e quina (74%) podem ser utilizados como alternativa em substituição ao uso de fungicida sintético. Portanto, a aplicação de produtos à base de compostos bioativos naturais é uma alternativa ao uso de produtos químicos sintéticos no controle sanitário durante o armazenamento de sementes de aroeira.
Palavras-chave: aroeira, Anacardiaceae, extratos vegetais, óleos essenciais, sementes florestais.

Abstract

The success of seed production and marketing depends on ideal conditions for storage. Some forest species have seed conservation problems due to the high incidence of fungi that reduce physiological quality. Thus, the objective was to evaluate the effectiveness of the application of bioactive compounds in diaspores of *Astronium urundeuva* (M.Allemão) Engl. (Anacardiaceae) to maintain physiological quality and reduce the incidence of fungi during storage. For this, two factorial trials were set up: (i) application of four essential oils (cinnamon, clove, orange and melaleuca) at five concentrations (0.00, 1.25, 2.50, 3.75 and 5.0 mL.kg^{-1}); and (ii) five plant extracts (clove, cinnamon, quina, garlic and lemongrass) at five concentrations (0%, 25%, 50%, 75% and 100%). Diaspores were evaluated at 0, 30, 60, 90, 120, 150 and 180 days for germination, seed vigor and fungal incidence. The essential oils of clove (4.6 mL.kg^{-1}) and melaleuca (3.7 mL.kg^{-1}) and plant extracts of clove (71%) and lemongrass (73%) can be applied to maintain physiological quality and reduce the incidence of fungi during the storage of *A. urundeuva* diaspores. In addition to these, the essential oils of cinnamon (3.8 mL.kg^{-1}) and orange (4.0 mL.kg^{-1}) and plant extracts of cinnamon (72%) and quina (74%) can be used as an alternative to synthetic fungicide. Therefore, the application of products based on natural bioactive compounds is an alternative to the use of chemicals in sanitary control during the storage of *A. urundeuva* seeds.
Keywords: aroeira, Anacardiaceae, plant extracts, essential oils, forest seeds.

INTRODUCTION

The occurrence of pathogenic fungi in seeds can cause damage to germination due to deterioration, abnormalities, lesions in seedlings and disease transmission (COPPO *et al*., 2017; ARAÚJO *et al*., 2019; SENIGALIA *et al*., 2020). Some forest species have seed conservation problems due to the high incidence of fungi during storage that reduce physiological quality, which is a challenge for seed technologists and seedling producers.

Astronium urundeuva (M.Allemão) Engl. (Anacardiaceae) is a native species that stands out for its socioeconomic importance and pharmacological properties. It has wood of excellent quality, appreciated in civil construction and furniture sectors due to its resistance to termites and phytopathogenic fungi (SILVA *et al*., 2020), in addition to the physical, chemical and energy characteristics (SILVA *et al*., 2017). Among the phytochemical properties, it has analgesic, anti-inflammatory, antioxidant, antifungal and antibacterial properties due to the presence of alkaloids, flavonoids, polyphenols and tannins (CECÍLIO *et al*., 2016; GALVÃO *et al*., 2018). Given this aspect and the need for propagative material, the use of seeds and their storage for the production of seedlings or formation of germplasm banks become essentially important.

The inclusion of minimum sanitary standards for forest seeds aimed at controlling the quality of seeds and seedlings produced can be a strategic measure to hinder the introduction of diseases in new areas and dissemination of pathogens (VECHIATO; PARISI, 2013). Unlike seeds of commercialized cultivars, there is no record of fungicides recommended for the treatment of forest species (COIMBRA *et al*., 2014). Therefore, it is necessary to look for alternatives of control, and the use of bioactive compounds is one of the options (OLINTO *et al*., 2021).

Bioactive compounds from plants pose no risks to ecosystems and are an alternative to the use of synthetic chemicals (NMON; AJURU, 2020). The use of secondary compounds produced by plants, due to antifungal potential, is an alternative for pathogen control (KOUASSI *et al*., 2017; ARAÚJO *et al*., 2019; OLINTO *et al*., 2021), as they are economically viable and environmentally correct.

Thus, the objective was to evaluate the effectiveness of the application of bioactive compounds (essential oils and plant extracts) in diaspores of *A. urundeuva* for maintaining physiological quality and reducing the incidence of fungi during storage. As an interrogative hypothesis: does the application of bioactive compounds in seeds reduce the incidence of fungi and/or help maintain physiological quality during the storage of *A. urundeuva* diaspores?

MATERIAL AND METHODS

A. urundeuva fruits were collected in a Decidual Seasonal Forest remnant (15º22’17” S and 56º12’14” W), located in the Agropecuária Guia Forest Reserve, in Cuiabá, Mato Grosso state, Brazil. Twenty trees, equidistantly spaced 50 m apart, were selected based on the good phytosanitary conditions of the crown, and their branches were shaken with the aid of a ladder and a machete to obtain the fruits, which were collected from a tarpaulin placed on the soil.

The diaspores were processed by manual maceration of fruits and an electric blower was used to clean the material. Then, they were subjected to drying (25 ± 5 °C/ 7 days) and application of treatments. The experiment was set up in two completely randomized factorial trials: (i) application of four essential oils, five concentrations, and seven evaluation periods (4 x 5 x 7); and (ii) five plant extracts, five concentrations and seven evaluation periods (5 x 5 x 7).

The essential oils of clove (*Syzygium aromaticum* (L.) Merr. & L.M. Perry), cinnamon (*Cinnamomum verum* J. Presl), orange (*Citrus sinensis* (L.) Osbeck) and melaleuca (*Melaleuca alternifolia* (Maiden & Betche) Cheel) were commercially acquired (Hygia®) and prepared with a non-ionic surfactant that acts as detergent (Tween 20) to obtain concentrations of 0.00 (control), 1.25, 2.50, 3.75 and 5.0 $mL.kg^{-1}$. For each essential oil solution, the diaspores were immersed for 5 min.

Aqueous plant extracts were obtained from bulbs of garlic (*Allium sativum* L.), bark of cinnamon (*Cinnamomum verum* J. Presl), floral buds of clove (*Syzygium aromaticum* (L.) Merr. & L.M. Perry), bark of quina-do-cerrado (*Strychnos pseudoquina* A. St. Hil.) and dehydrated leaves of lemongrass (*Cymbopogon citratus* (DC.) Stapf). The aqueous extracts were prepared from 100 g of dry material crushed in a blender with 1 L of distilled water for 2 min (LESSA *et al*., 2017), obtaining the crude concentration that was filtered through cotton and filter paper. This extract was then used to obtain the concentrations of 0% (control), 25%, 50%, 75% and 100% by the method of dilution in distilled water. For each plant extract, the diaspores were kept in contact with the solution for 5 min.

After application of the treatments, the diaspores were subjected to drying on sterile paper towels (25 ± 5 °C/ 24 h). Subsequently, they were placed separately in ziplock aluminum packaging for each month of evaluation and stored in a refrigerator (6 ± 2 °C) for six months. As a positive control, the synthetic chemical fungicide Carboxin + Thiram was used at 2.5 $mL.kg^{-1}$. Diaspores were evaluated at 0, 30, 60, 90, 120, 150 and 180 days for germination (%), germination speed (GSI), seedling length (cm), electrical conductivity ($\mu S.cm^{-1}.g^{-1}$ diaspores) and fungal incidence (%).

For the germination test, four replicates of 50 diaspores were arranged on three sheets of paper towel moistened with distilled water using a volume corresponding to two and a half times the weight of the paper. Then, the leaves were arranged in rolls, placed in transparent plastic bags and kept in a germination chamber at 25 °C (BRASIL, 2009a) and under constant lighting for 5 days.

Germination percentage was evaluated on the fifth day after sowing (2 mm of the main root), and germination speed was calculated based on the daily record of the number of germinated seeds (MAGUIRE, 1962). Four replicates of 20 seedlings were used to evaluate hypocotyl and main root lengths. Electrical conductivity (EC) was evaluated with four replicates of 50 diaspores, which were weighed on an analytical scale and placed in plastic cups containing 75 mL of distilled water. The sets were left in germinator at 25 °C for 24 h, with reading of the leachates performed in a portable conductivity meter.

For the evaluation of fungal infection, blotter tests were prepared with four replicates of 25 diaspores, which were placed in transparent acrylic boxes filled with two sheets of sterile blotter paper moistened with water water-restriction solution (NaCl) at osmotic potential of -0.75 MPa (SENIGALIA *et al*., 2020). Incubation was performed in germinator (25 °C/ photoperiod of 12 h) for seven days (BRASIL, 2009b). Fungal incidence was evaluated with the aid of an optical light microscope, and the fungi were identified at the genus level based on morphological characteristics.

Based on the results of fungal incidence over the storage period, the area under the disease progress curve (AUDPC) (CAMPBELL; MADDEN, 1990), was calculated using the following equation:

$$AUDPC = \Sigma \left[\left(\frac{y\,1 + y\,2}{2} \right) * (t\,2 - t\,1) \right]$$

Where y1 and y2 are two consecutive evaluations performed at times t1 and t2, respectively.

The data of physiological quality, fungal incidence and AUDPC were subjected to analysis of variance (ANOVA) in factorial scheme for the two trials, independently. The means were compared by the Scott-Knott test at 5% probability level for the factor bioactive compounds (Factor 1). Together, regression analysis was performed for the effect of bioactive compounds on fungal incidence as a function of the concentrations used and the storage period, adopting the significant equations with the highest coefficient of determination (R^2). Statistical analyses were performed in the Assistat program, 7.7 beta version (UFCG/ PB) (SILVA; AZEVEDO, 2016).

RESULTS

The diaspores of *A. urundeuva* had moisture content of 10.8%, thousand-diaspore weight of 16.9 g and initial germination of 77%. Seed viability was maintained when the essential oils of cinnamon, clove, orange and melaleuca and the plant extracts of clove, cinnamon, quina and lemongrass were used (Table 1). However, the applications of essential oils and plant extracts affected the physiological quality of *A. urundeuva* diaspores stored for 180 days (Factor 1).

Table 1. Physiological quality of *Astronium urundeuva* (M.Allemão) Engl. after application of essential oils and plant extracts in diaspores and storage for 180 days.

Tabela 1. Qualidade fisiológica de *Astronium urundeuva* (M.Allemão) Engl. após aplicação de óleos essenciais e extratos vegetais em diásporos, e armazenados durante 180 dias.

Bioactive compounds	Germination (%)	GSI	Length (cm)		EC ($\mu S.cm^{-1}.g^{-1}$)
			hypocotyl	root	
Essential oils					
Control	77 a	6.31 a	2.07 a	2.41 a	402.4 a
Cinnamon	79 a	5.47 d	1.99 b	1.94 c	375.9 b
Clove	78 a	5.65 c	2.11 a	2.14 b	374.1 b
Orange	77 a	6.12 b	2.00 b	2.07 b	371.7 c
Melaleuca	78 a	6.12 b	2.10 a	2.12 b	364.8 d
Plant extracts					
Control	77 a	6.31 a	2.07 a	2.41 a	402.4 b
Clove	77 a	5.77 c	2.04 b	1.99 d	393.3 c
Cinnamon	77 a	5.96 b	2.04 b	2.15 b	386.2 d
Quina	79 a	5.65 c	2.10 a	2.08 c	401.6 b
Garlic	75 b	4.87 d	1.99 c	1.79 e	398.8 b
Lemongrass	78 a	5.61 c	1.99 c	1.97 d	412.2 a

Means followed by the same letter in the column are statistically equal by the Scott-Knott test at 5% probability level for the bioactive compounds factor (Factor 1). Electrical conductivity (EC), Germination speed index (GSI).

Médias seguidas da mesma letra na coluna são iguais estatisticamente pelo teste de Scott-Knott ao nível de 5% de probabilidade para o fator compostos bioativos (Fator 1). Condutividade elétrica (CE), Índice de velocidade de germinação (IVG).

The essential oil of melaleuca and the plant extract of cinnamon promoted maintenance of the physiological quality of *A. urundeuva* diaspores, while the essential oil of cinnamon and the vegetable extracts of garlic and lemongrass caused losses of vigor in the seeds during storage (Table 1). The results of lower physiological quality of diaspores during storage were evidenced by the higher values of electrical conductivity, lower germination speed, and lower length of root and hypocotyl of the seedlings.

The application of essential oils and plant extracts reduced the incidence of fungi in *A. urundeuva* diaspores stored for 180 days. The incidence of fungi in the absence of bioactive compounds was 25% (0.0 mL.kg^{-1} and 0%), while the application of essential oils at concentrations between 3.73 and 4.59 mL.kg^{-1} promoted a reduction in the total incidence of fungi to 11% and 12%, respectively, with the use of cinnamon (3.78 mL.kg^{-1}), clove (4.59 mL.kg^{-1}), orange (4.00 mL.kg^{-1}) and melaleuca (3.73 mL.kg^{-1}) oils (Figure 1A). For plant extracts, the application of concentrations between 71.2% and 84.9% reduced fungal incidence to 11% and 15%, respectively, with the extracts of clove (71.2%), cinnamon (72.1%), quina (74.5%), garlic (84.9%) and lemongrass (73.1%) (Figure 1B).

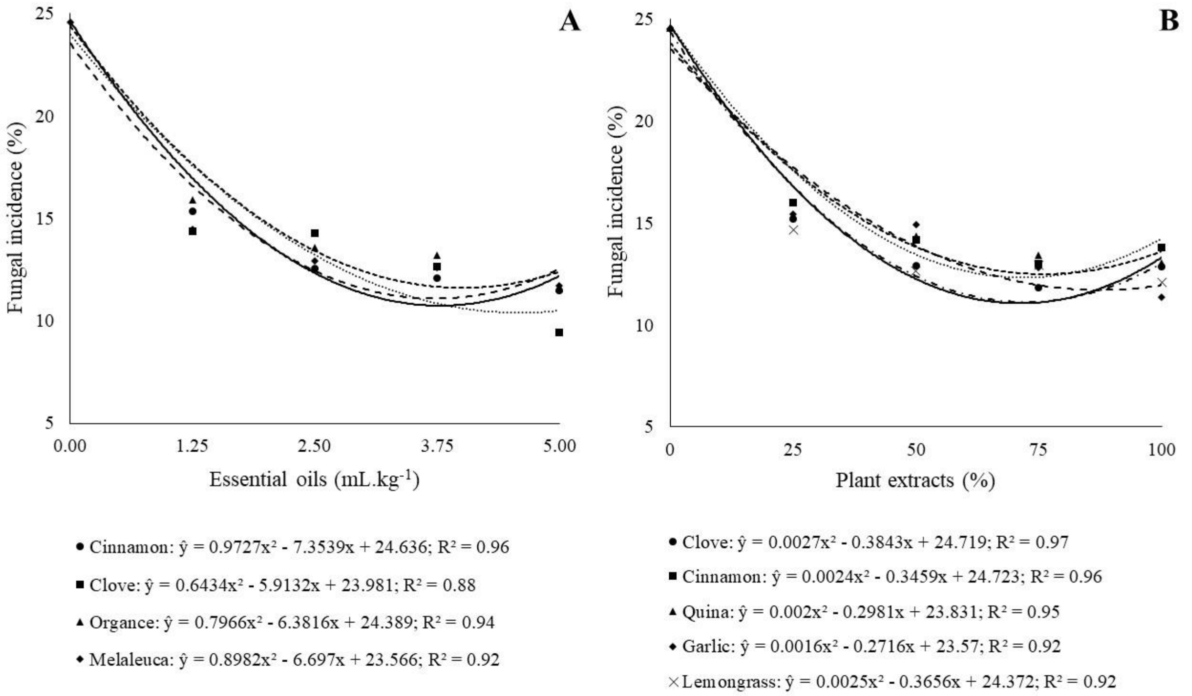

Figure 1. Incidence of fungi (%) after application of essential oils (A) and plant extracts (B) in diaspores of *Astronium urundeuva* (M.Allemão) Engl. and storage for 180 days.
Figura 1. Incidência de fungos (%) após aplicação de óleos essenciais (A) e extratos vegetais (B) em diásporos de *Astronium urundeuva* (M.Allemão) Engl. e armazenados durante 180 dias.

The incidence of fungi in *A. urundeuva* diaspores before storage was 30%. The application of essential oils and plant extracts reduced the percentage of fungi in the first month to values between 6% and 12% and between 11% and 14%, respectively. However, in the following months there was an increase in the incidence of fungi found in the seeds until reaching 17% to 19% with essential oils and 18% to 21% with plant extracts at 180 days of storage (Figures 2A and 2B).

Universidade Federal do Paraná
Setor de Ciências Agrárias
Pós-graduação em Engenharia Florestal
Revista Floresta

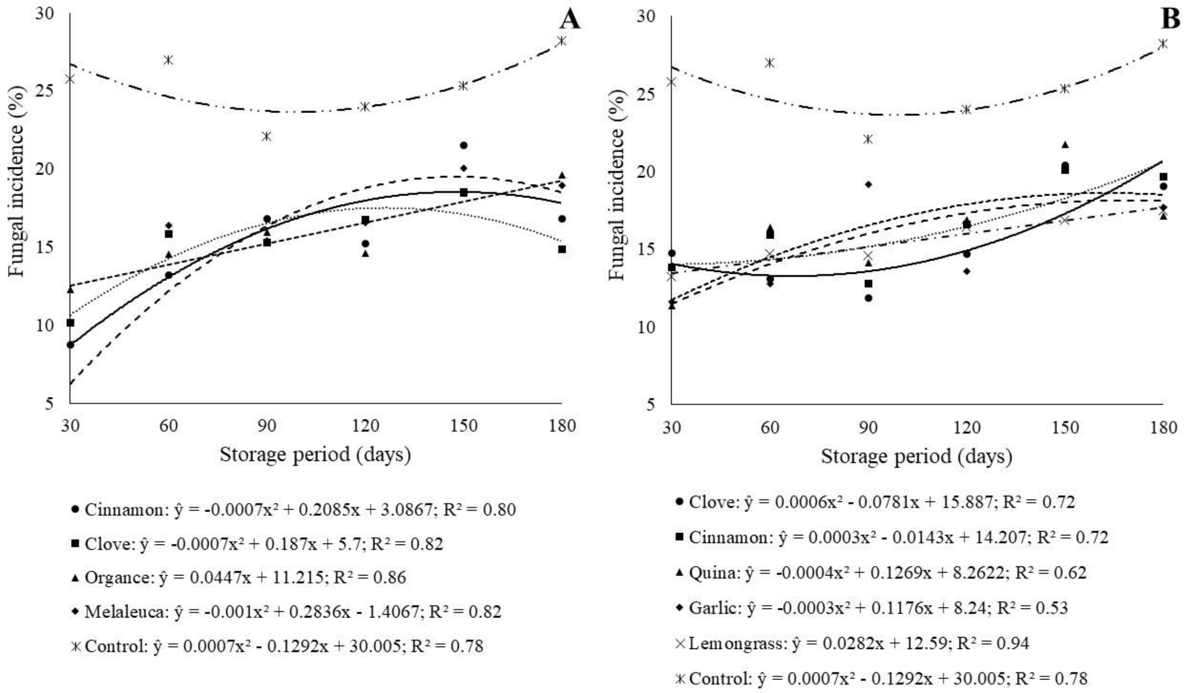

Figure 2. Incidence of fungi (%) after application of essential oils (A) and plant extracts (B) in diaspores of *Astronium urundeuva* (M.Allemão) Engl. during storage.
Figura 2. Incidência de fungos (%) após aplicação de óleos essenciais (A) e extratos vegetais (B) em diásporos de *Astronium urundeuva* (M.Allemão) Engl. durante o armazenamento.

The area under the disease progress curve (AUDPC) was affected by the application of bioactive compounds in *A. urundeuva* diaspores stored for 180 days. The application of essential oils of clove and melaleuca and plant extracts of clove, garlic and lemongrass promoted superior performance compared to the use of synthetic fungicide, leading to significant reduction compared to the control (Table 2). Cinnamon and orange oils and cinnamon and quina extracts performed similarly to the use of fungicide in controlling the advance in the occurrence of fungi in seeds of this species.

Table 2. Area under the disease progress curve (AUDPC) after application of essential oils and plant extracts in diaspores of *Astronium urundeuva* (M.Allemão) Engl. and storage for 180 days.
Tabela 2. Área abaixo da curva de progresso da doença (AACPD) após aplicação de óleos essenciais e extratos vegetais em diásporos de *Astronium urundeuva* (M.Allemão) Engl. e armazenados durante 180 dias.

Essential oils	AUDPC
Control	4,416.5 a
Synthetic fungicide	2,475.0 b
Cinnamon	2,491.7 b
Clove	2,136.7 c
Orange	2,571.7 b
Melaleuca	2,338.3 c
Plant extracts	
Control	4,416.5 a
Synthetic fungicide	2,475.0 b
Clove	2,296.9 c
Cinnamon	2,490.4 b
Quina	2,655.6 b
Garlic	2,144.6 c
Lemongrass	2,331.0 c

Means followed by the same letter in the column are statistically equal by the Scott-Knott test at 5% probability level for the bioactive compounds factor (Factor 1).
Médias seguidas da mesma letra na coluna são iguais estatisticamente pelo teste de Scott-Knott ao nível de 5% de probabilidade para o fator compostos bioativos (Fator 1).

In the initial evaluation in diaspores of *A. urundeuva*, 15 fungal genera were found: *Aspergillus* spp., *Alternaria* spp., *Bipolaris* spp., *Cercospora* spp., *Cladosporium* spp., *Curvularia* spp., *Fusarium* spp., *Mucor* spp., *Penicillium* spp., *Pestalotiopsis* spp., *Phoma* spp., *Phomopsis* spp., *Rhizopus* spp., *Peronospora* spp. and *Macrophomina* spp. The main genera found during storage were *Cladosporium* spp., *Alternaria* spp., *Pestalotia* spp., *Aspergillus* spp., *Cercospora* spp., *Penicillium* spp., *Curvularia* spp., *Fusarium* spp. and *Phomopsis* spp.

Essential oils and plant extracts acted differently on the fungi found in the seeds. The essential oils of melaleuca and cinnamon and the plant extracts of lemongrass, clove and quina promoted the highest reductions in the fungal genera evaluated (Table 3).

Table 3. Incidence of fungal genera after application of essential oils and plant extracts in diaspores of *Astronium urundeuva* (M.Allemão) Engl. and storage for 180 days.

Tabela 3. Incidência de gêneros fúngicos após aplicação de óleos essenciais e extratos vegetais em diásporos de *Astronium urundeuva* (M.Allemão) Engl. e armazenados durante 180 dias.

Bioactive compounds	Fungal genera								
	Cladosporium spp.	*Alternaria* spp.	*Pestalotia* spp.	*Aspergillus* spp.	*Cercospora* spp.	*Penicillium* spp.	*Curvularia* spp.	*Fusarium* spp.	*Phomopsis* spp.
Essential oils					(%)				
Control	96 a	11 a	6 c	20 a	53 a	23 a	6 a	31 a	3 c
Cinnamon	58 b	5 d	9 a	9 c	13 b	11 b	8 a	18 b	7 b
Clove	54 c	8 b	8 b	12 b	13 b	10 b	9 a	18 b	7 b
Orange	61 b	7 c	6 c	10 b	13 b	10 b	8 a	19 b	9 a
Melaleuca	61 b	6 c	6 c	12 b	14 b	11 b	8 a	14 c	5 c
Plant extracts					(%)				
Control	96 a	11 a	6 b	20 a	53 a	23 a	6 b	31 a	3 c
Clove	53 e	6 b	10 a	13 b	14 b	10 b	8 b	22 c	5 b
Cinnamon	62 c	6 b	9 a	11 c	13 b	11 b	8 b	21 c	7 a
Quina	66 b	6 b	9 a	11 c	10 c	11 b	6 b	20 c	7 a
Garlic	50 e	7 b	10 a	11 c	13 b	10 b	10 a	24 b	7 a
Lemongrass	57 d	5 c	11 a	10 c	13 b	11 b	7 b	20 c	5 b

Means followed by the same letter in the column are statistically equal by the Scott-Knott test at 5% probability level for the bioactive compounds factor (Factor 1).
Médias seguidas da mesma letra na coluna são iguais estatisticamente pelo teste de Scott-Knott ao nível de 5% de probabilidade para o fator compostos bioativos (Fator 1).

The different essential oils did not diverge in relation to *Cercospora* spp., *Penicillium* spp. and *Curvularia* spp., while the different plant extracts did not diverge in relation to *Pestalotia* spp. and *Penicillium* spp., with the genus *Cladosporium* spp. being the most incident in the diaspores, followed by *Fusarium* spp. (Table 3). As for the fungal genera, the pathogenicity and transmission of fungal diseases in forest species occurs heterogeneously, so pathogenicity can only be affirmed if Koch's postulates are applied and analysis of symptoms and signs is performed.

DISCUSSION

Bioactive compounds from plants act in different ways on fungal growth. Essential oils break through fungal membranes and cause the cellular content to leak, while plant extracts have secondary metabolites that act in different ways, such as alkaloids (cell wall rupture), tannins (inhibition of enzymes), terpenoids (membrane rupture), lectins (formation of disulfide bridges), flavonoids (enzymatic inactivation), coumarins (DNA interruption), polypeptides (formation of disulfide bridges), phenolic acids (enzymatic inactivation) and simple phenols (membrane disruption) (NMON; AJURU, 2020). For the use of a bioactive compound to be indicated, in case of seeds or diaspores, the supposed interference of the substance on physiological quality is mandatory. If there is a potential reduction in germination power, it cannot be used.

Depending on the concentration and on the seeds treated, there is a difference in allelopathic effects and alteration of the physiological quality of the seeds. The activity of different essential oils was evaluated and the essential oil of melaleuca (*M. alternifolia*) reduced the physiological quality of leucena (*Leucaena leucocephala* (Lam.) de Wit) seeds (OLINTO *et al.*, 2021). The higher the concentration of allelochemicals, the lower the germination and vigor levels of rice (*Oryza sativa* L.) seeds (KHATRI *et al.*, 2020). Different concentrations of cinnamon (*C. verum*) powder caused a linear decrease of approximately 22 to 15 mm (mean total length) between treatments 0.0, 0.13, 0.25, 0.50 and 1.00 g L^{-1}, with the lowest concentration of cinnamon (0.13 g L^{-1}) leading to the greatest development of *Catasentum x altaflorestense* Benelli & Grade seedlings (SIMIONI *et al.*, 2021). On the other hand, the extracts of turmeric (*Curcuma longa* L.) and rosemary (*Rosmarinus officinalis* L.) did not influence the germination of soybean seeds [*Glycine max* (L.) Merr.] (COPPO *et al*., 2017).

Although the essential oils and plant extracts tested have minimally affected the physiological quality of stored diaspores of *A. urundeuva*, the viability of the seeds was maintained, except for those treated with garlic (*A. sativum*) extract. The increase in the concentration of *A. sativum* extract reduced the physiological quality of *Chorisia glaziovii* O. Kuntze seeds (ARAÚJO *et al*., 2019), indicating a negative effect for seed storage and germination.

The incidence of fungi in the first months of storage and at the higher concentrations of essential oils and plant extracts was substantially reduced, which can be explained by the considerable presence of fungicide substances in natural extracts, such as flavonoids, phenolic compounds, tannins, among others (MACÊDO *et al*., 2020).

The eugenol present in clove (*S. aromaticum*) is responsible for causing changes in the cytoplasmic membrane, interruption of proton-motive force, electron flow, active transport, and coagulation of fungal cell content. This compound causes morphological alteration in vacuoles, disorganization of cell content and reduction of cell wall differentiation (COSTA *et al*., 2011).

The fungal reduction caused by the action of bioactive compounds was effective in this study, as well as in studies that highlighted the control of pathogenic fungi and saprophytes, with the use of compounds from lemongrass (*Cymbopogon citratus* (D.C.) Stapf.) (KOUASSI *et al*., 2017), cinnamon (*C. verum*) (YEOLE *et al*., 2014) and clove (*S. aromaticum*) (ABBASZADEH *et al*., 2014). Alves *et al*. (2019) evaluated the *in vitro* control of *Alternaria alternata* (Fr.:Fr.) Keissl. using different concentrations of melaleuca (*M. alternifolia*) oil and noticed that all treatments were effective in reducing mycelial growth. Plant extracts of turmeric (*C. longa*) and rosemary (*R. officinalis*) reduced the incidence of *Colletotrichum dematium* (Pers. Ex Fr.) Groove and *Fusarium* sp. in soybean seeds (COPPO *et al*., 2017).

Using bioactive compounds in *A. urundeuva* seeds is an alternative for species that have conservation problems due to the high incidence of fungi during storage. In this context, further studies with reapplication of the solutions indicated during storage can be explored in order to prolong the survival capacity of the seeds. In addition, testing these compounds in other species is an alternative to replace the use of synthetic fungicide or chemicals in seeds.

CONCLUSIONS

- The essential oils of clove (4.6 $mL.kg^{-1}$) and melaleuca (3.7 $mL.kg^{-1}$) and plant extracts of clove (71%) and lemongrass (73%) can be applied to maintain physiological quality and reduce the incidence of fungi during the storage of *A. urundeuva* diaspores.
- Essential oils of cinnamon (3.8 $mL.kg^{-1}$) and orange (4.0 $mL.kg^{-1}$) and plant extracts of cinnamon (72%) and quina (74%) can be used as an alternative to the use of synthetic fungicides.
- The application of products based on natural bioactive compounds is an alternative to the use of chemicals in the production and storage of *A. urundeuva* seeds.

ACKNOWLEDGEMENTS

The study was carried out with support from the Coordination for the Improvement of Higher Education Personnel - Brazil (CAPES) - Financing Code 001.

To the National Council for Scientific and Technological Development (CNPq) for granting scholarship and financial support to the sixth author.

REFERENCES

ABBASZADEH, S.; SHARIFZADEH, A.; SHOKRI, H.; KHOSRAVI, A. R.; ABBASZADEH, A. Antifungal efficacy of thymol, carvacrol, eugenol and menthol as alternative agents to control the growth of food-relevant fungi. **Journal de Mycologie Médicale**, Paris, v. 24, n. 2, p. 51-56, 2014.

ALVES, F. M. F.; FRANÇA, K. R. S.; ARAÚJO, I. G.; NÓBREGA, L. P.; XAVIER, A. L. S., LIMA, T. S., RODRIGUES, A. P. M. S., JÚNIOR, A. F. M., CARDOSO, T. A. L. Control of *Alternaria alternata* using melaleuca essential oil (*Melaleuca alternifolia*). **Journal of Experimental Agriculture International**, Tamil Nadu, v. 40, n. 3, p. 1-10, 2019.

ARAÚJO, A. K. O.; GOMES, R. S. S.; SILVA, M. L. M.; SANTOS, A. M. S.; NASCIMENTO, L. C. Sanitary and physiological quality of *Chorisia glaziovii* O. Kuntze seeds treated with plant extracts. **Ciência Florestal**, Santa Maria, v. 29, n. 2, p. 649-659, 2019.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. **Regras para análise de sementes**. Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Defesa Agropecuária. Brasília, Brasil: MAPA/ACS. 2009a, 395 p.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento. **Manual de análise sanitária de sementes**. Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Defesa Agropecuária. Brasília, Brasil: MAPA/ACS. 2009b, 200 p.

CAMPBELL, C. L., MADDEN, L. V. **Introduction to plant disease epidemiology**. New York, USA: John Wiley & Sons, 1990, 560 p.

CECÍLIO, A. B.; OLIVEIRA, P. C.; CALDAS, S.; CAMPANA, P. R. V.; FRANCISCO, F. L.; DUARTE, M. G. R.; MENDONÇA, L. A. M.; ALMEIDA, V. L. Antiviral activity of *Myracrodruon urundeuva* against rotavirus. **Revista Brasileira de Farmacognosia**, Seropédica, v. 26, n. 2, p.197-202, 2016.

COIMBRA, E. C.; VAZQUEZ, G. H.; NOGUEIRA, T. O. Breaking of dormancy and the fungicide use in teak fruits. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v.18, n.12, p.1281–1286, 2014.

COPPO, J. C.; MIORANZA, T. M.; COLTRO-RONCATO, S.; STARGALIN, J. R.; KUHN, O. J. SCHWAN-ESTRADA, K. R. F. Sanity and germination of soybean seeds treated with plants and fungi extracts. **Revista de Ciências Agroambientais**, Alta Floresta, v.15, n.2, p. 92-99, 2017.

COSTA, A. R. T.; AMARAL, M. F. Z. J.; MARTINS, P. M.; PAULA, J. A. M.; FIUZA, T. S.; TRESVENZOL, L. M. F.; PAULA, J. R.; BARA, M. T. F. Action of *Syzygium aromaticum* (L.) Merr. & L.M.Perry essential oil on the hyphae of some phytopathogenic fungi. **Revista Brasileira de Plantas Medicinais**, Botucatu, v. 13, n. 2, p. 240-245, 2011.

GALVÃO, W. R. A.; BRAZ FILHO, R.; CANUTO, K. M.; RIBEIRO, P. R. V.; CAMPOS, A. R.; MOREIRA, A. C. O. M.; SILVA, S. O.; MESQUITA FILHO, F A.; SANTOS, S. A. A. R.; MELO JUNIOR, J. M. A.; GONÇALVES, N. G. G.; FONSECA, S. G. C.; BANDEIRA, M. A. M. Gastroprotective and anti-inflammatory activities integrated to chemical composition of *Myracrodruon urundeuva* Allemão - a conservationist proposal for the species. **Journal of Ethnopharmacology**, Lausanne, v. 222, n. 1, p. 177–189, 2018.

KHATRI, K., KIRAN, B.; BHAWNA, N.; BARGALI, S.S. Germination and early seedling growth of two rice varieties as affected by invasive *Ageratina adenophora*. **Current Agriculture Research Journal**, Madhya Pradesh, v. 8, n.2, p. 108-117, 2020.

KOUASSI, E. K.; COULIBALY, I.; RODICA, P.; PINTEA, A.; OUATTARA, S.; ODAGIU, A. HPLC Phenolic compounds analysis and antifungal activity of extract's from *Cymbopogon citratus* (DC) Stapf against *Fusarium graminearum* and *Fusarium Oxysporum* sp tulipae. **Journal of Scientific Research & Reports,** West Bengal, v. 14, n. 5, p. 1-11, 2017.

LESSA, B. F. T.; SILVA, M. L. S.; BARRETO, J. H. B.; OLIVEIRA, A. B. Allelopathics effects of aqueous extracts of leaves of *Amburana cearensis* and *Plectranthus barbatus* on the germination of *Amaranthus deflexus*. **Revista de Ciências Agrárias**, Lisboa, v. 40, n. 1, p. 79-86, 2017.

MACÊDO, J. F. S.; RIBEIRO, L. S.; BRUNO, R. L. A.; ALVES, E. U.; ANDRADE, A. P.; LOPES, K. P.; COSTA, F. B.; ZANUNCIO, J. C.; RIBEIRO, W. S. Green leaves and seeds alcoholic extract controls *Sporobulus indicus* germination in laboratory conditions. **Scientific Reports**, United Kingdom, v. 10, e1599, 2020.

MAGUIRE, J. D. Speed of germination - aid in selection and evaluation for seedling emergence and vigour. **Crop Science**, Madison, v. 2, p. 176-177, 1962.

NMON, F. W.; AJURU, M. G. Plant bioactive chemicals for anti-fungal and biofungicidal potencies: a review. **International Journal of Advanced Academic Research**, Port Harcourt, v. 6, n. 12, p. 52-66, 2020.

OLINTO, F. A.; NUNES, M. S.; SILVA, L. G.; SILVA, H. F.; NASCIMENTO, L. C. Óleos essenciais sobre a qualidade de sementes de leucena. **Revista Principia**, João Pessoa, v. 54, p. 9-19, 2021.

SENIGALIA, R. L. C.; KRATZ, D.; COELHO, M. F. B.; CAMILI, E. C.; ARANTES, C. R. A.; SANTOS, A. S. R. M. Water restriction insanity testin diaspores of *Myracrodruon urundeuva* Fr. All. **Brazilian Journal of Development**, Curitiba, v. 6, n. 7, p. 49617-49627, 2020.

SILVA, F. A. S.; AZEVEDO, C. A. V. The Assistat software version 7.7 and its use in the analysis of experimental data. **African Journal of Agricultural Research**, Nairobi, v. 11, n. 39, p. 3733-3740, 2016.

SILVA, L. L. H.; OLIVEIRA, E.; CALEGARI, L.; PIMENTA, M. C.; DANTAS, M. K. L. Dendrometric, Physical and Chemical Properties Characteristics of *Myracrodruon urundeuva* and *Leucaena leucocephala*. **Floresta e Ambiente**, Seropédica, v. 24, e20160022, 2017.

SILVA, L. L. S.; ARAUJO, I. M. S.; COSTA, P. M. O.; OLIVEIRA, A. P. S.; OLIVEIRA, A. P.; SANTOS, A. D. C.; DUTRA, L. M.; ALMEIDA, J. R. G. S.; COELHO, L. C. B. B.; SOUZA-MOTTA, C. M.; NAPOLEÃO, T. H.; PAIVA, P. M. G. Evaluation of the use of *Myracrodruon urundeuva* heartwood extracts to protect *Moringa oleifera* seeds against *Nasutitermes corniger* attack and improve sanity. **South African Journal of Botany**, Pretoria, v. 129, p. 423-428, 2020.

SIMIONI, P. F.; SILVA, A. P. R.; SILVA, J. C. CORBELLINE, M.; RONDOM, M. J. P.; MARTINS, V.; KARSBURG, I. V. GALLO, R. Influence of *Cinnamon powder* in development seedling *in vitro Catasetum x altaflorestense* Benelli & Grade. **Brazilian Journal of development**, Curitiba, v. 7, n. 1, p. 10406-10421, 2021.

VECHIATO, M. H.; PARISI, J. J. D. Importance of sanitary quality of seeds in forestry seedling production. **Biológico**, São Paulo, v. 75, n. 1, p. 27-32, 2013.

YEOLE, G. J.; TELI, N. P.; KOTKAR, H. M.; MENDKI, P. S. *Cinnamomum zeylanicum* extracts and their formulations control early blight of tomato. **Journal of Biopesticides**, Tamil Nadu, v. 7, n. 2, p. 110-123, 2014.