

Research Article

Assessment of Fruit Production of Main Tree Species of Kon Chu Rang Nature Reserve, Gia Lai Province, Vietnam

Andrey Valer'evich Solonkin¹, Alexander Ivanovich Belyaev¹, Andrey Nikolaevich Kuznetsov^{2,3}, Anna Mikhailovna Pugacheva¹, Nguyen Dang Hoi², Alexandra Sergeevna Solomentseva^{1*}, Sergey Anatol'evich Egorov¹, Dang Hung Cuong², Tran Thi Thanh Huong²

1)Federal Scientific Center of Agroecology, Complex Reclamation and Protective Afforestation of the Russian Academy of Sciences, prosp. Universitetskiy, 97, 400062, Volgograd, Russia

2)Joint Russian–Vietnamese Tropical Research and Technology Center, Hanoi, Socialist Republic of Vietnam, 63 Nguyễn Văn Huyền, Nghĩa Đô, Cầu Giấy, Hà Nội

3)Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Moscow, Russian Federation, 119071, Leninsky prospect, 33

* Corresponding author, email: alexis2425@mail.ru

Keywords:

Development
Fruiting
Growth
Kon Chu Rang Nature Reserve
Rainforest

Submitted:

07 October 2024

Accepted:

13 August 2025

Published:

02 February 2026

Editors:

Furzani Binti Pa'ee
Sri Nopitasari

ABSTRACT

To carry out propagation work on the main tree species in the indigenous forests of Vietnam (Kon Chu Rang nature reserve), the primary tasks were to observe their development and fruiting, determine morphometric indicators, and apply processing methods to identify hidden defects and damage. Taxonomy and morphometric indicators of the main tree species were studied. The effects of sulfuric acid at various concentrations on the fruits of hard-shelled species with prolonged germination periods were studied. The X-ray method was employed to determine whether fruits and seeds were damaged by pests and diseases. The elements contained in the soil samples were determined, and methods for storing and sowing seeds of the trees under study were recommended. Due to the loss of a large amount of forest resources, the monsoon tropical forests of Vietnam require replenishment; the main task of forestry is to study the seed productivity of tree species, which plays a huge role in accelerating the development of nursery farming. Using the scarification method with sulfuric acid, it was established that the species *Ormisia balansae*, *Dialium cochinchinense*, and *Dipterocarpus kerrii* responded positively to a 2 % concentration, and growth differed from other experimental options by 2-3 cm along the length of the seedling.

Copyright: © 2026, J. Tropical Biodiversity Biotechnology (CC BY-SA 4.0)

How to cite:

Solonkin, A.V. et al., 2026. Assessment of Fruit Production of Main Tree Species of Kon Chu Rang Nature Reserve, Gia Lai Province, Vietnam. *Journal of Tropical Biodiversity and Biotechnology*, 11(1), jtbb16885. doi: 10.22146/jtbb.16885

INTRODUCTION

Reproduction and seed production play a key role in the restoration of Vietnam's forests after fires and deforestation. These characteristics determine the ability of forest ecosystems to regenerate. Restoration of forests depends on the availability of seeds of tree species and their ability to germinate under changed conditions. High reproduction and seed productivity help to minimise losses in biodiversity. This, in turn, contributes to preserving the ecological functions of forests, such as climate regulation, soil conservation, maintenance of the water regime, and provision of a natural habitat for many animal species.

In the context of the establishment of new economic ties and market relations, the problems of rational use and protection of forests are becoming particularly relevant not only in Vietnam but throughout the world (Šálek & Vřlupek 2012; Luong 2014; Dang 2020; Ngo et al. 2021). Long-term mismanagement of forests has led to significant deterioration of the national forest fund (Khuc et al. 2018; Trong et al. 2020; Huong & Cuong 2022).

In 2010, Gia Lai province (the location of the Kon Chu Rang Nature Reserve) had 673,541 hectares of natural forest, constituting more than 43 % of its total area (D.C. Nguyen et al. 2022). By 2022, the region had lost 4,08 thousand hectares of natural forest, equivalent to 2,80 million tons of CO₂ emissions (Tuan et al. 2022; Hop et al. 2023). Between 2001 and 2022, Gia Lai Province lost 931 ha of forest due to fires. The year with the largest loss of forestland due to fires during this period was 2016, when fires destroyed 530 hectares of forest, representing 2.9 % of all forest losses that year.

From 2001 to 2022, Gia Lai Province lost 38,200 hectares of monsoon rainforest, accounting for 23 % of its total forest loss during the same period. The total area of tropical monsoon forest in the study region declined by 11 % over the study period.

Understanding seed productivity is essential for forest restoration in Vietnam for the following reasons: determining the optimal sowing time, calculating the required number of seeds, selecting suitable tree species, developing seed storage and treatment methods, planning reforestation activities, and monitoring and evaluating effectiveness. In tropical conditions, many species' seed productivity aspects remain insufficiently studied, underscoring the relevance of this research topic. The study of seed productivity in woody plants is a main task of modern forestry, playing a crucial role not only in planting establishment but also in identifying adaptive capabilities. Tropical plant species generally do not exhibit seed dormancy period; their ripeness and maturity stages coincide. In reproductive biology, the fruiting rhythm of wild plants is rarely studied.

The quantitative and qualitative characteristics of fruits and seeds can vary significantly under the influence of meteorological, edaphic, biocenotic, and age factors, as well as depending on other individual characteristics of the plants being studied.

Observing the fruiting of main tree species in Vietnam's indigenous forests will help this issue by identifying new related species that are poorly distinguished by morphological characteristics. Short-term observations, combined with soil sampling, can help identify phenological phase shifts in the species that make up the observed community.

Seasonal observations make it possible to divide the plant community into synusia (homogeneous ecological groups belonging to the same tier and having similar development rhythms). An important and urgent task is to identify patterns and factors rhythms in plant communities depend. This can be solved by long-term observations of the complete cycles of plant growth and development, from the emergence of seedlings to an adult fruit-bearing.

The purpose of this research is to observe the development and fruiting

of main tree species in the indigenous forests of the Republic of Vietnam (Kon Chu Rang Nature Reserve), determine their morphometric parameters and processing methods, and identify hidden defects and damage for forest nursery creation.

MATERIALS AND METHODS

The field studies

The field studies were conducted in the Kon Chu Rang Nature Reserve (Gia Lai Province, Vietnam) on the Central Highlands Vietnam plateau (geographic coordinates: latitude 48.648232, longitude 44.435462). Geobotanical studies were conducted along the lines and at temporary standard sites. The main objects of observation included species (floristic) composition (Trong et al. 2020; Nagahama et al. 2023) and quantitative and qualitative relationships among plants.

Plant species names were based on literary sources (Phan et al. 2021). The names of families and genera of flowering plants were verified using taxonomy (Takhtajan 1967) and data from the International Plant Names Index (IPNI.org) database. Routes were created and navigated using waypoint map with a Garmin GPS device (GPSMAP 65). Multiband technology and advanced GNSS support (GPS, GLONASS, Galileo, QZSS, and IRNSS) provided optimal accuracy in mountainous terrain and dense forests.

The collected fruits and seeds were weighed using a laboratory scale SPS602F Ohaus (600 g x 0.01 g), and taxonomic characteristics along the survey routes were established using an Insize 1214-1004 (0-1000 mm) measuring fork and a Nikon Forestry Pro device. Soil samples were taken using a drill to a depth of 150 cm in increments of 10 cm (Phan et al. 2021); the study of soil samples was carried out in the soil analysis laboratory of the Science and Agroecology Center of the Russian Academy of Sciences.

During studies of fruiting and determination of fruit and seed maturity, the following phases were recorded: sprouts (from seeds and fruits), unripe fruits, mature fruits, fruit shedding, shell colour, and pulp.

Signs of seed heterogeneity were identified according to the criteria presented in Figure 1.

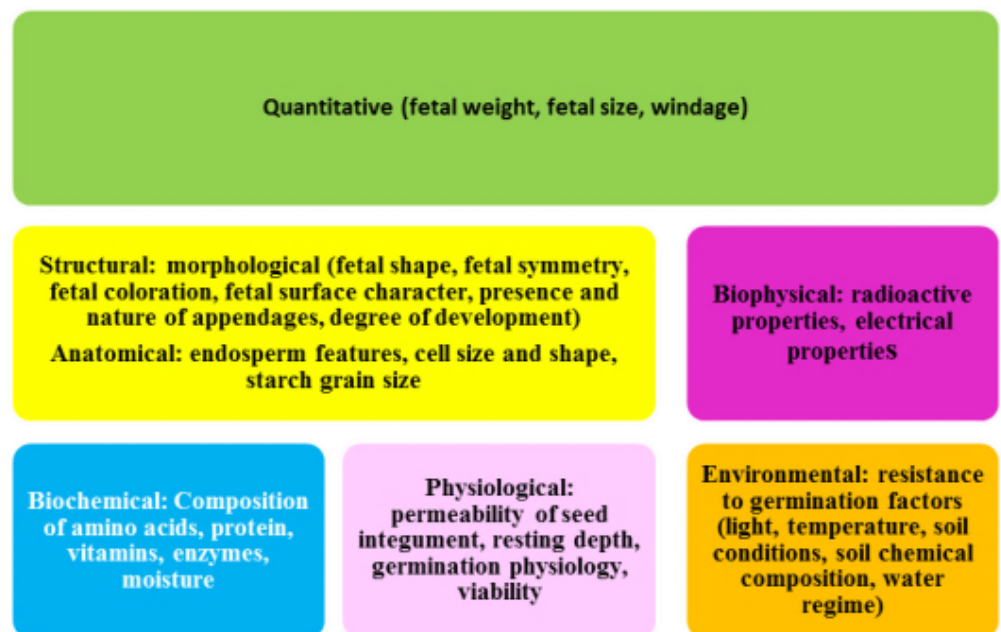


Figure 1. Signs of seed heterogeneity according to the category.

Under the conditions of the Kon Chu Rang Nature Reserve, the total area of the experimental nursery was 36 m². A pipeline was mounted at the

top of the pressure network with sprayers, enabling the production of a fog-like stream. This watering method did not displace seeds during surface sowing (Figure 2).

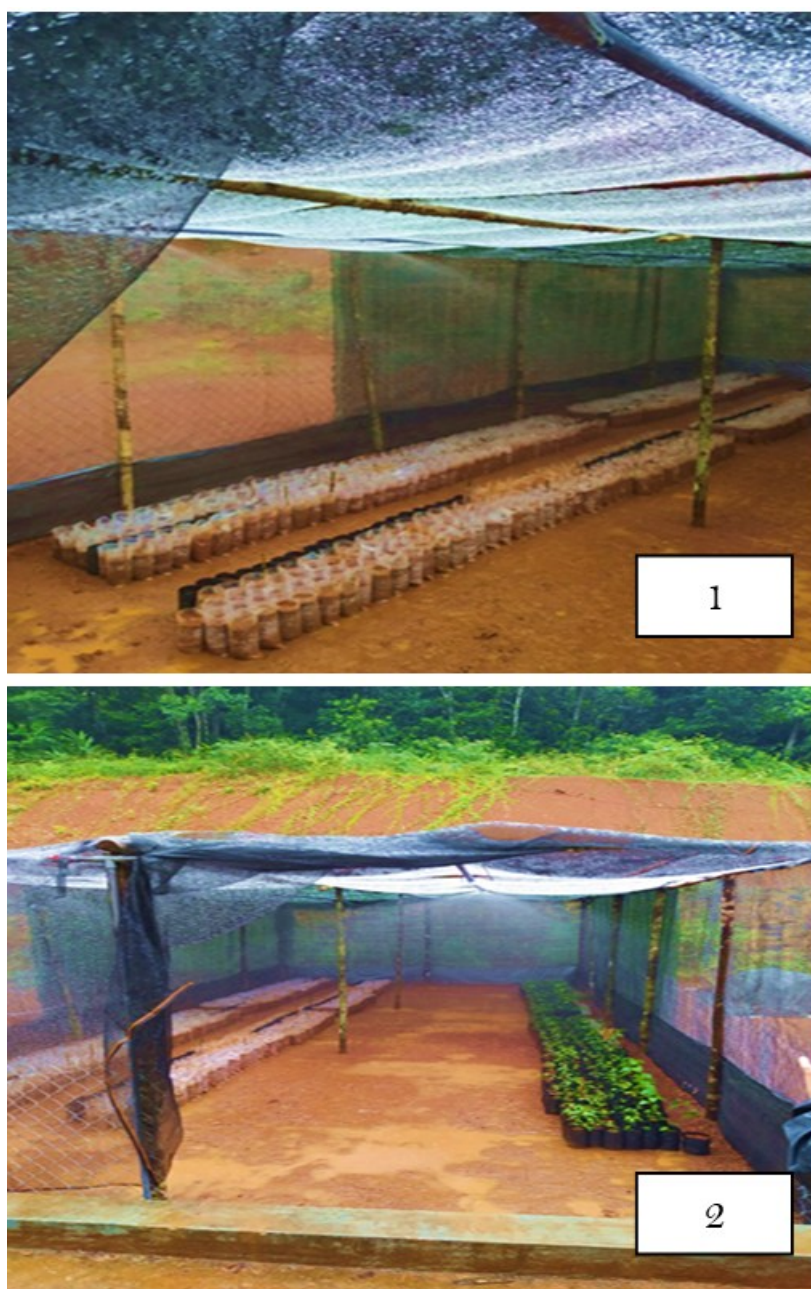


Figure 2. A pipeline with sprayers in an experimental nursery: 1 – general view of seed containers, 2 – general view of containers with seedlings.

A Saike Digital SK2009H2 digital biological trinocular microscope was used for observation. We studied weather conditions at a local weather station (Vietnam) and the Climate Monitor website (Pogodaiklimat.ru).

The study of the main bioecological characteristics of species valuable for reforestation enabled identification of the most promising species and selection of seeds for creating a collection area in the nursery. To isolate seeds from the external environment, they were bagged and pre-dried. This prevented free water from entering cells, which could cause a significant increase in respiratory rate. To avoid the effects of high temperatures, seeds were stored in a refrigerator.

Seeds sown in containers at the Kon Chu Rang Nature Reserve nursery in November 2022 were placed evenly in sunny and shaded areas. During the seed germination observations, it was established that a key classification cri-

terion for plants is their relationship to sunlight, both during the initial and subsequent growth.

The laboratory and radiographic studies

Laboratory and radiographic studies were conducted at the Laboratory Selection, Seed Production, and Nursery Production of the Science and Agroecology Center of the Russian Academy of Sciences (Volgograd, Russian Federation; geographic coordinates latitude 48.648232, longitude 44.435462) during 2022-2023.

Hidden defects in fruits and seeds were examined using a multifunctional mobile X-ray unit (PRDU) with the following technical specifications: ambient dose rate at a distance of 0.1 m from the chamber surface $1.0 \mu\text{Sv hour}^{-1}$, anode voltage of 50 KV; intermittent operating mode, X-ray exit angle of 45° , exposure time of 6 s. After treatment, seeds were placed in an IMA-1000THV climatic chamber and a KS-200 SPU-2 climatostat for further germination observation.

For chemical scarification of seeds, an experiment was carried out with sulfuric acid H_2SO_4 with a density of 1.84 % and concentration of 95 % in the following exposures: control (H_2O), option 1 - H_2SO_4 2 % (1.12-1.15 ml/100 ml of water), option 2 - H_2SO_4 3 %. (1.98-2 ml/100 ml water).

The concentration and duration of seed treatment with sulfuric acid depend on the thickness of the seed coat of the studied plant species.

Descriptive statistics included regression analysis to model relationships between multiple independent variables using Equation 1:

$$y = b_0 + b_1 x_1 + b_2 x_2 + \dots + b_n x_n \quad (1)$$

Where:

y – dependent variable,

x_1, x_2, \dots – independent variable,

b_0, b_1, b_2, \dots – coefficients of independent variables.

To compare the two groups, the Student's criterion was used as a variant of the analysis of variance, which is calculated using the equation 2:

$$t = \frac{XD}{sD} = \frac{XD}{sD / \sqrt{n}} \quad (2)$$

Where:

n – sample size,

XD – the average value for the measurement difference,

sD and XD – standard deviation and standard error of the mean difference.

The standard error was calculated by dividing the standard deviation of the sample by the square root of the number of sample elements using the equation 4:

$$mM = s / \sqrt{n} \quad (3)$$

Where:

s – standard error,

n – the number of elements.

Processing of the experimental results was performed using the following programs: Statistica, Excel, and MathLab (Takhtajan 1967; Vu 2017; Bui et al. 2022; Zimmer et al. 2022; Nagahama et al. 2023).

RESULTS AND DISCUSSION

The Kon Chu Rang Nature Reserve occupies 15,900 hectares (159,000,000 m^2). The reserve's topography is mountainous, with elevation decreasing from north to south (<https://konchurang.vn/>). The altitude ranges from ap-

proximately 900 to 1200 m. The vegetation consists predominantly of evergreen monsoon tropical forests, occupying 98 % of the reserve area (Chong et al. 2009; Q.V. Nguyen et al. 2022a). The floristic composition includes 546 species, of which 121 are medicinal (Nagahama et al. 2023; Zimmer et al. 2022; Q.V. Nguyen et al. 2022b). The climate of the study region is tropical monsoon (Figure 3, 4, and 5) (Earthdata n.d.; D.C. Nguyen et al. 2022).

During the research period (November to March), the following climatic characteristics were noted: humidity on the plateau averaged 79 %, precipitation was 99 mm (4 % of the total annual norm). During the research period, air temperatures ranged from 23 to 27 °C during the day, and 13 to 16 °C at night, with daylight lasting 12 hours and 2 minutes. Soil sample analysis from the reserve indicated that humus content decreased with increasing depth, with the highest humus content (5.05 %) found in the 20-30 cm layer. The content of chloride and sulfate increased at depths of 110-120 cm, indicating low salinity and pollution levels. Increasing pH with soil depth indicates a shift from neutral to alkaline conditions, necessitating amendments such as gypsum, sulfur, or ferrous sulfate to reduce alkalinity (Table 1).

During a route survey of the territory of the Kon Chu Rang nature reserve, the authors identified and collected fruits and seeds of valuable tree species promising for subsequent reforestation (Table 2, Figure 6).

The status of some species requires an increase in their numbers to counter the threat of extinction (IUCN n.d.; Vu 2017).

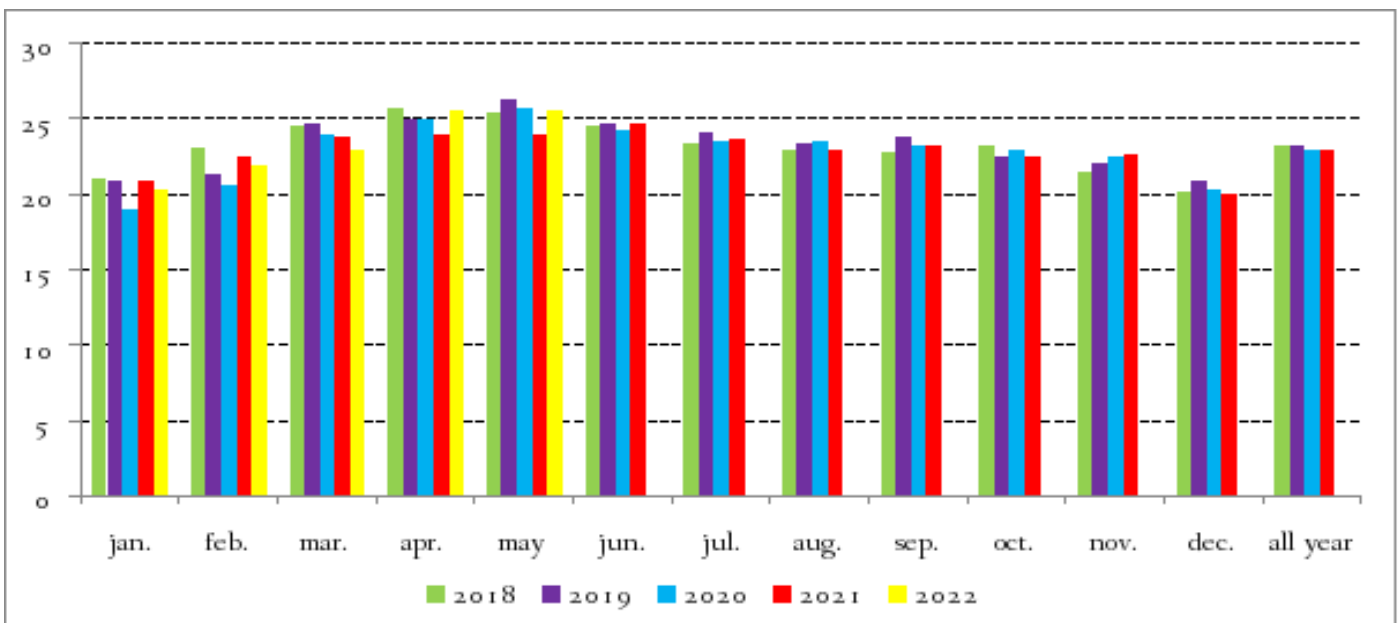


Figure 3. Average annual air temperature (°C) in Gia Lai Province, Vietnam.

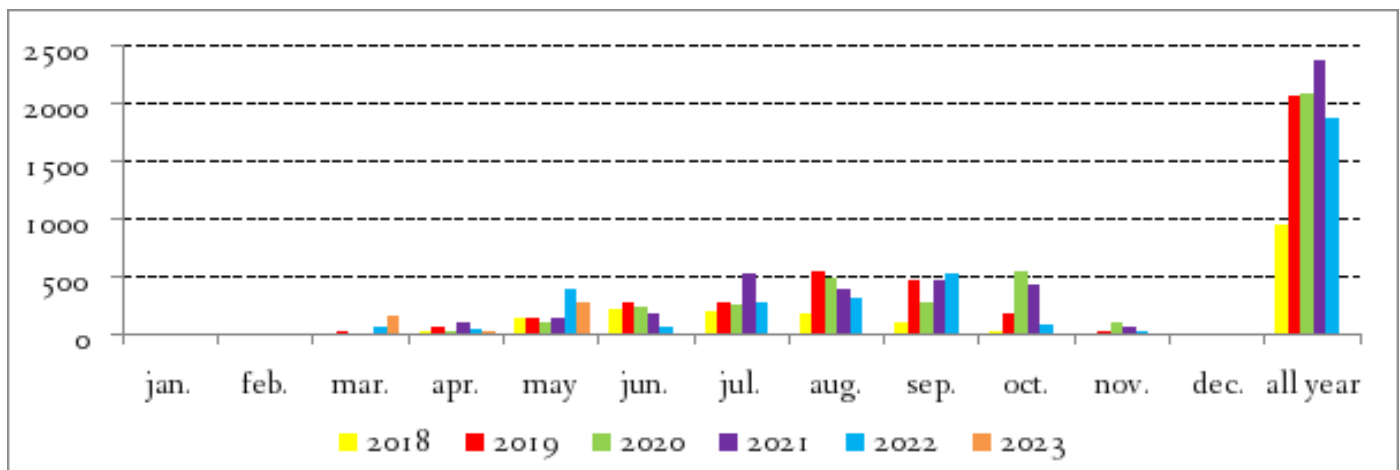


Figure 4. Monthly and annual precipitation amounts (mm) in Gia Lai province, Vietnam.

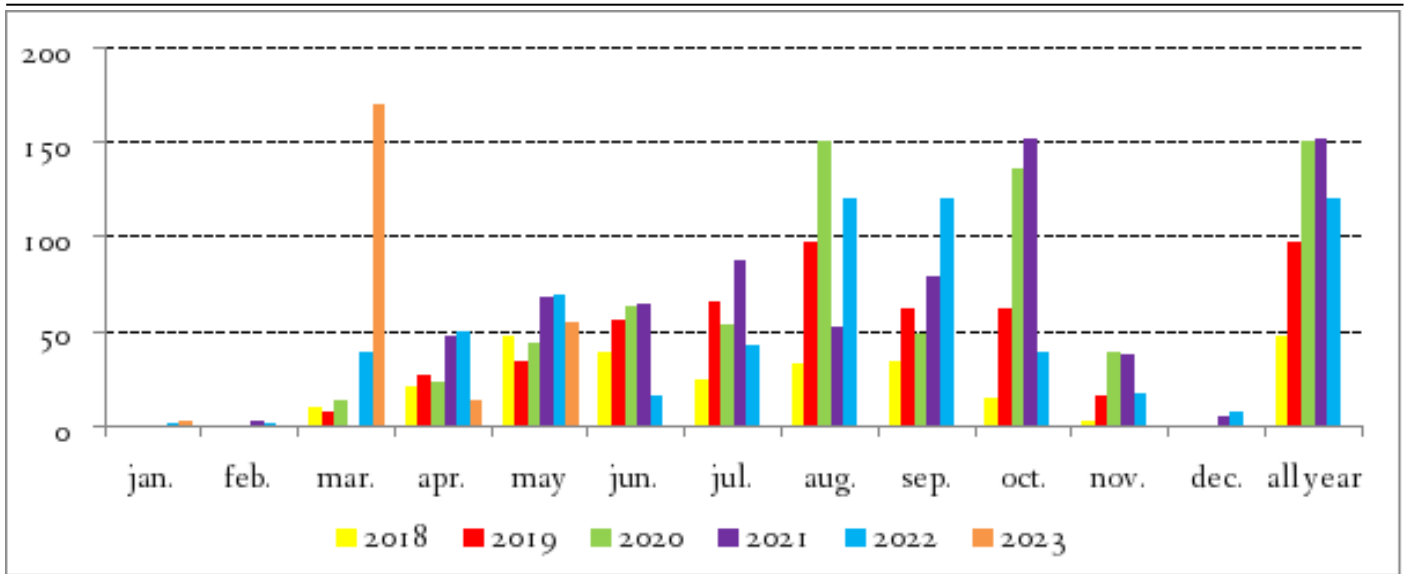


Figure 5. Maximum daily precipitation amount (mm) in Gia Lai province, Vietnam.



Figure 6. Seeds collected during species identity analyses.

Thus, *Parashorea stellata* is a vulnerable species due to habitat loss, causing range shifts. In Malaysia, approximately 805,000 mature trees within permanent protected forests. The lifespan of this species is around 100 years. Over the past 300 years, the populations have declined by 30-50 % due to habitat loss from agricultural expansion and clear-cutting. *Dipterocarpus kerrii* is also endangered., with approximately 224,000 mature trees in Malaysia's permanent conservation forests (Ashton 1982). The subpopulation is scattered, and the species' lifespan is approximately 100 years. Over the past 300 years, populations have declined by 30-50 % due to timber exploitation (Kuznetsov et al. 2003; Kuznetsov & Kuznetsova 2021; Kuznetsov et al.

Table 1. Results of soil sampling on the territory of the Kon Chu Rang nature reserve.

Indicators	Units	Analysis results											
		Ground depth, cm											
		110-120	100-110	90-100	80-90	70-80	60-70	50-60	40-50	30-40	20-30	10-20	0-10
Chloride	mg kg ⁻¹	32.0	20.6	20.5	26.1	14.5	18.8	41.7	12.9	26.0	29.0	14.7	25.1
Fluoride	mg kg ⁻¹	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Total phosphorus	%	0.116	0.149	0.158	0.208	0.196	0.208	0.152	0.090	0.076	0.089	0.124	0.121
Phosphate	mg kg ⁻¹	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
Formate	mg kg ⁻¹	2.65	2.10	1.95	2.70	< 1	1.55	3.85	2.00	3.95	4.20	< 1	1.25
Sulfate	mg kg ⁻¹	31.3	25.2	21.5	20.5	13.8	14.4	19.2	8.8	11.4	94	4.10	7.0
Mobile phosphorus	mln ⁻¹	0	0	0	0	0	0	0	0	0	0	0	0
Mobile potassium	mln ⁻¹	98	77	63	8.1	30	26	29	32	60	76	102	111
Humus	%	0.78	0.67	1.12	0.99	1.26	1.59	1.87	2.22	2.95	5.05	4.69	5.80
Oxalate	mg kg ⁻¹	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
Nitrate	mg kg ⁻¹	10.0	8.8	8.5	7.9	7.8	9.1	17.7	22.1	43.6	60.9	116	132
Sodium	mg kg ⁻¹	401	7.6	21.9	15.2	12.7	9.4	16.7	5.60	6.3	8.3	8.7	14.2
Magnesium	mg kg ⁻¹	13.8	1.98	3.50	2.85	2.35	1.90	3.27	1.55	2.30	3.65	5.85	7.8
Calcium	mg kg ⁻¹	32.1	7.9	20.6	11.0	9.2	7.3	12.3	6.2	12.5	11.3	15.4	22.2
Potassium	mg kg ⁻¹	14.1	3.50	12.9	7.1	6.05	4.55	6.05	5.50	9.1	13.6	26.5	30.3
pH	pH	7.3	6.1	6.2	6.1	6.3	6.2	6.1	6.2	6.1	5.9	5.8	5.7
Acetate	mg kg ⁻¹	3.65	3.10	< 3	5.5	< 3	3.05	5.95	4.05	8.1	12.3	8.2	13.4
Ammonium	mg kg ⁻¹	< 2	< 2	< 2	< 2	2.10	< 2	< 2	< 2	< 2	2.43	2.90	3.99
Nitrite nitrogen	mg kg ⁻¹	0.061	0.059	0.058	0.046	0.043	0.040	< 0.037	0.039	0.039	< 0.037	0.040	< 0.037
Nitrogen of nitrates	mln ⁻¹	7.6	5.4	3.9	4.1	4.0	4.4	4.6	5.5	12.9	16.0	> 23	> 23
Ammonium exchange	mln ⁻¹	< 5/0	8.1	< 5	< 5	< 5	< 5	< 5	< 5	< 5	0.12	0.13	> 0.3

Table 2. Information of dominant trees for collecting seeds.

TT	Species	Family	GPS		Fruit/Seed collection time
			E	N	
1.	<i>Endospermum chinense</i> Beth.	Euphorbiaceae	14° 29' 15.37"	108° 32' 28.36"	Nov.- Dec.
2.	<i>Lithocarpus pachylepsis</i> A. Camus.	Fagaceae	14° 29' 15.37"	108° 32' 28.36"	Jul.- Oct.
3.	<i>Dialium cochinchinense</i> Pierre.	Fabaceae	14° 29' 15.37"	108° 32' 28.36"	Jul. - Nov.
4.	<i>Endospermum chinense</i> Benth.	Euphorbiaceae	14° 29' 16.32"	108° 32' 23.76"	Nov.- Dec.
5.	<i>Dialium cochinchinense</i> Pierre.	Fabaceae	14° 29' 16.32"	108° 32' 23.76"	Jul.- Nov.
6.	<i>Castanopsis acussilata</i> (Blume.) A. DC.	Fagaceae	14° 29' 17.87"	108° 32' 22.5"	Jul.- Oct.
7.	<i>Bischofia javanica</i> Blume.	Euphorbiaceae	14° 29' 17.87"	108° 32' 22.5"	Jun.- Aug.
8.	<i>Reevesia pubescens</i> Mast.	Malvaceae	14° 29' 19.03"	108° 32' 21.74"	May - Jun.
9.	<i>Dialium cochinchinense</i> Pierre.	Fabaceae	14° 29' 19.48"	108° 32' 21.54"	Jul. - Nov.
10.	<i>Machilus parviflora</i> Meisn.	Lauraceae	14° 29' 20.87"	108° 32' 20.59"	Sept. - Febr.
11.	<i>Nephelium hypoleucum</i> Kurz.	Sapindaceae	14° 29' 22.82"	108° 32' 18.77"	Apr. - May
12.	<i>Dialium cochinchinense</i> Pierre.	Fabaceae	14° 29' 22.82"	108° 32' 18.77"	Jul.- Nov.
13.	<i>Ormosia balansae</i> Drake.	Fabaceae	14° 29' 35.65"	108° 32' 40.01"	Sept. - Oct.
14.	<i>Engelhardtia chrysolepis</i> Hance.	Juglandaceae	14° 29' 59"	108° 32' 44.2"	Dec. - May
15.	<i>Michelia mediocris</i> Dandy.	Magnoliaceae	14° 29' 57.85"	108° 34' 21.05"	Aug.- Oct.
16.	<i>Engelhardtia chrysolepis</i> Hance.	Juglandaceae	14° 29' 58.84"	108° 34' 17.93"	Dec. - May
17.	<i>Michelia mediocris</i> Dandy.	Magnoliaceae	14° 30' 0.13"	108° 34' 16.45"	Aug. - Oct.
18.	<i>Schima wallichii</i> (DC.) Korth.	Theaceae	14° 30' 3.46"	108° 34' 14"	Aug.- Oct.
19.	<i>Calophyllum calaba</i> L. var. bracteatum (Wight) P. Stevens	Clusiaceae	14° 30' 6.67"	108° 34' 11.81"	Apr. - May, Jul. - Sept.
20.	<i>Michelia mediocris</i> Dandy.	Magnoliaceae	14° 30' 7.65"	108° 34' 11.29"	Aug.- Oct.
21.	<i>Garuga pierrei</i> Guillaumin.	Burseraceae	14° 30' 11.15"	108° 34' 9.82"	Apr.- May., Sept. - Oct.
22.	<i>Endospermum chinense</i> Benth.	Euphorbiaceae	14° 30' 22.75"	108° 34' 11.4"	Nov.- Dec.
23.	<i>Mastixia arborea</i> (Wight.) C. B. Clarke.	Cornaceae	14° 30' 34.58"	108° 34' 16.79"	Feb.- May
24.	<i>Endospermum chinense</i> Benth.	Euphorbiaceae	14° 30' 37.03"	108° 34' 8.81"	Nov. - Dec.
25.	<i>Calophyllum calaba</i> L. var. bracteatum (Wight) P. Stevens	Clusiaceae	14° 30' 37.08"	108° 34' 18.96"	Apr., May, Jul., Sept.
26.	<i>Podocarpus neriifolius</i> D. Don.	Podocarpaceae	14° 30' 41.59"	108° 34' 21.79"	Aug.
27.	<i>Parashorea stellata</i> Kurz.	Dipterocarpaceae	14° 30' 45.9"	108° 34' 22.3"	Oct. - Dec.
28.	<i>Dipterocarpus Kerrii</i> King.	Dipterocarpaceae	14° 30' 7.45"	108° 34' 31.3"	Feb.
29.	<i>Dacrydium elatum</i> Roxb. Wall. ex Hook.	Podocarpaceae	14° 28' 16.4"	108° 32' 9.53"	Jun.
30.	<i>Dacrycarpus imbricatus</i> (Blume) de Laub.	Podocarpaceae	14° 28' 9.07"	108° 32' 36.1"	Aug. - Sep.

2025). The abundance of *Dacrycarpus imbricatus* and *Dacrydium elatum* are estimated to be declining. In Vietnam, these species are assessed as nationally vulnerable due to overexploitation for timber and habitat destruction for other purposes, such as rubber production (Thomas et al. 2007; Kim et al. 2015; Vu et al. 2021). In Malaysia and Indonesia, *D. elatum* primarily grows in peat bog drained for oil palm (*Elaeis guineensis* Jacq.) plantations, a valuable source of palm oil.

The studied tree species were categorised by height into three groups: 1 – tall (*Parashorea stellata*, *Dipterocarpus kerrii*, *Dacrydium elatum*, *Dacrycarpus imbricatus*, *Castanopsis acussilata*, *Bischofia javanica*, *Calophyllum calaba*, *Shima wallichii*), 2 – medium-sized (*Endospermum chinense*, *Dialium cochinchinense*, *Engelhardtia chrysolepis*, *Machilus parviflora*, *Nephelium hyroleucum*, *Ormosia balansae*, *Michelia mediocris*, *Mastixia arborea*, *Lithocarpus pachylepsis*), and 3 – shorter-growing (*Garuga pierrei*, *Reevesia pubescens*) Table 3.

Significant differences in germination and subsequent development were observed depending on whether the seed containers were placed on the sunny or shady side (Table 4).

Table 3. Indicators of growth and fruit size of tree species on the territory of the Kon Chu Rang nature reserve.

TT	Species	Taxacion			
		Tall, m		Fruit, mm	
		L	D	L	D
1	<i>Endospermum chinense</i> Beth.	6 ± 0.01	35 ± 0.16	8 ± 0.03	10 ± 0.01
2	<i>Lithocarpus pachylepsis</i> A. Camus.	10 ± 0.10	20 ± 0.11	25 ± 0.25	65 ± 0.40
3	<i>Dialium cochinchinense</i> Pierre.	20 ± 0.18	35 ± 0.21	20 ± 0.14	15 ± 0.15
4	<i>Castanopsis acussilata</i> (Blume.) A. DC.	30 ± 0.31	40 ± 0.19	1 ± 0.01	8 ± 0.02
5	<i>Bischofia javanica</i> Blume.	15 ± 0.11	40 ± 0.10	8 ± 0.07	10 ± 0.03
6	<i>Reevesia pubescens</i> Mast.	10 ± 0.08	18 ± 0.11	35 ± 0.20	25.4 ± 0.24
7	<i>Machilus parviflora</i> Meisn.	23 ± 0.17	30 ± 0.24	15 ± 0.10	13 ± 0.07
8	<i>Nephelium hyroleucum</i> Kurz.	25 ± 0.18	30 ± 0.18	30 ± 0.18	50 ± 0.31
9	<i>Ormosia balansae</i> Drake.	22 ± 0.15	30 ± 0.19	13 ± 0.11	17 ± 0.11
10	<i>Engelhardtia chrysolepis</i> Hance.	20 ± 0.11	35 ± 0.27	48 ± 0.20	55 ± 0.22
11	<i>Michelia mediocris</i> Dandy.	18 ± 0.14	25 ± 0.19	5.8 ± 0.03	5 ± 0.02
12	<i>Schima wallichii</i> (DC.) Korth.	37 ± 0.24	47 ± 0.24	20 ± 0.16	30 ± 0.35
13	<i>Calophyllum calaba</i> L. var. <i>bracteatum</i> (Wight) P. Stevens	30 ± 0.28	40 ± 0.29	6 ± 0.04	16 ± 0.14
14	<i>Garuga pierrei</i> Guillaumin.	8 ± 0.02	15 ± 0.18	10 ± 0.08	16 ± 0.10
15	<i>Mastixia arborea</i> (Wight.) C. B. Clarke.	20 ± 0.19	25 ± 0.15	25 ± 0.17	32 ± 0.31
16	<i>Parashorea stellata</i> Kurz.	40 ± 0.24	50 ± 0.28	8 ± 0.03	10 ± 0.01
17	<i>Dipterocarpus kerrii</i> King.	45 ± 0.35	50 ± 0.21	20 ± 0.16	160 ± 0.61
18	<i>Dacrydium elatum</i> Roxb. Wall. ex Hook.	8 ± 0.08	40 ± 0.34	40 ± 0.32	30 ± 0.35
19	<i>Dacrycarpus imbricatus</i> (Blume) de Laub.	43 ± 0.29	50 ± 0.21	50 ± 0.39	60 ± 0.41

Table 4. Seed germination and seedling growth depending on placement in the nursery, March 2023, Kon Chu Rang nature reserve, Vietnam.

Family	Sunny side		Shadow side	
	Germination (%)	Growth (cm)	Germination (%)	Growth (cm)
Fagaceae	96.5 ± 4.9	28.0 ± 1.2	108.7 ± 3.5	35.0 ± 2.4
Fabaceae	42.8 ± 3.1	14.0 ± 1.8	71.4 ± 1.9	23.0 ± 2.0
Myrtaceae	87.6 ± 3.8	15.0 ± 1.1	70.0 ± 2.4	11.0 ± 0.9
Sapindaceae	92.0 ± 1.2	19.0 ± 2.1	81.2 ± 3.0	20.0 ± 1.2
Nyssaceae	0.0	0.0	0.0	0.0
Meliaceae	30.0 ± 1.9	8.0 ± 1.0	60.0 ± 1.6	10.0 ± 0.4
Dipterocarpaceae	0.0	0.0	174.0 ± 6.3	15.0 ± 0.6

The appearance of healthy shoots was observed in species belonging to the *Fagaceae*, *Myrtaceae*, and *Sapindaceae* families. These species also exhibited significant growth ranging from 7 to 20 cm. Seedlings growth up to 8 cm on the shady side of the nursery were obtained from valuable species such as *Parashorea stellata* and *Dipterocarpus Kerrii* of the *Dipterocarpaceae* family.

At the same time, seeds of some species, particularly *Mastixia arborea* and *Ormosia balansae*, failed to germinate. Inspection of containers with ungerminated seeds suggests a prolonged dormancy, indicating the need for further observation of stratification and germination timing.

Seedling growth in containers also varied depending on whether they were placed on the sunny or shady side. At the same time, the growth differences of seedlings were generally insignificant, except for *Dacrydium elatum*, which died completely on the sunny side (Table 5).

Seed germination and seedlings survival are significantly influenced by sowing methods. Studies show that treatment with 2 % sulfuric acid promotes faster seedling emergence in the initial period. However, no significant differences in height were observed, possibly due to species-specific growth rhythms (Table 6).

This method of treating hard-coated seeds may accelerate germination and, combined with full-rate organo-mineral fertilisation, enables high yields

Table 5. Growth of seedlings depending on placement in the nursery, March 2023, Kon Chu Rang nature reserve, Vietnam.

Family	Seedling growth, cm	
	Sunny side	Shadow side
Fagaceae	11.0 ± 0.04	2.0 ± 0.01
Lauraceae	3.0 ± 0.03	3.0 ± 0.01
Euphorbiaceae	3.0 ± 0.01	6.0 ± 0.01
Magnoliaceae	4.0 ± 0.02	5.0 ± 0.04
Podocarpaceae	8.0 ± 0.04	12.0 ± 0.07
Myrtaceae	4.0 ± 0.01	4.0 ± 0.02

Table 6. Dynamics of growth in seedlings depending on the concentration of sulfuric acid for seed treatment.

Experiment	Observation dates, growth, cm								
	30.11	15.12	1.01	15.02	30.03	1.04	15.05	01.06	3.07
	2022	2022	2023	2023	2023	2023	2023	2023	2023
<i>Ormosia balansae</i>									
H ₂ SO ₄ 2 %	1.0 ± 0.01	1.5 ± 0.02	1.6 ± 0.02	1.6 ± 0.02	1.7 ± 0.03	1.7 ± 0.02	8.7 ± 0.4	9.4 ± 0.5	10.7 ± 0.5
H ₂ SO ₄ 3 %	1.3 ± 0.02	1.5 ± 0.01	1.7 ± 0.02	1.7 ± 0.03	1.8 ± 0.03	1.8 ± 0.04	9.5 ± 0.5	10.1 ± 0.6	11.0 ± 0.4
Control	1.1 ± 0.01	1.3 ± 0.01	1.3 ± 0.02	1.4 ± 0.01	1.4 ± 0.02	1.5 ± 0.02	8.1 ± 0.4	9.1 ± 0.6	9.9 ± 0.5
<i>Dialium cochinchinense</i>									
H ₂ SO ₄ 2 %	1.0 ± 0.01	1.6 ± 0.02	1.8 ± 0.02	1.8 ± 0.02	1.9 ± 0.02	1.9 ± 0.03	16.4 ± 0.7	18.9 ± 0.7	21.0 ± 0.6
H ₂ SO ₄ 3 %	1.0 ± 0.01	1.5 ± 0.02	1.7 ± 0.02	1.8 ± 0.02	1.8 ± 0.02	1.9 ± 0.03	15.0 ± 0.6	16.7 ± 0.6	18.8 ± 0.5
Control	1.1 ± 0.01	1.4 ± 0.01	1.5 ± 0.02	1.5 ± 0.02	1.6 ± 0.01	1.7 ± 0.03	13.9 ± 0.4	15.1 ± 0.5	17.6 ± 0.4
<i>Dipterocarpus kerrii</i>									
H ₂ SO ₄ 2 %	1.1 ± 0.01	1.4 ± 0.01	1.7 ± 0.02	2.1 ± 0.04	2.7 ± 0.02	4.3 ± 0.03	5.8 ± 0.2	6.9 ± 0.3	10.0 ± 0.3
H ₂ SO ₄ 3 %	1.0 ± 0.01	1.2 ± 0.01	1.4 ± 0.02	1.7 ± 0.03	2.5 ± 0.01	4.1 ± 0.02	5.1 ± 0.1	7.2 ± 0.4	8.3 ± 0.2
Control	1.1 ± 0.01	1.2 ± 0.01	1.6 ± 0.01	2.4 ± 0.02	2.6 ± 0.02	4.1 ± 0.02	5.0 ± 0.2	6.8 ± 0.4	9.1 ± 0.3

of standard seedlings at one year. The use of soil and climatic resources is determined by agricultural technology. Modern agricultural technology in forest nurseries enables regulation of water and nutrient regimes at near-optimal levels for plant growth and development. Other natural resource factors essential for plant growth (e.g., heat and light) are difficult to regulate outdoors and currently constitute limiting factors for forest nursery productivity (Figure 7).

The studies established that the biological temperature requirements of individual species are constant, independent of growing conditions and geographical location. Thus, if species require a biological temperature sum of 24-90 °C in Vietnam, then to grow them in Volgograd (Russia), where the temperature sum is below this requirement, limits the growth potential of annual seedlings. In the arid zone, low early-autumn temperatures (<10 °C artificially end the growing season before growth potential is fully realised.

Dipterocarpus kerrii. fruits are considered ripe when they turn light brown. After falling, seeds rapidly lose viability; thus, they should not be recommended to be stored for more than 10-15 days, and they must also be kept in damp sand.

For hard-shelled seeds, a 3 % sulfuric acid solution is recommended. For softer shells, the concentration is reduced to 2 % to prevent shell rupture,

which allows acid penetration that destroys the embryo. At lower concentrations, acid acts as a growth stimulant; concentrations above 3 % are toxic (Al-Hadedy et al. 2024). To accelerate germination, the seeds can be treated with 2 % H_2SO_4 solution. Before sowing, fruits are soaked in clean water for 6 hours after lionfish have been removed. When sowing on a light substrate, plants should be watered sufficiently until seeds crack or germinate, but no longer than five days post-sowing, after which they can be transplanted into containers.

For transplanting, fruits must be placed horizontally within the container. The soil mixture for nursery sowing comprises 90 % zonal soil, 9 % manure, and 1 % superphosphate, filling up to two-thirds of the container volume. Containers should measure 9x13 cm or 10x15 cm, and have 4-6 drainage holes. Containers are arranged in rows one metre wide and as long as nursery conditions allow, with 40-50 cm row spacing. Crops require regular care: weeding the grass and loosening the soil every 10-15 days.

If planting occurs during the rainy season, soil loosening should be done 3-4 days after the rain. Shading is maintained 70-75 % during the first month, 40 % in the second, 20 % in the third, and completely removed in the fourth month. To control pests, seedlings must be sprayed with pesticides twice monthly; recommended preparations are Benlat 0.05 % and Bookdo at of 0.5-1.0 % concentration.



Figure 7. Stages of scarification and seed germination in the Science and Agroecology Center, Russian Academy of Sciences: 1, 2 – containers with seeds in sulfuric acid; 3 – seeds of *Ormosia balansae* sprouted after the experiment; 4 – containers with seeds after being placed in sulfuric acid; 5, 6, 7, 8 – successful germination of seeds of experimental plants.

Mastixia arborea: The fruits are blue-violet drupes. No germination was observed after the seed dispersal. Collected seeds can be dried and stored in a refrigerator or in a dark, cool storage room.

Seeds are collected from mature trees exhibiting good growth and development, a dense crown, and no signs of pests or disease damage. Seeds are sown in the nursery containers after one day of soaking and in the greenhouse after five days of soaking.

These seeds do not respond to sulfuric acid treatment intended to accelerate germination. Sowing substrate consists of zonal soil, and the container should be filled to 2/3 of the total volume. Containers should have dimensions of 9x13 cm or 10x15 cm, with 4–6 holes. The plants are lined up in rows 1 m wide, with a length depending on the specific conditions of the nursery. The row spacing is 40–50 cm.

Pest control was performed with Katera 50 EC at 0.75 mL L⁻¹ water, and disease control with Cymanil 720 WP at 3 g L⁻¹ water. Upon seedling emergence, liquid complex NPK fertilizers are applied. Pest and disease treatments are applied every 15–20 days; combined treatments (two chemicals in one solution) are possible. Fertilisers are applied every 20 days. Five months after sowing, treatment was carried out with the fungicide Sat Khuan (pH 6, Cu content – 15 mg L⁻¹), along with root feeding of plants with Nem at a dosage of 20 g/10 l of water. Watering with these preparations should be repeated after seven days.

Ormosia balansae: Seeds can be stored in cool, dark places. Before direct planting in the nursery (light substrate), it is recommended to pour boiling water over the seeds and sow them in containers after they swell, typically after one day.

Unswollen seeds are recommended to be re-soaked in boiling water for five days before sowing in sandy soil in a greenhouse. To accelerate germination, treat seeds with 3 % H₂SO₄. Seedlings reaching 8–10 cm should be transplanted into nursery containers. The substrate for sowing seeds and seedlings consists of zonal soil, with containers filled to 2/3 of the total volume. Fresh seed germination rate was 50 %.

Dialium cochinchinense: Seeds are collected from mature healthy trees with dense crowns and no pest or disease damage. Collected seeds may be dried and stored in a refrigerator or cool, dark storage.

Seeds are planted in containers at the nursery after a day of soaking in warm water. Sowing substrate consists of zonal soil, and the container should be filled to 2/3 of the total volume. To accelerate germination, H₂SO₄ can be treated at a concentration of 2 %.

Pest and disease treatments, as well as fertiliser applications, are consistent with those described for other species. Using a multifunctional mobile X-ray installation (PRDU) at Science and Agroecology Center of the Russian Academy of Sciences, the authors examined hidden fruit and seed defects — including microdamage by insect pests, cracks, mechanical defects, and internal germination — providing comprehensive, reliable information on internal structure and damage presence.

Thus, studies identified areas of seeds that have symptoms of physiological necrosis – for example, areas of black tissue, cotyledons with isolated areas of necrosis or damage caused by fungi, bacteria, insects, or mechanical damage, as well as cotyledons with natural pigmentation, without visible defects.

Poor fruit condition in *Lithocarpus pachylepsis* and *Mastixia arborea* has varying effects depending on damage type, including reduced seedling vigour, chlorosis, chromosomal damage, and ultimately decreased germination lead-

ing to seedling mortality.

In cases of widespread visible seed mould, germination rates should be calculated every two days. Dead and diseased seeds, which can be sources of infection for healthy seeds, should be removed and their number should be noted at each count (Figure 8 and 9).

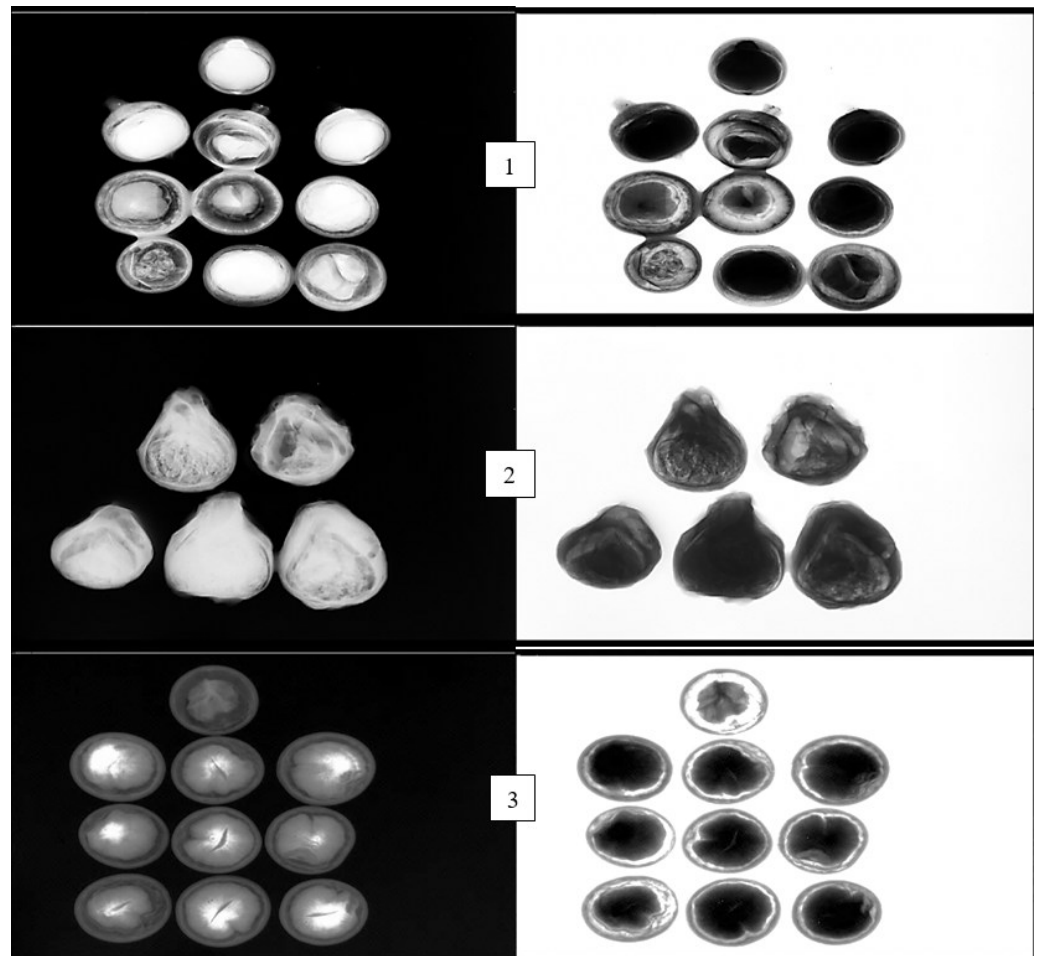


Figure 8. Seeds of some tree species under negative and positive conditions, X-ray duration 6 sec. (exposure time) 1) *Lithocarpus pachylepis*, 2) *Dipterocarpus kerrii*, 3) *Michelia mediocris*.

Research on growing seedlings of the main species of indigenous trees of Vietnam is particularly important for studying and selecting species capable of resisting the aggressive effects of tropical climate factors (Nagahama et al. 2023). Seedling cultivation, nursery management, biodiversity conservation (gene pool), study of nature and climate transformation, ecosystem restoration and management, and biosystem protection are relevant to Vietnam (Trong et al. 2020; Dang 2020).

Conservation and restoration of tropical forest ecosystems currently face numerous difficulties, as tropical forests have complex structures; most are secondary forests influenced by anthropogenic factors, making natural restoration difficult (Kuznetsov et al. 2025; Ngo et al. 2021). Considering the data obtained as a result of studying the growth, development, and reproduction methods of tree and shrub species, it is possible to develop the nursery base of the industry, the main task of which will be the cultivation of high-quality planting material with optimal conditions for its cultivation (Šálek & Vylupek 2012; Khuc et al. 2018). This will enable standardised yields of planting material per unit area, ensure high survival rates when transplanting seedlings to forest-cultural areas, promote subsequent growth, and address urgent challenges related to forest reproduction measures, species composi-

tion improvement, productivity enhancement, and the preservation of biodiversity as well as historical, cultural, and natural heritage within forest fund lands (Luong 2014).

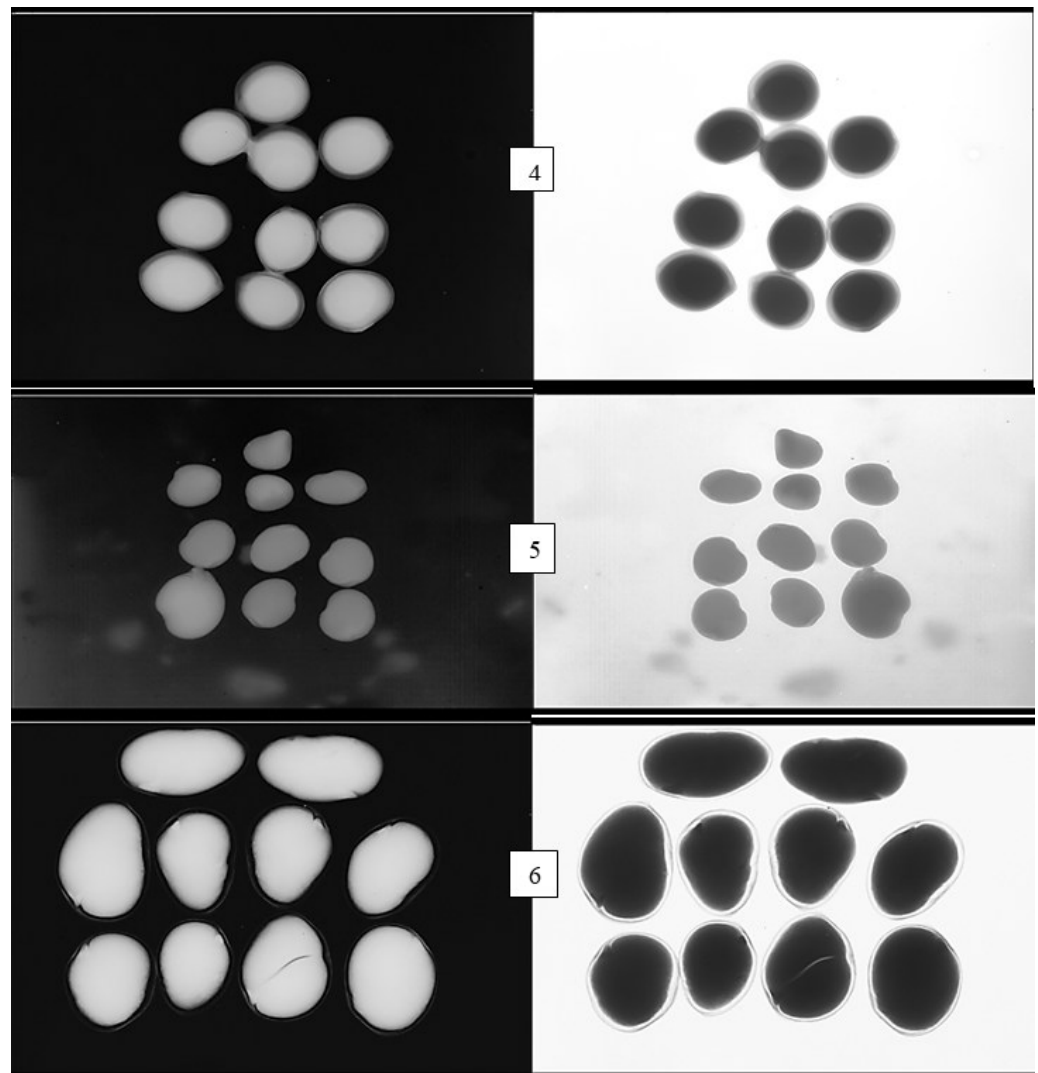


Figure 9. Seeds of some tree species under negative and positive conditions, X-ray duration 6 sec. (exposure time): 4) *Ormosia balansae*, 5) *Dialium cochinchinense*, 6) *Mastixia arborea*, negative - magnification factor 2.1 ERMF, shutter speed 50 seconds, positive - magnification factor 3.5 ERMF, shutter speed 50 seconds.

CONCLUSIONS

The soil of the Kon Chu Rang Nature Reserve contains a small amount of humus, most of which is found in the upper layers. Increased alkalinity can affect plant growth and development without the use of agrotechnical measures such as gypsum or the addition of ferrous sulfate. It has been established that some tree species (*Parashorea stellate*, *Dipterocarpus kerrii*, *Dacrycarpus imbricatus*, *Dacrydium elatum*) endemic to the reserve are endangered and require population increases through reproduction, including seed propagation.

Large, medium, and small-fruited species are distinguished by variations in their morphological characteristics, as evidenced by the high correlation coefficient. Low humidity and air temperature are necessary for seed storage. When sowing seeds, the relationship between the species and sunlight should be considered.

The fastest-growing plants were members of the *Fagaceae* family, whose seedlings had higher rates of germination, vitality, and growth compared to others. Further study of other species is required due to the large sample size. Studies on methods for treating seeds with a hard shell have shown that it is

optimal to treat seeds with 2 % sulfuric acid to accelerate germination, which has made it possible to provide recommendations for the cultivation of individual species.

AUTHOR CONTRIBUTION

A.S.S. and S.A.E. were responsible for literature searching, selecting and coding references, drafting the manuscript, synthesising content, and revising the final version. D.H.C. and T.T.T.H. conceptualised the draft, analysed reference coding, and reviewed the entire manuscript. A.V.S. prepared the work plan, defined bibliographic search parameters, conceptualised the draft, and reviewed the manuscript. A.I.B., A.N.K., and A.M.P. selected relevant references, analysed reference coding, and reviewed the manuscript analysis.

ACKNOWLEDGMENTS

This work was conducted within the framework of the Ecolan theme E-1.6, “Development of technology for growing seedlings of main tree species in indigenous forests of Vietnam as a basis for solving the fundamental scientific problem of tropical forest restoration,” at the Joint Vietnam-Russian Tropical Science and Technology Research Center.

CONFLICT OF INTEREST

The authors declare no conflicts of interest regarding the publication of this study. Furthermore, ethical issues including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been fully observed by the authors.

REFERENCES

- Al-Hadedy, S.H.A. et al., 2024. Sulfuric acid and hot water treatment effects on the seed germination and growth traits of *Sesbania punicea* L. *SABRAO Journal of Breeding and Genetics*, 56(1), pp.444-452. doi:10.54910/sabrao2024.56.1.40.
- Ashton, P.S., 1982. *Dipterocarpaceae*. In *Flora Malesiana Series I, Vol. 9. Part 2*. Netherlands: National Herbarium of the Netherlands, pp.237-552.
- Bui, M.H. et al., 2022. Allometric relationships among tree size variables under tropical forest stages in Gia Lai, Vietnam. *Ecological Questions*, 34(2), pp.43-55. doi: 10.12775/EQ.2023.017.
- Chong, K.Y., Tan, H.T.W. & Corlett, R.T., 2009. *A checklist of the total vascular plant flora of Singapore: native, naturalised and cultivated species*. Raffles Museum of Biodiversity Research, National University of Singapore.
- Earthdata, n.d., ‘GIS at NASA’, in *EARTHDATA*, viewed 2 April 2024, from <https://www.earthdata.nasa.gov/learn/gis>
- Dang Phung, T.K., 2020. Forestry Policy and Legitimacy: The Case of Forest Devolution in Vietnam. *Journal of Asian and African Studies*, 55(6), pp.848-862. doi: 10.1177/0021909620935424.
- Huong, P.V. & Cuong, L.V., 2022. The ecological interaction between endangered, precious and rare woody species in rich forest community: A case study in Tanphu protection forest, Vietnam. *Biodiversitas Journal of Biological Diversity*, 23(12), pp.6119-6127. doi: 10.13057/biodiv/d231205.
- Hop, N.V. et al., 2023. Woody plant diversity and aboveground carbon stock of Dipterocarpus chartaceus dominant forests in Binh Chau-Phuoc Buu Nature Reserve, South Vietnam. *Asian Journal of Forestry*, 7(2), pp.115-125. doi: 10.13057/asianjfor/r070206
- IUCN, n.d., *The IUCN Red List*, viewed 12 June 2024, from <https://www.iucnredlist.org/>

- Kim, Y.S., Lee, K.H. & Wong, A.H.H., 2015. Occurrences of mild wood compression in *Agathis borneensis* and *Dacrydium elatum*. *IAWA Journal*, 36 (4), pp.378-386. doi: 10.1163/22941932-20150108.
- Khuc, V.Q. et al., 2018. Drivers of deforestation and forest degradation in Vietnam: An exploratory analysis at the national level. *Forest Policy and Economics*, 90, pp.128-141. doi: 10.1016/j.forpol.2018.02.004.
- Kuznetsov, A.N. et al., 2003. *Tropical dipterocarp forest: an example of a closed high-stemmed moist lowland dipterocarp forest in the Ma Da massif, South Vietnam*, Moscow: GEOS Publ.
- Kuznetsov, A.N. et al., 2025. Characteristics of Vietnam monsoon tropical forest. *Tạp chí Khoa học và Công nghệ nhiệt đới*, 1, pp.28-40. doi: 10.58334/vrtc.jtst.n01.05.
- Kuznetsov, A.N. & Kuznetsova S.P., 2021. Features of the vertical structure of stands of indigenous monsoon tropical forests of Vietnam. *Proceedings of the Karadag Scientific Station named after T. I. Vyazemsky, a nature reserve of the Russian Academy of Sciences*, 1(13), pp.27-44. doi: 10.21072/eco.2021.13.04.
- Luong, H.T., 2014. Forest resources and forestry in Vietnam. *Journal of Vietnamese Environment*, 6, pp.171-177. doi: 10.13141/jve.vol6.no2.pp171-177.
- Nagahama, A. et al., 2023. Phenology of Tropical Montane Forests in Southern Vietnam: Leafing is Associated with Precipitation but Flowering is not. *Authorea*, pp.4-16. doi: 10.22541/au.167607905.53005700/v1.
- Ngo, T.T.H. et al., 2021. Forest - Related Culture and Contribution to Sustainable Development in the Northern Mountain Region in Vietnam. *Forest and Society*, 5(1), pp.32-47. doi: 10.24259/fs.v5i1.9834.
- Nguyen, M.D., Ancev, T. & Randall, A., 2020. Forest governance and the economic value of forest ecosystem services in Vietnam. *Land Use Policy*, 97, 103297. doi: 10.1016/j.landusepol.2018.03.028.
- Nguyen, D.C., Pham, D.C. & Truong, T.A.T., 2022. Vulnerability assessment of protected area to forest landscape restoration and climate change mitigation: A case study from Vietnam. *Ecology, Environment and Conservation*, 28(August Suppl. Issue), pp.59-69. doi: 10.53550/EEC.2022.v28i04s.009
- Nguyen, Q.V. et al., 2022a. Spatial Structure of the Dominant Tree Species in an Evergreen Broadleaved Forest Stand in South Vietnam. *Biology Bulletin*, 49(Suppl. 1), pp.S69-S82. doi: 10.1134/S1062359022130131.
- Nguyen, Q.V. et al., 2022b. Spatial Distribution and Association Patterns of Two Dipterocarp Tree Species in a Tropical Moist Semi-Deciduous Forest, Southern Vietnam. *Biology Bulletin*, 49(Suppl. 2), pp.S46-S58. doi: 10.1134/S1062359022140114.
- Phan, T.H. et al., 2021. Physical and Chemical Soil Properties of Mangrove Forests in Vietnam. *Lesnoy Zhurnal (Russian Forestry Journal)*, 5, pp.9-21. doi: 10.37482/0536-1036-2021-5-9-21.
- Šálek, L. & Vylupek, O., 2012. Contribution to the Restoration of Mixed Forests in Central Vietnam. *Journal of Sustainable Forestry*, 31(6), pp.549-562. doi: 10.1080/10549811.2011.648525.
- Takhtajan, A.L., 1967. *System and phylogeny of the flowering plants*, Moscow, Leningrad: Nauka.
- Thomas, P. et al., 2007. New records of conifers in Cambodia and Laos. *Edinburgh Journal of Botany*, 64(1), pp.37-44. doi: 10.1017/S0960428606000734.
- Trong, N.H., Nguyen, T.D. & Kappas, M., 2020. Land Cover and Forest Type Classification by Vegetation Indices and Forest Structure in Tropical Lowland Forests in Central Vietnam. *International Journal of Forestry Research*, 2020(1), 8896310. doi: 10.1155/2020/8896310.

- Tuan, N.T. et al., 2022. Effects of tree diversity and stand structure on above-ground carbon storage in evergreen broad-leaved and deciduous forests in Southeast Vietnam. *Dendrobiology*, 88, pp.38-55. doi: 10.12657/denbio.088.003.
- Vu, N.A., 2017. Grassroots Environmental Activism in an Authoritarian Context: The Trees Movement in Vietnam. *VOLUNTAS: International Journal of Voluntary and Nonprofit Organizations*, 28, pp.1180-1208. doi: 10.1007/s11266-017-9829-1.
- Vu, D.D., Nguyen, Q.K. & Pham, M.P., 2021. Genetic structure in natural populations of *Dacrydium elatum* (Roxb.) Wall. (Podocarpaceae) in the Central Highlands of Vietnam inferred by Microsatellites. *E3S Web of Conferences*, 265, 01030. doi: 10.1051/e3sconf/202126501030.
- Zimmer, H. et al., 2022. Rehabilitating forest and marginal land using native species in mountainous northern Vietnam. *Trees, Forests and People*, 10, 100323. doi: 10.1016/j.tfp.2022.100323.