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ECOLOGICAL CHARACTERISTICS OF *Lumnitzera littorea* (Jack) Voigt IN MANGROVE PLANT COMMUNITIES IN SOME COASTAL PROVINCES OF SOUTHERN VIETNAM

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LIST OF THE PUBLICATIONS RELATED TO THE DISSERTATION

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2. Quach Van Toan Em, Nguyen Quoc Bao, Nguyen Thi Anh Linh, Hoang Nhat Minh (2019), Genetic diversity of the *Lumnitzera littorea* (Jack) Voigt population in Can Gio Mangrove Biosphere Reserve using RAPD markers, Journal of Biology 2019, 41(2se1&2se2): 211–219,

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4. Quach Van Toan Em, Nguyen Quoc Bao (2021), Study on some morphological and anatomical characteristics of the *Lumnitzera littorea* (Jack) Voigt species distributed in the South, Vol. 18 No. 3 (2021): Journal of Science, Ho Chi Minh City University of Education, ISSN 1859-3100,

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5. Quach Van Toan Em, Vien Ngoc Nam, Ngo Xuan Quang (2022), Evaluation of some physical and chemical indicators of soil in communities of *Lumnitzera littorea* (Jack) Voigt distributed in the South, Vol. 19 No. 11 (2022): Journal of Science, Ho Chi Minh City University of Education, ISSN 2734-9918,

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6. Quach Van Toan Em, Vien Ngoc Nam, Ngo Xuan Quang (2024). Composition And Diversity Of Mangrove Species Of Lumnitzera Littorea Communities In Southern Vietnam, ACADEMIA JOURNAL OF BIOLOGY. ISSN 2615-9023 (accepted).

INTRODUCTION

1. The urgency of the dissertation

In Vietnam, *Lumnitzera littorea* is listed in the Red Book with the VU level [9]. Currently, *L. littorea* populations are concentrated in Can Gio (Ho Chi Minh City), Phu Quoc (Kien Giang), Con Dao (Vung Tau). In addition, they are also scattered in some other places such as Cam Ranh (Khanh Hoa), Ha Tien (Kien Giang), Dong Nai, ... In recent years, with the research and conservation attention of some scientists along with the protection efforts of managers where *Lumnitzera* populations still exist in mangrove forests, it has contributed to the restoration of protective forests as well as the conservation of some remaining *L. littorea* populations. However, to date, there has not been any research project that has fully, comprehensively and systematically assessed the ecological characteristics of communities with *L. littorea* populations distributed in the Southern region. To have a basis for the conservation and development of *L. littorea* tree in the future in different ecological environmental conditions, we conduct the topic: "**Ecological characteristics of *Lumnitzera littorea* (Jack) Voigt in mangrove plant communities in some coastal provinces of Southern Vietnam**".

2. Objectives

Identify some morphological, anatomical and genetic diversity characteristics of the *L. littorea* tree species; ecological characteristics such as flooding regime, chemical and physical properties of soil, etc. of mangrove vegetation with the distribution of *L. littorea* tree concentrated in the South. Identifying ecological relationships of the *L. littorea* tree population with other plant populations in the community in the research areas. Based on the research results, propose measures to conserve *L. littorea* populations in the research areas.

3. The main research contents of the thesis

- Identify research locations.
- Study on ecological characteristics of *L. littorea* populations in research areas.
- Study on biological characteristics and genetic diversity of *L. littorea* tree populations in research areas.
- Determine the community types and biodiversity of the studied communities.
- Determine the distribution relationship of the *L. littorea* population with other populations in the research community.
- Proposing measures to conserve and develop *L. littorea* tree.

CHAPTER 1. LITERATURE REVIEW

1.1. Overview of mangrove ecosystem

Mangroves are limited to a large area between 30 ^{o}N and south of the equator, with significant northern extensions to Bermuda (32 ^{o} 20' N) and Japan (31 ^{o} 22' N), and to the south to Australia (38 ^{o} 45' N), New Zealand (38 ^{o} 03' N) and the east coast of South Africa (32 ^{o} 59' N). In the Pacific Ocean, natural mangrove communities are limited to the western regions and many of the islands of this region [12].

The total area of mangrove in 2,000 was estimated at about 137,760 km^2 distributed in 118 countries and territories in the tropical and subtropical regions of the world [13]

In Southeast Asia, Indonesia is the country with the largest mangrove area in the region (nearly 60 % of the total mangrove area in Southeast Asia), followed by Malaysia (11.7 %), Myanmar (8.8 %), Papua New Guinea (8.7 %), Thailand (5.0 %) and Vietnam (2.1 %). [14]

1.2. Overview of research works

There are many domestic and foreign authors who have described the works on the morphological and anatomical characteristics of the vegetative and reproductive organs of the *L. littorea* tree, but only on the morphology of the vegetative and reproductive organs: authors Pham Van Quy and Vien Ngoc Nam (2005). *Initially, cultivating the rare L. littorea tree in the Can Gio Mangrove Biosphere Reserve*, author Le Duc Tuan and et al (2002) also gave a preliminary description of this species in the book *Can Gio Mangrove Biosphere Reserve* and in the world, author Chapman (1975) also described the morphology of the *L. littorea* tree in the book *Mangrove Plants*... However, there has not been a complete research work on the anatomical characteristics of the species' adaptive morphology and anatomy of the vegetative and reproductive organs.

Genetic diversity of many mangrove species has been studied by Lam

Vy Nguyen (2006), *Research on genetic diversity of Rhizophora apiculata* Blume *in Can Gio Mangrove Biosphere Reserve using RAPD technique. Regarding genetic diversity of L. littorea tree, there is* a group of authors Guohua Su and add (2006) studied the genetic diversity of five populations of *L. littorea* from the eastern Pacific part of the Indo-Pacific archipelago (South China, Malay Peninsula, Sri Lanka, South Australia), assessed by ISSR makers method, showing the genetic diversity of this species in the China region. There have been many studies using different methods to study genetic diversity, however, the species studied are mainly pharmaceuticals and fruit trees, and there has not been any study on the genetic diversity of mangrove species in general and *L. littorea* in Vietnam in particular.

The ecological distribution factors of mangrove forests in terms of tidal flooding, height, soil mechanical composition, and soil physicochemical properties have also been studied extensively in Vietnam and abroad. According to the research of Sukadjo, 1994; Moreno and Calderon, 2011, it was shown that the salinity value in some mangrove forests is up to 30 ‰. In the book Mangrove Forest, author Wang and et al (2011) also pointed out many studies on Avicennia *germinans* and *Lumnitzera racemosa* that can grow in a large salinity spectrum, ranging from 0 to 100 ‰ and 0 to 90 ‰, similarly, *the effect of high external NaCl concentration on the permeability of wood sap, leaf tissue and leaf gland secretion of Avicennia germinans in mangrove forests* was also studied to learn about the salinity effect on the plant species here. Studies by Hossain et al., 2012; Das et al., 2012 showed that soil pH in mangrove forests ranges from 7.4 to 8.22. Regarding the physical and chemical indicators of the soil, Vo Nguyen Thao et al. (2013), when studying mangrove forests in Ong Trang islet, Ca Mau province; Author Coulta (1980) studied organic matter present in the swamp soil of the Florida River. Some other mechanical

components of the soil have also been studied by many authors such as Feller IC et al. (2003) surveyed nitrogen content of mangrove forests on the coast of the Belize archipelago. Topography and tides of mangrove forests have also been mentioned by authors Phan Nguyen Hong (1997) and Lugo (1974) in many books on Mangrove Ecosystem. However, up to now, there has been no research work specifically mentioning the ecological factors of mangrove areas with the distribution of *L. littorea* species in the world in general and in Vietnam in particular.

Research on biodiversity of mangrove plant communities has been widely studied in Vietnam as well as in the world, but mainly qualitative studies on species composition, species number and diversity of uses. Abdul Malik et al. (2015) recorded 10 mangrove species in South Sulawesi, Indonesia. Some recent studies by Valiela et al., (2001) [130]; FAO (2003); Spalding et al. (2010); Giri et al. (2011), Bijeesh et al. (2018) have listed about 24 mangrove species in Myanmar. Vo Thi Hoai Thong (2011) with the research work "Research on the current status and propose measures to conserve and restore the mangrove flora in Duy Xuyen district, Quang Nam province" recorded 17 species of mangrove flora belonging to 11 plant families, including 8 official mangrove species and 9 participating plant species. Duong Viet Tinh and Nguyen Trung Thanh (2012) with the work " *Mangrove forests at Gianh estuary, Quang Binh province and solutions for sustainable development of wetlands* " recorded 23 species belonging to 17 plant families. According to the results of *the investigation of mangrove plant resources in Can Gio Mangrove Biosphere Reserve* , Dang Van Son (2018) investigated and recorded 112 species, 87 genera, 45 families, 29 orders belonging to two higher plant branches. However, up to now this is not it Have one labour maintain research any help fight price one full way enough, whole face and have system on ecological characteristics and

biodiversity of *L. littorea* communities distributed in the world in general and in Vietnam in particular.

CHAPTER 2. RESEARCH OBJECTS AND METHODS

2.1. Research subjects

Species: *Lumnitzera littorea* (Jack) Voigt

Family: Combretaceae

Order: Myrtales [9]

2.2. Time and place of research

Fieldwork period: September 2017 - September 2020, phase 1 from September 2 - 30, 2017, phase 2 from April 3 - 25, 2018 and additional phase 3 from September 2018 - September 2020.

Research locations: Sub-areas 4, 7, and 14 of Can Gio Mangrove Biosphere Reserve; Dam Quat - Hon Ba area of Con Dao National Park; Rach Tram area of Phu Quoc National Park.

Laboratory of Ecology – Plants M203, Faculty of Biology, Ho Chi Minh City University of Education. Laboratory of Biochemistry – Molecular Biology A403, Faculty of Biology, Saigon University.

2.3. Research method

2.3.1. Research method on some morphological and anatomical characteristics of the stem and leaves of *L. littorea* tree distributed in the South

Collecting young stem samples (primary stem) of *L. littorea* [153]: take 30 stem segments from 10 different trees, each tree takes 3 young stem segments at a position of 1.5 m . Collecting *L. littorea* leaves: take 30 young leaves (leaves from 2 - 3 from the top down) and 30 old leaves from 10 different trees, taken at the same determined position . Collecting flower and fruit samples: collect all stages of *L. littorea* flowers and fruits, arrange in order of development, fix in 5 ‰ formalin .

Sample cutting and dyeing method

Using the double staining method of Tran Cong Khanh (1981) [154], cut the sample directly by hand with a razor blade.

2.3.2. Research method on some reproductive biological characteristics of flowers, fruits and seeds of *L. littorea* tree distributed in the South

Seed development process: Collect flowers and fruits in the field. Peel the fruits with a razor blade and pliers, hold them up to a magnifying glass to observe and take pictures of the stages of seed development. Flowers: Use a lancet to count the number of flowers in a cluster. Describe the morphological characteristics of mature flowers, write the floral formula, draw a floral diagram, draw a mature flower, half a mature flower (1/2 of the right flower). Fruits: Use a lancet to count the number of fruits in a cluster. Describe the morphological characteristics of the fruits, the color and size of ripe fruits.

2.3.3. Method for determining the level of genetic differentiation of *L. littorea* in Phu Quoc, Can Gio and Con Dao using ISSR markers

Total DNA extraction: Total DNA extraction was performed using the mechanical EB (Extraction Buffer SDS) method with some adjustments during the extraction process [155].

DNA quality testing by electrophoresis and spectroscopy : measuring optical density (OD) with a spectrophotometer at a wavelength of 260 nm – 280 nm. The purity of the product is determined by the ratio 260/280 nm.

ISSR – PCR technique: Using 15 ISSR primers denoted H1- H15 according to Guohua Su et al. [30] with specific sequences presented in Table 2.3 (Primers provided by Phu Sa Chemical Company).

2.0% agarose gel *electrophoresis method*

2.10 software: NTSYSpc software applies a simple method in arranging genetic groups, which is the method of calculating the average interval with algebraic values (UPGMA) [1 56].

2.3.4. Research method on ecological characteristics of *L. littorea* tree species distributed in the South

Survey method and establishment of measuring plots

Data on the structure of communities containing *L. littorea* trees were measured on measurement plots (ODD) established according to the method of English et al. (1997) with dimensions of 10 m x 10 m [157]. We conducted surveys in 3 areas (Figure 2.8). In each plot, measure and collect information on: Identifying plant species; Determining location. (OX, OY) the base of each tree in the plot; Measure the trunk diameter ($D_{1,3}$); Measure the tree height; Measure the canopy radius; Draw the cross-sectional and vertical diagram of the sample plot. The area in Can Gio Mangrove Biosphere Reserve - Ho Chi Minh City established 07 plots. The area in Phu Quoc National Park - Kien Giang established 10 plots. The research area in Con Dao National Park - Ba Ria - Vung Tau established a total of 03 plots.

Method of measuring an ecological factor affecting the distribution of L. littorea tree

- Topographic measurement: To measure the topography of the study plots, we used the hydrometer measurement method.

- Determining the tidal regime: by combining field surveys (2017, 2018 and 2019) and the Tide Table of the Center for Hydrometeorological Forecasting.

- *Analysis of physical and chemical soil indicators*

The method of collecting soil samples and analyzing some physical and chemical soil indicators was carried out according to the procedures stated in the document "Handbook of soil, water, fertilizer and plant analysis" compiled by the Institute of Soil and Fertilizer Chemistry (1998)

and Vietnamese standards (TCVN) [160]. Soil samples from the layers (depth from ground surface): 0 – 30 cm, 30 – 60 cm were collected using a specialized soil drilling tool (hand drill).

2.3.5. Method of determining biodiversity indicators in the study area's biome

Determine the biodiversity indexes of mangrove plants and mangrove plant communities in each area according to the research methods of quantitative analysis of plant biodiversity indexes according to: Margalef species richness index (d), Shannon - Weiner index, Pielou similarity index (J'), Simpson dominance index (D); Similarity index (SI); Importance value index (IVI %). Using PRIMER-7 statistical software of Clarke and Warwick and Biodiversity Pro 2.0 to determine biodiversity indexes; analyzing species and community distribution patterns in each survey plot.

2.4. Data processing

Using all statistics, Excel 2013 software calculates the average value. The study of detecting ecological factors through coding and establishing multivariate regression models is processed in ANOVA variable analysis software in Statgraphic plus [176] .

CHAPTER 3. RESULTS AND DISCUSSION

3.1 . Distribution of *L. littorea* populations in the South

3. 1. 1. Location of *L. littorea* distribution points concentrated in Can Gio

- Sub-zone 14 has coordinates 10°32'15.18" N (North) and 106°58'39.55" E (East), total area is 1,478.3 ha; forest area is 939 ha, of which planted forest is 663.9 ha and natural forest is 275.1 ha.
- Sub-zone 7 has coordinates 10°32'29.44" N and 106°55'52.64" E, total area is 927.9 ha, forest area is 727.6 ha, of which planted forest is 496.4 ha and natural forest is 31.2 ha.

- Sub-zone 4 point has coordinates 10°33'57.22" N and 106°53'24.66" E, total area is 956.1 ha, forest area is 801 ha, of which, planted forest is 491.7 ha and natural forest is 309.3 ha. Mangrove forest was planted from 1978 - 1991 and natural forest has mixed Avicennia forest, Date Palm forest, shrub forest, and Ráng.

3.1.2. Location of the distribution point of *L. littorea* concentrated in Con Dao

Dam Quat - Hon Ba: Coordinates 8 º 38'52"N and 106 º 33'6"E. Forest area with a community type of many tree species participating in the forest structure such as Red Coc, Da Voi, Duoc Tap, Su Do,... In which, *L. littorea* is the dominant species.

3.1. 3. Location of *L. littorea* distribution points concentrated in Phu Quoc

- *Area 1* has coordinates 10 º 14'33.57"N and 103 º 58'52.24"E, a forest area with a community type consisting of many tree species participating in the forest structure such as Red Coc, Vet, Gia, Tram,... In which, *L. littorea* is the dominant species.
- *Area 2* has coordinates 10 º 24'41.17"N and 103 º 58'55.16"E, forest area with the main community type of *L. littorea* - Melaleuca, with *L. littorea* being the dominant species, along with strong regeneration of many young *L. littorea* trees at different age stages.

3.2. Biological characteristics and genetic diversity of *L. littorea* tree populations in the study areas

3.2.1. Morphological and anatomical characteristics of leaves and stems of *L. littorea* tree

About leaf morphology: Leaves are simple, whole, smooth and shiny, the leaf tip is slightly concave, the leaf blade is oval, the main vein is prominent on the underside. When the leaves are born, they are jade green due to the low chlorophyll content in the leaves. When they develop into mature

leaves, the amount of chlorophyll is high, the leaves of the *L. littorea* turn dark green [9], [19], [177], [178], [179], [180].

Leaf blade structure : the adaptive structure of the *L. littorea* species is suitable for adaptation in mangrove plants such as: water tissue, developed dermis to dilute excess salt, structure to prevent water loss such as thick cuticle layer, small wood bundles enhance transportation and water supply to help plants adapt to mangrove environmental conditions [181], [182], [183], [184].

3.2.2. Morphological and anatomical characteristics of reproductive organs of *L. littorea* tree

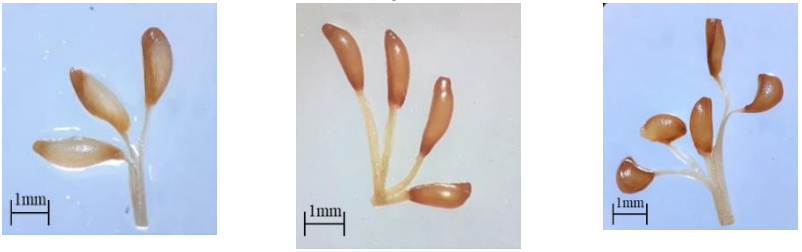
Flowering and fruiting are important biological and ecological phenomena that illustrate the adaptation of plants to their living environment. The flowering time of the *L. littorea* tree in the research areas is usually concentrated in June - August and the fruit ripens from August - October. The observed results are consistent with the authors Voigt, 1845 [178]; Tomlinson, 2016 [179]; Chapman, 1975 [19]; Zhang et al., 2017 [2176]; Ho, 2000 [177]; Ministry of Science and Technology, 2007 [9]. Flowering pattern of the *L. littorea* tree: $\ast\ K_{2+(5)}\ C_{5}\ A_{5+5}\ G_{(1)}$

L. littorea flower has some characteristics adapted to pollination by insects such as: small flowers, beautiful colors that help attract insects. Flowers grow in clusters, flowers have nectar discs located at the base of the ovary, the style is almost as high as the stamen (9 - 10 mm), the style is enlarged at the end, the stigma creates conditions for pollen to fall in. The ovary is enlarged, oval in shape, the ovary is submerged in the flower base, attached to the flower base, in the ovary there are from 3 to 5 ovules that develop evenly [9], [179], [185].

***L. littorea* Flower Ovary**

The ovules of the *L. littorea* flower (*Figure 3.25*) are egg-shaped, with a long ovary stalk, which is the bridge that brings nutrients from the ovary to

the ovary. When surveying the ovules in the Can Gio, Con Dao and Phu Quoc areas, we found that the shape of the ovules in the two areas is not different. The average number of ovules is 4 ovules, the number of ovules 3 and the number of ovules 5 are very rare [179], [185], [186].



a. 3 ovules b. 4 ovules c. 5 ovules

Figure 3.25. Number of ovules of *L. littorea* flower

Formation of L. littorea fruit

Table 3.9. Number of flowers and fruits per cluster

Status	Cluster	Can Gio	Con Dao	Phu Quoc
1	Number of flowers/cluster	21.86 ± 6.19 b	21.16 ± 4.87 b	15.70 ± 3.64a
2	Number of fruits/cluster	21.36 ± 4.19 c	18.20 ± 6.17b	13.67 ± 3.22a

Through the results of *Table 3.9* , it shows that in Can Gio area, the average number of flowers per cluster is 21 flowers, after pollination, the average number of fruits per cluster is 21, the probability of pollinated and fertilized flowers in Can Gio area is almost 100%. Compared to Con Dao area, the average is about 21 flowers per cluster, after pollination the number of fruits is only 18, the probability of pollinated flowers is only 86%, Phu Quoc area has an average of about 15 flowers per cluster, after pollination the number of fruits is 13 per cluster, the rate of pollinated flowers is 86%. The above results are also similar to the research results of Yang et al., 2016 or Zhang et al., 2017 [185], [186].

***L. littorea* fruit and Seeds**

In Can Gio, Con Dao and Phu Quoc areas, only one ovule forms one seed, a single embryo. During the fruit development process, the fertilized ovule will develop into a seed, the remaining ovules gradually disappear. During the seed development process, the number of *L. littorea* embryos has decreased because the ovules are not fertilized or do not provide enough nutrients for the embryo to develop .

Figure 3.29. Seed types in *L. littorea* fruit

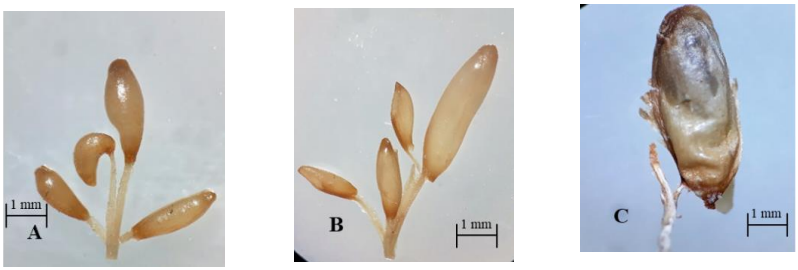


Figure 3.29. Seed types in *L. littorea* fruit

3.2.3. Genetic diversity of *L. littorea* populations distributed in the South

Genetic variation of 16 *L. littorea* samples based on ISSR - PCR results, simple similarity index SM by cluster analysis using UPGMA method [191], [192], we have built a genetic relationship tree between *L.*

littorea samples in the area (*Figure 3.23*). The results obtained on the clustering tree show that the genetic similarity coefficient between the studied *L. littorea* samples ranges from 0.54 - 1.00. Thereby, it shows that the *L. littorea* samples in the research area are divided into 3 distinct groups:

Group I includes samples in Can Gio: CG14.1, CG14.2, CG14.4, CG4.1, CG4.3, CG7.1, CG7.4, with similarity coefficients ranging from 0.65 to 1.00. In which, the 2 samples CG7.1 and CG7.4 have a similarity coefficient of 1.00. This shows that the 2 samples above may have the same origin and are closely related to each other.

PQ2, PQ3, PQ5, PQ6, PQ4, PQ7 have similarity coefficients ranging from 0.74 to 0.88.

Group III includes CD1, CD2, CD5, with similarity coefficients ranging from 0.67 to 0.78.

From the genetic relationship tree between the *L. littorea* samples, we initially identified the diversity in the *L. littorea* samples in the South. It can be seen that *L. littorea* lives in the same different environments but the ability to adapt to harsh environments is relatively similar, so there is no difference in morphology. However, in the study, the plants have genetic differences between 3 populations in 3 different areas. This may be due to ecological differences leading to genetic differences.

Initial identification of a set of ISSR – PCR markers to help distinguish research sources in research

In the study, the *L. littorea* samples were all morphologically similar, but there were differences depending on the age of the tree. After analyzing their genetic diversity, another important result we obtained was that we found homomorphic bands within each sample and identified polymorphic bands that helped distinguish the trees from each other.

In the study, when using 15 primers to perform the ISSR-PCR reaction, the result was 4 primers for amplification products, 4 primers (H1,

H8, H9 and H12) for amplification products, reaching 27.75% of the total number of selected primers . The amplification primers for the bands were not many but were enough to show the difference in the study .

The results obtained show that the ISSR – PCR indicator initially used to determine the genetic diversity of the species at a certain level . This is also the basis for using ISSR – PCR indicators as a tool to research and conserve this rare gene source.

3.3 . Some ecological characteristics of *L. littorea* populations in the study areas

3.3.1. Terrain

- *In Can Gio* , the terrain in the study areas is generally located in the low tide area and the ground is relatively compact. The height of the measurement cells in each sub-area varies little (the difference is not more than 0.25 m) (Table 3.1). Measurement cell 1 of TK4 (CG1) has the highest height (4.00 m) compared to TK7 (3.82 m) and TK14 (3.75 m).
- *In Con Dao*, the terrain in the research areas is generally relatively flat, with a relatively small difference in elevation (about 10 - 20 cm), CD 1 has a higher terrain than the other two cells. Specifically, CD 1 has an elevation of 4.0 m, CD 2 and CD 3 have an elevation of 3.90 m.
- *In Phu Quoc*, the terrain in the research areas is generally located in the low-tide zone. At Point 2, with higher terrain and less tree cover, the *L. littorea* trees regenerated strongly and much more than at Point 1. This helps explain why in this area, most of the *L. littorea* trees regenerated next to Melaleuca trees of different ages.

3.3.2. Tidal flooding regime

In general, in the ODĐs in the 3 research areas, the number of flooded days/month is lowest in the months: March, September and October (low tide flooding time) corresponding to the middle of the rainy season and the middle of the dry season, and there is even no flooding at all in September.

This is a reproductive adaptation characteristic of the *L. littorea* tree according to 2 seasons: Dry season: Flowering from December to February, fruit ripening from March to April and falling at the low tide of the dry season. Rainy season: Flowering from June to July, fruit ripening in August to September and falling during this period (less flooding and more rain) is favorable for the *L. littorea* tree to regenerate strongly.

3 .3.3. Physical and chemical properties of soil

3.3.3.1 . Mechanical components

- Consideration between sub-areas in Can Gio area: The soil is relatively mature, the soil at sampling locations in Can Gio area is all clay loam.
- Considered at the location in Hon Ba area in Con Dao: in both layers 0 - 30 cm and 30 - 60 cm, the mechanical composition is very coarse because it is mostly sand and gravel. Therefore, the soil here is not mature, the structure is completely loose.
- Considered at locations in Area 1 and Area 2 in Phu Quoc: Similar to Hon Ba - Con Dao, the soil (layer 0 - 30 cm and 30 - 60 cm) at 2 locations in Phu Quoc has a very light mechanical composition, with sand grain size accounting for almost 100 %.

3.3.3.2 . Soil pH

Results of soil pH analysis in the study areas, shows:

+ Fluctuation of soil pH in the dry season as well as the rainy season, soil pH values are not significantly different ($P_{value} = 0.4580 > 0.05$). Fluctuation of soil pH according to soil depth: pH values at the 0 - 30 cm layer (pH = 5.67 - 5.82) and 3 0 - 60 cm is not significantly different ($P_{value} = 0.078 > 0.05$.

+ Soil pH variation according to sampling area: pH values have significant differences between research areas . In Phu Quoc, the average soil pH value is always lower than in Can Gio and Con Dao in both rainy and dry seasons and in both surveyed soil layers (*Appendix table 1.2.1*).

3.3.3.3 . Total dissolved salt

In general, the TMT content (%) in soil in the study areas and by season had a statistically significant difference (P_{value} - area = 0.0000 < 0.05 and P_{value} - season = 0.0001 < 0.05). However, the difference in TMT content between the two soil layers (0 - 30 cm; 30 - 60 cm) had a lower level of difference and no statistically significant difference (P_{value} = 0.4731 > 0.05). Soil in the dry season had a higher TMT content than in the rainy season.

3.3.3. 4. Organic matter

In general, the soil in Can Gio areas is rich in organic matter; accordingly, the soil here has a fairly high clay content in both soil layers. Next is the soil in Con Dao area with a fairly high organic matter content. The soil in Phu Quoc is the poorest in organic matter, the soil has a very coarse mechanical composition with sand, gravel and stone accounting for almost 100% of the proportion of soil particles.

3.3.3. 5. Total nitrogen

The results of the analysis of N_ts content in soil in the areas, in general, N_ts (%) at sampling points in Can Gio, Con Dao are much higher than in Phu Quoc (the difference is statistically significant (P value = 0.0000 < 0.05). N_ts (%) in the upper soil layer is often higher than in the lower layer. Because, in the upper soil layer there are many favorable conditions that help the ability to decompose plant residues (containing nitrogen) is always higher and faster than in the lower layer. However, this difference is not statistically significant (P_{value} = 0.9373 > 0.05).

3.3.3. 6. C/N ratio

The C/N ratio in soil in all sampling areas in Can Gio, Con Dao and Phu Quoc fluctuated greatly, ranging from 9 to 36. Comparing the average C/N data by area (Can Gio, Con Dao and Phu Quoc), by soil layer (0 to 30; 30 to 60), there was a clear difference between the areas. The average C/N in soil in Can Gio was between 11 and 15, showing that the soil had a fairly

good mineralization rate; moreover, the organic matter and total nitrogen content in this area was also rich. Therefore, it can be concluded that the soil has the ability to provide good N nutrition for plants, is rich in organic matter and is not too acidic, which is a suitable environment for salt-tolerant organisms (plants, animals, microorganisms, etc.) to exist and develop favorably; including the *L. littorea* tree community.

3.4. Structure of *L. littorea* populations distributed in the South

3.4.1. Structure of *L. littorea* populations according to diameter class

Comments: From the results of the study on the distribution of the number of trees according to the diameter of *L. littorea* in the research areas, it can be seen that the distribution curve of the number of trees according to the diameter class $D_{1.3}$ in the 3 research areas all have a peak that is left-skewed and sharper than the standard distribution curve, the peak is concentrated at the $D_{1.3\ class}$ from 3 - 12 cm. In Can Gio alone, there is a diameter class distribution curve with many consecutive peaks. The *L. littorea* population here has a phenomenon of cyclical regeneration and a very clear $D_{1.3\ class.}$

3.4.2. Structure of *L. littorea* populations according to height levels

Comments: From the results of the study on the distribution of the number of trees according to the height of the *L. littorea* tree in the research areas presented in *Figure 3.37*, it can be seen that the distribution curve of the number of trees according to the height class Hvn_{in} the 3 research areas shows that the distribution curve of the number of trees according to the height class Hvn (m) in the 3 research areas has 3 different types of height class distribution curves. In which, the *L. littorea* population distributed in Dam Quat, Con Dao has a height of Hvn not exceeding 7 m and has a left-skewed peak concentrated at about 2 - 3 m. The *L. littorea* population distributed in Rach Tram, Phu Quoc has a left-skewed height class distribution curve (Hvn concentrated from 3 - 6 m), with many consecutive peaks. In contrast, in Can Gio, the distribution curve of the height class is

right-skewed (Hvn concentrated from 10 - 13 m), with many consecutive peaks. This shows that the height of trees distributed in island areas, sandy soil (Phu Quoc), gravel and rock (Con Dao) will be more limited than in mainland areas, clay loam soil (Can Gio).

3.5. Composition, structure and biodiversity of *L. littorea* communities distributed in the South

3.5.1. Species composition of *L. littorea* communities in the study area

Through the survey results of 20 measuring plots in 3 research areas, 15 plant species were recorded (*Table 3.12*), including 13 official mangrove species and 2 participating species (Tram and Tra bien). According to the IUCN Red List, 15/15 species are listed in the Red List, of which, Aegiceras *floridum* R. & Sch. is classified as Near Threatened (NT) and the remaining 14 species are classified as Least Concern (LC) . According to the Vietnam Red Book, *Lumnitzera littorea (Jack) Voigt) is classified as* Vulnerable (VU).

3.5.2. Structure of *L. littorea* communities in the study areas

L. littorea community types distributed in Can Gio: In general, there are 2 community types that have Red Cocklebur trees: Red Cocklebur - Lime tree - Double Rhizophora community type; Red Cocklebur - Double Rhizophora community type.

L. littorea community types distributed in Con Dao: In general, in the research area there is a *L. littorea* - Dang community **type.**

Red Cocklebur community types distributed in Phu Quoc: In general, in the research area there are 2 types of Red Cocklebur community: Red Cocklebur - Price - Parasol community type; Red Cocklebur - Melaleuca community type.

3.5.3. Biodiversity indices of *L. littorea* communities

Frequency of occurrence: In the measured plots, the frequency of occurrence of species fluctuates greatly from 5 - 100%, with an average of

27.33%. Of which, 6/15 species account for 40% such as Red Coc, Da Voi, Duoc Doi, Gia, Tram with frequency of occurrence above average. On the contrary, some species have very low frequency of occurrence (White Coc, Tra Bien, Xu Giui, Ban Trang, ...) because they only appear in 1 or 2 plots in 1 area.

Species composition: The analysis results show that the number of species in each ODD is from 2 to 6 species, with an average of 4.05 ± 1.36 species. Of which, the number of research plots with a larger number of species than the average is 08 plots (Can Gio 3/7 plots, Phu Quoc 5/10 plots), accounting for 40% of the total 20 measured plots. In contrast, all 3 plots in the Con Dao area have 4 species per plot.

Individual density: In the measured plots, the number of individuals varied from 11 - 88 individuals/plot, with an average of 28.8 ± 16.86 individuals/plot. Of which, 6 plots had an above-average number of individuals, accounting for 30%, and 14 plots had an below-average number of individuals, accounting for 70%. This shows that there is a large fluctuation in the number of individuals in the community in the study areas, especially in the Con Dao area, with an average of only 17.67 ± 6.11 individuals/plot.

Margalef species diversity (d): In the plots, the average species diversity index = 0.95 ± 0.39. Of which, 2 areas have a diversity index greater than the average, accounting for 66.67%, 1 area has a diversity index lower than the average, accounting for 33.33%. Of which, the highest species diversity index is in Con Dao (d = 1.08) and the lowest diversity index is in Phu Quoc (d = 0.89). The results show that the diversity index d in the study areas is relatively low.

Pielou uniformity (J'): Pielou uniformity ranges from 0.75 - 0.83, average = 0.80 ± 0.19 , 2 cells with uniformity higher than average account for 66.67%, in which the area with the highest average uniformity is in Phu

Quoc area (J' = 0.83). Can Gio area has the lowest uniformity (J' = 0.75). Due to the different species composition and number of species in the 3 research areas, the uniformity is also different.

index (H'): fluctuates from 0.43 – 0.49, average = *0.45* ± 0.14 **,** 2 areas with diversity index above the average index account for 66.67%. Of which, the highest Shannon diversity index is in Con Dao (H' = 0.49), the lowest Shannon diversity index is in Phu Quoc (H' = 0.45).

Simpson dominance index (D): This index fluctuates from 0.56 - 0.62, average = 0.57 ± 0.15, In Con Dao area (D = 0.62), the dominant index is greater than the average dominant index , accounting for 33.33%, and in Can Gio and Phu Quoc areas (D = 0.56), the dominant index is less than the average dominant index , accounting for 66.67%.

3.5.4. Importance index (IVI%) of species in *L. littorea* communities in the study areas

Through the analysis of the important indexes of species in the *L. littorea* community distributed in the South presented in *Figure 3.47* and *Appendix Table 18* , it can be seen that *L. littorea* is the most important species, consistent with the orientation and research objectives of the topic, focusing on analyzing the ecological characteristics of *L. littorea* communities. In addition, Rhizophora and Acanthopanax are two species with high important indexes after *L. littorea*. However, when analyzing different areas, the important indexes of species are also different.

3.6. Analysis of the relationship between environmental factors and *L. littorea* communities distributed in the South

3.6.1. The influence of tidal flooding regime on the dominant distribution of mangrove trees in the Southern region

Through the MDS analysis results, the influence of tidal regime on the distribution of CNM species in the study areas (*Figure 3.49a*) is divided into 3 main groups, including:

plants distributed in unusually high tidal regime include: *Lumnitzera littorea, Thespesia populnea*) and *Melaleuca cajuputi* (Figure 3.49b and Figure 3.49c).

- Group 2 mangrove trees distributed in the medium high tide regime include: *Ceriops tagal, Xylocarpus granatum* and *Rhizophora stylosa* (Figure 3.49d and Figure 3.49e).

- Group of 3 mangrove trees distributed in high tide regime includes: *Rhizophora apiculata, Sonneratia alba, Aegiceras floridum* and *Bruguiera gymnorrhiza* (Figure 3.49f and Figure 3.49g).

3.6.4. Relationship between environmental factors and *L. littorea* communities distributed in the South

The general analysis results for the distribution areas of *L. littorea* communities show that the limiting factors in the soil environment are: *sand grain size composition and C/N ratio*. In which, soil grain size composition (- 0.71 to - 0.96) and C/N ratio in the 0 - 30 cm soil layer (- 0.50 to - 0.68) have a close influence on the distribution and growth of the species in the studied communities.

3.6.4.2. Community relationships between research areas in the South through cluster branch diagram

Through the cluster diagram *in Figure 3.63*, it can be seen that the *L. littorea* communities in Can Gio and Con Dao have higher similarities than the *L. littorea* communities in Phu Quoc. This result is consistent with the analysis of the diversity and species composition of the 3 *L. littorea* communities distributed in the South, in which the *L. littorea* community distributed in Phu Quoc has the highest species diversity (9 species). At the same time, when analyzing the SI index, Can Gio and Con Dao have the highest similarity, only reaching SI = 0.5, while Can Gio and Phu Quoc have very low similarity (SI = 0.29).

Through the Cluster diagram *in Figure 3.56*, it can be seen that the Tra Bien and Xu sung tree groups or the Tram, Gia and Vet groups are two groups of species that are closely similar to each other (from 60 to nearly 100%), distributed in the low-tidal soil environment and recorded randomly, with a clear separation from the remaining tree groups in the community. In addition, the remaining tree groups of the family Duoc such as Trang and Vet den, Da voi and Duoc doi in the two similar groups also show a correlation in similar living environment conditions (similarity of over 40% - 60%). Next, Ban dang and Mam den groups are 2 mangrove species that live in soil environment conditions but have relatively low similarity. In particular, the Coc trang and Duoc voi groups are 2 tree species that are similar to each other and have low clustering, because these species may have a random distribution pattern in the *L. littorea* communities.

Thus, the results of the analysis of the correlation between the *L. littorea* communities distributed in the South are considered as the basis for choosing the option of replanting and conserving the *L. littorea* species in different areas. Depending on the characteristics of the substrate, the tidal regime and the type of intercropped plants.

3.7.2. Proposed measures for mixed planting of *L. littorea* trees

Through the results of PCA analysis of factors affecting mangrove plant communities with *L. littorea* trees distributed in the research areas, it is shown that in different areas there are factors with different "positive" and "negative" impacts (Table 3.17). Therefore, in proposing the restoration of this *L. littorea* tree species in nature, it is necessary to pay attention to factors with "negative" impacts to choose the appropriate substrate type.

Through the analysis of ecological characteristics of *L. littorea* communities distributed in the South, we propose intercropping different *L. littorea* species in areas with some ecological characteristics: tidal flooding

regime from high tide, medium high tide to abnormally high tide; clay loam soil type is better than sandy and gravel soil type. The soil has a pH value of $_{H2O}$ at a slightly acidic, salty level; organic matter content, total N and easily digestible N are quite rich. Intercropping with official mangrove species, mainly Da voi and Duoc doi (in Can Gio) or Da voi, Duoc voi (in Con Dao), or individually intercropping with Tram (in Phu Quoc).

CONCLUSION AND RECOMMENDATIONS

CONCLUDE

Communities with *L. littorea* trees are distributed in areas with high tidal flooding to abnormally high tidal flooding. The areas have different soil physicochemical characteristics in the research areas. In each area, the indicators of pH, salinity, conductivity, CHC, Ndt, ... have differences according to the season and the surveyed soil layer. The total soluble salt content with electrical conductivity in the soil , the organic matter content with total N, the organic matter content with readily available N and the total N content with readily available N all have a close positive correlation.

The community types are relatively different in each area: in Can Gio there are two types of Da - *L. littorea* communities and the Duoc Doi - *L. littorea* - Da community; in Con Dao there is one type of *L. littorea* - Duoc Tap community; in Phu Quoc there are two *L. littorea* - Gia - Vet Du communities and the *L. littorea* - Tram community.

Biodiversity of *L. littorea* communities in the study areas such as Margalef species diversity, Pielou evenness, Shannon – Wiener index and Simpson dominance index of *L. littorea* communities distributed in the South did not have statistically significant differences. The D index had a very strong negative correlation with H' and J'.

The distribution of *L. littorea* populations in different areas depends on the substrate, tidal regime and correlation with other mangrove species in the community. Depending on each area, the form and type of mixed

planting with *L. littorea* should be selected appropriately.

The theoretical regeneration ability of the *L. littorea* populations distributed in the South of Vietnam of the *L. littorea* fruit in all three regions is very low (13.08 - 30.00 %). The natural regeneration ability by seeds (in the fruit) of the *L. littorea* tree species in the rainy season is higher than in the dry season.

It is recommended to intercrop *Lumnitzera littorea* in areas with tidal flooding from high tide, medium high tide to abnormally high tide; the soil type is clay loam. The soil has a slightly acidic pH_{H_2O} value, high salinity; the organic matter, total N and easily available N is quite rich. Intercrop *L. littorea* with true mangrove species, mainly *Ceriops tagal* and *Rhizophora apiculata* in Can Gio or *Ceriops tagal and Rhizophora stylosa* in Con Dao, or individually intercrop with *Melaleuca cajuputi* in Phu Quoc.

RECOMMENDATIONS

The analysis results show that the pollination, fertilization and fruit set rate of the *Lumnitzera littorea* tree is very low. Therefore, it is necessary to continue to study the factors that affect the pollination and development of seeds and fruits.

Research on intercropping *Lumnitzera littorea* trees with Rhizophora and Ceriops species on relatively compact soil, in areas with high to medium high tides.

It is necessary to study the germination of seeds and the ability to survive and preserve the embryo of the *Lumnitzera littorea* fruit after falling. This is of great significance for the study of the law of regeneration, when there are measures to enhance their regeneration ability. From there, we can expand the distribution area and accelerate the recovery process of this rare species through ex situ conservation.