Evaluating the Adaptation of Five Plant Species to Tropical Coral Island Environments Based on Functional Traits: Postprint

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Abstract

Vegetation establishment is a critical step for protecting and improving ecosystems of tropical coral islands. The extremely arid habitats of tropical coral islands represent one of the main limiting factors affecting plant survival and colonization; therefore, selecting suitable plant species is crucial for vegetation establishment on tropical coral islands. By measuring photosynthetic/hydraulic functional traits of five plant species—Scaevola taccada, Ipomoea pescaprae, Casuarina equisetifolia, Arachis hypogaea, and Cocos nucifera—grown in a nursery in Wenchang City, Hainan Province and on tropical coral islands, we explored plant adaptation to tropical coral island habitats. The results showed that, compared with the control (Wenchang nursery), the maximum photosynthetic rate (Amax) of Scaevola taccada, Ipomoea pescaprae, and Casuarina equisetifolia on tropical coral islands increased significantly; except for Cocos nucifera, the specific leaf area (SLA) of the other four species decreased, while long-term water use efficiency increased (with significant increases in Casuarina equisetifolia and Arachis hypogaea); leaf carbon content (LC) of all five species decreased to varying degrees. Additionally, leaf hydraulic conductivity (Kleaf) of Ipomoea pescaprae, Casuarina equisetifolia, and Cocos nucifera increased significantly; leaf turgor loss point (Ψtlp) of Ipomoea pescaprae and Arachis hypogaea decreased significantly; and stomatal conductance (gs) of Ipomoea pescaprae and Casuarina equisetifolia increased significantly. The results indicate that Scaevola taccada, Cocos nucifera, and Arachis hypogaea mainly adapt to the arid environment of tropical coral islands through non-stomatal regulation (increasing Kleaf, decreasing Ψtlp and SLA, etc.); whereas Ipomoea pescaprae and Casuarina equisetifolia promote carbon assimilation and water utilization through both stomatal regulation (decreasing gs) and non-stomatal regulation (increasing Kleaf, decreasing Ψtlp and SLA, etc.). In summary, Scaevola taccada, Ipomoea pescaprae, and Casuarina equisetifolia exhibit higher photosynthetic capacity and water use efficiency, can effectively coordinate carbon assimilation and water utilization, and demonstrate good adaptive capacity, making them suitable for vegetation establishment on tropical coral islands.

Full Text

Preamble

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Using Functional Traits to Evaluate the Adaptability of Five Plant Species on Tropical Coral Islands

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Abstract

Vegetation establishment is a critical component for protecting and improving tropical coral island ecosystems. Selecting suitable species is therefore essential for successful vegetation restoration on these islands. In this study, we quantified photosynthetic and hydraulic functional traits of five plant species—*Casuarina equisetifolia*, *Ipomoea pescaprae*, *Scaevola taccada*, *Arachis hypogaea*, and *Cocos nucifera*—grown in a nursery in Wenchang, Hainan Province, and transplanted to a tropical coral island with harsh habitats characterized by high solar radiation and low freshwater availability.

Compared to nursery-grown plants, the maximum photosynthetic rate (A) of *S. taccada*, *C. equisetifolia*, and *I. pescaprae* on the coral island increased significantly, with particularly notable increases in *C. equisetifolia* and *A. hypogaea*. All five species showed decreased leaf carbon content (LC) on the island. The turgor loss point (Ψ) of *I. pescaprae* and *A. hypogaea* decreased significantly, while leaf hydraulic conductivity (K f) increased significantly in *I. pescaprae* and *C. equisetifolia*. However, stomatal conductance (g) of *C. nucifera* increased significantly.

Our results demonstrate that *S. taccada* and *A. hypogaea* adapted to the island environment primarily through non-stomatal regulation (i.e., increased K f but decreased Ψ and SLA). In contrast, *I. pescaprae* and *C. equisetifolia* employed both stomatal regulation (i.e., decreased g) and non-stomatal regulation (increased K f but decreased Ψ and SLA) to promote carbon assimilation and water use. *C. equisetifolia* exhibited higher photosynthetic capacity and water use efficiency, enabling better coping with harsh environmental conditions. Therefore, *C. equisetifolia*, *I. pescaprae*, and *S. taccada* are recommended as suitable species for vegetation restoration on tropical coral islands.

Keywords: tropical coral island; ecological adaptability; vegetation restoration; photosynthesis; functional traits

Introduction

With rapid global economic development and depletion of terrestrial resources, ocean development has become a strategic priority for many countries. As important components of marine systems, islands possess tremendous resource value, and their rational development is crucial for national sustainable development, attracting high attention from governments and academia. Islands also serve as important tourism resources that satisfy growing recreational demands. However, tropical coral islands present extreme environmental challenges including high temperatures, intense light, and substrates with low water-holding capacity, minimal soil, high salinity, and poor nutrient content. These conditions severely limit plant survival and establishment, making vegetation restoration essential for creating habitable environments and supporting sustainable development.

Species selection is key to successful vegetation restoration on tropical coral islands. Plant adaptability is influenced by multiple factors including soil conditions, species characteristics, and environmental stress. Drought stress represents a primary limiting factor, significantly affecting plant survival rates. During long evolution, plants have developed effective mechanisms to adapt to drought through stomatal regulation (physiological control of transpiration through stomatal structure and environmental feedback) and non-stomatal regulation (including leaf hydraulic conductivity, turgor loss point, and specific leaf area). Leaf hydraulic resistance constitutes a major bottleneck (>30%) in whole-plant water transport, with leaf hydraulic conductivity reflecting water transport rates and efficiency closely linked to photosynthesis. The turgor loss point indicates drought resistance capacity, while specific leaf area (SLA)—the fresh leaf area per unit dry weight—is associated with drought tolerance, with lower SLA indicating stronger turgor maintenance capacity.

Previous research on tropical coral island ecology has focused on environmental assessment and community dynamics, with few studies examining physiological adaptation mechanisms of suitable species. While Li et al. investigated ecological adaptability of four plant species from carbon assimilation perspectives, they did not consider hydraulic traits or differences in drought strategies. This study examines five potential suitable species transplanted from a Wenchang nursery to a tropical coral island, comparing their photosynthetic and hydraulic characteristics to evaluate adaptability to the island' s arid environment.

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1. Study Site Description

The experimental nursery was located in the suburbs of Wenchang City, Hainan Province (110°45 E, 19°31 N), characterized by a tropical maritime monsoon climate with mean annual temperature of ~24°C and precipitation of ~1,800 mm. The soil type was coastal deposit sandy loam.

The tropical coral island study site had an elevation of approximately 5 m, with tropical maritime monsoon climate, mean annual temperature of ~28°C, and precipitation of ~2,800 mm with uneven distribution. The substrate consisted of coral sand with extreme environmental characteristics including high salinity and poor nutrient content, supporting virtually no vegetation.

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2. Experimental Materials and Methods

Based on previous surveys of the Xisha Islands, five potential suitable species were selected: *Scaevola taccada*, *Ipomoea pescaprae*, *Casuarina equisetifolia*, *Arachis hypogaea*, and *Cocos nucifera*. All island plants were transplanted in March 2015. Except for minimal imported soil used during transplantation to improve survival, no additional artificial care was provided. The differences in environmental factors (water conditions, light radiation) between sites were the focus of this comparative study.

Measurements were taken on fully expanded, healthy mature leaves in September 2015.

2.1 Photosynthesis

Maximum photosynthetic rate (A), transpiration rate (Tr), and stomatal conductance (g) were measured in situ on sunny days between 9:00–11:00 using a LI-6400 portable photosynthesis system (LI-COR, Nebraska, USA). Light intensity was set at 1,500 mol m^{2} s^{1}, CO concentration at 400 mol/mol, and data were recorded after 3–5 minutes of stabilization. Instantaneous water use efficiency was calculated as WUE = A /Tr.

2.2 Turgor Loss Point

Sun-exposed leaves were collected, immediately placed in water-filled buckets, sealed in black plastic bags to prevent transpiration, and saturated overnight

(16:00–18:00). Saturated fresh weight (SW) and water potential (Ψ) were measured using a pressure chamber (PMS, Corvallis, Oregon, USA). Leaves were then placed on a bench to desiccate, with water potential and weight measured repeatedly until water potential declined insignificantly. After measurement, leaves were oven-dried to determine dry weight (DW). Relative water content was calculated as: RWC = 100 × (FW - DW)/(SW - DW). The turgor loss point water potential (Ψ) was determined by fitting the water potential-RWC curve.

2.3 Leaf Hydraulic Conductivity

Leaf hydraulic conductivity (K f) was measured using the method of Franks: K f = Δ /(10 × A f × (Ψ - Ψ)^2), where Δ is water flow rate over 10 seconds, A f is leaf area, Ψ is saturated leaf water potential, and Ψ is applied pressure potential (0.3–0.5 MPa).

2.4 Specific Leaf Area

Leaf area (LA) was measured with a leaf area meter (Li-3000A, Li-Cor, Lincoln, NE, USA). Leaves were then oven-dried to determine dry weight (DW). SLA was calculated as: SLA = LA/DW.

2.5 Stable Carbon Isotope Content

Dried, ground samples were sent to the South China Botanical Garden Public Laboratory for stable carbon isotope analysis using an IsoPrime100 isotope ratio mass spectrometer (IsoPrime, Manchester, UK). Stable carbon isotope content (^{13}C) is a reliable indicator of long-term water use efficiency, with higher values indicating greater efficiency.

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3. Data Analysis

SPSS 18.0 software was used for t-tests comparing traits of the same species between habitats. Origin 16.0 was used for graphical presentation.

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3. Results

3.1 Photosynthetic Rate and Leaf Economic Traits

Compared to Wenchang nursery plants, A of *S. taccada*, *C. equisetifolia*, and *I. pescaprae* on the coral island increased significantly, while *C. nucifera* showed no significant difference. Transpiration rate of *C. equisetifolia* on the island increased significantly, while other species showed no significant differences. Specific leaf area (SLA) of four species (except *C. nucifera*) on the island decreased significantly compared to nursery plants. Leaf carbon content (LC) of all five species on the island decreased, with significant reductions in *S. taccada* and *C. nucifera*.

[Figure 1: see original paper] Comparison of A , Tr, SLA, and LC values of five plant species in Wenchang nursery and island (Mean±SE). * indicates significant difference between sites (P<0.05); ** indicates highly significant difference (P<0.01); NS indicates no significant difference.

3.2 Water Use Efficiency

Instantaneous water use efficiency (WUE) of *I. pescaprae* on the coral island was significantly higher than nursery plants, while *C. equisetifolia* and *A. hypogaea* showed significant differences. Stable carbon isotope content (^{13}C) of all species except *C. nucifera* increased on the island, with significant differences in *C. equisetifolia* and *A. hypogaea*.

[Figure 2: see original paper] Comparison of WUE and ^{13}C values of five plant species in Wenchang nursery and island.

3.3 Hydraulic Traits

Stomatal conductance (g) of *I. pescaprae* and *C. equisetifolia* on the coral island increased significantly compared to nursery plants, while other species showed no significant differences. Leaf hydraulic conductivity (K f) of *I. pescaprae* and *C. nucifera* increased significantly, while *A. hypogaea* decreased significantly. Turgor loss point water potential (Ψ) of *I. pescaprae* and *A. hypogaea* on the island decreased significantly compared to Wenchang.

[Figure 3: see original paper] Comparison of g , K f, and Ψ values of five plant species in Wenchang nursery and island.

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4. Discussion

4.1 Photosynthetic Rate and Leaf Economic Traits

Photosynthetic rate reflects carbon assimilation capacity and is an important indicator of comprehensive environmental adaptability. This study found that A of transplanted *S. taccada*, *I. pescaprae*, and *C. equisetifolia* was higher than nursery plants, indicating strong adaptability to coral island conditions. The lack of significant difference in *C. nucifera* suggests different adaptive strategies. Previous studies show transplanted seedlings undergo tolerance, recovery, and stable phases with different physiological responses, which may explain discrepancies with earlier research.

Specific leaf area (SLA) is closely related to drought resistance and photosynthetic capacity. Lower SLA indicates greater investment in protective structures and higher mesophyll cell density to prevent excessive water loss. The strong light and drought conditions on coral islands promoted most species to allocate more resources to leaf construction, reducing SLA to avoid radiation damage and water loss.

Leaf carbon content (LC) represents construction costs and reflects the leaf economics spectrum—the trade-off between resource investment and returns. The worldwide leaf economics spectrum shows that species with low LC and high photosynthetic rates occupy one end, while the opposite traits occupy the other. The significant increase in photosynthetic rate combined with decreased LC in island plants confirms this trade-off, showing greater energy allocation to photosynthetic capacity rather than leaf construction.

4.2 Water Use Efficiency

Water use efficiency (WUE) measures assimilated carbon per unit water consumed. Instantaneous WUE (A /Tr) reflects short-term efficiency, while stable carbon isotope composition (^{13}C) estimates long-term efficiency. Our results show that *I. pescaprae* and *C. equisetifolia* on the island had significantly higher instantaneous WUE, while ^{13}C increased in all species except *C. nucifera*, indicating improved long-term water use efficiency under drought conditions. This aligns with research showing drought increases ^{13}C values.

4.3 Stomatal vs. Non-stomatal Regulation

Stomata regulate the balance between water loss and carbon assimilation. Compared to nursery plants, *I. pescaprae* and *C. equisetifolia* on the island showed increased g but no corresponding increase in transpiration rate, suggesting stomatal structural adjustments that maintain photosynthesis while reducing water loss. This contradicts some studies showing stomatal closure under drought, indicating that island stress may trigger structural modifications for more uniform stomatal distribution.

Leaf hydraulic conductivity (K f) is positively correlated with photosynthetic rate within certain ranges. *I. pescaprae* and *C. nucifera* significantly increased K f on the island, enhancing water transport to support photosynthesis. In contrast, *A. hypogaea* showed decreased K f, suggesting its stress tolerance mechanisms were compromised.

The significantly lower Ψ in *I. pescaprae* and *A. hypogaea* indicates enhanced osmotic adjustment capacity, an important non-stomatal adaptation to drought. Combined with reduced SLA, these mechanisms prevent excessive water loss and improve drought tolerance.

5. Conclusion

This study demonstrates that different species employ distinct strategies to adapt to tropical coral island environments. *Arachis hypogaea* primarily uses non-stomatal regulation (increased K f, decreased Ψ and SLA). *Casuarina equisetifolia* and *Ipomoea pescaprae* use both stomatal and non-stomatal regulation to promote carbon assimilation and water use. *C. equisetifolia* and *I. pescaprae* exhibit higher photosynthetic capacity and water use efficiency, showing good adaptability and suitability for tropical coral island restoration.

Considering photosynthesis, water transport, and drought resistance, these three species demonstrate strong adaptability to the harsh conditions of tropical coral islands and are recommended for ecosystem restoration. However, plant adaptation is a long-term process requiring continuous monitoring of more species to provide a scientific basis for selecting suitable plants and improving ecosystem services on tropical coral islands.

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Note: Figure translations are in progress. See original paper for figures.