

Resilient Orchids: Understanding the Heat Tolerance of *Vanda tessellata* in Changing Climate in the Western Ghats, Wayanad

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Abstract— This study examines the heat resistance and adaptive strategies of *Vanda tessellata*, a resilient wild orchid species thriving in the semi-arid conditions of Wayanad, Western Ghats. Over five years (2019–2024), comprehensive field observations, physiological assessments, and environmental monitoring were conducted to evaluate its ability to withstand extreme temperatures and minimal water availability.

Our findings highlight that *Vanda tessellata* exhibits multiple survival mechanisms, including Crassulacean Acid Metabolism (CAM) photosynthesis, which allows it to minimize water loss by absorbing CO₂ at night. The orchid also develops thickened cuticles and an extensive aerial root system that enhances moisture retention and nutrient uptake from humid air. Additionally, anthocyanin pigmentation was observed to provide photoprotective benefits by reducing oxidative stress under intense solar radiation. Microhabitat selection played a crucial role in heat tolerance, with orchids growing in shaded areas demonstrating higher survival rates than those in direct sunlight. Soil and substrate analysis revealed that the species primarily thrives on host trees with high water-holding capacity, suggesting a strong dependency on specific ecological conditions.

The study underscores the importance of habitat conservation, particularly in the context of climate change, which threatens the stability of these microhabitats. Conservation strategies should focus on protecting key forest patches, promoting assisted propagation techniques, and implementing long-term monitoring programs to track climate-induced changes in orchid populations. By understanding the adaptive strategies of *Vanda tessellata*, this research contributes to broader conservation efforts aimed at preserving heat-resistant orchid species in tropical ecosystems.

Keywords— *Vanda tessellata*, heat resistance, Western Ghats, Wayanad, CAM photosynthesis, orchid adaptation, climate resilience, aerial roots, habitat conservation, anthocyanin pigmentation.

I. INTRODUCTION

1.1 Background:

Orchids are one of the most diverse and ecologically significant plant groups in the Western Ghats, playing a crucial role in maintaining ecosystem balance. They serve as bio-indicators of environmental health due to their sensitivity to climatic changes. Among them, *Vanda tessellata* is a robust, epiphytic orchid well-adapted to extreme heat conditions, making it a key species for studying plant resilience under stress. As global temperatures rise, understanding the physiological and ecological mechanisms enabling this species to endure high temperatures and moisture fluctuations becomes increasingly important.

This orchid species is known for its ability to thrive in exposed environments with limited water availability, thanks to specialized adaptations like CAM (Crassulacean Acid Metabolism) photosynthesis, aerial roots, and thickened cuticles. These features help it survive in semi-arid and dry deciduous forests where other orchids struggle. Given the increasing threat posed

by climate change and deforestation, a comprehensive study of *Vanda tessellata*'s resilience is crucial for developing effective conservation strategies.

1.2 Objectives:

- To investigate the morphological adaptations of *Vanda tessellata*, including leaf structure, cuticle thickness, and root system modifications that enhance heat tolerance.
- To analyze the physiological mechanisms, such as CAM photosynthesis and stomatal regulation, that contribute to its survival under extreme environmental conditions.
- To assess the ecological factors influencing its distribution, including temperature fluctuations, moisture availability, and symbiotic relationships with host trees and mycorrhizal fungi.
- To propose effective conservation measures, including habitat preservation, assisted propagation, and long-term monitoring, to ensure the sustainability of wild orchid populations in the face of climate change.

By addressing these objectives, this study aims to provide valuable insights into the resilience of *Vanda tessellata* and inform broader conservation efforts for heat-resistant orchid species in tropical ecosystems.

II. METHODOLOGY

2.1 Study Area:

The study was conducted in the Wayanad district of the Western Ghats, covering elevations between 700–1200 meters. Selected study sites included dry deciduous forests and exposed rocky terrains where *Vanda tessellata* is naturally found.

TABLE 1
EXPERIMENTAL DESIGN AND DATA COLLECTION FOR VANDA TESSELLATA STUDY

Parameter	Methodology	Purpose
Climate Monitoring	Automated weather stations recorded temperature, humidity, and precipitation levels	Assess environmental conditions affecting <i>Vanda tessellata</i>
Morphological Assessments	Microscopy used to measure leaf thickness, root structure, and cuticle characteristics	Evaluate physical adaptations to heat stress
Physiological Studies	Diurnal gas exchange measurements and chlorophyll fluorescence analysis conducted	Confirm CAM activity and assess photosynthetic efficiency
Soil and Substrate Analysis	Water retention and nutrient levels in host trees and rock surfaces analyzed	Understand substrate influence on orchid survival
Survival Rate Monitoring	Annual surveys recorded population trends and plant health over five years	Track long-term viability and response to climate change

2.2 Data Collection:

A combination of field observations, laboratory analysis, and remote monitoring techniques were employed to ensure comprehensive data collection. The following parameters were examined:

TABLE 2
KEY MORPHOLOGICAL ADAPTATIONS CONTRIBUTING TO HEAT TOLERANCE IN *VANDA TESSELLATA*

Morphological Feature	Adaptation	Function/Benefit
Thick, succulent leaves	Leaves are fleshy and store water	Reduces water loss, helps retain moisture during dry periods
Waxy cuticle on leaves	A thick, waxy outer layer on leaf surfaces	Minimizes water loss through transpiration
Extensive aerial root system	Roots extend outwards into the air	Absorbs atmospheric moisture, provides hydration in humid environments
Minimal leaf surface area	Smaller or fewer leaves in relation to plant size	Reduces transpiration and water loss under heat stress

This structured approach allowed for a holistic understanding of *Vanda tessellata*'s adaptation strategies and its resilience to environmental stressors.

III. RESULTS AND DISCUSSION

3.1 Morphological Adaptations:

The morphological features of *Vanda tessellata* were observed to be crucial for its survival in its native environment. Key adaptations include:

TABLE 3
PHYSIOLOGICAL RESPONSES TO ENVIRONMENTAL STRESS IN *VANDA TESSELLATA*

Physiological Response	Observation/Characteristic	Function/Benefit
CAM photosynthesis	Nocturnal CO ₂ uptake, storing CO ₂ in vacuoles during cooler night temperatures	Minimizes water loss by performing photosynthesis at night, conserving moisture
High levels of anthocyanin pigments	Pigment synthesis observed, especially in exposed individuals	UV protection and reduction of oxidative stress caused by intense sunlight
Low stomatal conductance	Stomata remained closed during peak heat stress, reducing water loss	Helps the plant conserve water during extreme temperatures

3.2 Physiological Responses:

Physiological responses to environmental stressors were significant, contributing to the orchid's ability to conserve water and thrive in dry, hot climates.

TABLE 4
ENVIRONMENTAL INFLUENCES ON *VANDA TESSELLATA* GROWTH AND DISTRIBUTION

Environmental Factor	Influence on <i>Vanda tessellata</i>	Adaptation/Observation
Shaded microhabitats	Populations in shaded areas exhibited better water retention and overall health	Shaded areas reduce temperature extremes, leading to more consistent water availability
Exposure to sunlight and heat	Orchids in exposed sites developed thicker cuticles and smaller stomata	Thicker cuticles and smaller stomata help reduce water loss under intense sun
Population density and humidity	Positive correlation between population density and humidity fluctuations	Higher density populations may influence local microclimates, providing better humidity for growth

3.3 Environmental Influence:

The environmental factors observed greatly influenced the growth and distribution of *Vanda tessellata*. Notably, the following patterns were recorded:

TABLE 5
CONSERVATION STRATEGIES FOR VANDA TESSELLATA

Conservation Strategy	Action Required	Reason/Benefit
Habitat protection	Protect host trees in dry zones from deforestation and climate change	These trees are crucial for orchid survival, providing necessary support and microhabitats
Assisted propagation techniques	Explore seed banking and tissue culture techniques to propagate the orchid	Helps preserve genetic diversity and increase populations for conservation purposes
Monitoring programs	Establish programs to track the distribution and shifts of orchid populations	Tracks effects of climate change, helping to adapt conservation efforts and assess long-term viability

3.4 Conservation Implications:

The findings suggest several important conservation strategies for *Vanda tessellata* to ensure its continued survival and sustainability.

IV. CONCLUSION

This five-year study underscores **Vanda tessellata** as one of the most heat-resistant orchid species in Wayanad, demonstrating its remarkable adaptability to extreme environmental conditions. Despite prolonged exposure to high temperatures and minimal water availability, this species has exhibited exceptional resilience, making it a key candidate for conservation in the face of climate change.

The ability of **Vanda tessellata** to withstand such harsh conditions highlights its ecological significance. As rising temperatures and unpredictable rainfall patterns threaten the survival of many plant species, this orchid's natural resilience offers valuable insights into climate-adaptive conservation strategies. Its ability to thrive in high-heat environments suggests that it could serve as a model species for studying stress tolerance mechanisms in orchids and other epiphytic plants.

Given the increasing threats of habitat destruction and climate change, future conservation efforts should prioritize **ex-situ propagation** and **habitat restoration**. Establishing controlled propagation programs in botanical gardens and research institutions will help ensure the survival of the species outside its natural habitat. Additionally, restoring degraded habitats through afforestation and microclimate management could support the natural regeneration of wild populations.

Further studies should also explore the genetic basis of its heat resistance, which could provide valuable information for breeding programs aimed at developing more resilient orchid varieties. Collaborative efforts between conservationists, researchers, and local communities will be crucial in safeguarding **Vanda tessellata** for future generations, ensuring that this resilient species continues to thrive in its natural ecosystem despite ongoing environmental challenges.

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