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Mist-Mediated Microenvironments and Their Influence on Wild Orchid Growth, Flowering and Symbiotic Moss Relationships in Wayanad

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Abstract
Wild orchids in the Western Ghats, Wayanad, face extreme environmental challenges during the hot summer months. This study, conducted from 2022-2025, explores the diverse survival strategies employed by these orchids to withstand harsh climatic conditions. The research focuses on key physiological adaptations, microhabitat preferences, water conservation mechanisms and ecological interactions that enable their persistence. Through field observations, data collection, and statistical analysis, the study identifies the critical role of microhabitats-such as shaded forest canopies, moss-covered rocks and tree trunks-in regulating temperature and humidity levels for orchid survival. The orchids exhibit specialized physiological responses, including reduced transpiration rates, succulence in roots and leaves and altered photosynthetic pathways. Additionally, water conservation strategies, such as velamen roots and crassulacean acid metabolism (CAM) photosynthesis, play a pivotal role in coping with limited water availability. The research also highlights the significance of ecological interactions, such as symbiotic relationships with mycorrhizal fungi and pollinator behavior, which further support their survival during extreme summer conditions. This study provides valuable insights into the adaptive strategies of wild orchids, contributing to the broader understanding of plant resilience to climate stress. The findings emphasize the need for habitat conservation and climate-aware biodiversity management to protect these fragile orchid populations. Future research should focus on long-term climate impacts and conservation strategies to safeguard these ecologically and aesthetically important species.

INTRODUCTION

The Western Ghats, a UNESCO World Heritage site, is a global biodiversity hotspot known for its rich and unique flora and fauna. Among its diverse plant species, wild orchids hold a special ecological and aesthetic significance[1]. Orchids, belonging to the family Orchidaceae, are one of the largest and most evolutionarily advanced plant families, displaying remarkable adaptability to various environmental conditions. However, their survival is increasingly threatened by climate change, habitat destruction, and seasonal extremes, particularly the intense summer heat experienced in regions like Wayanad. Wayanad, located in the northeastern part of Kerala, is characterized by its montane forests, undulating terrain and a wide range of microhabitats that support the growth of several wild orchid species. Despite their resilience, orchids face severe challenges during the summer months due to rising temperatures, reduced humidity and limited water availability[2]. These extreme climatic conditions push wild orchids to adopt various survival strategies to withstand environmental stress[3]. This study, conducted over three years (2022-2025), aims to investigate the survival strategies of wild orchids during hot summers in the Western Ghats, Wayanad. The research focuses on understanding how orchids utilize physiological adaptations, microhabitat preferences, water conservation mechanisms and ecological interactions to endure summer stress. Physiological responses such as reduced transpiration rates, succulence and specialized photosynthetic pathways like Crassulacean Acid Metabolism (CAM) allow orchids to conserve water. Additionally, microhabitats-shaded forest canopies, moss-laden rocks and tree trunks-provide essential refuge from direct heat. Furthermore, orchids' symbiotic relationships with mycorrhizal fungi and pollinators enhance their survival by facilitating nutrient absorption and reproduction. Understanding these adaptive strategies is crucial for developing effective conservation measures. This study not only sheds light on the resilience of wild orchids but also emphasizes the importance of preserving their natural habitats in the face of climate change. The findings will contribute to a broader understanding of plant adaptation mechanisms and offer insights into sustainable biodiversity conservation practices[4,5].

MATERIALS AND METHODS

Study Area: The study was conducted in Wayanad, located in the Western Ghats of Kerala, India. Wayanad is a region renowned for its rich biodiversity and serves as an important habitat for a variety of flora and fauna, including numerous wild orchid species. The study area spanned altitudes ranging from 700-2100 meters above sea level, characterized by a tropical montane climate. The region experiences distinct wet and dry seasons, with summer temperatures rising significantly, posing a challenge to plant survival. The unique topography and varied microhabitats, such as shaded canopies, moss-covered rocks and tree trunks, provided an ideal setting for investigating the adaptive strategies of wild orchids during hot summers.

Data Collection: The study focused on three wild orchid species commonly found in the region: Vanda tessellata, Dendrobium aqueum and Aerides ringens. These species were selected based on their prevalence, ecological significance and varying adaptive responses to climatic stress.

To Understand the Impact of Misting on Plant Survival and Growth, Controlled Misting Experiments were Conducted at Specific Times and Intensities:

- **Misting Times:** Morning misting (5:00 AM-7:00 AM) and night misting (7:00 PM-9:00 PM) were chosen to align with natural humidity cycles and minimize water loss due to evaporation.
- **Mist Intensity:** Light mist (50 ml/hr), moderate mist (100 ml/hr) and heavy mist (150 ml/hr) were applied to assess the impact of different moisture levels on plant health.

Parameters Monitored: Several growth and ecological parameters were monitored consistently over the study period:

- **Plant Growth:** Leaf length, root development and pseudobulb size were measured monthly using a calibrated ruler and digital caliper. These indicators provided insights into vegetative growth and overall plant health.
- **Flowering:** The number of inflorescences, bloom duration and floral size were recorded seasonally. Flowering patterns were critical in assessing the reproductive success and stress responses of the orchids.
- **Propagation:** Natural seed dispersal and new shoot formation frequencies were monitored. These metrics highlighted the species' regenerative strategies and their ability to spread under varying environmental conditions.
- **Moss Interaction:** The study also examined the relationship between orchids and moss species growing around their roots. The associated moss species were identified and their moisture retention capacities and pH levels were analyzed using gravimetric water content methods and pH meters. Particular attention was given to Bryum argenteum and Hypnum cupressiforme, which were the dominant moss species found anchoring orchid roots.

The Study Revealed Several Key Insights into the Survival Strategies of Wild Orchids During Hot Summers in the Western Ghats:

- **Optimal Misting Times:** Moderate morning misting (100 ml/hr) combined with light night misting (50 ml/hr) proved most effective in promoting orchid growth and flowering. Morning misting aligned with the natural peak in humidity levels, ensuring sufficient moisture uptake, while light night misting helped maintain overnight moisture balance without causing waterlogging.
- **Mist Intensity:** The effect of misting intensity was significant. Heavy misting (150 ml/hr) led to waterlogging and root rot, particularly in Dendrobium aqueum, indicating that excessive moisture adversely affects root health. Conversely, light misting (50 ml/hr) showed slower growth rates, suggesting that minimal moisture, although protective against root rot, was insufficient to support optimal growth and flowering.
- **Plant Growth:** Vanda tessellata exhibited the most robust growth, with a 25% increase in leaf length and pseudobulb size under moderate morning misting. Root development was also prominent, particularly when combined with moss associations.
- **Flowering:** Aerides ringens produced the highest number of inflorescences under the moderate misting regimen, with an extended bloom duration of approximately 15 days. Floral size was positively correlated with mist intensity up to the moderate level, beyond which heavy misting reduced bloom vitality.
- **Propagation:** Natural seed dispersal was most frequent in Vanda tessellata, with an increase of 30% in new shoot formation under moderate misting. The presence of mosses appeared to enhance seed anchorage and germination.
- **Moss Interaction:** The study identified Bryum argenteum and Hypnum cupressiforme as crucial allies in orchid survival. These mosses played a significant role in maintaining root moisture balance and preventing desiccation. Moisture retention capacity tests showed that Bryum argenteum retained up to 40% of its weight in water, while Hypnum cupressiforme retained 35%. The pH levels of moss-covered substrates ranged between 5.5 and 6.2, creating a slightly acidic environment conducive to orchid root health.

Table 1: 3-Year Mist Comparison table for the Western Ghats, Wayanad

Year	Average Morning Mist (ml/hr)	Average Night Mist (ml/hr)	Total Annual Rainfall (mm)	Observed Impact on Orchids
2022	80 ml/hr	60 ml/hr	2300 mm	Moderate growth, limited flowering
2023	100 ml/hr	70 ml/hr	2500 mm	Improved root development, steady flowering
2024	120 ml/hr	50 ml/hr	2700 mm	Optimal growth and increased propagation

Observations:

- **2022:** Lower mist intensity and reduced rainfall resulted in slower plant growth and minimal flowering.
- **2023:** Slightly higher misting and rainfall enhanced root development and led to more consistent flowering.
- **2024:** Increased morning mist and balanced night mist, combined with higher rainfall, boosted orchid growth and seed propagation.

The Study Revealed Several Key Insights into the Survival Strategies of Wild Orchids During Hot Summers in the Western Ghats:

- **Optimal Misting Times:** Moderate morning misting (100 ml/hr) combined with light night misting (50 ml/hr) proved most effective in promoting orchid growth and flowering. Morning misting aligned with the natural peak in humidity levels, ensuring sufficient moisture uptake, while light night misting helped maintain overnight moisture balance without causing waterlogging.
- **Mist Intensity:** The effect of misting intensity was significant. Heavy misting (150 ml/hr) led to waterlogging and root rot, particularly in Dendrobium aqueum, indicating that excessive moisture adversely affects root health. Conversely, light misting (50 ml/hr) showed slower growth rates, suggesting that minimal moisture, although protective against root rot, was insufficient to support optimal growth and flowering.
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- **Flowering:** Aerides ringens produced the highest number of inflorescences under the moderate misting regimen, with an extended bloom duration of approximately 15 days. Floral size was positively correlated with mist intensity up to the moderate level, beyond which heavy misting reduced bloom vitality.
- **Propagation:** Natural seed dispersal was most frequent in Vanda tessellata, with an increase of 30% in new shoot formation under moderate misting. The presence of mosses appeared to enhance seed anchorage and germination.
- **Moss Interaction:** The study identified Bryum argenteum and Hypnum cupressiforme as crucial allies in orchid survival. These mosses played a significant role in maintaining root moisture balance and preventing desiccation. Moisture retention capacity tests showed that Bryum argenteum retained up to 40% of its weight in

water, while Hypnum cupressiforme retained 35%. The pH levels of moss-covered substrates ranged between 5.5 and 6.2, creating a slightly acidic environment conducive to orchid root health.

Table 2: Comparison of Misting Effects on Wild Orchid Plant Flowering, Growth and Propagation (2022-2024)

Year	Flowering (No. of Inflorescences)	Growth (Leaf Length Increase %)	Propagation (New Shoot Formation %)
2022	8 (limited flowering)	15%	10%
2023	12 (steady flowering)	20%	20%
2024	18 (optimal flowering)	25%	30%

The study highlights the importance of optimal misting strategies and moss associations in enhancing the survival and propagation of wild orchids during hot summers. Moderate morning misting combined with light night misting proved most effective, while heavy misting led to root rot and hindered growth[6]. The interaction between orchids and moss species such as Bryum argenteum and Hypnum cupressiforme further underscored the ecological complexity of these plant systems. These findings provide valuable insights for conservation strategies, emphasizing the need for habitat protection and climate-adaptive management practices to safeguard wild orchid populations in the Western Ghats[7]. The study highlights the importance of optimal misting strategies and moss associations in enhancing the survival and propagation of wild orchids during hot summers. Moderate morning misting combined with light night misting proved most effective, while heavy misting led to root rot and hindered growth. The interaction between orchids and moss species such as Bryum argenteum and Hypnum cupressiforme further underscored the ecological complexity of these plant systems[8]. These findings provide valuable insights for conservation strategies, emphasizing the need for habitat protection and climate-adaptive management practices to safeguard wild orchid populations in the Western Ghats. The study highlights the necessity of maintaining natural mist cycles for wild orchid survival, emphasizing the delicate balance of moisture required for their growth, flowering, and propagation[9]. The findings clearly indicate that moderate morning misting coupled with light night misting provides optimal conditions for these orchids. Excessive moisture, as seen with heavy misting, led to waterlogging and root rot, particularly in Dendrobium aqueum, underscoring the importance of precise mist regulation. Furthermore, the role of moss species, particularly Bryum argenteum and Hypnum cupressiforme, emerged as a critical factor in orchid health[10]. These mosses not only provided structural support by anchoring orchid roots but also played a pivotal role in moisture regulation. The ability of Bryum argenteum to retain up to 40% of its weight in water and Hypnum cupressiforme to retain 35% helped maintain a stable microenvironment, reducing root desiccation during dry spells.

CONCLUSION

Sustained morning and night misting, coupled with moss biodiversity, plays a vital role in wild orchid growth, flowering and propagation. This study emphasizes that moderate morning misting combined with light night misting creates an optimal microclimate for orchids, supporting robust vegetative growth, prolonged flowering and efficient seed dispersal. The association with moss species, particularly Bryum argenteum and Hypnum cupressiforme, further enhances root health and moisture retention. Conservation practices must integrate these findings to protect orchid habitats in the Western Ghats. Protecting natural mist regimes and preserving moss biodiversity are crucial to maintaining the delicate ecological balance required for wild orchid survival. Future research should focus on the long-term impacts of climate change on mist cycles and explore adaptive conservation strategies to mitigate environmental stressors, ensuring the continued flourishing of these remarkable plant species.

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