Abstract

Global warming is affecting ecosystem functioning worldwide at an unprecedented pace, with Arctic regions and high mountain areas experiencing these changes in a particularly pronounced manner. The Himalayas and the Arctic—both characterized by low temperatures and short growing seasons—are witnessing some of the most marked ecological shifts. Although plants in these regions have developed various adaptations, overlapping factors such as rising temperatures, glacier retreat, permafrost degradation, and physiological drought intensify environmental stress, posing a threat to both biodiversity and ecosystem functioning. Gaining a deeper understanding of how Arctic and high-mountain plants respond to climatic changes is crucial for predicting and mitigating their impacts.

This dissertation employs dendrochronological and wood anatomical analyses to examine how selected Arctic and high-mountain plant species adapt to changing environmental conditions and serve as indicators of these changes. By analyzing growth patterns, xylem structures, and correlations with climatic conditions, the presented findings provide insights into the effects of contemporary warming on plant communities in these extreme habitats. Incorporating dendroclimatological analyses, this work introduces new growth chronologies for various species and determines their dendroclimatic responses. Using dendroecological analyses, it assesses how the studied plant species respond to diverse environmental factors. The dissertation consists of a series of thematically linked articles, each focusing on a specific species or region and describing how annual growth rings in shrubs and dwarf shrubs record current climate change.

Article I concerns the dwarf willow (*Salix herbacea*) from subarctic Iceland, examining its capacity to capture environmental changes in two contrasting climatic regimes. Despite these climatic differences, the research demonstrates that *S. herbacea* is a valuable drought indicator, especially in the relatively dry region of northeastern Iceland. Building on this, **Article II** compares growth-ring chronologies of two species—*Salix herbacea* and *Salix arctica*—highlighting their different responses to variations in air temperature and precipitation. In addition, the variability in vessel size and fiber structures underscores the importance of wood anatomy in shaping each species' climatic adaptations. *S. arctica* responds positively to rising temperatures, whereas *S. herbacea* shows improved growth under higher precipitation. This contrasting response illustrates the diverse adaptive strategies within the genus to evolving environmental conditions.

Article III focuses on the polar willow (*Salix polaris*) from Central Spitsbergen in the High Arctic. The study found that summer temperature alone does not fully explain this species' growth. Instead, local factors—such as increased soil water infiltration, snowmelt timing, and winter "rain-on-snow" events—strongly influence dwarf shrub development. At lower elevations, *S. polaris* growth depends on soil moisture and early-summer precipitation, while at higher sites, late-season temperature exerts a more pronounced effect. These findings indicate that relying solely on air temperature as a determinant of plant growth may overlook critical microhabitat factors.

Turning to high mountain areas, **Article IV** presents a 66-year growth-ring chronology of the East Carpathian rhododendron (*Rhododendron myrtifolium*). A strong positive relationship was found between summer temperature and the width of annual growth rings in this species. This pattern contrasts with results for tree species (*Picea abies, Abies alba*) growing in the forest zone, where August air temperature showed a negative effect on annual growth-ring width. These results emphasize the resilience of *R. myrtifolium* to rising temperatures and its potential as a sensitive climate indicator.

Article V shifts attention to the Himalayas, where the wood anatomy of the shrub *Rhododendron campanulatum* was analyzed in detail. For the first time in the literature, anatomical evidence of wood development disturbances linked to aphid invasions in high- mountain habitats is presented—an issue largely associated with increasingly frequent drought events. Until now, this factor had not been considered in the context of threats to Himalayan high-mountain flora or in the interpretation of growth-ring chronologies. Such disturbances may have a significant impact on reliable reconstructions of climatic conditions in this part of Asia.

Overall, the results confirm that the response of the studied plant species to climatic changes is complex, depending on both the species and local habitat conditions. Dendrochronological and wood anatomical analyses form an essential foundation for investigating how Arctic and alpine plants respond to climate change. By integrating these methods with climate data and ecological observations, this approach deepens our understanding of how selected species adapt to rapidly changing climatic conditions across different regions. The findings highlight factors that may influence observed “greening” and “browning” trends in tundra ecosystems or trigger insect outbreaks (e.g., aphids).