Influence of canopy structure and light on the regeneration of Numidian fir (*Abies numidica* de Lannoy) in the mixed forest of Mount Babor

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The Numidian fir (*Abies numidica*) is a Tertiary relict conifer of North Africa belonging to the circum-Mediterranean fir complex. This species is strictly endemic to Algeria and exhibits an extremely restricted distribution, being confined to the high elevations of Mount Babor and Mount Tababort. Within the Babor-Tababort National Park, it occurs primarily in mixed mountain forests, where it forms structurally complex stands associated with several tree species, notably the Atlas cedar (*Cedrus atlantica*), oak (*Quercus canariensis*), aspen (*Populus tremula*), maple (*Acer obtusatum*), and yew (*Taxus baccata*). The species is largely restricted to the humid northern slopes of the Babor-Tababort massif, where it occupies a narrow altitudinal belt ranging from 1500 to 2000 m, with its highest abundance typically observed between 1717 and 1788 m a.s.l. These high-elevation environments are characterized by exceptionally humid microclimates that strongly influence the species' ecology. Given its extremely narrow ecological amplitude and highly limited geographic range, the long-term persistence of *A. numidica* largely depends on the success of its natural regeneration.

This study aimed to evaluate the influence of light conditions and canopy openness on the natural regeneration of *A. numidica* in the mixed forests of Mount Babor. Hemispherical photographs were analyzed in R using specialized packages to quantify canopy structure and estimate understory light availability. From these images, the Diffuse Non-Interceptance (DIFN) index was derived, representing the fraction of diffuse radiation transmitted through the canopy to the forest floor. Juveniles of *A. numidica* were counted within 10 × 10 m plots around each sampling point to assess regeneration density. Finally, Gaussian models were fitted to examine the relationship between juvenile density and light availability under different canopy openness.

The results revealed a nonlinear response of fir regeneration to light availability. Juvenile density reached its maximum at intermediate levels of canopy openness, suggesting an optimal light range for the species' establishment. Very dense canopies limited regeneration due to low light availability, whereas excessively open conditions were associated with reduced seedling density, likely due to increased water and thermal stress. Differences were also observed according to canopy openness, with regeneration generally more abundant under *A. numidica* canopies than under those dominated by *C. atlantica*.

These findings highlight the usefulness of smartphone-based hemispherical photography as a low-cost and efficient method for assessing canopy structure in mountainous forest ecosystems. They also indicate that moderate canopy openings favor the natural regeneration of Numidian fir. The heterogeneous canopy structure of the Babor mixed forest, therefore, appears to play a key role in the regeneration dynamics of this relict Mediterranean mountain species, providing valuable insights for its conservation and sustainable forest management.