doi 10.18699/PlantGen-2025-269

Envirotyping of spruce (*Picea abies*) geographical provenances in Russia

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Motivation and aim: Utilizing all relevant data on the geographical provenances of Norway spruce, collected by various researchers and foresters over approximately 45 years, is essential for gaining new insights into their adaptability to changing climates. Our goal is to create a comprehensive database that includes a range of biological and economic parameters for each provenance, along with associated climatic data. We also aim to apply modern methods of analysis to uncover the genetic foundations underlying the different climatypes of Norway spruce, which have been used to establish these geographical cultures and have adapted to their environments over time. Using this database, we will develop a model to analyze the existing data and predict how these climatypes are likely to respond to ongoing environmental changes in the context of climate change.
Materials and methods: This study is based on 45 years of measurement data from Norway spruce (*Picea abies*) geographical cultures established in the late 1970s. These cultures were intended to reveal evolutionary and geographical population patterns, identify suitable seed sources for preserving and improving forest productivity, and inform forest seed zoning and breeding programs. However, many of these goals were not fully achieved, as research and maintenance were sustained by only a small group of dedicated scientists. We combine existing data from published and proprietary sources with climatic databases, satellite imagery, and other resources for comprehensive phenotypic and environmental analyses. Since nearly identical planting material was used to establish these cultures, we also genotype several preserved climatypes and add these results to our database. The resulting dataset can be used to develop machine learning and AI models in Python, aiming to uncover correlations between environmental, phenotypic, and genotypic characteristics.
Results: The study produces a predictive model that identifies correlations and underlying principles of genotype-environment interactions in Norway spruce (*Picea abies*), utilizing extensive historical data to forecast adaptation strategies under climate change.
Conclusions: These findings will inform updates to forestry policies to counteract climate-driven threats and provide science-based guidelines for sustainable management, conservation, and resilient reforestation practices.
Funding: This work is supported by a Russian Science Foundation grant, project No. 25-16-00109.