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Short communication

Integrated *ex situ* conservation and cultivation approach for *Sideritis scardica* on Shara Mountain

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Introduction

Mountain tea (*Sideritis scardica* Griseb.) is an endemic Balkan medicinal plant highly valued for its antioxidant, anti-inflammatory, and gastroprotective activities, driven by its rich flavonoid and phenolic content. Intense, uncontrolled wild harvesting on Shara Mountain threatens its natural populations. The increasing medicinal and commercial importance of *S. scardica*, together with its characteristic phytochemical and aromatic profile, has been documented in several studies on Balkan *Sideritis* species (Todorova and Trendafilova, 2014; Qazimi et al., 2014). This study implemented an integrated *in situ* and *ex situ* cultivation model combined with phytochemical profiling to evaluate bioactive metabolite preservation and support sustainable utilization of the species, building upon previous environmental adaptation concepts.

Materials and methods

Field mapping and seed collection

Field activities included precise GPS mapping and population density assessments of wild *S. scardica* populations around the Ljuboten vincinity. Phenological phases were closely monitored to enable manual harvesting of mature seed heads. Seed collection protocols were strictly regulated, ensuring that no more than 20–30% of available mature seed heads were collected. This threshold was maintained to preserve the long-term reproductive and regenerative capacity of native alpine populations.

Establishment of mother plantation

To secure a reliable pool for seed production and protect the natural gene pool from anthropogenic pressure and grazing, a dedicated mother population was established *in situ*. A plot measuring 10×10 m (total surface area of 100 m^2) was selected and fenced behind the Ljuboten mountain hut. Wild individual donor plants were carefully transplanted into this protected perimeter along with their native root systems and natural soil substrate.

Seed stratification and laboratory germination

Collected seeds underwent a standardized cold-moist stratification protocol at a controlled temperature range of 2–5 °C for a duration of 30–60 days, maintaining strict control over aeration and substrate humidity. Following stratification, *ex situ* laboratory germination was carried out under controlled environmental conditions (optimized temperature, photoperiod, and humidity) at the Laboratory of the Institute of Ecology and Technology on Popova Shapka. Vegetative monitoring metrics included absolute germination rate, emergence time, and overall seedling vigor.

Field cultivation and agro-technical management

Acclimated and stabilized seedlings were subsequently transplanted to a 1000 m² experimental

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plot near the Ljuboten Mountain Hut. Following established agro-ecological methodologies for Balkan mountain species (Evstatieva, 2002), transplantation was executed using a specialized planting grid featuring 70 cm inter-row spacing and 50 cm intra-row spacing (approximately 2,800 plants/decare). Crop maintenance relied exclusively on manual weeding and natural irrigation, strictly avoiding synthetic fertilizers, pesticides, or agrochemicals. Three-level monitoring protocols were established to track ecological, biological, and generative parameters.

Phytochemical analysis

Aerial parts of wild and cultivated *S. scardica* were collected at full flowering, air-dried, and extracted following established procedures (Petreska et al., 2011). Major secondary metabolites were analyzed by HPLC-DAD, focusing on phenylethanoid glycosides, hydroxycinnamic acid derivatives, and flavonoid glycosides characteristic of the species.

Statistical processing

All analyses were performed in triplicate. Data were evaluated using ANOVA and Pearson correlation analysis, with statistical significance set at $p < 0.05$.

Results and discussion

The application of cold-moist stratification significantly enhanced seed germination capacity, yielding a cumulative germination rate exceeding 60%, which substantially outperformed unstratified control seed groups. Controlled nursery conditions at Popova Shapka optimized early seedling vigor, successfully mitigating the extreme environmental variability typical of natural alpine habitats. Post-transplantation within the fenced perimeter, *ex situ* propagated seedlings demonstrated superior initial vegetative stability compared to direct wild transplants, achieving a survival and long-term reproductive success rate above 70% under the alpine conditions of the Ljuboten locality.

As a perennial, *S. scardica* gradually can produce vegetative biomass, with optimal dry yields reaching 100–150 kg/dekar in subsequent growing seasons, matching recorded multi-year agricultural outputs for the region (Evstatieva, 2002). HPLC-DAD analysis identified the characteristic phenolic acids and flavonoid glycosides of *S. scardica*, including verbascoside, echinacoside, chlorogenic acid derivatives, and flavonoids derived from apigenin, hypolaetin, and isoscutellarein. The phytochemical profiles of cultivated material should remain comparable to those observed in wild populations of *S. scardica* from North Macedonia (Qazimi et al., 2014).

Conclusion

The study demonstrated a successful conservation model for *S. scardica* integrating *in situ* protection, *ex situ* propagation, and field cultivation. This approach provides a sustainable biomass source, reduces pressure on natural populations, and offers a replicable framework for the conservation of other threatened Balkan medicinal plants.

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