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The rare, threatened liverwort *Pallavicinia lyellii* (Hook.) Carruth. in North Africa (Kroumiria, Tunisia) – A unique population

Imen BEN OSMAN, Vincent HUGONNOT, Amina DAOUD-BOUATTOUR & Serge D. MULLER

Pallavicinia lyellii (Hook.) Carruth. (Pallaviciniaceae) is a globally widespread species recorded in Asia from Turkey to Oceania (Grolle and Piipo 1984, 1986; Mamontov et al. 2015; Kürschner and Frey 2020), in Africa (see below), in North America and the Caribbean (Schuster 1992), and in South America (Hässel de Ménéndez and Rubies 2009). Concerns have been voiced about the taxonomic identity of several records (see for instance Mamontov et al. 2015) such that the Asian mentions (and possibly others) should be revised.

Pallavicinia lyellii has a southern-temperate suboceanic distribution in Europe. It has been recorded from the Atlantic coasts of continental Europe to Ukraine, and from Greece and Spain to Denmark, Lithuania and Macaronesia (Hodgetts and Lockhart 2020). It has vanished from Austria, the Czech Republic, Slovakia and Sweden. Its rarity and vulnerability are such that it is listed as ‘Vulnerable’ on the European Red List (Hodgetts and Lockhart 2020).

Although widespread at the world scale, the species is uncommon in Africa: it is localised in East Africa (Wigginton and Grolle 1996), recorded in West Africa only in Cameroon, Nigeria and Sao Tomé (Wigginton 2004), and mentioned on Reunion Island (Grolle 1995). In North Africa, the species was only known in Tunisia (Ros et al. 2007), where its current status is uncertain. Given the species’ apparent rarity and considerable phytogeographical interest, we undertook field and herbarium studies to relocate it in nature based on our knowledge of its local ecological requirements and to assess the possibility of implementing conservation measures.

We examined all North African specimens of *Pallavicinia lyellii* stored in PC and in MHLCLF (which corresponds to a part of Jelenc herbarium). For each herbarium specimen, after checking the taxonomic identity, we estimated the surface size of thalli in cm², recorded the details of location and ecology, and deliberately searched for sexual individuals. Thalli were noted as male, female, or sterile. We compiled all bibliographical records of the species from publications dealing with North Africa (Labbe 1953; Jovet-Ast and Bischler 1971; Ros et al. 1999, 2007). From April 1-13, 2019, we conducted field surveys in Kroumiria, North Tunisia, in major peatlands and *Alnus glutinosa* swamps. We revisited localities where the species was previously mentioned. We evaluated the surface occupied by patches of *Pallavicinia lyellii* and recorded sexual individuals. We confirmed the identification of all specimens stored under the name *Pallavicinia lyellii* (Table 1), except PC0762698 (s.d, Aïn Draham) that only contained *Pellia* sp. All five North African specimens of *Pallavicinia lyellii* come from North Tunisia. Three main localities in Aïn Draham delegation are mentioned:

- Mérij valley: coll. Labbe in 1948 (Jovet-Ast and Bischler 1971; herbarium 510) and Allorge in 1951 (Labbe 1953; PC0762694);
- Ouled Ayed bridge: coll. Labbe (Jovet-Ast and Bishler 1971; PC0762693, PC0167851);
- Dar Fatma: coll. Labbe (Labbe 1953; Jovet-Ast and Bishler 1971, s.n.).

Jovet-Ast and Bischler (1971) travelled intensively in North Tunisia without finding this liverwort again. We were fortunate enough to locate a micro-population (total occupation size: 100 cm²) of this species in the field (Table 1), which may correspond to the historical population of Merij. All specimens that we checked were either sterile or female. No male individuals or sporophytes were found. In herbaria, sample sizes range from 10 to 90 cm².

The unique extant Tunisian population is located at Camp du 18° (36°45'12.48"N, 8°41'17.25"E, 657 m a.s.l.; site 2019-34), in a peatland of 0.2 ha fed by a small stream. The habitat is located within an oak forest that is locally dominated by *Quercus canariensis* Willd. and *Q. suber* L. The peatland is extremely degraded, partially burned and dominated by high clumps of *Juncus* (*J. conglomeratus* L. and *J. effusus* L.), associated with *Erica scoparia* L., *Pteridium aquilinum* (L.) Kuhn and *Rubus ulmifolius* Schott. The wettest areas are occupied by *Eleocharis multicaulis* (Sm.) Desv., *Hypericum afrum* Lam., *Lysimachia tyrrhenia* (Thore) U.Manns & Anderb., *Lythrum junceum* Banks & Sol., *Potentilla reptans* L. and *Solenopsis bicolor* (Batt.) Greuter & Burdet. Two species of *Sphagna* grow here: *Sphagnum auriculatum* Schimp. and *S. subnitens* Russow & Warnst. *Pallavicinia lyellii* was growing on disintegrated tussocks of *Juncus*. It was associated with *Calypogeia arguta* Nees & Mont., *Campylopus introflexus* (Hedw.) Brid., *Cephalozia bicuspidata* (L.) Dumort. and *Fuscocephaloziopsis connivens* (Dicks.) Vána & L.Söderstr.

The occurrence of oceanic species in North African peat-forming habitats is generally considered to be relictual. Neogene Late Cenozoic glaciations led to the decline of Tethyan subtropical flora (Cronk 1992; Rodríguez-Sánchez and Arroyo 2010), which have partly persisted on Macaronesian archipelagos (Fernández-Palacios et al. 2011), in southwestern Morocco (Médail and Quézel 1999), on the Atlantic Iberian coast (Postigo Mijarra et al. 2009) and in a few favourable habitats scattered around the Mediterranean (Quézel and Médail 2003). Moreover, *Pallavicinia lyellii* is a dioicous species, with no means of specialized vegetative multiplication other than clonal expansion followed by decay of older parts. In Tunisia, the evident individual gender isolation (only female individuals were spotted, either in herbariums or in the field), totally precludes spore production. Globally, it is not known if sporophytes are rare. In England, where detailed studies have been undertaken, sporophytes are considered to be rare (Blockeel et al. 2014), probably because of sexual isolation, and female populations seem to be more frequent than male ones (Turner 2007; Callaghan 2019). Sexual depletion is often associated with the relictual occurrence of a bryophyte population (Blackstock 2020; Hugonnot et al. 2020), arguing in favour of the species' ancient origin. *Pallavicinia lyellii* thus appears as a remarkable element of this relict Neogene flora. The habitats where it develops have high historical and conservation values.

The ecology of the Tunisian populations of *Pallavicinia lyellii* remarkably matches that described in Western Europe (Blockeel et al. 2014). The species is a hygrophyte that grows mainly on shaded, wet, organic substrates (Düll 1992; Dierssen 2001; Turner 2007; Hugonnot and Celle 2012; Lavate et al. 2015; Mamontov et al. 2015; Stebel et al. 2018). Notably, it is often associated with *Sphagna*, which are extremely rare and threatened in North Africa (Muller et al. 2010, 2011; Ben Osman et al. 2021).

Pallavicinia lyellii was certainly over-collected by bryologists in North Africa. No less than 325 cm² (collected from 1948 to 1955) are stored in herbariums. Compared with what remains of the species (approximately 100 cm²), this can be considered unreasonable. In comparison, the size of the known European populations is often very small, reaching at most several tenths of cm² (Turner 2007; Hugonnot and Celle 2012; unpub. records). The specimen I.217 came from a museum exchange society (*Société d'échanges de Muscinées* under the auspices of the *Société Botanique du Centre-Ouest*), which means that other specimens have been collected and offered. Whereas direct evidence of the responsibility of botanists in the extinction process

of threatened plants is often scarce (Norton et al. 1994; Foley 2009; Sperduto et al. 2018), here we have a clear demonstration.

Our results attest to the persistence of *Pallavicinia lyellii* in Northern Tunisia 70 years after its first observation, and after decades of over-collecting, which clearly gives hope for its conservation. They also highlight the importance of the peatland located near the Camp du 18^e that harbors the rare and threatened *Sphagnum auriculatum*, *S. subnitens* (Ben Osman et al. 2021) and *Fuscocephaloziopsis connivens* (Dicks.) Vána & L.Söderstr. The alarming state of the site (overgrazed, illegal logging, fires) clearly threatens the short-term survival of this exceptional bryophytic community. Management and protection policies must be implemented urgently to ensure the persistence of this invaluable heritage.

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Table 1. Tunisian specimens examined. n.a., not available.

Data origin	Herbarium	Specimen number	Herbarium patch size	Date	Collector	Delegation	Locality	Mentioned ecology	Total surface of population	Sexuality
Herbarium	MLCLF	I.217	80 cm ²	n.a.	Labbe	Aïn Draham	n.a.	n.a.	n.a.	female
Herbarium	PC	PC0049473	50 cm ²	13/07/1955	Labbe	Aïn Draham	Ouled Ayed Bridge	n.a.	n.a.	female
Herbarium	PC	PC0762694	35 cm ²	June 1951	Labbe	Aïn Draham	El Mérij	<i>Sphagnum</i> station	n.a.	female
Herbarium	PC	PC0762693	90 cm ²	13/07/1955	Labbe	Aïn Draham	E of Ouled Ayed Bridge	n.a.	n.a.	female
Herbarium	PC	PC0167852	10 cm ²	n.a.	Labbe	Tunisia	n.a.	n.a.	n.a.	sterile
Herbarium	PC	PC0167851	60 cm ²	13/07/1955	Labbe	Aïn Draham	After Ouled Ayed Bridge	wet soil with varying degrees of shade	n.a.	female
Field of this study	TUN/personal herbarium	TUN2019-113		05/04/2019	Hugonnot and Ben Osman	Aïn Draham	Camp du 18 ^e	degraded peatland	100 cm ²	female