RELATIONSHIPS BETWEEN MYCOBIONT IDENTITY, PHOTOBIONT SPECIFICITY AND ECOLOGICAL PREFERENCES IN THE GENUS PELTIGERA (ASCOMYCOTA)

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Peltigera Willd.

Peltigera canina: bi-partite association

Cephalodia containing *Nostoc* on upper surface

Peltigera leucophlebia: tri-partite association

(Photos by J. Rikkinen, https://vanha.laji.fi/taxon)

Genus *Peltigera*

- The genus includes eight monophyletic lineages (sections) (Miadlikowska & Lutzoni 2000):

  Peltigera, *Polydactylon*, *Chloropeltigera*, *Peltidea*, *Horizontales*, *Retifoveatae*, *Phlebia*, *Hydrothyriae*

- 66 well-accepted species in 2003 (Martinez et al. 2003)
- section *Polydactylon:* number of species inincreased from 14 to 38 (Magain et al. 2017a, b)
- section *Peltigera:* 88 species, including 50 species new to science (Magain et al. 2018)

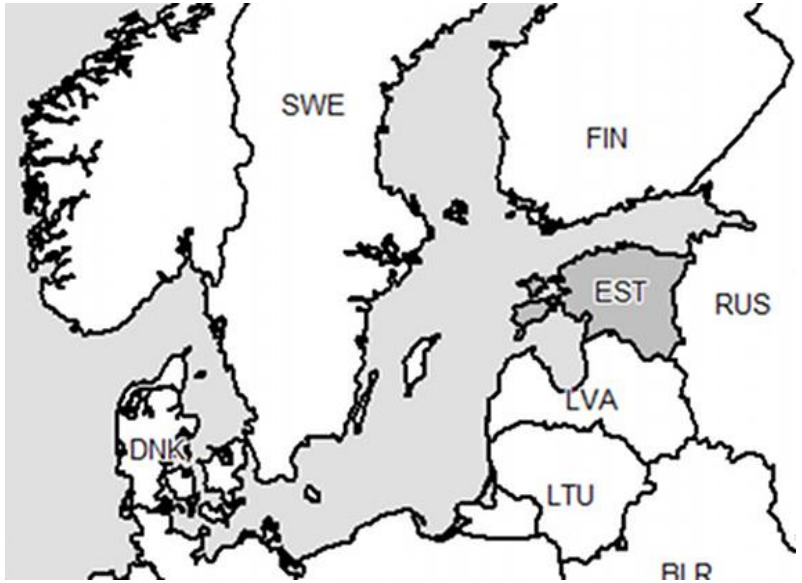
- In genus *Peltigera*, the specificity of mycobionts in their association with *Nostoc* ranges from strict specialists to broad generalists (Magain et al. 2018)
- Widespread species associating a broader selection of *Nostoc* phylogroups (=„species“) than species with limited distributions (Magain et al. 2017, 2018)
- Photobiont switches within individual fungal species have been identified along longitudinal gradients (Magain et al. 2017)

Study area - Estonia

- We studied the habitat and substrate relationships of cyanobionts in local scale
- We were interested

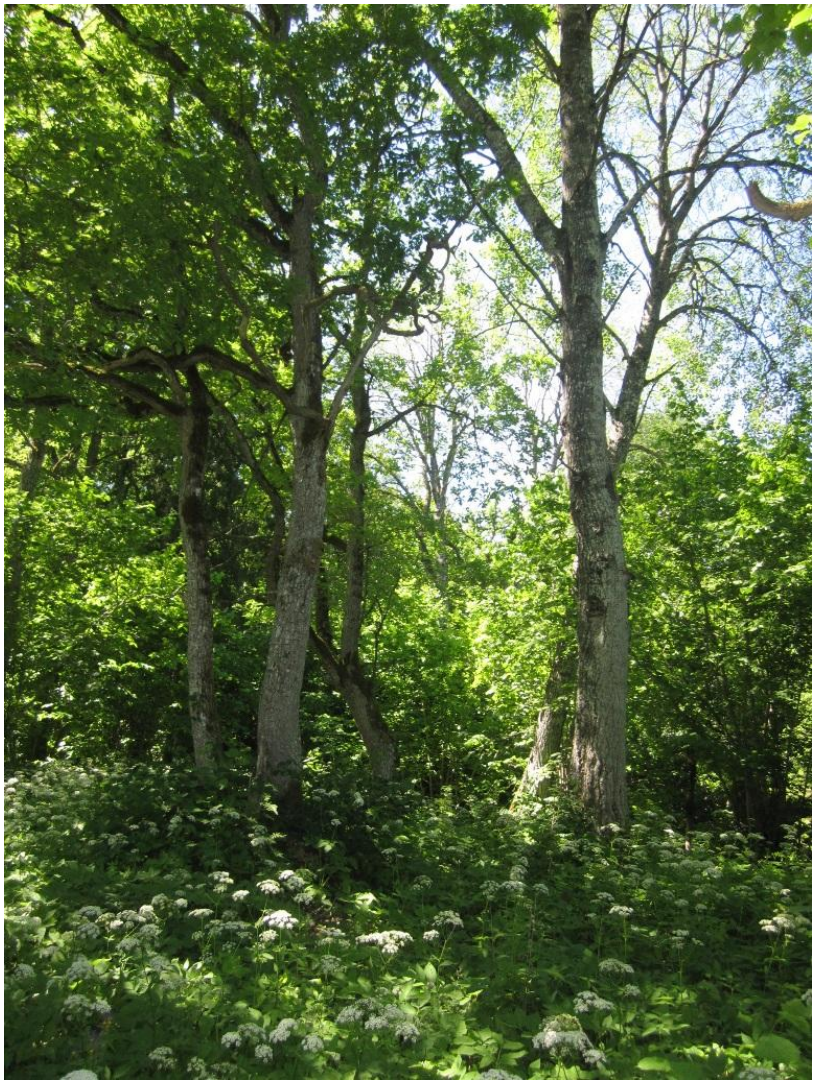
(1) if *Peltigera* species growing on grasslands or forest representing similar set of *Nostoc* genotypes and

(2) does substrate type effect the presence of certain *Nostoc* genotypes



Mesotrophic and eutrophic forest types

- herb-rich forests on fertile, mesic soils
- mixed or dominated by spruce (*Picea abies*) or deciduous broad-leaved trees



Oligotrophic forest types

- nutrient-poor soil
- soil pH 5.3
- dominated by pine

(*Pinus sylvestris*)

Park

- Park stands within agricultural landscape
- soil pH 6.4
- disturbed habitats – trampling, mowing

Roadsides

- grasslands by unpaved or hard-surfaced roads
- soil pH 7.2
- disturbed

Dunes

- coastal and inland sand dunes
- soil pH 6.6
- around the Baltic Sea and Lake Peipsi

Alvars

- thin calcareous soil (thickness -20 cm)
- soil pH 7.3
- formed on calcareous sediments of the Ordovician or Silurian age or on monolithic calcareous rock

Peltigera malacea

Peltigera aphthosa

Peltigera neckeri

Peltigera praetextata 2 x

Mycobiont of *Peltigera*

- the identity of the fungal hosts was determined based on the fungal ITS sequences
- 252 fungal ITS sequences → 31 OTUs (operational taxonomic units)
- we revealed 19 described *Peltigera* taxa from five different sections of the *Peltigera*
- and several putative undescribed taxa (Miadlikowska et al. 2003, Goffinet et al. 2003, Magain et al. 2018): e.g. *P*. „*neorufescens*“, *P*. „*neocanina*“

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Specialist taxa restricted to threatened habitats contribute significantly to the regional diversity of *Peltigera* (Lecanoromycetes, Ascomycota) in Estonia

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Alvars
Forests
Parks

ABSTRACT

The widespread cyanolichen genus *Peltigera* comprises many insufficiently known poorly delimited and/or undescribed species. Phylogenetic analysis of 252 *Peltigera* specimens from a wide range of habitat types in Estonia revealed 31 putative taxa (OTUs). Multivariate analysis revealed habitat-specific segregation between the *Peltigera* species along a gradient from humid eutrophic forests to dry oligotrophic forests and grasslands and along a soil pH gradient from alkaline soils of alvar grasslands to acidic soils of conifer forests. The diversity of *Peltigera* was the highest on roadsides and dunes and the lowest in alvar habitats which, however, supported the unique assemblage of undescribed *Peltigera* taxa. Deciduous broad-leaved forests, too, included several undescribed or rare and red-listed species. The results demonstrate that in Estonia many *Peltigera* species have narrow habitat requirements and are at present threatened by habitat loss and degradation.

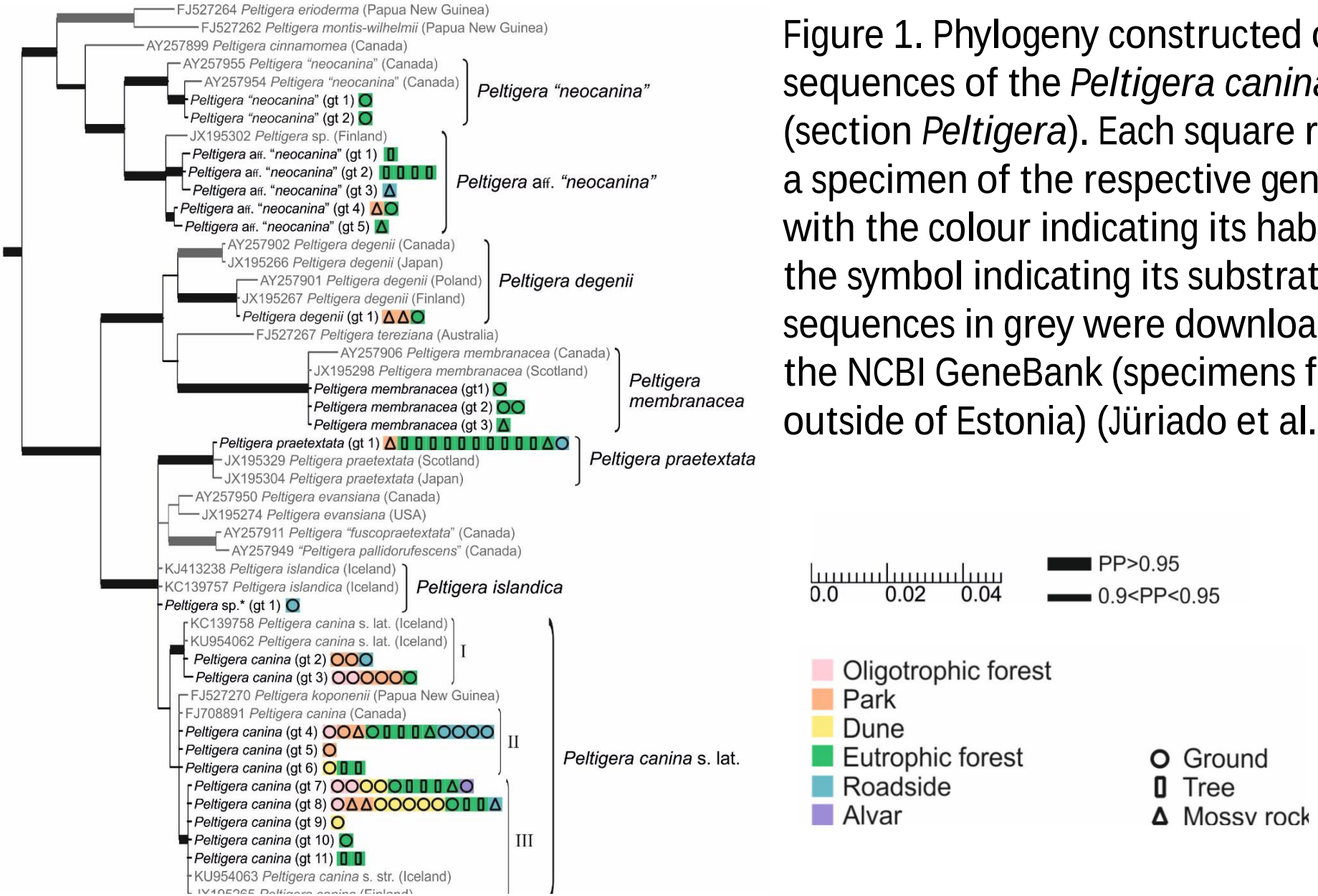
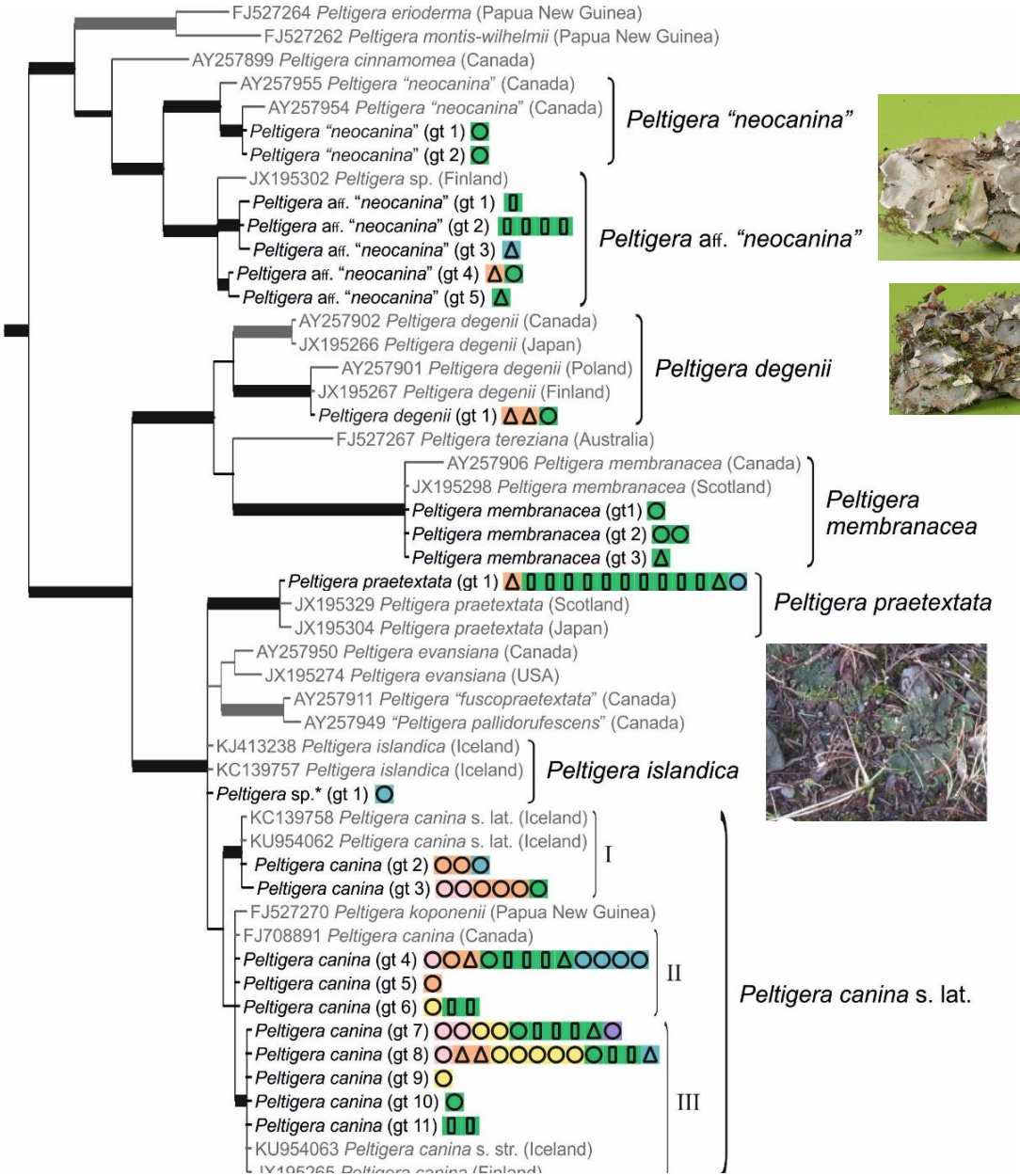


Figure 1. Phylogeny constructed of the ITS-sequences of the *Peltigera canina*-group (section *Peltigera*). Each square represents a specimen of the respective genotype, with the colour indicating its habitat and the symbol indicating its substrate. The sequences in grey were downloaded from the NCBI GeneBank (specimens from outside of Estonia) (Jüriado et al. 2017).



P. islandica — Manoharan-Basil et al. 2016

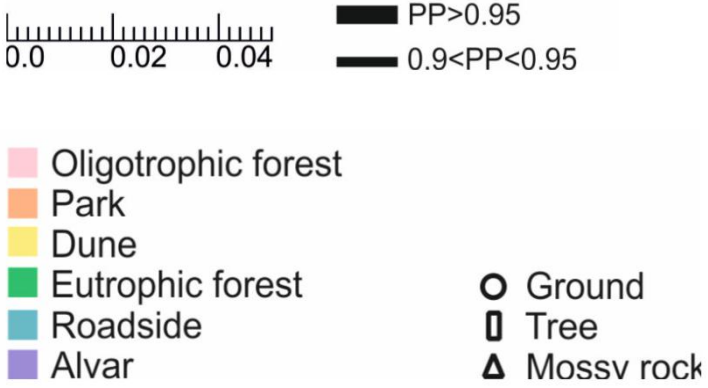
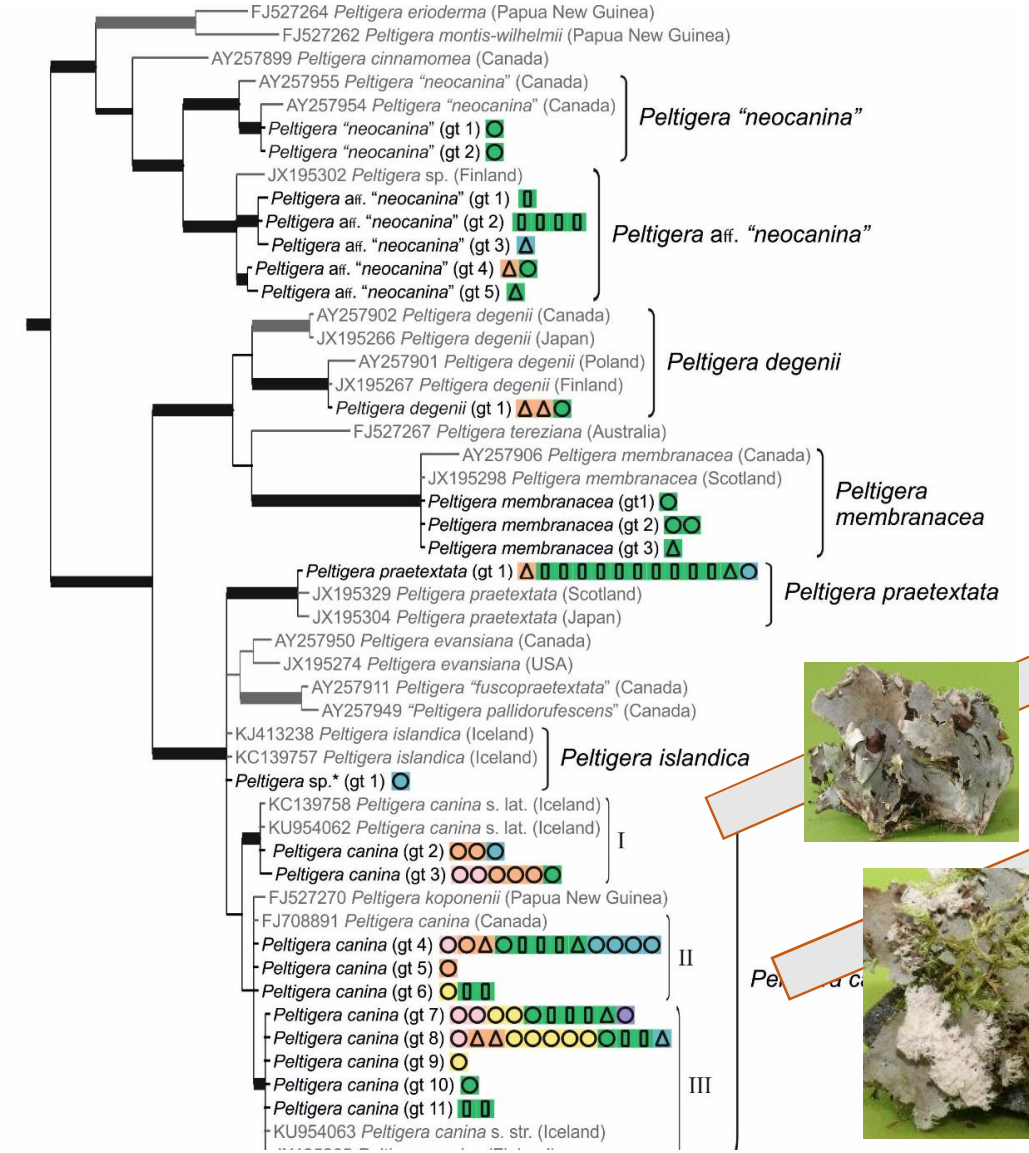


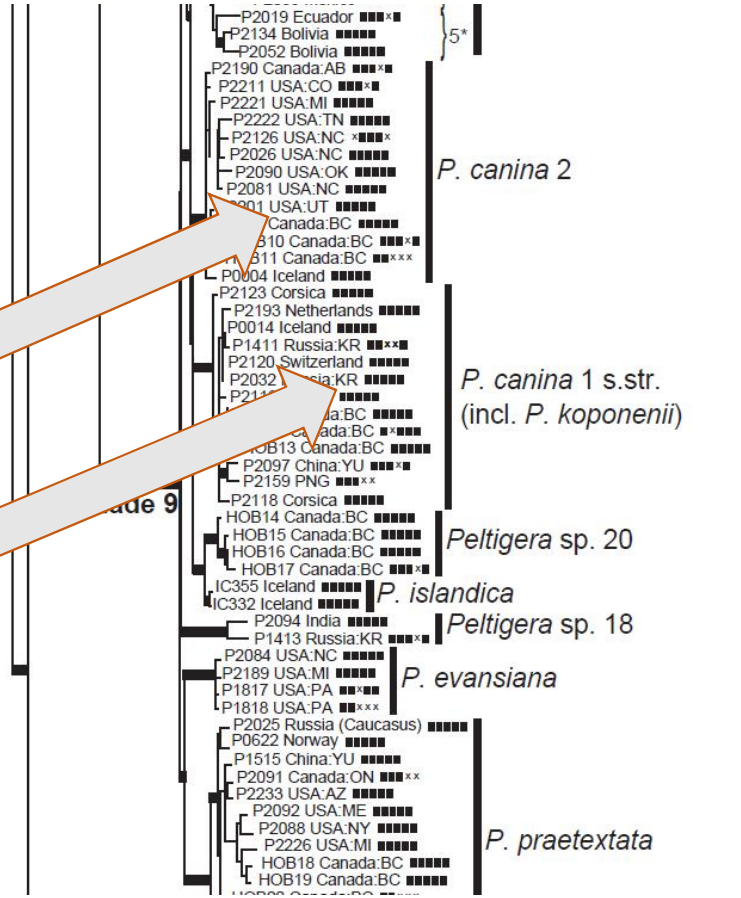
Figure 1. Jüriado et al. 2017



SYSTEMATICS AND PHYLOGENY

Species delimitation at a global scale reveals high species richness with complex biogeography and patterns of symbiont association in *Peltigera* section *Peltigera* (lichenized Ascomycota: Lecanoromycetes)

Nicolas Magain,[1] Camille Truong,[1,2] Trevor Goward,[3] Dongling Niu,[4] Bernard Goffinet,[5] Emmanuel Sérusiaux,[6] Orvo Vitikainen,[7] François Lutzoni[1,8] & Jolanta Miadlikowska[1,8]



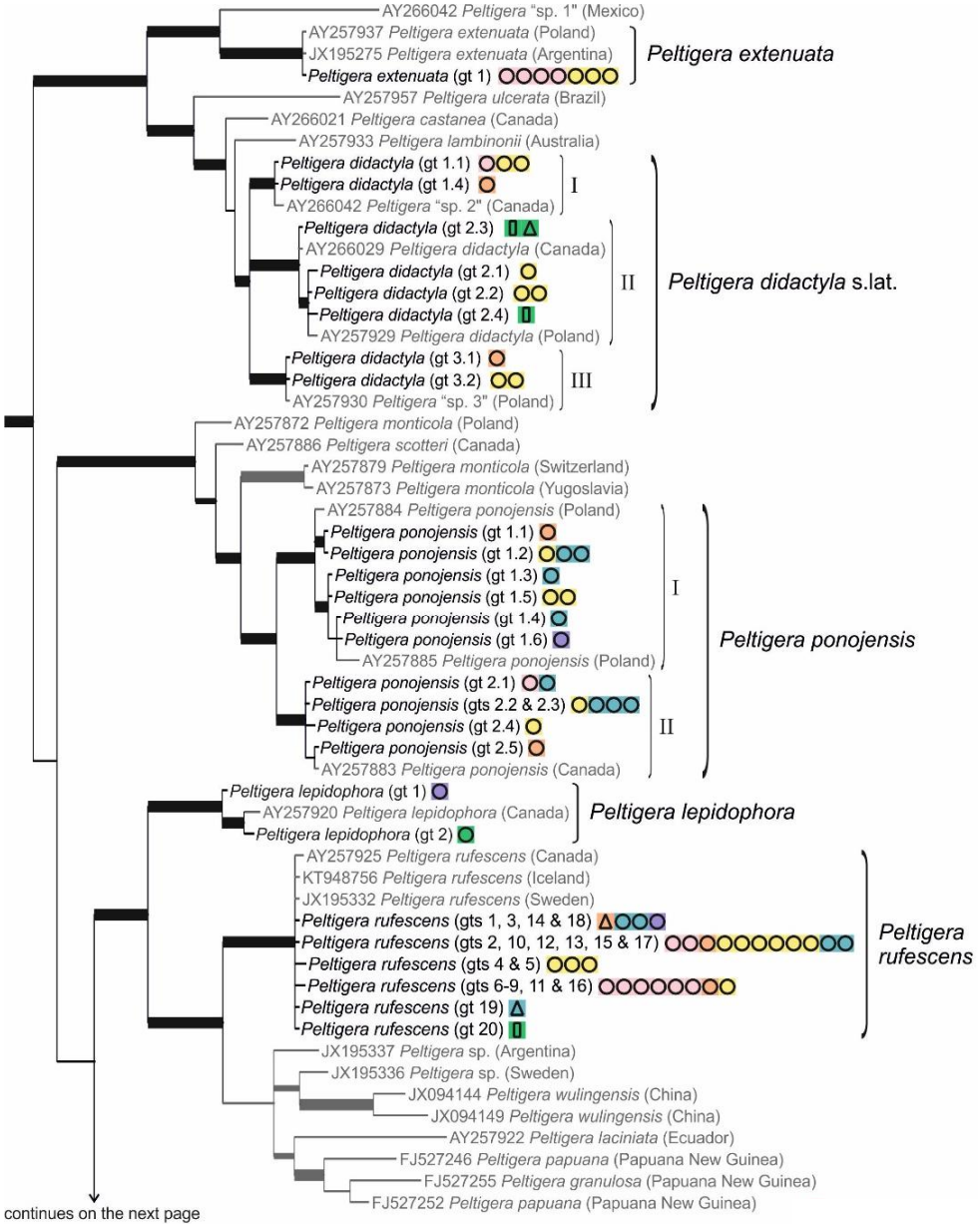
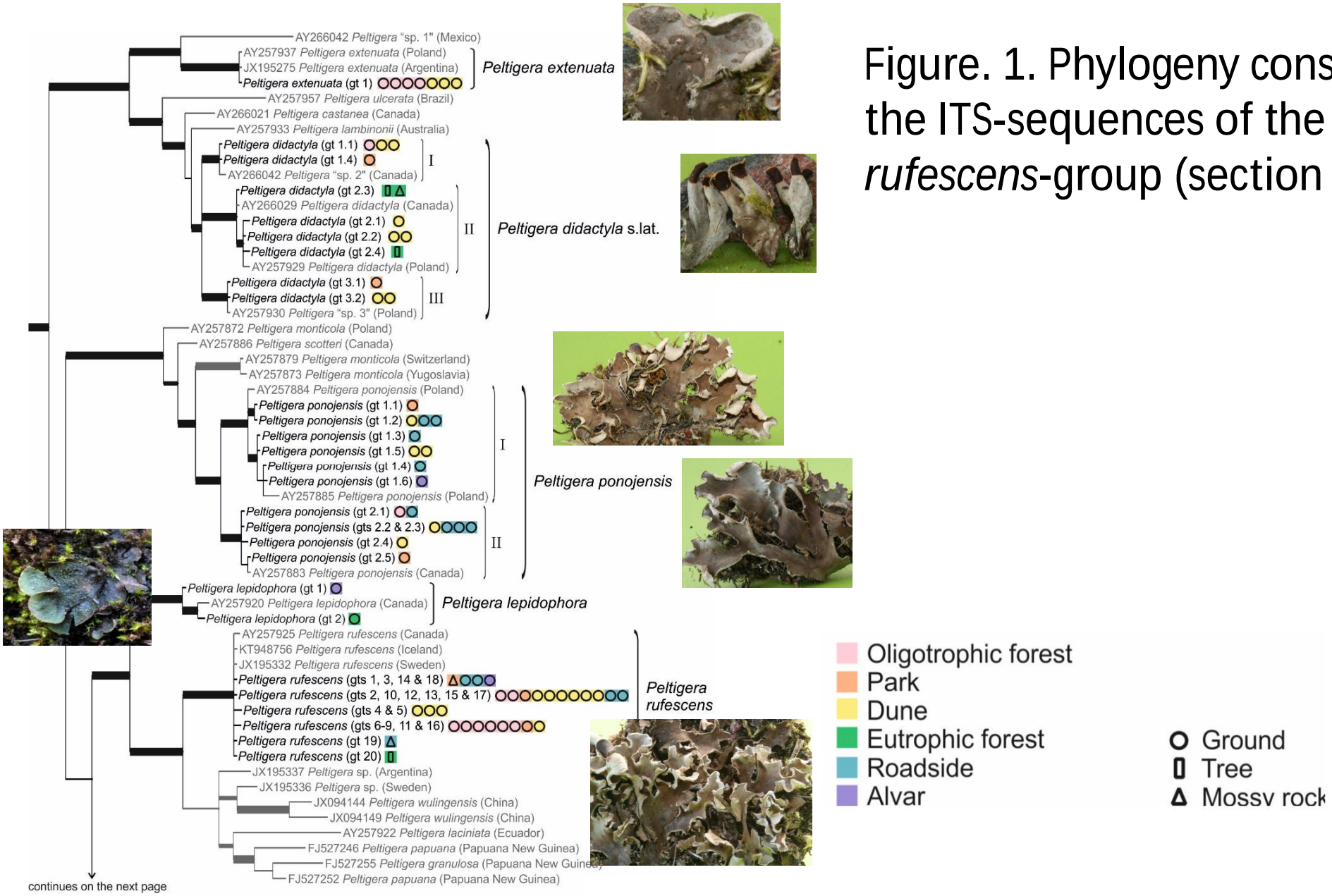


Figure. 1. Phylogeny constructed of the ITS-sequences of the *Peltigera rufescens*-group (section *Peltigera*)



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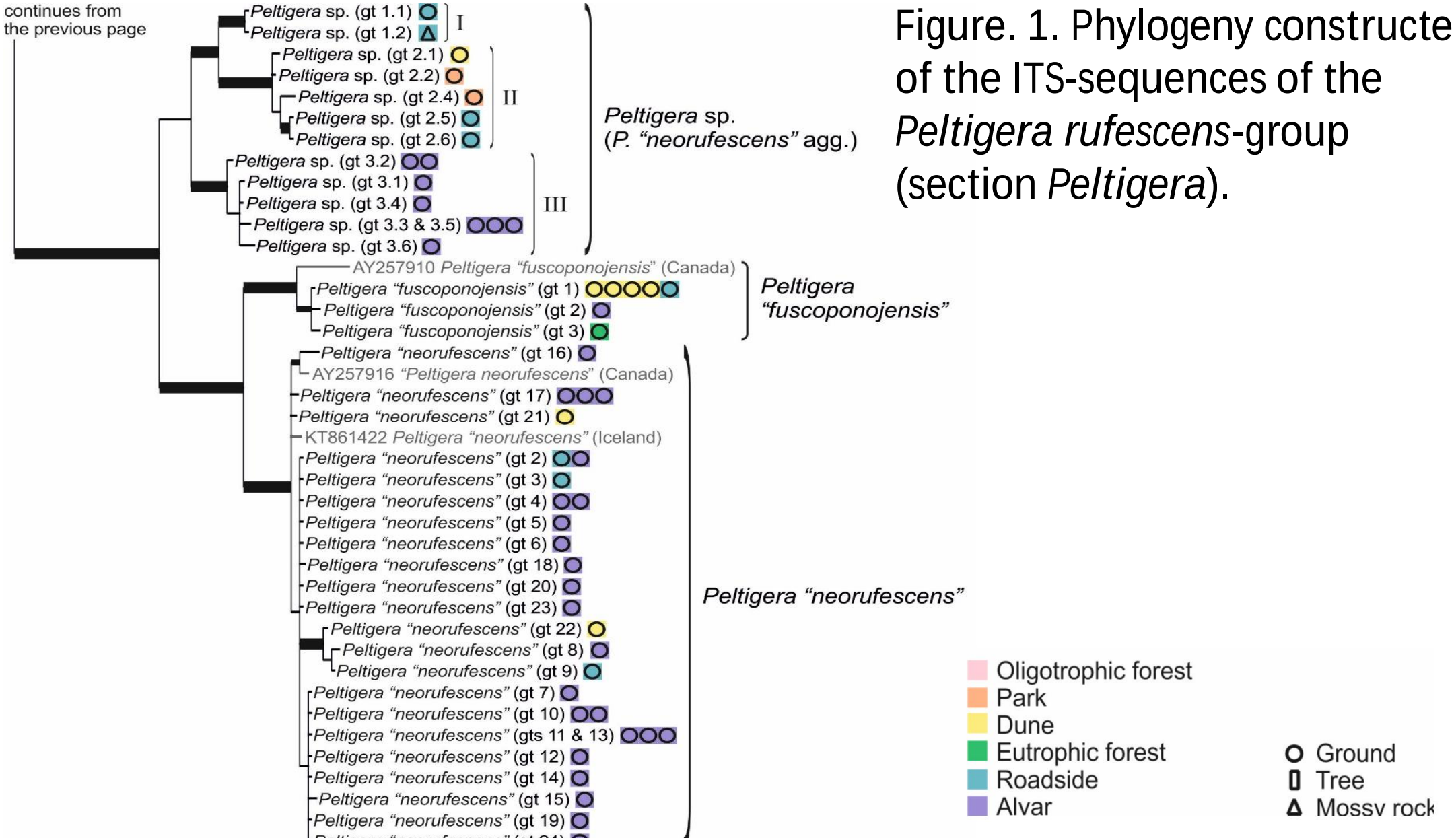

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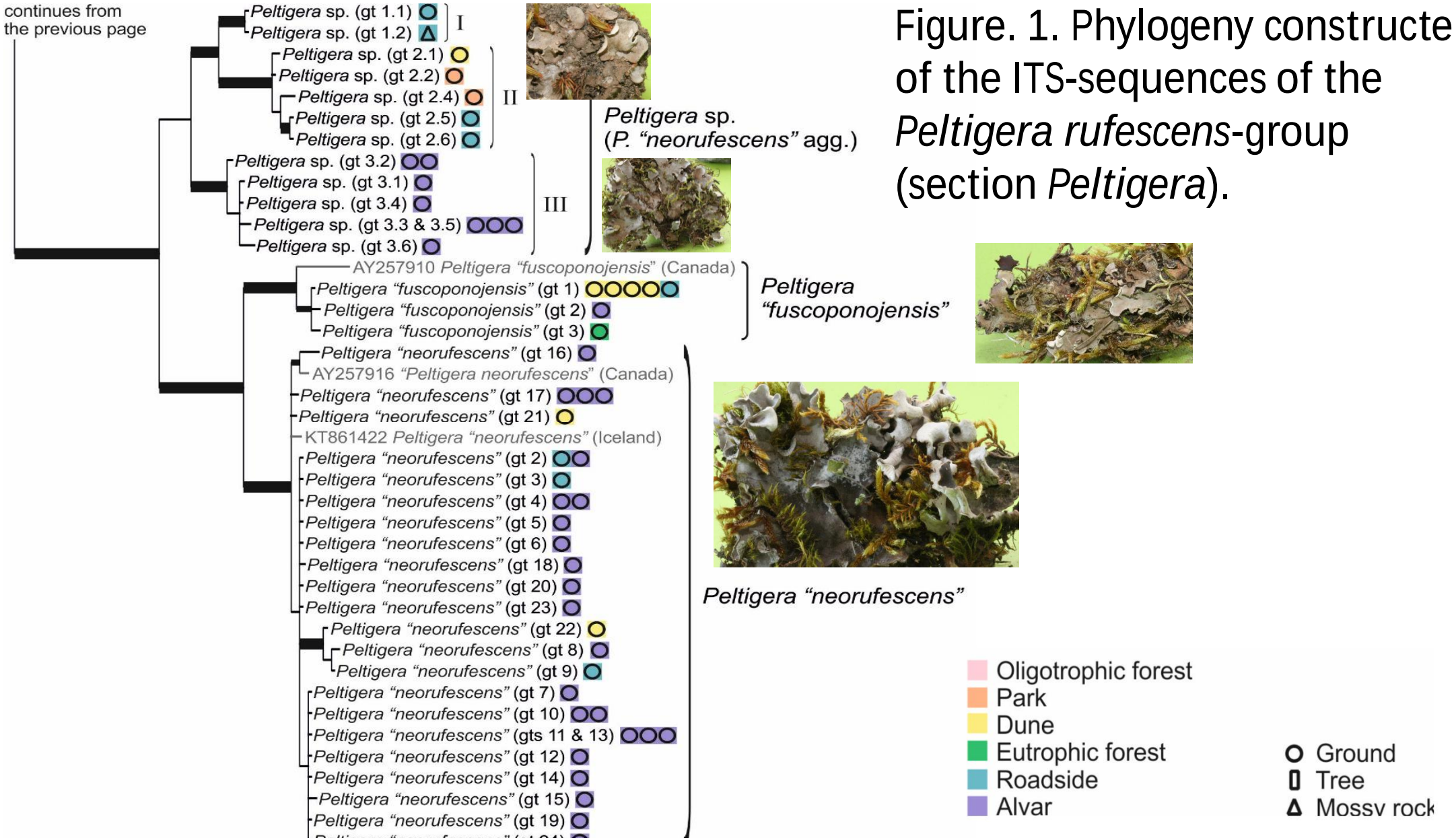

Figure. 1. Phylogeny constructed of the ITS-sequences of the *Peltigera rufescens*-group (section *Peltigera*).

Table 2
Number of sequenced *Peltigera* specimens from different substrates (ground, rock, tree) and habitat types; number of taxa (S); and value of Shannon diversity index (H) for each habitat type.

Habitat	Ground	Rock	Tree	S	H
Oligotrophic forests	27	1	—	10	2.09
Eutrophic forests	21	9	44	18	2.37
Park stands	15	10	—	14	2.47
Alvars	43	—	—	10	1.49
Dunes	47	—	—	15	2.46
Roadsides	30	5	—	14	2.48
Total	183	25	44		
Average				13.5	2.22

- The diversity of *Peltigera* was the highest on roadsides, parks and dunes and the lowest in alvar habitats which, however, supported the unique assemblage of undescribed *Peltigera* taxa
- Deciduous broad-leaved forests, too, included several undescribed or rare and red-listed species
- The results demonstrate that many *Peltigera* species have narrow habitat requirements and are at presently threatened by habitat loss and degradation

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Relationships between mycobiont identity, photobiont specificity and ecological preferences in the lichen genus *Peltigera* (Ascomycota) in Estonia (northeastern Europe)

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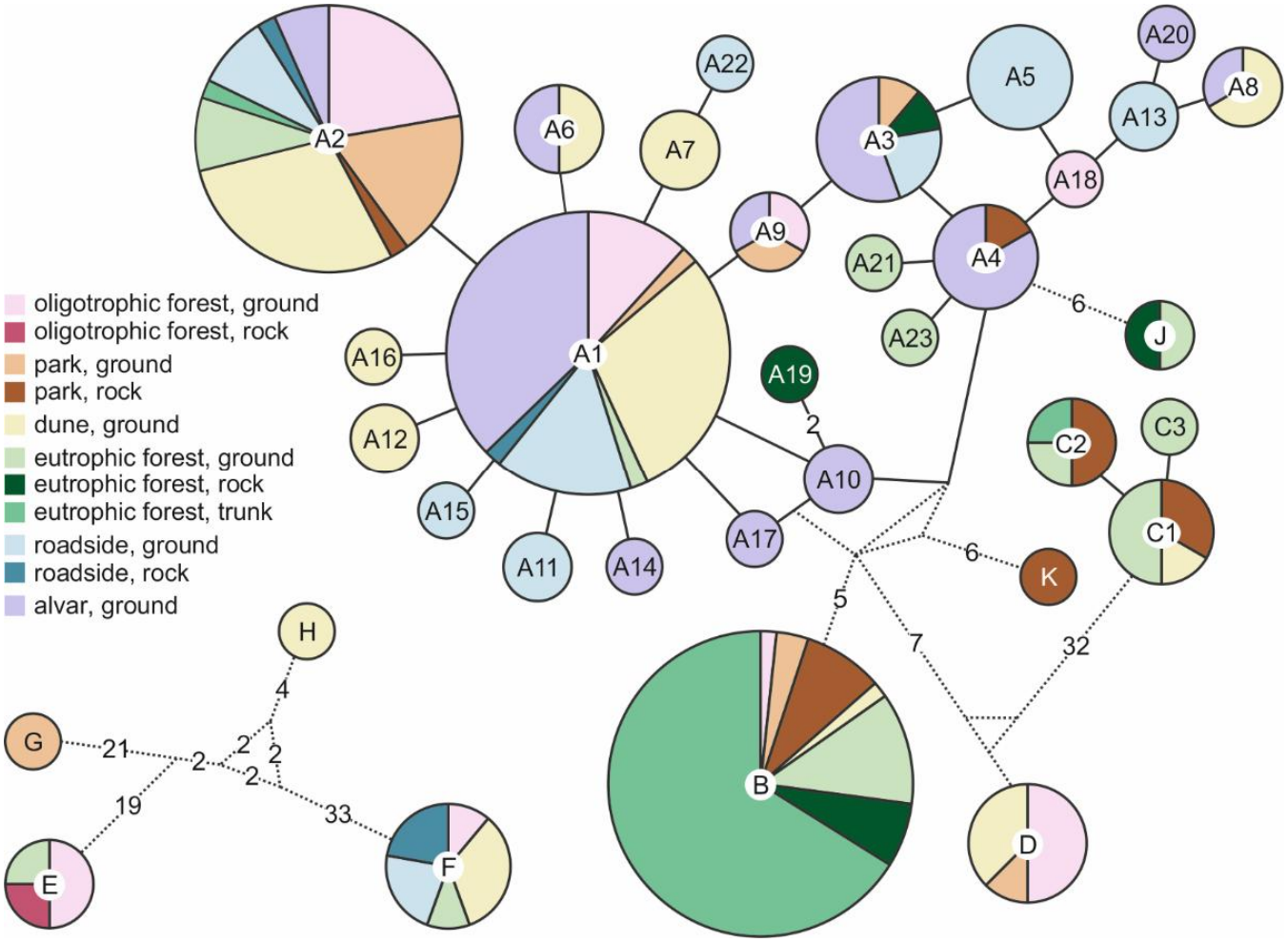
ABSTRACT

We studied the genotype diversity of cyanobacterial symbionts in the predominately terricolous cyanolichen genus *Peltigera* (Peltigerales, Lecanoromycetes) in Estonia. Our sampling comprised 252 lichen specimens collected in grasslands and forests from different parts of the country, which represented all common *Peltigera* taxa in the region. The cyanobacteria were grouped according to their tRNA^{Leu} (UAA) intron sequences, and mycobiont identities were confirmed using fungal ITS sequences. The studied *Peltigera* species associated with 34 different "*Peltigera*-type" *Nostoc trnL* genotypes. Some *Peltigera* species associated with one or a few *trnL* genotypes while others associated with a much wider range of genotypes. Mycobiont identity was the primary factor that determined the presence of the specific *Nostoc* genotype within the studied *Peltigera* thalli. However, the species-specific patterns of cyanobiont selectivity did not always reflect phylogenetic relationships among the studied fungal species but correlated instead with habitat preferences. Several taxa from different sections of the genus *Peltigera* were associated with the same *Nostoc* genotype or with genotypes in the same habitat, indicating the presence of functional guild structure in the photobiont community. Some *Nostoc trnL* genotypes were only found in the *Peltigera* species of moist and mesic forest environments, while another set of *Nostoc* genotypes was typically found in the *Peltigera* species of xeric habitats. Some *Nostoc trnL* genotypes were only found in the *Peltigera* taxa that are common on alvars and may have specialized to living in this unusual and threatened habitat type.



Cyanobiont of *Peltigera*

- *Nostoc* tRNA Leu sequences
- 35 different *Nostoc* genotypes

(Jüriado et al. 2019)

Fig. 1. Nostoc trnL genotype networks. The number of single nucleotide differences is shown on connecting lines; genotypes separated by six or more differences are connected via dashed lines and denoted by different letters. The size of each pie chart is proportional to the number of specimens.

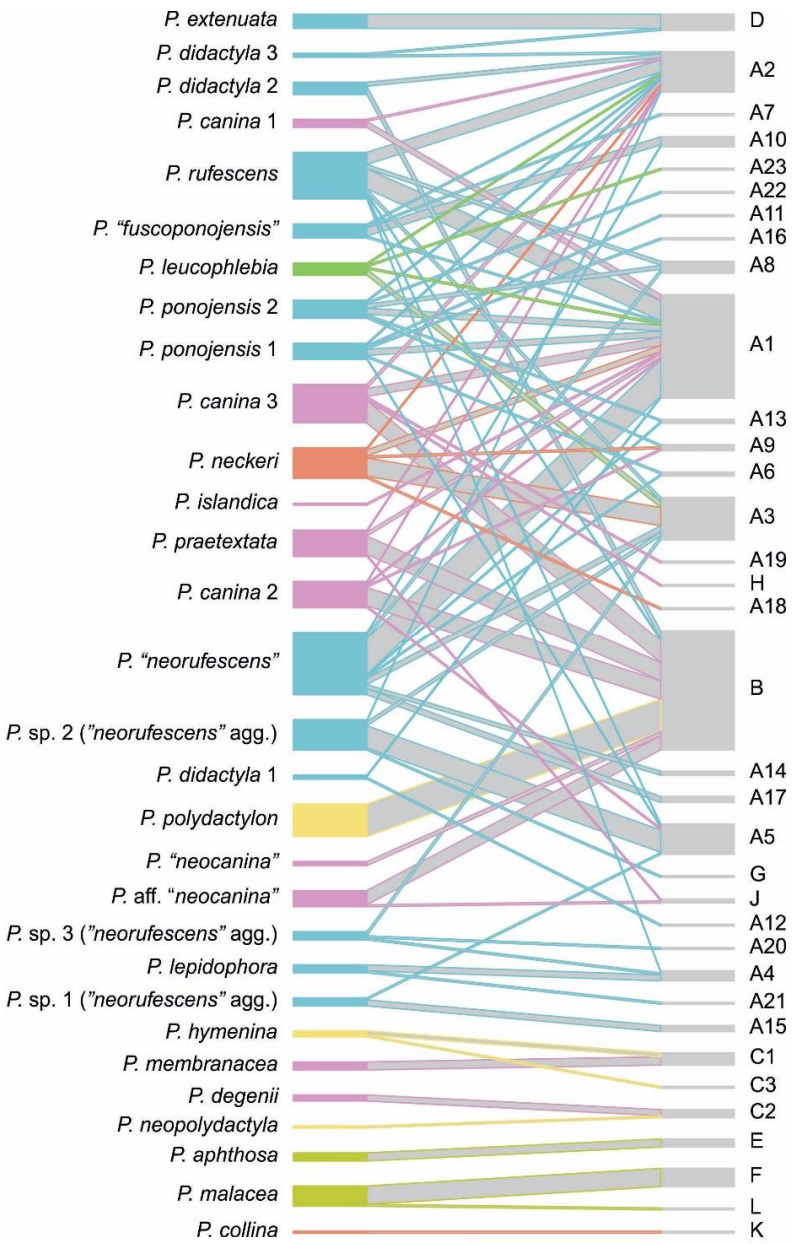
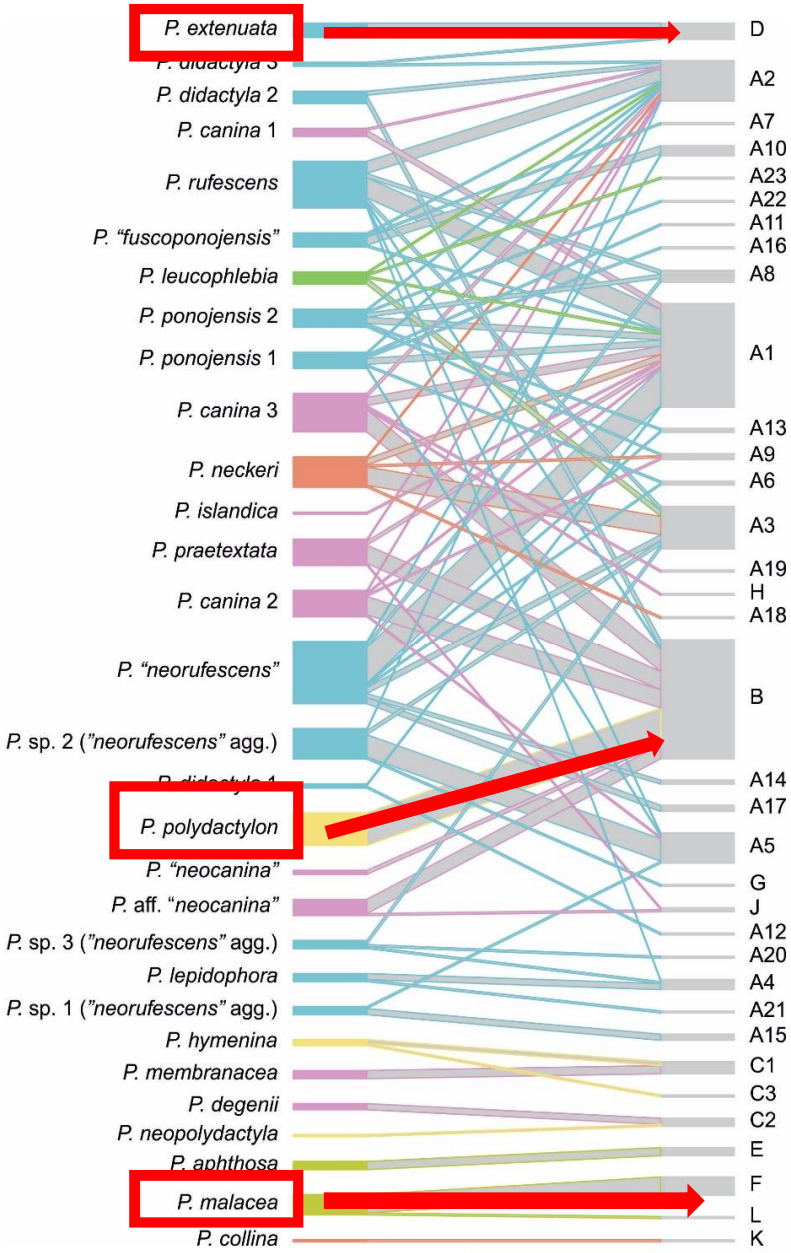


Figure 2. Interaction network structure between lichen mycobiont (*Peltigera* taxa) and cyanobiont genotypes.
The width of the links is proportional to the number of specimens forming the association.
Colours shown for the *Peltigera* taxa correspond to sections of *Peltigera* (Jüriado et al. 2919).

Peltigera sections

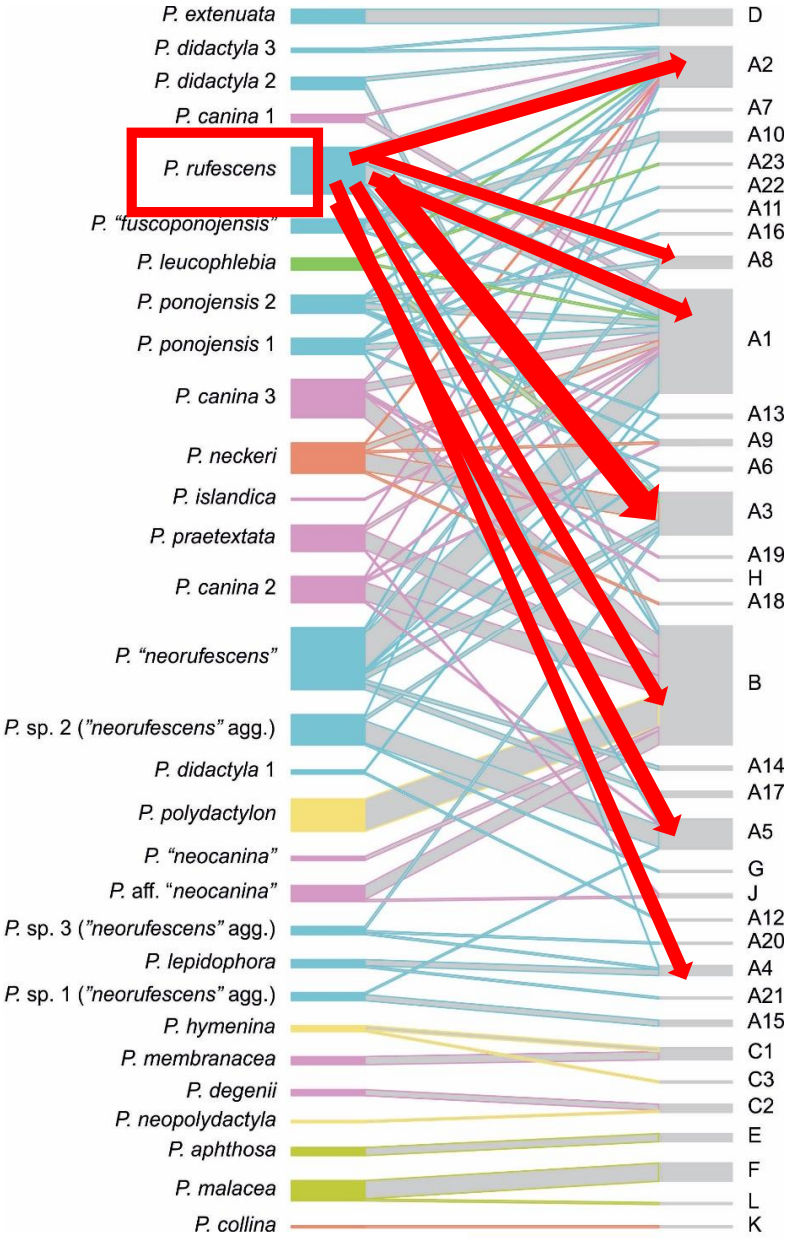
- *Chloropeltigera*
- *Horizontales*
- *Peltidea*
- *Peltigera* 'group *canina*'
- *Peltigera* 'group *rufescens*'
- *Polydactylon*



- *some Peltigera* taxa (e.g. *P. malacea*, *P. polydactylon*, *P. extenuata*) associate with a single or a few closely related *Nostoc* genotypes

Peltigera sections

- *Chloropeltigera*
- *Horizontales*
- *Peltidea*
- *Peltigera* 'group *canina*'
- *Peltigera* 'group *rufescens*'
- *Polydactylon*



- others (e.g. *P. leucophlebia*, *P. rufescens*, *P. didactyla*) associate with a spectrum of different *Nostoc* genotypes

***Peltigera* sections**

- *Chloropeltigera*
- *Horizontales*
- *Peltidea*
- *Peltigera* 'group *canina*'
- *Peltigera* 'group *rufescens*'
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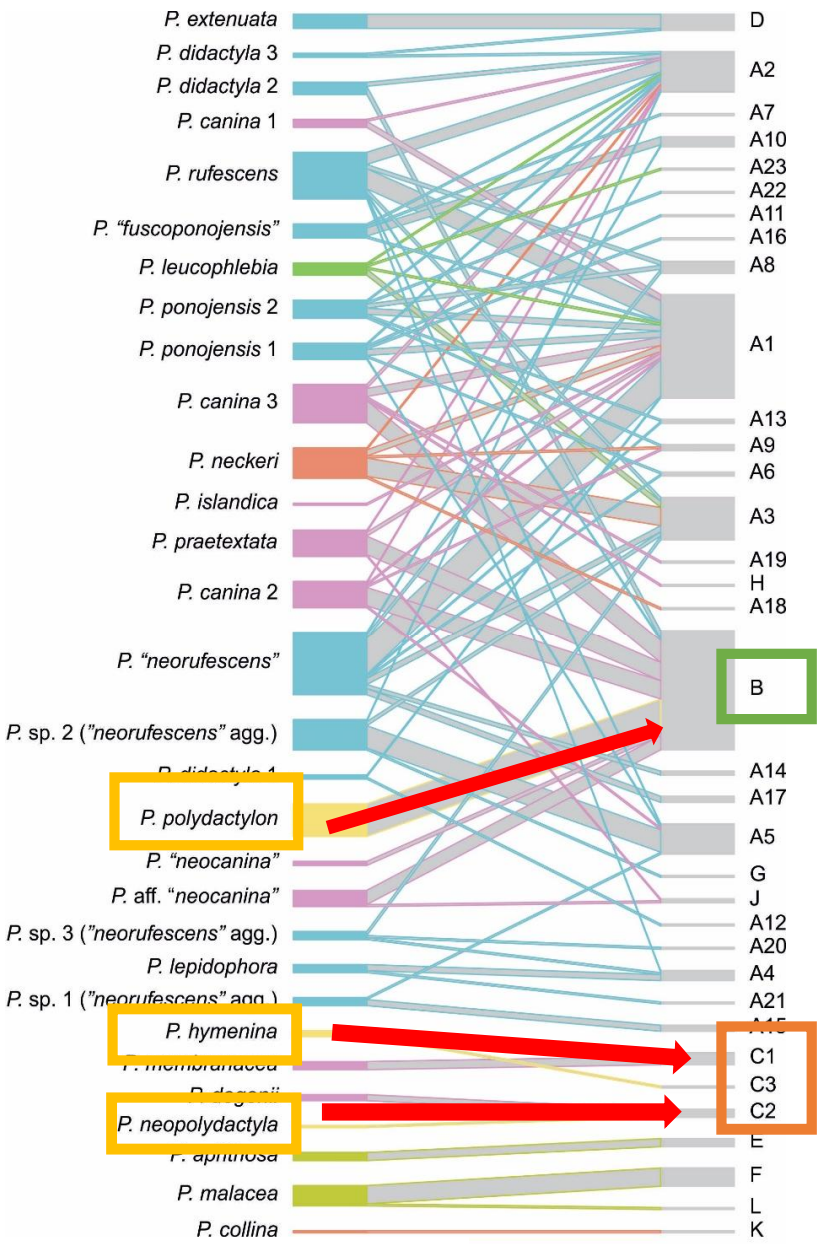

- taxa from from same section associate with different *Nostoc* genotypes

***Peltigera* sections**

- *Chloropeltigera*
- *Horizontales*
- *Peltidea*
- *Peltigera* 'group *canina*'
- *Peltigera* 'group *rufescens*'
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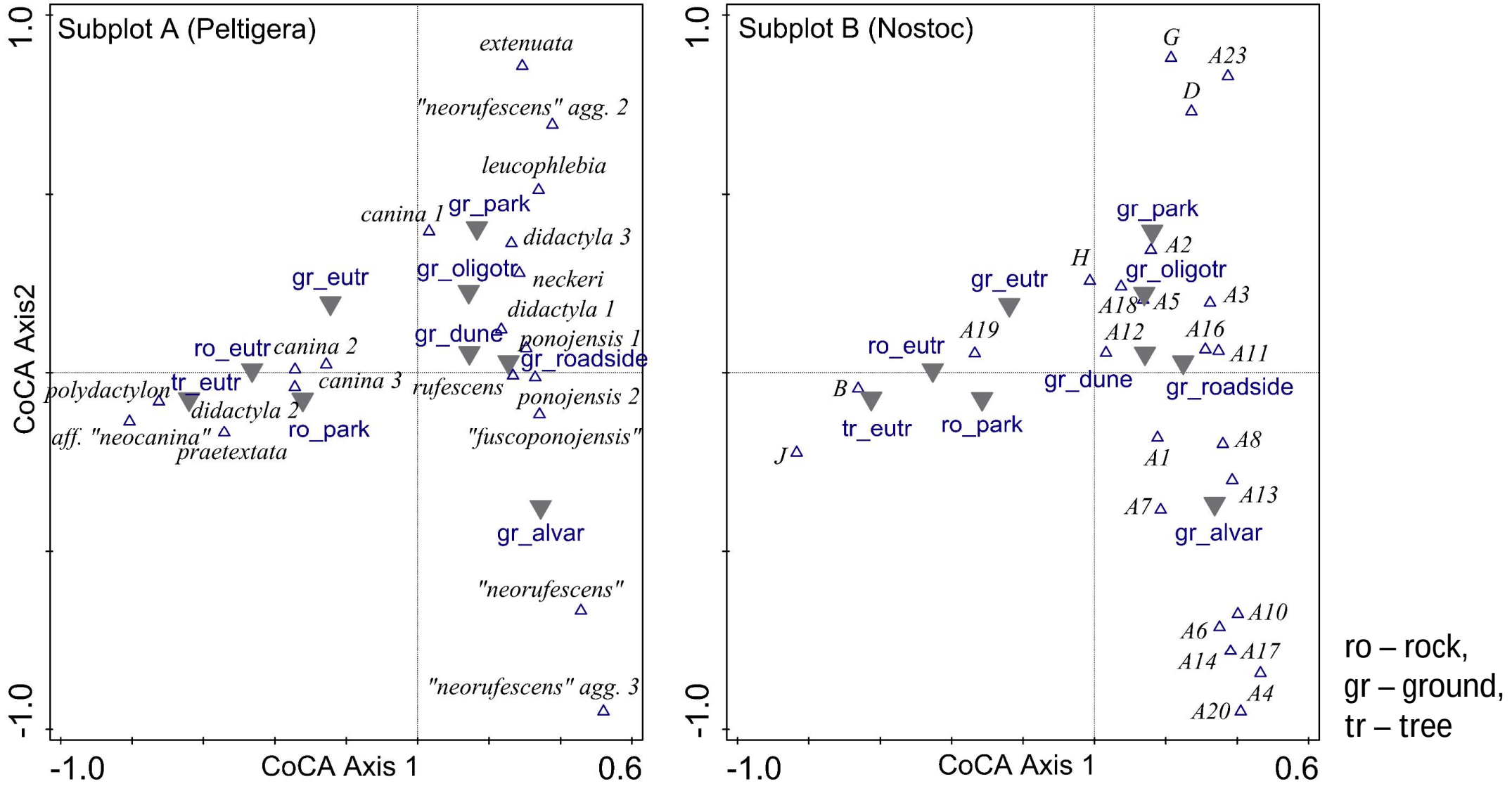
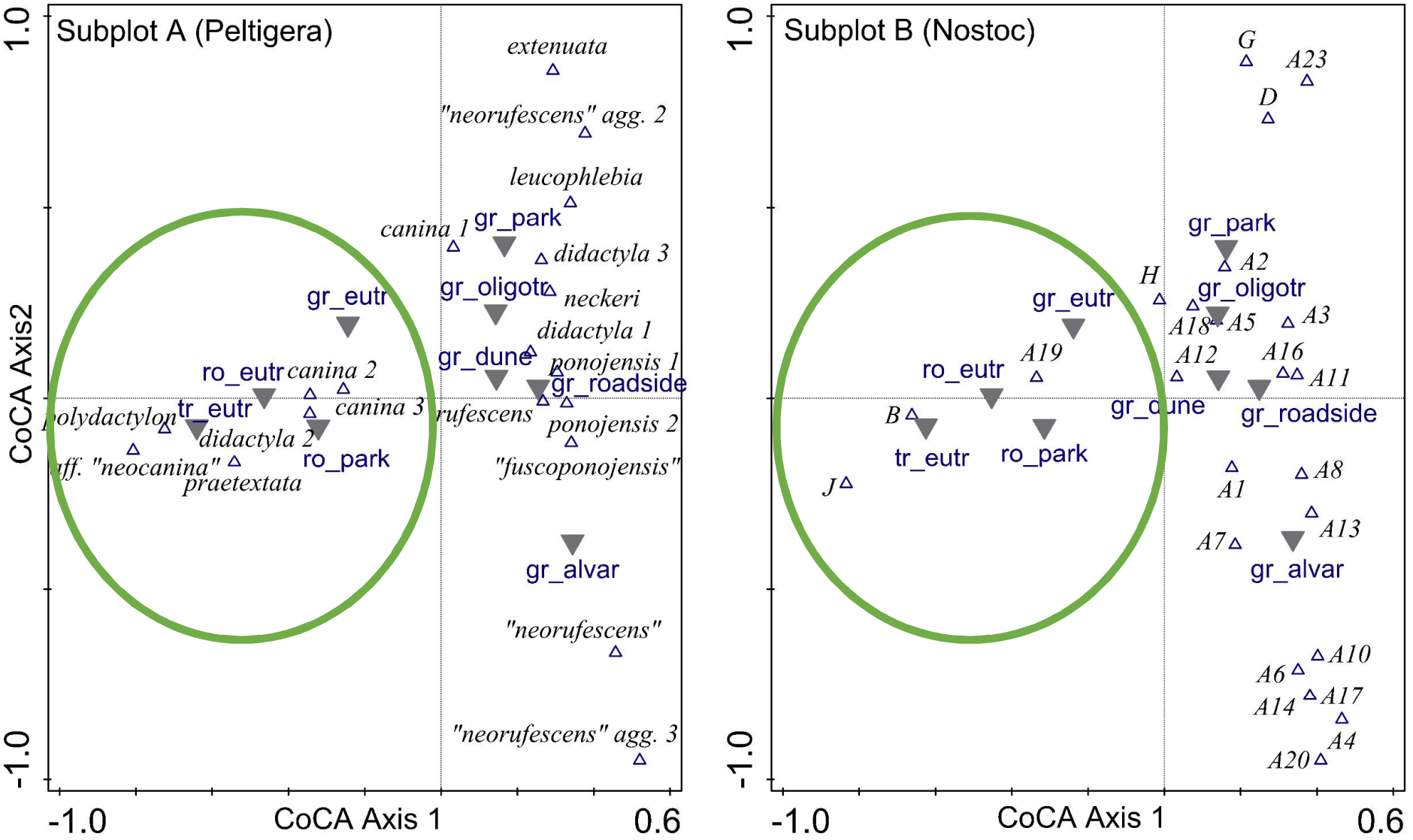
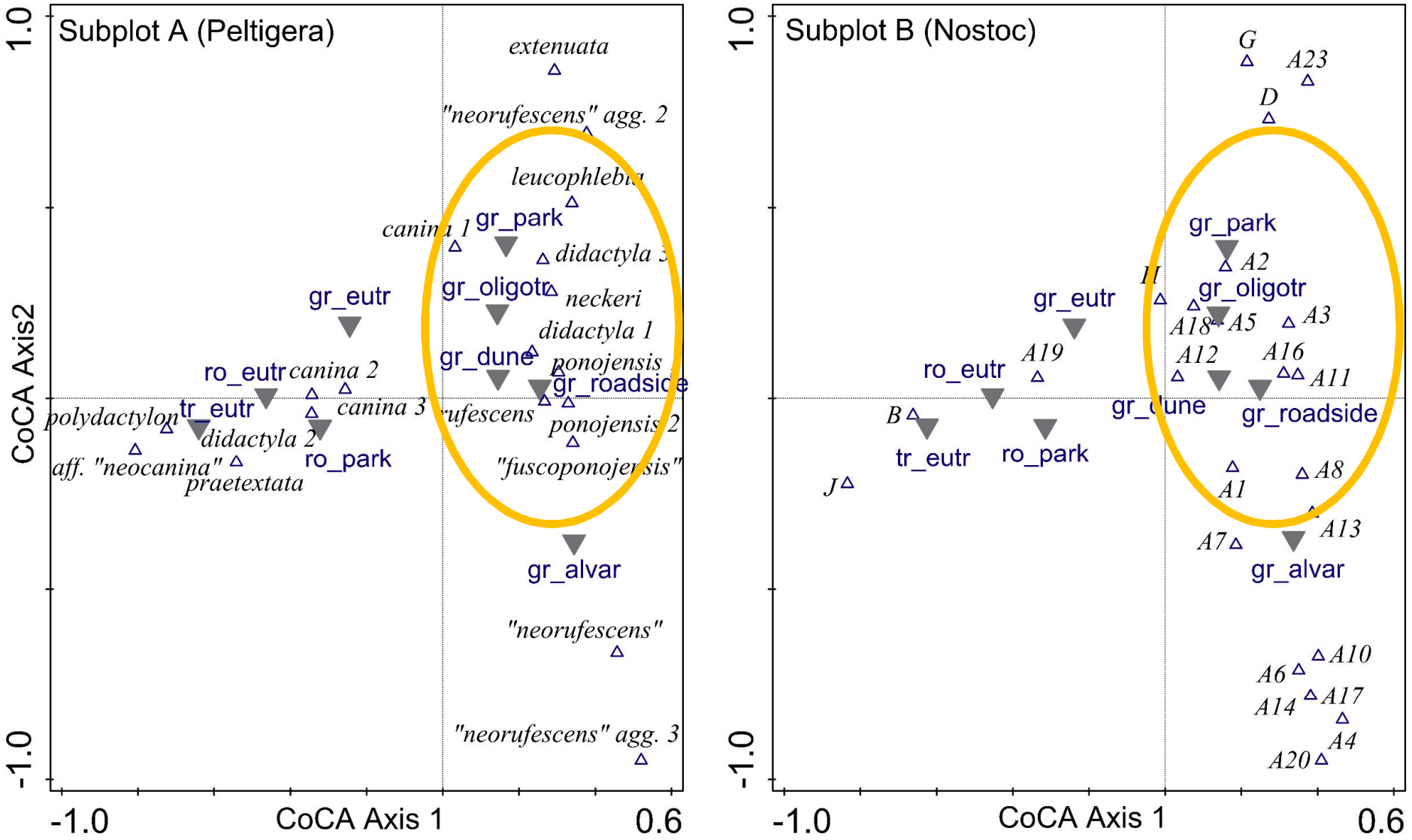


ro – rock,
gr – ground,
tr – tree

Fig. 3. Dual ordination diagram of Co-correspondence analysis (CoCA) (Jüriado et al. 2019).



Dual CoCA diagram. Eigenvalues of the first and second axes are 0,89 and 0,62.



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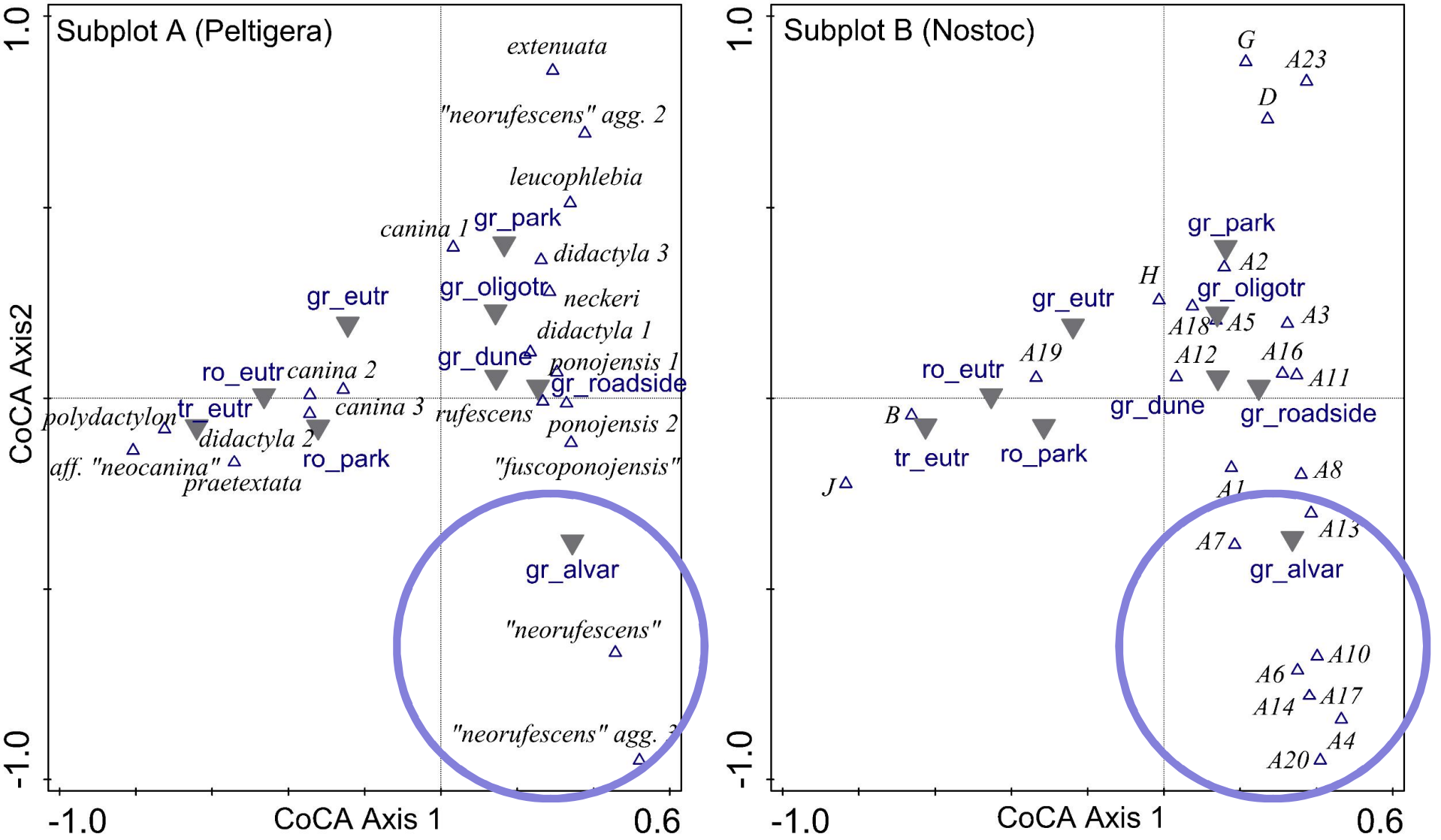

Dual CoCA diagram. Eigenvalues of the first and second axes are 0,89 and 0,62.

Conclusions

- the strain of photosynthetic partner selected by the fungal symbiont could be influenced by environmental conditions as different genotypes (phylogroups) of *Nostoc* is selected by the same mycobiont of *Peltigera* in different habitat types
- selectivity does not reflect the distinct phylogenetic relationships within the genus *Peltigera;* instead they reflect the mycobiont habitat preference

Thanks!

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