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Species richness, distribution, bioindication and ecology of lichens in oak forests of Kroumiria, North West of Tunisia

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Abstract

Lichen communities were studied in deciduous oak forests across Kroumiria region, northern west of Tunisia to find out the lichen species richness, make an idea about their ecology, relative distribution and actual statute. All lichen species were collected of mainly all *Quercus canariensis* Wild and *Quercus suber* L. trunks from their base up to the highest canopy twigs. Identification of taxa is based on stereo-microscopic examinations and usual chemical tests (K, C, P, I and KC). Results reveal important lichen diversity with 211 species belonging to 63 genera and 36 lichenological families distributed into 8 groups (growth forms). The most represented group is the crustose growth form (about 42%) whereas foliose and fruticose were represented by 64 and 22 species, respectively. Within each group, various taxa known for their high sensitivity to certain toxic air compounds (essentially SO_2 and some NO_x) have been inventoried (mainly fruticose and foliose). Such taxa qualified as bioindicators reflect a buffer capacity of these forest ecosystems to physical changes of the environment and some stability of their functioning without concealing artificialisation and simplification of the forest environment in response to various activities carried out by rural people and their livestock.

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Introduction

Lichens are a symbiosis between a fungus, known as the mycobiont, and a photosynthetic organism, either a green algae or *cyanobacteria* species, the photobiont. The mycobiont almost always dictates the form of the lichen thalli (Raven *et al.*, 2005). When *cyanobacteria* (prokaryotic algae) constitute the photosynthetic component, we speak about the cyanobiont (cf. Kappen, 2000). Cyanobionts are selected as an adaptation to distribution in harsh environments rather than to metabolic mechanisms. (cf. Wirtz *et al.*, 2003). Lichens have a wide variety of growth forms, the main morphotypes being crustose (lichen thalli form a crust over the substrate), foliose (thalli are 'leafy' with distinct upper and lower sides) and fruticose (the thallus has a shrub-like appearance or is branched) (Swinscow and Krog, 1988). Lichens dominate vegetation life forms comprise about 8% of the terrestrial surface of the earth and are found in a diverse range of habitats (Ahmadjian, 1995). They grow on a wide range of substrates, both natural and man-made, and obtain their required nutrients and water directly from the atmosphere.

In recent years, concern about the loss of lichen diversity in relation with forest management and forest fragmentation has led to many studies assessing and monitoring the patterns and trends of lichen biodiversity in forests worldwide (Rose, 1974; Seaward, 1975; James *et al.*, 1977; Howksworth and Hill, 1984; Coppins, 1984; Alexander *et al.*, 1989; Broad, 1989; Cullen and Fox, 1999; Wolseley and Pryor, 1999; Gilbert, 2000; Fox *et al.*, 2001; Coppins and Coppins, 2002; Humphrey *et al.*, 2002; Rose and Coppins, 2002; Will-Wolf *et al.*, 2002; Higgins *et al.*, 2004; Hauck, 2005; etc.). Forest environments are an important refuge for lichens. Knowing which factors influence lichen diversity improves understanding of lichens' development requirements and helps to identify forest management techniques with lesser negative impact on lichen diversity. Since it is generally known that the undisturbed character of woods and persistent ecological continuity are important for lichen diversity (Rose, 1974; Rose and Coppins, 2002; Coppins and Coppins, 2002) this in turn facilitates the preservation of natural native woodlands.

Uptake of nutrients from the atmosphere allows lichens to be good indicators of environmental disturbance as they bio-accumulate airborne pollutants. Excessive levels of pollutants in the atmosphere, in particular sulphur dioxide (SO_2) and nitrogen oxides (NO_X), can alter the physiology and morphology of sensitive species, ultimately killing them and thus changing lichen community structure (Haffner *et al.*, 2001; Purvis, 2000). Diversity of lichens and their use as indicators of air pollution have been well studied in Europe and northern America (Wiseman and Wadleigh, 2002; Pinho *et al.*, 2004; Loppi and Frati, 2006; Thormann, 2006). In North Africa, diversity richness of lichens has been well studied in Algeria since the second half of the eighteens (Nylander, 1853 and 1854 ; Werner, 1939; 1941; 1946; 1954; 1955 and 1956; Faurel *et al.*, 1951a; 1951b; 1952; 1953a and 1953b; Ozenda and Clauzade, 1970; Semadi, 1989; Zouaoui, 1989; Haluwyn and Letrouit-Galinou, 1990; Semadi *et al.*, 1989; Semadi et Tahar, 1995; Semadi *et al.*, 1997; Haluwyn *et al.*, 1994; Rahali, 2003; Bendaikha, 2006; Ajaj *et al.*, 2007; Ait Hammou *et al.*, 2008, 2011 and 2013; Rebbas *et al.*, 2011; Khedim, 2012; Serradj *et al.*, 2013; Slimani *et al.*, 2013; Ait Hammou *et al.*, 2014), less more for the Moroccan lichen flora whose main works are (Maire, 1924; Maheu and Gillet, 1924 and 1925; Maheu, 1928. Maheu and Werner, 1933 and 1935; Gattefossé and Werner, 1931 and 1935; Egea, 1996; Nattah *et al.*, 2012a; 2012b and 2013; Ajaj *et al.*, 2013). However not much is known about Tunisia lichen flora diversity and distribution. According to Werner (1951a), sporadic collection of lichens from Tunisia has occurred since 1640, but the first recorded species are attributable to Desfontaines in 1783, followed by Kralik in 1854. First published lists are those of Hue (1897) and Pitard and Bouly de Lesdain (1909). The most comprehensive published list is to be found in the phytogeographical interpretation of the Tunisian lichen flora by Werner

(1951a) and the most extensive unpublished list resulted from the expedition led by Poelt in 1968. Further information on the history of lichenological recording in Tunisia, albeit scant, is to be found in Patouillard (1897), Werner (1951a) and Faurel *et al.* (1951). When Werner (1951a; 1951b; 1956) made his phytogeographical interpretations of the Tunisian lichen flora, there were only 186 species recorded. Then a checklist published by Seaward (1996) includes 415 taxa (395 species, 3 subspecies, l3 varieties and 4 forms). Since this checklist, very scarce studies have been carried out dealing with diversity richness and/or eventual air pollution and its effects on Tunisian lichen flora (El Mokni *et al.*, 2010; 2011a; 2011b; 2013a; 2013b; Neffati et El Mokni, 2013). In continuity, this research aims to assess lichen distribution and diversity in natural oak forests of Kroumiria (northern-west of Tunisia) and the possible effect, if any, of air pollutants on the presence of some bioindicators species. The main focus is to advance understanding more all factors that drive the sensitive and dynamic patterns for epiphytic lichen abundance and distribution in such woodlands in order to develop a complementary monitoring network for the assessment of atmospheric pollution, based jointly on lichen biomonitoring and physio-chemical methods.

Materials and methods

General setting of the study areas / Sampling sites

Study areas (EF: El Feïdja, GH: Ghorra, A.S: Aîn Soltane, A.Dr: Aîn Draham, MJ: Mridj, BM: Béni Mtir, OZ: Oued Zéen, A.Z: Aîn Zana) belong to the oak forest region of Kroumiria, in the Northern West of Tunisia (Fig.1).

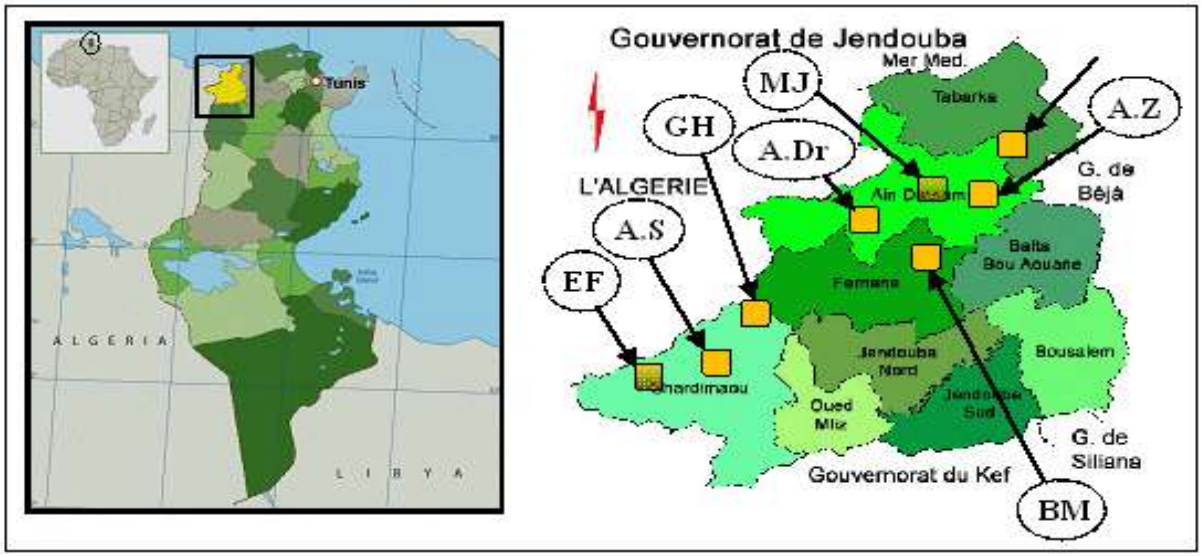

Fig. 1. Location maps of the prospected areas within the Kroumiria region, North Western of Tunisia. EF: El Feîdja, GH: Ghorra, A.S: Aîn Soltane, A.Dr: Aîn Draham, MJ: Mridj, BM: Béni Mtir, OZ: Oued Zéen, A.Z: Aîn Zana.

These areas have different coordinates, altitudes but show almost similar dominant and shrubby species (cf. Table 1). The Kroumiria region (255,335 ha area with Mogods) is located above 500 meters and culminating at Jebel Ghorra (1.203 m) on the border with Algeria. Rainfall is abundant with an average of 800 mm (1500 mm at A.Dr; sometimes more than 2000 mm at BM) with temperate winters thus these oak forests are attached to vegetation levels of the meso to supramediterranean (cf. Ozenda, 1975) of humid and very locally perhumid bioclimatic types with usually alternating of three to four seasons through spring and autumn. Geologically, it is dominated by "*Numidian flysch*" of the Oglio-

Miocene age, and whose summit term consists of two levels separated by siliceous rocks gray dolomitic concretions in shales and sandstones glauconitic (Rouvier, 1977; Riahi *et al.*, 2010). Dominant soils are moderately acidic and often leached. Forest soils are heavy; hydromorphic and fairly rich in well decomposed humus (cf. Onupaa, 1985). The canopy is made mainly of cork oak (*Quercus suber* L.) and Mirbeck's oak (*Quercus canariensis* Willd.) above 800 m altitude, with scarce sporadic pine stands. Sampling period extends throughout the year but mostly from September to April. In a first step after thin raining, for all trees (200-800) including a plot of one hectare area, selected and limited in advance according to its representativity of the stand. The census was qualitative and involved every species of the trunks that can get to touch (0-3 m in height) for trees and all species for shrubs. In a second step, we sampled after windy storms looking for species attached on the high boughs (diameter between 1 and 10 cm), that fell in the same hectare or elsewhere in the stand.

Identification

The gross morphology and anatomy of the collected specimens and their reproductive organs were examined by a dissecting microscope (Leica). The chemical characters (K, C, P, I and KC) were examined by medullar and apothecia color reaction as known in lichenology (Tiévant, 2001; Van Haluwyn *et al.*, 2009). The nomenclature and synonymy used are those of Boistel (1986), adopted by Roux *et al.*, (2006; 2008), Van Haluwyn *et al.*, (2009) and more recently by Roux *et al.*, 2011; Roux, 2012 then Roux *et coll.* (2015) or directly on line on some Web links: Coste Clother(http://lichenologie.coste.pagesperso orange.fr/these.htm), Claude Roux et Jean Pierre Gavériaux (http://www2.aclille.fr/myconord/Photos_AFL/Photos_AFL_Liste.htm). The infra specific taxonomic ranks were not specified; we limited our identification to the specific row (specific epithet) in the large sense (*s.l.*). Growth forms are identified as followed:

- *Crustose* (crusty) lichens are tightly attached to the substrate with their lower surface;
- *Foliose* (leafy) lichens have a leaf-like shape of the thallus, are flat and only partially attached to substrate;
- *Fruticose* (shrubby) lichens are hair-like, strap-shaped or shrubby and subunits (or ramifications) may be flat or cylindrical;
- *Leprose* lichens are powdery masses with little or no organized structure;
- *Squamulose* are much the same as crustose, but have raised edges, which can be folded and lobe-like;
- *Umbilicate* lichens look like foliose thallus attached by a single point (an umbilicus);
- *Gelatinose* or *gelatinous* lichens are structureless in which the phycobiont (The principal symbiont) is a *cyanobacterium*; often dark blue-green, brown, or black in color. In wet it's from the mucilage commonly found on the exterior of blue-green algae cells.

Evaluating air pollution

Polluo-sensitivity overlooked sulfur dioxide (SO_2)

Species showing sensitivity towards SO_2 atmospheric concentrations were identified referring to scale established by Hawksworth and Rose (1970). Indicative sensitivity scale ranges from 1: 'tolerant' to 10: 'sensitive' (cf. Tiévant, 2001).

Polluo-sensitivity overlooked Nitrogen dioxides (NO_x)

Species showing sensitivity NO_x towards atmospheric concentrations were identified referring to scale established by Davies and al., (2007). Indicative sensitivity scale ranges also from 1: 'tolerant' to 10: sensitive'.

Type of rarity

Different types of rarity within the prospected area are estimated and identified as followed:

- CC: Very common, very frequent in our studied area;
- C: Common, frequent in our studied area;

- R: Rare, found in some sites of our studied area;
- RR: Very rare, found in scare sites of our studied area;
- V: Vulnerable, found only in very restricted scare sites of our studied area.

Lichen collection

Samples of lichen species found in each site were collected for later identification (if necessary) and in order to create a reference '*Lichenarium*' for the Kroumiria region.

Results and discussion

Species diversity, rarity and new records

A total of 211 species were recorded and are alphabetically listed in table 2. These species belong to 63 genera and 36 lichenological families (Fig. 2). Lichens with crustose growth form were represented by the higher percentage (about 42%) whereas foliose and fruticose were represented by 64 and 22, respectively (Fig. 3). Types of rarity (cf. Table 3) show (Fig. 4) that almost 70% of recorded specimens are very common (CC) where as only 7% are very rare (RR) to vulnerable (V).

Table 1. Characteristics of the various prospected areas within Kroumiria region in the North Western of Tunisia.

Area	Geographical coordinates	Altitude (m)	Dominant forest Trees	Typical high shrubby species
1. EF: El Feîdja	Latitude: 36°31'09.45" N Longitude : 08°17'29.94" E	746-1075	- *Quercus canariensis*, *Q. suber* - *Populus alba*, *P. nigra* - *Celtis australis*, *Pinus* sp.pl. - *Cupressus sempervirens* - *Fraxinus angustifolia* - *Prunus avium*	*Erica arborea*, *Arbutus unedo*, *Crataegus monogyna*, *Prunus* sp.pl., *Salix* sp.pl., *Viburnum tinus*
2. GH: Ghorra	Lat.: 36°36'06.44" N Long. : 08°25'06.56" E	773-1192	- *Quercus canariensis*, *Q. suber*, *Q. afares*	*Erica arborea*, *Arbutus unedo*, *Crataegus monogyna*, *Ilex aquifolium*, *Prunus* sp.pl.
3. A.S: Aîn Soltane	Lat.: 36°31'51.45" N Long. : 08°20'11.05" E	699-804	- *Quercus canariensis*, *Q. suber* - *Tilia cordata* - *Cupressus sempervirens*	*Erica arborea*, *Arbutus unedo*, *Crataegus monogyna*, *Prunus* sp.pl., *Viburnum tinus*
4. A.Dr: Aîn Draham	Lat.: 36°46'10.14" N Long. : 08°41'57.26" E	806-992	- *Quercus canariensis*, *Q. suber* - *Fraxinus angustifolia* - *Cupressus sempervirens* - *Cedrus atlantica* - *Castanea sativa*, *Populus* sp.pl. - *Prunus avium*, *Ulmus minor*	*Erica* arborea, *Arbutus unedo*, *Crataegus monogyna*, *Prunus* sp.pl., *Salix* sp.pl., *Viburnum tinus*
5. MJ: Mridj	Lat.: 36°44'39.94" N Long. : 08°42'01.63" E	540-821	- *Quercus canariensis*, *Q. suber* - *Prunus avium* - *Ulmus minor*	*Erica arborea*, *Arbutus unedo*, *Crataegus monogyna*, *Ilex aquifolium*, *Laurus nobilis*, *Alnus glutinosa*, *Salix* sp.pl.
6. BM: Béni Mtir	Lat.: 36°43'45.68" N Long. : 08°41'33.21" E	565-815	- *Quercus canariensis*, *Q. suber* - *Populus nigra* - *Celtis australis* - *Prunus avium*	*Erica arborea*, *Arbutus unedo*, *Crataegus monogyna*, *Viburnum tinus*
7. OZ: Oued Zéen	Lat.: 36°49'30.26" N Long. : 08°51'05.78" E	331-601	- *Quercus canariensis*, *Q. suber* - *Castanea sativa*	*Erica arborea*, *Arbutus unedo*, *Crataegus monogyna*, *Alnus glutinosa*, *Sambucus nigra*, *Viburnum tinus*
8. A.Z: Aîn Zana	Lat.: 36°46'28.17" N Long. : 08°50'20.73" E	543-603	- *Quercus canariensis*, *Q. suber*, *Q. afares* - *Pinus* sp.pl.	*Erica arborea*, *Arbutus unedo*, *Crataegus monogyna*, *Viburnum tinus*

In addition and compared to the checklist provided by Seaward (1996), this study reveals 115 species and 15 genera reported for the first time to the Tunisian lichens flora. New reported taxa are marked with an asterisk (*) in tables 2 and 3. New record species belong mainly to crustose and foliose growth forms and with a lesser degree to composite and fruticose ones (Fig. 5).

Bioindicators lichens in Kroumiria oak forests

This study reveals at least 23 species indicators of the approximate average content of atmospheric air ($\mu g.m^{-3}$) of SO_2 and 22 species indicators of the approximate average content of atmospheric air ($\mu g.m^{-3}$) of NO_X (Table 3).

Table 2. Exhaustive list of lichen species recorded in the oak forests of Kroumiria Mountains, northwestern of Tunisia. (∗ , asterisk is usually used for new record taxa).

n°	Lichen Taxa	Family	Growth forms	Substrata
001	∗*Acarospora nitrophila* H. Magn.	*Acarosporaceae*	Crustose	On rocks
002	∗*Acarospora scabrida* Hedl. Ex Magn	*Acarosporaceae*	Crustose	On rocks
003	∗*Acarospora sinopica* (Wahlenb.) Körber	*Acarosporaceae*	Crustose	On rocks
004	∗*Acarospora umbilicata* Bagl.	*Acarosporaceae*	Crustose	On rocks
005	*Acrocordia gemmata* (Ash.) Massal. (syn. *A.alba* (Schrader) B. de Lesd.)	*Monoblastiaceae*	Crustose	On bark
006	∗*Alectoria achroleuca* (Hoffm.) Massal.	*Alectoriaceae*	Fruticose	On soil with moss
007	∗*Alectoria sarmentosa* (Ash.) Ash.	*Alectoriaceae*	Fruticose	On bark
008	∗*Amygdalaria athroocarpa* Ash.	*Lecideaceae*	Crustose	On rocks
009	*Anaptychia ciliaris* (L.) Körber ex Massal	*Physciaceae*	Fruticose	Crustose
010	*Anaptychia runcinata* (With.) Laundon (Syn. *A. fusca* (Huds.) Vainio)	*Physciaceae*	Foliose	On bark and soil
011	∗*Arthonia punctiformis* Ash.	*Arthoniaceae*	Crustose	On bark
012	*Arthonia radiata* (Pers.) Ash.	*Arthoniaceae*	Crustose	On bark
013	∗*Arthonia spadicea* Leighton	*Arthoniaceae*	Crustose	On bark
014	*Aspicilia intermutans* (Nyl.) Arnold	*Hymeneliaceae*	Crustose	On rocks
015	*Aspicilia radiosa* (Hoffm.) Poelt. (Syn. *Lobothallia radiosa* (Hoffm.) Haf.)	*Hymeneliaceae*	Crustose	On rocks
016	∗*Bacidia inundata* (Fr.) Körb.	*Ramalinaceae*	Crustose	On rocks
017	*Bacidia rubella* (Hoffm.) Massal.	*Ramalinaceae*	Crustose	On bark
018	*Bacidia subacerina* Vain.	*Ramalinaceae*	Crustose	On bark
019	∗*Bacidia viridifarinosa* Coppins & P. James	*Ramalinaceae*	Crustose	On bark
020	*Brodoa intestiniformis* (Vill.) Goward. (Syn. *Hypogymnia intestiniformis* (Vill.) Räsänen	*Parmeliaceae*	Foliose	On bark
021	∗*Bryoria chalybeiformis* auct.	*Parmeliaceae*	Fruticose	On soil with moss
022	∗*Bryoria fuscescens* (Gyelnik) Brodo & Hawksw.	*Parmeliaceae*	Fruticose	On bark
023	∗*Buellia aethalea* (Ash.) Th. Fr.	*Physciaceae*	Crustose	On bark
024	∗*Buellia saxorum* Massal.	*Physciaceae*	Crustose	On rocks
025	∗*Buellia subdisciformis* (Leight.) Vaino	*Physciaceae*	Crustose	On rocks
026	∗*Caloplaca arenaria* (Pers.) Müll. Arg.	*Teloschistaceae*	Crustose	On rocks
027	*Caloplaca aurantia* (Pers.) J. Steiner	*Teloschistaceae*	Crustose	On rocks
028	*Caloplaca cerina* (Ehrh. Ex Hedwig) Th. Fr.	*Teloschistaceae*	Crustose	On bark
029	*Caloplaca chalybaea* (Fr.) Müll. Arg.	*Teloschistaceae*	Crustose	On rocks
030	*Caloplaca crenularia* (With.) Laundon (Syn. *C. festiva* (Ach.) Zwackh.)	*Teloschistaceae*	Crustose	On rocks
031	*Caloplaca erythrocarpa* (Pers.) Zwackh.	*Teloschistaceae*	Crustose	On rocks
032	*Caloplaca ferruginea* (Hudson) Th. Fr.	*Teloschistaceae*	Crustose	On bark
033	*Caloplaca flavescens* (Huds.) Laundon (Syn. *C. heppiana* (Müll. Arg.) Zahlbr.)	*Teloschistaceae*	Crustose	On rocks
034	*Catillaria chalybeia* (Borrer) Massal.	*Catillariaceae*	Crustose	On rocks
035	*Catillaria nigroclavata* (Nyl.) Schuler	*Catillariaceae*	Crustose	On bark
036	*Cetraria chlorophylla* (Wild.) Vainio	*Parmeliaceae*	Foliose	On bark
037	∗*Cetraria nivalis* (L.) Ach.	*Parmeliaceae*	Fruticose	On soil with moss
038	∗*Cetraria olivetorum* (Nyl.) Culb. & Culb.	*Parmeliaceae*	Foliose	On soil with moss

039	∗*Chrysothrix candelaris* (L.) Laundon	*Chrysothricaceae*	Crustose	On bark
040	∗*Chrysothrix chlorina* (Ash.) Laundon	*Chrysothricaceae*	Crustose	On soil
041	∗*Cladonia arbuscula* (Wallr.) Flotow	*Cladoniaceae*	Composite	On soil with moss
042	∗*Cladonia cervicornis* (Ash.) Flotow	*Cladoniaceae*	Composite	On soil with moss
043	∗*Cladonia chlorophaea* (Flöke ex Sommerf.) Spreng.	*Cladoniaceae*	Composite	On soil with moss
044	∗*Cladonia ciliata* Stirton	*Cladoniaceae*	Composite	On soil with moss
045	∗*Cladonia coccifera* (L.) Wild.	*Cladoniaceae*	Composite	On soil with moss
046	∗*Cladonia coniocraea* (Flörke) Spreng.	*Cladoniaceae*	Composite	On soil with moss
047	*Cladonia fimbriata* (L.) Fr.	*Cladoniaceae*	Composite	On soil with moss
048	*Cladonia foliacea* (Huds.) Wild.	*Cladoniaceae*	Composite	On soil with moss
049	*Cladonia furcata* (Huds.) Schrad.	*Cladoniaceae*	Composite	On soil with moss
050	∗*Cladonia gracilis* (L.) Wild.	*Cladoniaceae*	Composite	On soil with moss
051	∗*Cladonia macilenta* Hoffm.	*Cladoniaceae*	Composite	On soil with moss
052	∗*Cladonia parasitica* (Hoffm.) Hoffm.	*Cladoniaceae*	Composite	On soil with moss
053	*Cladonia portentosa* (Dufour) Coem.	*Cladoniaceae*	Composite	On soil with moss
054	∗*Cladonia rangiferina* (L.) Weber ex Wigg.	*Cladoniaceae*	Composite	On soil with moss
055	*Cladonia rangiformis* Hoffm.	*Cladoniaceae*	Composite	On soil with moss
056	∗*Cladonia squamosa* (Scop.) Hoffm.	*Cladoniaceae*	Composite	On soil with moss
057	∗*Cladonia subulata* (L.) Webber ex Wigg.	*Cladoniaceae*	Composite	On soil with moss
058	∗*Cladonia uncialis* (L.) Webber ex Wigg.	*Cladoniaceae*	Composite	On soil with moss
059	*Collema auriforme* (With.) Coppins & Laundon (Syn. *C. auriculatum* Hoffm.)	*Collemataceae*	Gelatinose	On rocks and bark
060	*Collema crispum* (Huds.) Webber ex Wigg.	*Collemataceae*	Gelatinose	On rocks and bark
061	*Collema cristatum* (L.) Webber ex Wigg.	*Collemataceae*	Gelatinose	On rocks and bark
062	*Collema flaccidum* (Ash.) Ash.	*Collemataceae*	Gelatinose	On rocks and bark
063	*Collema furfuraceum* (Arnold) Du Rietz	*Collemataceae*	Gelatinose	On rocks and bark
064	*Collema tenax* (Swartz) Ash.	*Collemataceae*	Gelatinose	On rocks and bark
065	∗*Dermatocarpon miniatum* (L.) Mann	*Verrucariaceae*	Foliose	On rocks
066	∗*Diploicia canescens* (Dickson) Massal.	*Caliciaceae*	Crustose	On rocks
067	*Dirina stenhammari* (Stenham.) (Syn. *D. massiliensis* f. *sorediata* (Müll. Arg.) Tehler)	*Roccellaceae*	Crustose	On rocks
068	*Enterographa crassa* (DC.) Fée	*Roccellaceae*	Crustose	On bark
069	∗*Ephebe lanata* (L.) Vainio.	*Lichinaceae*	Fruticose	On soil with moss
070	∗*Evernia divaricata* (L.) Ash.	*Parmeliaceae*	Foliose	On bark
071	*Evernia prunastri* (L.) Ash.	*Parmeliaceae*	Foliose	On bark
072	*Flavoparmelia caperata* (L.) Hale. (Syn. *Parmelia caperata* (L.) Ach.)	*Parmeliaceae*	Foliose	On bark
073	∗ *Flavoparmelia soredians* (Nyl.) Hale (Syn. *Parmelia soredians* Nyl.)	*Parmeliaceae*	Foliose	On bark
074	∗*Graphis elegans* (Borrer ex Sm.) Ash.	*Graphidaceae*	Crustose	On bark
075	∗*Graphis scripta* (L.) Ash.	*Graphidaceae*	Crustose	On bark
076	∗*Hymenelia lactustris* (With.) Choisy	*Hymeneliaceae*	Crustose	On rocks
077	∗*Hypogymnia farinacea* Zopf (Syn. *H. bitteriana* (Zahlbr.) Räsänen)	*Parmeliaceae*	Foliose	On bark
078	∗*Hypogymnia physodes* (L.) Nyl.	*Parmeliaceae*	Foliose	On bark
079	∗*Hypogymnia tubulosa* (Schaerer) Havaas	*Parmeliaceae*	Foliose	On bark
080	∗ *Hypotrachyna laevigata* (Sm.) Hale	*Parmeliaceae*	Foliose	On bark

	(Syn. *Parmelia laevigata* (Sm.) Ach.)			
081	*Hypotrachyna revoluta* (Flörke) Hale (Syn. *Parmelia revoluta* (Flörke) Hale)	*Parmeliaceae*	Foliose	On bark
082	*Lasalia pustulata* (L.) Mérat	*Umbilicariaceae*	Foliose	On rocks
083	∗*Lecania erysibe* (Ash.) Mudd.	*Bacidiaceae*	Crustose	On rocks
084	∗*Lecanora albella* (Pers.) Ash. (Syn. *L. pallida* (Schreber) Rabenh.)	*Lecanoraceae*	Crustose	On bark
085	*Lecanora albescens* (Hoffm.) Branth & Rostrup	*Lecanoraceae*	Crustose	On rocks
086	∗*Lecanora allophana* (Ash.) Nyl.	*Lecanoraceae*	Crustose	On bark
087	∗*Lecanora badia* (Hoffm.) Ash.	*Lecanoraceae*	Crustose	On bark
088	*Lecanora campestris* (Schaerer) Hue	*Lecanoraceae*	Crustose	On rocks
089	*Lecanora carpinea* (L.) Vain	*Lecanoraceae*	Crustose	On bark
090	*Lecanora chlarotera* Nyl.	*Lecanoraceae*	Crustose	On bark
091	∗*Lecanora conizaeoides* Nyl. Ex Crombie	*Lecanoraceae*	Crustose	On bark
092	∗*Lecanora expallens* Ash.	*Lecanoraceae*	Crustose	On bark
093	∗*Lecanora gangaleoides* Nyl.	*Lecanoraceae*	Crustose	On rocks
094	∗*Lecanora hangenii* (Ash.) Ash.	*Lecanoraceae*	Crustose	On bark
095	∗*Lecanora intricata* (Ash.) Ash.	*Lecanoraceae*	Crustose	On rocks
096	*Lecanora muralis* (Schreber) Rabenh	*Lecanoraceae*	Crustose	On rocks
097	∗*Lecanora polytropa* (Ehrh. Ex Hoffm.) Rabenh	*Lecanoraceae*	Crustose	On rocks
098	*Lecanora rupicola* (L.) Zahlbr.	*Lecanoraceae*	Crustose	On rocks
099	*Lecanora schistina* (Nyl.) Arnold	*Lecanoraceae*	Crustose	On rocks
100	∗*Lecanora strobilina* (Spreng.) Kieff.	*Lecanoraceae*	Crustose	On bark
101	∗*Lecanora subcarnea* (Lilj.) Ash.	*Lecanoraceae*	Crustose	On rocks
102	*Lecanora sulphurea* (Hoffm.) Ash.	*Lecanoraceae*	Crustose	On rocks
103	∗*Lecidea lapicida* (Ash.) Ash.	*Lecideaceae*	Crustose	On rocks
104	∗*Lecidea lithophila* (Ash.) Ash.	*Lecideaceae*	Crustose	On rocks
105	∗*Lecidea promiscua* Nyl.	*Lecideaceae*	Crustose	On rocks
106	∗*Lecidea tesselata* Flörke	*Lecideaceae*	Crustose	On rocks
107	∗*Lecidella alaiensis* (Vain) Hertel	*Lecanoraceae*	Crustose	On rocks
108	*Lecidella carpathica* Körber	*Lecanoraceae*	Crustose	On rocks
109	*Lecidella elaeochroma* (Ash.) Choisy	*Lecanoraceae*	Crustose	On bark
110	*Lecidella stigmatea* (Ash.) Hertel	*Lecanoraceae*	Crustose	On bark
111	∗*Lepraria incana* (L.) Ash.	*Stereocaulaceae*	Leprose/ Powdery	On bark/ On rocks
112	*Lepraria neglecta* (Nyl.) Lettau	*Stereocaulaceae*	Leprose/ Powdery	On rocks
113	∗*Leptogium cyanescens* (Rabenh) Körb.	*Collemataceae*	Gelatinose	On bark/ On rocks
114	*Lobaria amplissima* (Scop.) Forss.	*Lobariaceae*	Foliose	On bark/ On rocks
115	∗*Lobaria virens* (With.) Laundon (Syn. *L. laetevirens* Zahlbr.)	*Lobariaceae*	Foliose	On bark/ On rocks
116	*Lobaria pulmonaria* (L.) Hoffm.	*Lobariaceae*	Foliose	On bark/ On rocks
117	*Lobaria scrobiculata* (Scop.) DC.	*Lobariaceae*	Foliose	On bark
118	*Melanelixia glabratula* (Lamy) Sandler & Arup (Syn. *Parmelia glabratula* (Lamy.) Nyl.)	*Parmeliaceae*	Foliose	On bark
119	∗ *Melanelixia subargentifera* (Nyl.) O. Blanco *et al.* (Syn. *Parmelia subargentifera* Nyl.)	*Parmeliaceae*	Foliose	On bark
120	*Melanelixia subaurifera* (Nyl.) O.Blanco *et al.* (Syn.	*Parmeliaceae*	Foliose	On bark

	Parmelia subaurifera Nyl.; *Melanelia subaurifera* (Nyl.) Essl.)			
121	∗ *Melanohalea exasperata* (De Not.) Essl. O. Blanco *et al.* (Syn. *Parmelia exasperata* De Not.)	*Parmeliaceae*	Foliose	On bark
122	∗ *Melanohalea laciniatula* (Flagey ex H. Olivier) O. Blanco *et al.* (Syn. *Parmelia laciniatula* (Flagey ex Oliv.) Zahlbr).	*Parmeliaceae*	Foliose	On bark
123	∗*Micarea bauschiana* (Körb.) V. With & Vezda	*Micareaceae*	Crustose	On rocks
124	*Nephroma laevigatum* Ash.	*Nephromataceae*	Gelatinose	On bark
125	∗*Nephroma parile* (Ash.) Ash.	*Nephromataceae*	Gelatinose	On bark
126	*Normandina pulchella* (Borr.) Nyl.	*Verrucariaceae*	*Squamulose*	On bark
127	*Ochrolechia parella* (L.) Massal.	*Pertusariaceae*	Crustose	On bark/ On rocks
128	∗*Ochrolechia tartarea* (L.) Massal.	*Pertusariaceae*	Crustose	On rocks
129	*Opegrapha atra* Pers.	*Opegraphaceae*	Crustose	On bark
130	∗*Opegrapha lichenoides* Pers.	*Opegraphaceae*	Crustose	On bark
131	∗*Opegrapha pulicaris* auct. non Hoffm. ex Behlen & Desberg.	*Opegraphaceae*	Crustose	On bark
132	*Opegrapha stictica* Nyl.	*Opegraphaceae*	Crustose	On bark
133	∗*Opegrapha virdis* (Ash.) Nyl.	*Opegraphaceae*	Crustose	On bark
134	∗*Ophioparma ventosa* (L.) Norman (Syn.*Haematomma vebtosum* (L.) Massal.)	*Ophioparmaceae*	Crustose	On bark
135	∗*Pannaria conoplea* (Ash.) Bory	*Pannariaceae*	Foliose	On bark with moss
136	∗*Pannaria leucophaea* (Vahl.) P.M.Jørg.	*Pannariaceae*	Foliose	On rocks with moss
137	*Pannaria rubiginosa* (Ash.) Bory	*Pannariaceae*	Foliose	On bark with moss
138	∗ *Parmotrema crinitum* (Ach.) M. Choisy.(Syn. *Parmelia crinita* Ach.)	*Parmeliaceae*	Foliose	On bark
139	∗ *Parmotrema hypoleucinum* (J. Steiner) Hale (Syn. *Parmelia hypoleucina* Steiner)	*Parmeliaceae*	Foliose	On bark
140	∗ *Parmelina pastillifera* (Harm.) Hale	*Parmeliaceae*	Foliose	On bark
141	*Parmotrema perlatum* (Huds.) M.Choisy (Syn. *Parmelia perlata* (Huds.) Vain.).	*Parmeliaceae*	Foliose	On bark
142	*Parmelia pulla* Ash.	*Parmeliaceae*	Foliose	On rocks
143	*Parmelina carporrhizans* (Taylor) Poelt & Vezda (Syn. *Parmelia quercina* (Willd.) Vain.)	*Parmeliaceae*	Foliose	On bark
144	*Parmelia saxatilis* (L.) Ach.	*Parmeliaceae*	Foliose	On bark
145	*Parmelia sulcata* Taylor	*Parmeliaceae*	Foliose	On bark
146	*Parmelina tiliacea* (Hoffm.) Hale	*Parmeliaceae*	Foliose	On bark
147	∗*Peltigera aphtosa* (L.) Willd.	*Peltigeraceae*	Foliose	On soil with moss
148	∗*Peltigera canina* (L.) Wild.	*Peltigeraceae*	Foliose	On soil
149	∗*Peltigera horizontalis* (Huds.) Baumg.	*Peltigeraceae*	Foliose	On bark with moss / On soil with moss
150	∗*Peltigera polydactyla* (Necker) Hoffm.	*Peltigeraceae*	Foliose	On bark with moss / On soil with moss
151	*Peltigera rufescens* (Weis.) Humb.	*Peltigeraceae*	Foliose	On soil
152	*Pertusaria albescens* (Huds.) Choisy & Werner	*Pertusariaceae*	Crustose	On bark
153	*Pertusaria amara* (Ach.) Nyl.	*Pertusariaceae*	Crustose	On bark
154	*Pertusaria lactea* (L.) Arnold	*Pertusariaceae*	Crustose	On rocks
155	*Pertusaria pertusa* (Weigel) Tuck.	*Pertusariaceae*	Crustose	On bark

156	*Pertusaria rupicola* (Fr.) Harm.	*Pertusariaceae*	Crustose	On rocks
157	*Phaeophyscia hirsuta* (Merschk.) Moberg	*Physciaceae*	Foliose	On bark
158	*Phaeophyscia orbicularis* (Necker) Moberg	*Physciaceae*	Foliose	On bark
159	*Phlyctis agelaea* (Ach.) Flotow.	*Phlyctidaceae*	Crustose	On bark
160	∗*Phlyctis argena* (Sprengel) Flotow.	*Phlyctidaceae*	Crustose	On bark
161	*Physcia adscendens* (Fr.) Oliv.	*Physciaceae*	Foliose	On bark
162	*Physcia aipolia* (Ehrh. Ex Humb.) Fürnr.	*Physciaceae*	Foliose	On bark
163	*Physcia caesia* (Hoffm.) Fürnr.	*Physciaceae*	Foliose	On rocks
164	∗*Physcia dubia* (Hoffm.) Lett.	*Physciaceae*	Foliose	On rocks
165	*Physcia semipinnata* (Gmel.) Moberg (Syn. *Physcia leptalea* (Ach.) DC.)	*Physciaceae*	Foliose	On bark
166	*Physcia tenella* (Scop.) DC.	*Physciaceae*	Foliose	On bark
167	*Physconia distorta* (With.) Laundon (Syn. *Ph. Pulverulacea* Moberg)	*Physciaceae*	Foliose	On bark
168	∗*Physconia grisea* (Lam.) Poelt.	*Physciaceae*	Foliose	On bark
169	*Physconia venusta* (Ash.) Poelt.	*Physciaceae*	Foliose	On bark
170	∗*Platismatia glauca* (L.) Culb. & C. Culb.	*Parmeliaceae*	Foliose	On bark
171	*Pleurosticta acetabulum* (Neck.) Elix & Lumbsch (Syn.*Parmelia acetabulum* (Necker) Duby)	*Parmeliaceae*	Foliose	On bark
172	∗*Porpidia crustulata* (Ach.) Hertel	*Lecideaceae*	Crustose	On rocks
173	*Pseudevernia furfuracea* (L.) Zopf.	*Parmeliaceae*	Fruticose	On bark
174	*Psilolechia lucida* (Ach.) M. Choisy	*Pilocarpaceae*	Leprose/ Powdery	On soil
175	∗ *Punctelia borreri* (Sm.) Krog (Syn. *Parmelia borreri* (Sm.) Turner)	*Parmeliaceae*	Foliose	On bark
176	*Ramalina calicaris* (L.) Fr.	*Ramalinaceae*	Fruticose	On bark
177	*Ramalina canariensis* J. Steiner	*Ramalinaceae*	Fruticose	On bark
178	*Ramalina farinacea* (L.) Ach.	*Ramalinaceae*	Fruticose	On bark
179	∗*Ramalina fastigiata* (Pers.) Ash.	*Ramalinaceae*	Fruticose	On bark
180	∗*Ramalina fraxinea* (L.) Ach.	*Ramalinaceae*	Fruticose	On bark
181	∗*Ramalina pollinaria* (Westr.) Ach.	*Ramalinaceae*	Fruticose	On bark
182	*Ramalina polymorpha* (Lilj.) Ach.	*Ramalinaceae*	Fruticose	On rocks
183	∗*Ramalina siliquosa* (Hudson) A.L. Sm.	*Ramalinaceae*	Fruticose	On rocks
184	∗*Rhizocarpon geminatum* Köorber	*Rhizocarpaceae*	Crustose	On rocks
185	∗*Rhizocarpon lavatum* (Fr.) Hazsl.	*Rhizocarpaceae*	Crustose	On rocks
186	∗*Rhizocarpon lecanorinum* Andres	*Rhizocarpaceae*	Crustose	On rocks
187	*Rhizocarpon polycarpum* (Hepp) Th. Fr.	*Rhizocarpaceae*	Crustose	On rocks
188	∗*Rinodina atrocinerea* (Dicks.) Körber	*Physciaceae*	Crustose	On rocks
189	∗*Schaereria fuscocinerea* (Nyl.) Clauz. & Roux (Syn. *Sch. tenebrosa* (Flotow) Hertel & Poelt)	*Schaereriaceae*	Crustose	On rocks
190	∗*Schismatomma decolorans* (Turn. & Borr. ex Sm.) Clauz. & Vezda	*Roccellaceae*	Crustose	On bark
191	∗*Spilonema revertens* Nyl.	*Coccocarpiaceae*	Fruticose	On rocks
192	∗*Sticta fuliginosa* (Hoffm.) Ach.	*Lobariaceae*	Foliose	On bark with moss / On rocks with moss
193	∗*Sticta sylvatica* (Huds.) Ach.	*Lobariaceae*	Foliose	On bark with moss / On rocks with moss
194	∗*Teloschistes chrysophthalmus* (L.) Th. Fr.	*Teloschistaceae*	Fruticose	On bark

195	*Teloschistes villosus* (Ach.) Norman	*Teloschistaceae*	Fruticose	On bark
196	∗*Tephromela atra* (Huds.) Hafellner (Syn. *Lecanora atra* (Huds.) Ach.)	*Bacidiaceae*	Crustose	On rocks
197	∗*Trapelia coarctata* (Sm.) M. Choisy	*Trapeliaceae*	Crustose	On rocks/ on soil
198	∗*Umbilicaria crustulosa* (Ach.) Frey	*Umbilicariaceae*	Umbilicate	On rocks
199	∗*Umbilicaria cylindrica* (L.) Delise ex Duby	*Umbilicariaceae*	Umbilicate	On rocks
200	∗*Umbilicaria hirsuta* (Sw. ex Westr.) Hoffm.	*Umbilicariaceae*	Umbilicate	On rocks
201	∗*Usnea cornuta* Körb.	*Parmeliaceae*	Fruticose	On bark
202	∗*Usnea filipendula* Stirt	*Parmeliaceae*	Fruticose	On bark
203	∗*Usnea glabrescens* (Nyl.) Ras.	*Parmeliaceae*	Fruticose	On bark
204	*Usnea hirta* (L.)Wigg.	*Parmeliaceae*	Fruticose	On bark
205	∗ *Xanthoparmelia conspersa* (Ehrh. *ex* Ach.) Hale (Syn.*Parmelia conspersa* (Ehrh. *ex* Ach.) Ach.)	*Parmeliaceae*	Foliose	On bark
206	*Xanthoparmelia delisei* (Duby) O. Blanco *et al.* (Syn. *Parmelia delisei* (Duby) Nyl.)	*Parmeliaceae*	Foliose	On bark/ On rocks
207	∗ *Xanthoparmelia mougeotii* (Schaer. *ex* D.Dietr.) Hale (Syn.*Parmelia mougeotii* Schaer. ex Dietr.)	*Parmeliaceae*	Foliose	On rocks
208	*Xanthoria elegans* (Link.) Th. Fr.	*Teloschistaceae*	Foliose	On rocks
209	∗*Xanthoria fallax* (Hepp) Arnold	*Teloschistaceae*	Foliose	On rocks
210	*Xanthoria parietina* (L.)	*Teloschistaceae*	Foliose	On bark
211	∗*Xanthoria polycarpa* (Hoffm.) Th. Fr. ex Rieber	*Teloschistaceae*	Foliose	On bark

Among these bioindicators, the presence of high sensitive epiphytic species as *Evernia prunastri*, *Lobaria amplissima*, *L. pulmonaria*, *L. scrobiculata*, *L. virens*, *Physcia adsendens*, *Ph. aipolia*, *Ph. sempinnata*, *Physconia distorta, Ph. grisea*, *Ramalina fastigiata*, *R. farinacea* , *R. fraxinea*, in response to toxic air pollutants (all categories included) remains a strong indicator of an unpolluted forestry ambience. In addition, others species, fruticose (*Teloschistes chrysophthalmus*, *T. villosus, Usnea cornuta*, *U. filipendula*, *U. hirta)* or umbilicate (*Umbilicaria crustulosa*, *U. cylindrica*, *U. hirsuta*) and despite their rarity remain excellent indicators of air purity (even to a very occasional low level of contamination) within this forest region.

Table 3. Locality, Type of rarity and Estimating air purity of recorded species in the oak forests of Kroumiria Mountains, northwestern of Tunisia. (∗ , asterisk is usually used for new record taxa).

n°	Lichen Taxa	Locality								Type of rarity	Estimated average content of atmospheric (µg.m^{-3} d'air) / Indicative sensitivity scale value	
		EF	GH	AS	A Dr	MJ	BM	OZ	AZ		SO_2	NO_x
001	∗*Acarospora nitrophila* H. Magn.	+	+	-	+	-	+	+	-	CC	--	--
002	∗*Acarospora scabrida* Hedl. Ex Magn	+	+	-	+	-	+	+	-	CC	--	--
003	∗*Acarospora sinopica* (Wahlenb.) Körber	+	+	-	+	-	+	+	-	CC	--	--
004	∗*Acarospora umbilicata* Bagl.	+	+	-	+	-	+	+	-	CC	--	--
005	*Acrocordia gemmata* (Ash.) Massal. (syn. *A.alba* (Schrader) B. de Lesd.)	+	+	+	+	+	+	+	+	CC	--	--
006	∗*Alectoria achroleuca* (Hoffm.) Massal.	+	+	+	+	+	+	+	+	C	--	--

007	*Alectoria sarmentosa* (Ash.) Ash.	+	-	+	+	+	+	+	-	C	--	--
008	*Amygdalaria athroocarpa* Ash.	+	-	-	+	-	+	+	-	CC	--	--
009	*Anaptychia ciliaris* (L.) Körber ex Massal	+	+	+	+	+	+	+	+	CC	< 50 /6	--
010	*Anaptychia runcinata* (With.) Laundon (Syn. *A. fusca* (Huds.) Vainio)	-	-	-	+	-	+	-	-	RR	--	--
011	*Arthonia punctiformis* Ash.	+	+	+	+	+	+	+	+	CC	<125 /3	--
012	*Arthonia radiata* (Pers.) Ash.	+	+	+	+	+	+	+	+	CC	<125 /3	--
013	*Arthonia spadicea* Leighton	+	+	+	+	+	+	+	+	CC	<125 /3	--
014	*Aspicilia intermutans* (Nyl.) Arnold	-	+	-	+	-	+	+	-	C	--	--
015	*Aspicilia radiosa* (Hoffm.) Poelt. (Syn. *Lobothallia radiosa* (Hoffm.) Haf.)	+	+	+	+	+	+	+	+	CC	--	< 200
016	*Bacidia inundata* (Fr.) Körb.	+	-	-	+	+	+	+	-	CC	--	--
017	*Bacidia rubella* (Hoffm.) Massal.	+	+	+	+	+	+	+	+	CC	<125 /3	< 200
018	*Bacidia subacerina* Vain.	+	+	+	+	-	+	+	+	CC	--	--
019	*Bacidia viridifarinosa* Coppins & P. James	+	+	+	+	+	+	+	-	CC	--	--
020	*Brodoa intestiniformis* (Vill.) Goward. (Syn. *Hypogymnia intestiniformis* (Vill.) Räsänen	+	+	+	+	+	+	+	-	C	--	--
021	*Bryoria chalybeiformis* auct.	+	+	+	+	+	+	+	-	V	--	--
022	*Bryoria fuscescens* (Gyelnik) Brodo & Hawksw.	+	-	+	-	+	+	+	-	RR	--	--
023	*Buellia aethalea* (Ash.) Th. Fr.	+	+	+	+	+	+	+	+	CC	--	--
024	*Buellia saxorum* Massal.	+	-	-	-	-	-	-	-	R	--	--
025	*Buellia subdisciformis* (Leight.) Vaino	+	-	-	-	-	-	-	-	R	--	--
026	*Caloplaca arenaria* (Pers.) Müll. Arg.	+	+	-	+	-	+	+	-	CC	--	--
027	*Caloplaca aurantia* (Pers.) J. Steiner	-	-	-	-	-	+	-	-	RR	< 30 /9	--
028	*Caloplaca cerina* (Ehrh. Ex Hedwig) Th. Fr.	+	+	+	+	+	+	+	+	C	--	--
029	*Caloplaca chalybaea* (Fr.) Müll. Arg.	+	-	-	-	-	+	-	-	R	--	--
030	*Caloplaca crenularia* (With.) Laundon (Syn. *C. festiva* (Ach.) Zwackh.)	+	+	+	+	+	+	+	+	CC	--	--
031	*Caloplaca erythrocarpa* (Pers.) Zwackh.	-	+	-	-	-	+	-	-	RR	--	--
032	*Caloplaca ferruginea* (Hudson) Th. Fr.	+	+	+	+	+	+	+	+	CC	--	--
033	*Caloplaca flavescens* (Huds.) Laundon (Syn. *C. heppiana* (Müll. Arg.) Zahlbr.)	-	+	-	-	-	+	-	-	RR	--	--
034	*Catillaria chalybeia* (Borrer) Massal.	+	+	+	+	+	+	+	+	C	--	--
035	*Catillaria nigroclavata* (Nyl.) Schuler	+	+	+	+	+	+	+	+	CC	--	--
036	*Cetraria chlorophylla* (Wild.) Vainio	-	-	-	+	-	-	+	-	RR	--	--
037	*Cetraria nivalis* (L.) Ach.	-	-	+	-	+	+	+	+	V	--	--
038	*Cetraria olivetorum* (Nyl.) Culb. & Culb.	-	-	-	-	+	+	-	-	V	--	--
039	*Chrysothrix candelaris* (L.) Laundon	+	-	-	+	-	-	+	-	RR	--	--
040	*Chrysothrix chlorina* (Ash.) Laundon	+	+	+	+	+	+	+	+	CC	--	--
041	*Cladonia arbuscula* (Wallr.) Flotow	+	+	+	+	+	+	+	+	CC	--	--
042	*Cladonia cervicornis* (Ash.) Flotow	+	+	+	+	+	+	+	+	CC	--	--
043	*Cladonia chlorophaea* (Flöke ex Sommerf.) Spreng.	+	+	+	+	+	+	+	+	CC	--	--
044	*Cladonia ciliata* Stirton	+	+	+	+	+	+	+	+	CC	--	--
045	*Cladonia coccifera* (L.) Wild.	+	+	+	+	+	+	+	+	CC	--	--
046	*Cladonia coniocraea* (Flörke) Spreng.	+	+	+	+	+	+	+	+	CC	--	--

047	*Cladonia fimbriata* (L.) Fr.	+	+	+	+	+	+	+	+	CC	--	--
048	*Cladonia foliacea* (Huds.) Wild.	+	+	+	+	+	+	+	+	CC	--	--
049	*Cladonia furcata* (Huds.) Schrad.	+	+	+	+	+	+	+	+	CC	--	--
050	∗*Cladonia gracilis* (L.) Wild.	+	+	+	+	+	+	+	+	CC	--	--
051	∗*Cladonia macilenta* Hoffm.	+	+	+	+	+	+	+	+	CC	--	--
052	∗*Cladonia parasitica* (Hoffm.) Hoffm.	-	-	-	-	-	-	+	-	R	--	--
053	*Cladonia portentosa* (Dufour) Coem.	+	+	+	+	+	+	+	+	CC	--	--
054	∗*Cladonia rangiferina* (L.) Weber ex Wigg.	+	+	+	+	+	+	+	+	CC	--	--
055	*Cladonia rangiformis* Hoffm.	-	+	-	-	-	-	+	-	R	--	--
056	∗*Cladonia squamosa* (Scop.) Hoffm.	-	+	-	-	-	+	+	-	C	--	--
057	∗*Cladonia subulata* (L.) Webber ex Wigg.	+	+	+	+	+	+	+	+	CC	--	--
058	∗*Cladonia uncialis* (L.) Webber ex Wigg.	+	+	+	+	+	+	+	+	CC	--	--
059	*Collema auriforme* (With.) Coppins & Laundon (Syn. *C. auriculatum* Hoffm.)	+	+	+	+	+	+	+	+	CC	--	--
060	*Collema crispum* (Huds.) Webber ex Wigg.	+	+	+	+	+	+	+	+	CC	--	--
061	*Collema cristatum* (L.) Webber ex Wigg.	+	+	+	+	+	+	+	+	CC	--	--
062	*Collema flaccidum* (Ash.) Ash.	+	+	+	+	+	+	+	+	CC	--	--
063	*Collema furfuraceum* (Arnold) Du Rietz	+	+	+	+	+	+	+	+	CC	--	--
064	*Collema tenax* (Swartz) Ash.	-	+	-	-	-	-	+	-	R	--	--
065	∗*Dermatocarpon miniatum* (L.) Mann	+	-	-	-	-	-	-	-	RR	--	--
066	∗*Diploicia canescens* (Dickson) Massal.	+	+	-	-	-	-	+	-	C	<125 /3	< 80 /7
067	*Dirina stenhammari* (Stenham.) (Syn. *D. massiliensis* f. *sorediata* (Müll. Arg.) Tehler)	-	+	-	-	-	-	+	-	R	--	--
068	*Enterographa crassa* (DC.) Fée	+	-	-	-	+	+	+	+	C	--	--
069	∗*Ephebe lanata* (L.) Vainio.	+	-	+	-	+	+	+	+	C	--	--
070	∗*Evernia divaricata* (L.) Ash.	+	+	+	+	+	+	+	+	CC	--	--
071	*Evernia prunastri* (L.) Ash.	+	+	+	+	+	+	+	+	CC	< 60 /5	< 82 /6
072	*Flavoparmelia caperata* (L.) Hale. (Syn. *Parmelia caperata* (L.) Ach.)	+	+	+	+	+	+	+	+	CC	--	< 90 /4
073	∗ *Flavoparmelia soredians* (Nyl.) Hale (Syn. *Parmelia soredians* Nyl.)	+	+	+	+	-	+	+	+	CC	--	< 80 /7
074	∗*Graphis elegans* (Borrer ex Sm.) Ash.	-	+	-	+	+	+	+	+	C	--	--
075	∗*Graphis scripta* (L.) Ash.	-	+	-	+	+	+	+	-	C	--	--
076	∗*Hymenelia lactustris* (With.) Choisy	+	+	+	+	+	+	+	+	CC	--	--
077	∗*Hypogymnia farinacea* Zopf (Syn. *H. bitteriana* (Zahlbr.) Räsänen)	+	+	+	+	+	+	+	+	CC	--	--
078	∗*Hypogymnia physodes* (L.) Nyl.	+	-	+	+	+	+	+	+	CC	--	< 80 /7
079	∗*Hypogymnia tubulosa* (Schaerer) Havaas	+	-	+	+	+	+	+	+	CC	--	--
080	∗ *Hypotrachyna laevigata* (Sm.) Hale (Syn. *Parmelia laevigata* (Sm.) Ach.)	+	+	+	+	+	+	+	+	CC	--	--
081	*Hypotrachyna revoluta* (Flörke) Hale (Syn. *Parmelia revoluta* (Flörke) Hale)	+	+	+	+	-	+	+	+	CC	--	--
082	*Lasalia pustulata* (L.) Mérat	+	+	-	-	-	-	+	-	R	--	--
083	∗*Lecania erysibe* (Ash.) Mudd.	+	+	-	-	-	-	+	-	R	--	
084	∗*Lecanora albella* (Pers.) Ash. (Syn. *L. pallida* (Schreber) Rabenh.)	+	+	+	+	+	+	+	+	CC	--	< 85 /5
085	*Lecanora albescens* (Hoffm.) Branth &	+	-	-	-	-	+	-	-	R	--	--

	Rostrup												
086	∗*Lecanora allophana* (Ash.) Nyl.	+	+	+	+	+	+	+	+	CC	--	--
087	∗*Lecanora badia* (Hoffm.) Ash.	+	+	+	+	+	+	+	+	CC	--	--
088	*Lecanora campestris* (Schaerer) Hue	+	-	-	-	-	+	-	-	R	--	--
089	*Lecanora carpinea* (L.) Vain	+	+	+	+	+	+	+	+	CC	--	< 80 /7
090	*Lecanora chlarotera* Nyl.	+	+	+	+	+	+	+	+	CC	< 60 /5	< 85 /5
091	∗*Lecanora conizaeoides* Nyl. Ex Crombie	-	-	-	+	-	-	+	-	R	<150 /2	< 85 /5
092	∗*Lecanora expallens* Ash.	+	+	-	+	+	+	+	+	CC	<125 /3	< 70 /3
093	∗*Lecanora gangaleoides* Nyl.	+	+	+	+	-	+	+	-	C	--	--
094	∗*Lecanora hangenii* (Ash.) Ash.	+	+	-	+	+	+	+	+	CC	--	--
095	∗*Lecanora intricata* (Ash.) Ash.	+	+	+	+	-	+	+	-	CC	--	--
096	*Lecanora muralis* (Schreber) Rabenh	+	+	-	+	+	+	+	-	CC	--	< 80 /7
097	∗*Lecanora polytropa* (Ehrh. Ex Hoffm.) Rabenh	+	+	+	+	+	+	+	+	CC	--	--
098	*Lecanora rupicola* (L.) Zahlbr.	+	+	+	+	+	+	+	-	CC	--	--
099	*Lecanora schistina* (Nyl.) Arnold	+	+	+	+	+	+	+	-	CC	--	--
100	∗*Lecanora strobilina* (Spreng.) Kieff.	+	+	-	+	-	+	+	+	CC	--	--
101	∗*Lecanora subcarnea* (Lilj.) Ash.	+	+	+	+	-	+	+	-	CC	--	--
102	*Lecanora sulphurea* (Hoffm.) Ash.	+	+	+	+	-	+	+	-	CC	--	--
103	∗*Lecidea lapicida* (Ash.) Ash.	+	+	+	+	+	+	+	+	CC	--	--
104	∗*Lecidea lithophila* (Ash.) Ash.	+	+	+	+	-	+	+	-	CC	--	--
105	∗*Lecidea promiscua* Nyl.	+	+	+	+	-	+	+	-	CC	--	--
106	∗*Lecidea tesselata* Flörke	-	+	-	+	-	-	-	-	C	--	--
107	∗*Lecidella alaiensis* (Vain) Hertel	+	+	+	+	-	+	+	+	CC	--	--
108	*Lecidella carpathica* Körber	+	+	+	+	+	+	+	+	CC	--	--
109	*Lecidella elaeochroma* (Ash.) Choisy	+	+	-	+	-	+	+	+	CC	--	--
110	*Lecidella stigmatea* (Ash.) Hertel	+	+	-	+	-	+	+	+	CC	--	< 90 /4
111	∗*Lepraria incana* (L.) Ash.	+	+	+	+	+	+	+	+	CC	<125 /3	< 70 /3
112	*Lepraria neglecta* (Nyl.) Lettau	+	+	-	+	-	-	+	+	CC	--	--
113	∗*Leptogium cyanescens* (Rabenh) Körb.	+	+	-	+	-	+	+	+	CC	--	--
114	*Lobaria amplissima* (Scop.) Forss.	+	+	-	+	-	+	+	+	CC	< 30 /9	--
115	∗*Lobaria virens* (With.) Laundon (Syn. *L. laetevirens* Zahlbr.)	+	+	-	+	-	+	+	+	CC	< 30 /9	--
116	*Lobaria pulmonaria* (L.) Hoffm.	+	+	+	+	+	+	+	+	CC	< 30 /9	--
117	*Lobaria scrobiculata* (Scop.) DC.	+	-	-	-	+	+	-	+	R	<10 /10	--
118	*Melanelixia glabratula* (Lamy) Sandler & Arup (Syn. *Parmelia glabratula* (Lamy.) Nyl.)	+	+	+	+	-	+	+	+	CC	--	--
119	∗ *Melanelixia subargentifera* (Nyl.) O. Blanco *et al*. (Syn. *Parmelia subargentifera* Nyl.)	+	+	+	+	-	+	+	+	CC	--	--
120	*Melanelixia subaurifera* (Nyl.) O.Blanco *et al*. (Syn. *Parmelia subaurifera* Nyl.; *Melanelia subaurifera* (Nyl.) Essl.)	+	+	+	+	-	+	+	+	CC	--	< 75 /3
121	∗ *Melanohalea exasperata* (De Not.) Essl. O. Blanco *et al*. (Syn. *Parmelia exasperata* De Not.)	+	+	+	+	-	+	+	+	CC	--	--
122	∗ *Melanohalea laciniatula* (Flagey ex H.	+	+	+	+	+	+	+	+	CC	--	--

	Olivier) O. Blanco *et al.* (Syn. *Parmelia laciniatula* (Flagey ex Oliv.) Zahlbr).												
123	∗*Micarea bauschiana* (Körb.) V. With & Vezda	+	+	-	+	-	+	+	-	CC	--	--	
124	*Nephroma laevigatum* Ash.	+	+	-	+	+	+	+	+	CC	--	--	
125	∗*Nephroma parile* (Ash.) Ash.	+	+	-	+	+	+	+	+	CC	--	--	
126	*Normandina pulchella* (Borr.) Nyl.	+	-	-	+	+	+	+	+	CC/V	--	--	
127	*Ochrolechia parella* (L.) Massal.	+	+	+	+	+	+	+	+	CC	--	--	
128	∗*Ochrolechia tartarea* (L.) Massal.	+	+	+	+	+	+	+	+	CC	--	--	
129	*Opegrapha atra* Pers.	+	+	+	+	-	+	+	+	CC	--	--	
130	∗*Opegrapha lichenoides* Pers.	+	+	+	+	-	+	+	+	CC	--	--	
131	∗*Opegrapha pulicaris* auct. non Hoffm. ex Behlen & Desberg.	+	+	+	+	-	+	+	+	CC	--	--	
132	*Opegrapha stictica* Nyl.	+	+	+	+	-	+	+	+	CC	--	--	
133	∗*Opegrapha virdis* (Ash.) Nyl.	+	+	+	+	+	+	+	+	CC	--	--	
134	∗*Ophioparma ventosa* (L.) Norman (Syn.*Haematomma vebtosum* (L.) Massal.)	+	+	+	+	-	+	+	+	CC	--	--	
135	∗*Pannaria conoplea* (Ash.) Bory	+	-	+	+	+	+	+	+	CC	--	--	
136	∗*Pannaria leucophaea* (Vahl.) P.M.Jørg.	-	+	-	-	-	-	+	-	R	--	--	
137	*Pannaria rubiginosa* (Ash.) Bory	+	+	+	+	+	+	+	+	CC	--	--	
138	∗ *Parmotrema crinitum* (Ach.) M. Choisy.(Syn. *Parmelia crinita* Ach.)	+	+	+	+	+	+	+	+	CC	--	--	
139	∗ *Parmotrema hypoleucinum* (J. Steiner) Hale (Syn. *Parmelia hypoleucina* Steiner)	+	+	+	+	-	+	+	+	CC	--	--	
140	∗ *Parmelina pastillifera* (Harm.) Hale	+	+	+	+	+	+	+	+	CC	--	--	
141	*Parmotrema perlatum* (Huds.) M.Choisy (Syn. *Parmelia perlata* (Huds.) Vain.).	+	+	+	+	+	+	+	+	CC	--	--	
142	*Parmelia pulla* Ash.	+	+	-	+	-	+	+	-	C	--	--	
143	*Parmelina carporrhizans* (Taylor) Poelt & Vezda (Syn. *Parmelia quercina* (Willd.) Vain.)	+	+	+	+	-	+	+	+	CC	--	--	
144	*Parmelia saxatilis* (L.) Ach.	+	+	+	+	-	+	+	+	CC	--	--	
145	*Parmelia sulcata* Taylor	+	+	+	+	+	+	+	+	CC	--	< 75 /3	
146	*Parmelina tiliacea* (Hoffm.) Hale	+	+	+	+	+	+	+	+	CC	--	--	
147	∗*Peltigera aphtosa* (L.) Willd.	+	+	-	+	-	-	+	-	R	--	--	
148	∗*Peltigera canina* (L.) Wild.	+	-	-	-	-	+	+	-	R	--	--	
149	∗*Peltigera horizontalis* (Huds.) Baumg.	+	+	-	+	-	-	+	-	R	--	--	
150	∗*Peltigera polydactyla* (Necker) Hoffm.	+	-	-	-	+	-	+	-	R	--	--	
151	*Peltigera rufescens* (Weis.) Humb.	+	-	-	-	+	+	+	-	C	--	--	
152	*Pertusaria albescens* (Huds.) Choisy & Werner	+	+	+	+	-	+	+	+	CC	--	--	
153	*Pertusaria amara* (Ach.) Nyl.	+	+	+	+	-	+	+	+	CC	--	--	
154	*Pertusaria lactea* (L.) Arnold	-	+	-	-	-	-	+	-	R	--	--	
155	*Pertusaria pertusa* (Weigel) Tuck.	+	+	+	+	+	+	+	+	CC	--	--	
156	*Pertusaria rupicola* (Fr.) Harm.	+	+	+	+	-	+	+	+	CC	--	--	
157	*Phaeophyscia hirsuta* (Merschk.) Moberg	+	+	+	+	+	+	+	+	CC	--	--	
158	*Phaeophyscia orbicularis* (Necker) Moberg	+	-	+	+	+	+	-	+	CC	< 60 /5	< 100 /1	
159	*Phlyctis agelaea* (Ach.) Flotow.	+	-	+	-	+	+	+	+	CC	--	--	

160	∗*Phlyctis argena* (Sprengel) Flotow.	+	-	+	-	+	+	+	+	CC	--	< 85 /5
161	*Physcia adscendens* (Fr.) Oliv.	+	+	+	+	+	+	+	+	CC	< 70 /4	< 90 /2
162	*Physcia aipolia* (Ehrh. Ex Humb.) Fürnr.	+	+	+	+	+	+	+	+	CC	< 40 /7	< 90 /2
163	*Physcia caesia* (Hoffm.) Fürnr.	+	+	+	+	+	+	+	+	CC	<125 /3	< 80 /7
164	∗*Physcia dubia* (Hoffm.) Lett.	+	+	-	+	+	+	+	+	CC	--	< 75 /8
165	*Physcia semipinnata* (Gmel.) Moberg (Syn. *Physcia leptalea* (Ach.) DC.)	+	+	+	+	+	+	+	+	CC	< 40 /7	--
166	*Physcia tenella* (Scop.) DC.	+	+	+	+	+	+	+	+	CC	--	< 90 /2
167	*Physconia distorta* (With.) Laundon (Syn. *Ph. Pulverulacea* Moberg)	+	+	+	+	+	+	+	+	CC	< 50 /6	--
168	∗*Physconia grisea* (Lam.) Poelt.	+	+	+	+	+	+	+	+	CC	< 60 /5	< 80 /7
169	*Physconia venusta* (Ash.) Poelt.	+	+	+	+	+	+	+	+	CC	--	--
170	∗*Platismatia glauca* (L.) Culb. & C. Culb.	+	+	+	+	+	+	+	+	CC	--	--
171	*Pleurosticta acetabulum* (Neck.) Elix & Lumbsch (Syn.*Parmelia acetabulum* (Necker) Duby)	+	+	+	+	+	+	+	+	CC	--	--
172	∗*Porpidia crustulata* (Ach.) Hertel	+	+	+	+	-	+	+	+	CC	--	--
173	*Pseudevernia furfuracea* (L.) Zopf.	+	+	+	+	+	+	+	+	CC	--	--
174	*Psilolechia lucida* (Ach.) M. Choisy	-	+	-	+	-	+	+	-	C	--	--
175	∗ *Punctelia borreri* (Sm.) Krog (Syn. *Parmelia borreri* (Sm.) Turner)	+	+	+	+	+	+	+	+	CC	--	--
176	*Ramalina calicaris* (L.) Fr.	+	+	+	+	+	+	+	+	CC	--	--
177	*Ramalina canariensis* J. Steiner	+	+	+	+	+	+	+	-	CC	--	--
178	*Ramalina farinacea* (L.) Ach.	+	+	+	+	+	+	+	+	CC	< 60 /5	< 82 /6
179	∗*Ramalina fastigiata* (Pers.) Ash.	+	+	+	+	+	+	+	+	CC	< 30 /9	--
180	∗*Ramalina fraxinea* (L.) Ach.	+	+	+	+	+	+	+	+	CC	< 30 /9	--
181	∗*Ramalina pollinaria* (Westr.) Ach.	+	+	+	+	+	+	+	+	CC	--	--
182	*Ramalina polymorpha* (Lilj.) Ach.	+	+	+	+	+	+	+	+	CC	--	--
183	∗*Ramalina siliquosa* (Hudson) A.L. Sm.	+	+	+	+	+	+	+	+	CC	--	--
184	∗*Rhizocarpon geminatum* Köorber	-	+	-	-	-	+	+	-	C	--	--
185	∗*Rhizocarpon lavatum* (Fr.) Hazsl.	-	+	-	-	-	+	+	-	C	--	--
186	∗*Rhizocarpon lecanorinum* Andres	-	+	-	-	-	+	+	-	C	--	--
187	*Rhizocarpon polycarpum* (Hepp) Th. Fr.	-	+	-	-	-	+	+	-	C	--	--
188	∗*Rinodina atrocinerea* (Dicks.) Körber	-	+	-	-	-	-	+	-	R	--	--
189	∗*Schaereria fuscocinerea* (Nyl.) Clauz. & Roux (Syn. *Sch. tenebrosa* (Flotow) Hertel & Poelt)	-	+	-	-	-	+	+	-	R	--	--
190	∗*Schismatomma decolorans* (Turn. & Borr. ex Sm.) Clauz. & Vezda	-	-	-	-	-	+	+	-	R	--	< 90 /2
191	∗*Spilonema revertens* Nyl.	+	+	+	+	+	+	+	+	CC	--	--
192	∗*Sticta fuliginosa* (Hoffm.) Ach.	+	+	+	+	+	+	+	+	CC	--	--
193	∗*Sticta sylvatica* (Huds.) Ach.	+	+	+	+	+	+	+	+	CC	--	--
194	∗*Teloschistes chrysophthalmus* (L.) Th. Fr.	+	-	-	+	-	+	+	+	C	--	--
195	*Teloschistes villosus* (Ach.) Norman	-	-	-	-	-	-	+	-	RR	--	--
196	∗*Tephromela atra* (Huds.) Hafellner (Syn. *Lecanora atra* (Huds.) Ach.)	+	+	-	+	-	+	+	+	CC	--	--
197	∗*Trapelia coarctata* (Sm.) M. Choisy	+	+	+	+	+	+	+	+	CC	--	--

198	∗*Umbilicaria crustulosa* (Ach.) Frey	+	-	-	-	-	-	+	-	R	--	--
199	∗*Umbilicaria cylindrica* (L.) Delise ex Duby	+	-	-	-	-	-	+	-	R	--	--
200	∗*Umbilicaria hirsuta* (Sw. ex Westr.) Hoffm.	+	-	-	-	-	-	+	-	R	--	--
201	∗*Usnea cornuta* Körb.	+	-	-	-	-	+	-	+	R	--	< 75 /8
202	∗*Usnea filipendula* Stirt	-	-	-	-	-	+	-	-	RR	<10 /10	--
203	∗*Usnea glabrescens* (Nyl.) Ras.	+	-	-	-	+	+	-	-	R	--	--
204	*Usnea hirta* (L.)Wigg.	+	-	-	+	-	+	+	+	C	--	--
205	∗ *Xanthoparmelia conspersa* (Ehrh. *ex* Ach.) Hale (Syn.*Parmelia conspersa* (Ehrh. *ex* Ach.) Ach.)	+	+	+	+	+	+	+	+	CC	--	--
206	*Xanthoparmelia delisei* (Duby) O. Blanco *et al.* (Syn. *Parmelia delisei* (Duby) Nyl.)	+	+	-	+	-	-	+	-	C	--	--
207	∗ *Xanthoparmelia mougeotii* (Schaer. *ex* D.Dietr.) Hale (Syn.*Parmelia mougeotii* Schaer. ex Dietr.)	+	+	-	-	-	-	+	-	C	--	--
208	*Xanthoria elegans* (Link.) Th. Fr.	+	+	+	+	+	+	+	-	CC	--	--
209	∗*Xanthoria fallax* (Hepp) Arnold	+	+	+	+	+	+	+	-	CC	--	--
210	*Xanthoria parietina* (L.)	+	+	+	+	+	+	+	+	CC	--	< 90 /2
211	∗*Xanthoria polycarpa* (Hoffm.) Th. Fr. ex Rieber	+	+	+	+	+	+	+	+	CC	--	< 90 /2

Hypogymnia physodes L.

(Nyl.). (Fig 7.a.). This lichen is also often used as a biomonitoring organism because it is considered as one of the most tolerant epiphytic lichens to SO_2 (Herzig *et al.*,1989; Pfeiffer and Barclay-Estrup, 1992).

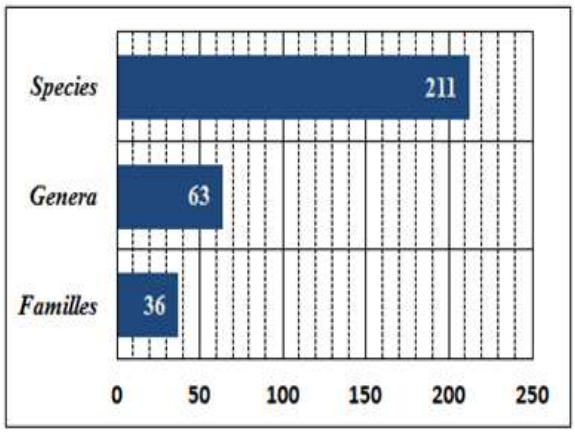

Fig. 2. Numerical allocation of recorded specimens in genera and lichen families.

Teloschistes chrysophthalmus (L.)

Th. Fr. First record for Tunisian lichens flora (Fig 6.e.). A subcosmopolitan species (cf. Werner 1949), indicator of wetlands grows on branches of *Quercus canariensis* Willd. This fruticose lichen is widespread in Mediterranean climate of both hemispheres. However, it is known only in a few locations in North Africa (cf. GBIF, 2013). It is considered in sharp decline in Western Europe and to be extinct in Northern Ireland (cf. UK Biod. G., 1999). Considering its status, the species is listed as threatened on the preliminary European Red List for macrolichens (Sérusiaux, 1989).

Usnea barbata (L.)

F.H. Wigg. (Fig 6.l.). The species is very polymorphic and may represent a collection of intergrading taxa; several characters (e.g. presence of fibrils, papillae and isidia; degree of depressions and ridges) vary greatly. Reported in Europe: Austria, Bulgaria, Czech Republic, Denmark, Estonia, Finland, Germany, Greece, Italy, Latvia, Lithuania, Norway, Poland, Romania, Caucasus, Slovakia, Slovenia, Spain, Sweden, Switzerland and Ukraine (cf. Tiina *et al.*, 2009). The lichen, *Usnea barbata* is usually used as bioindicator organism in the Mediterranean Sea (Villeneuve *et al.*, 1988).

Discussion

Some species are well-known bioindicators for clean air. The presence of the species, *Ramalina fraxinea*, *Anaptychia ciliaris*, *Lobaria pulmonaria*, *Physconia distorta*, *Parmelina pastillifera* and *Flavoparmelia caperata* in this oak forests region suggests that the region has low levels of air pollution and sources of poisonous gaz.

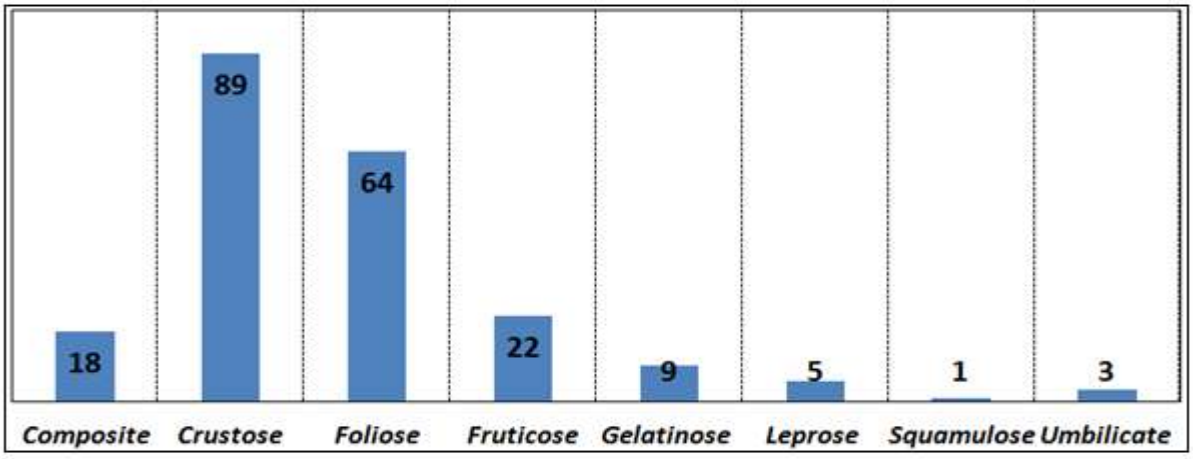

Fig. 3. Numerical allocation of recorded specimens according to their growth forms.

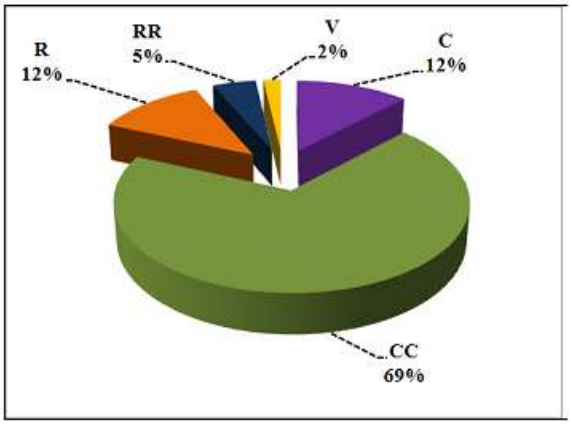

Fig. 4. Numerical allocation of recorded specimens according to their type of rarity.

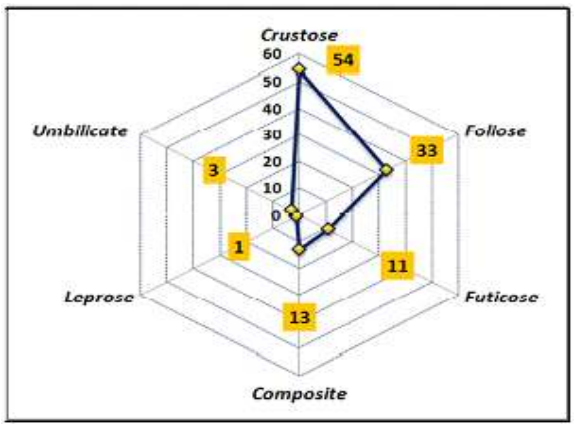

Fig. 5. Numerical allocation of new recorded taxa for Tunisia according to their growth forms.

For the Kroumiria oak forests, preliminary lichenological study indicates that epiphytic lichen succession on trunks largely proceeds as follows. Crustose lichens dominate in the first stages of the forest. Species richness is greatest when the macrolichen component starts to mix with the dominating crustose lichens. In old-growth, foliose and fruticose lichens dominate, and crustose species are of little importance on tree trunks. Old-growth forests have higher macrolichen species richness with abundance of *Normandina pulchella* (Borr.) Nyl. However, the crustose lichen component is mostly found on the younger smooth-bark trees and higher up in the canopy, as found on fallen branches and trees after storms.

Macrolichen diversity and abundance showed a general increase with humidity, high density and the closing of the canopy. This relationship was mainly obvious for *Lobariaceae*, Parmeliaceae and *Ramalinaceae* on oak species. The importance of humidity for abundance and diversity was also reported by Galloway from Chile (1992) and Nash and Moser (1982) from the USA. The positive effect of increasing precipitation on lichen diversity may largely be attributed to longer coherent periods of

growth in high-precipitation sites, whereas low-precipitation sites might suffer from extended dry periods when lichen thalli cannot photosynthesize (Hauck and Meissner, 2002; Dahlman and Palmqvist, 2003).

Stand age influenced epiphytic macrolichen abundance and diversity, which confirms results from other parts of the world (Lesica *et al.*, 1991; McCune, 1993; Dettki and Esseen, 1998; Boudreault *et al.*, 2000; Price and Hochachka, 2001). For many lichen species, old-growth stands provide more suitable microhabitats. Young or managed stands have a narrow spectrum of microhabitats for lichen establishment and younger, less abundant populations of the relatively slow growing lichens. Furthermore, poor dispersal of epiphytic lichens may delay recolonisation of secondary stands (Sillett *et al.*, 2000).

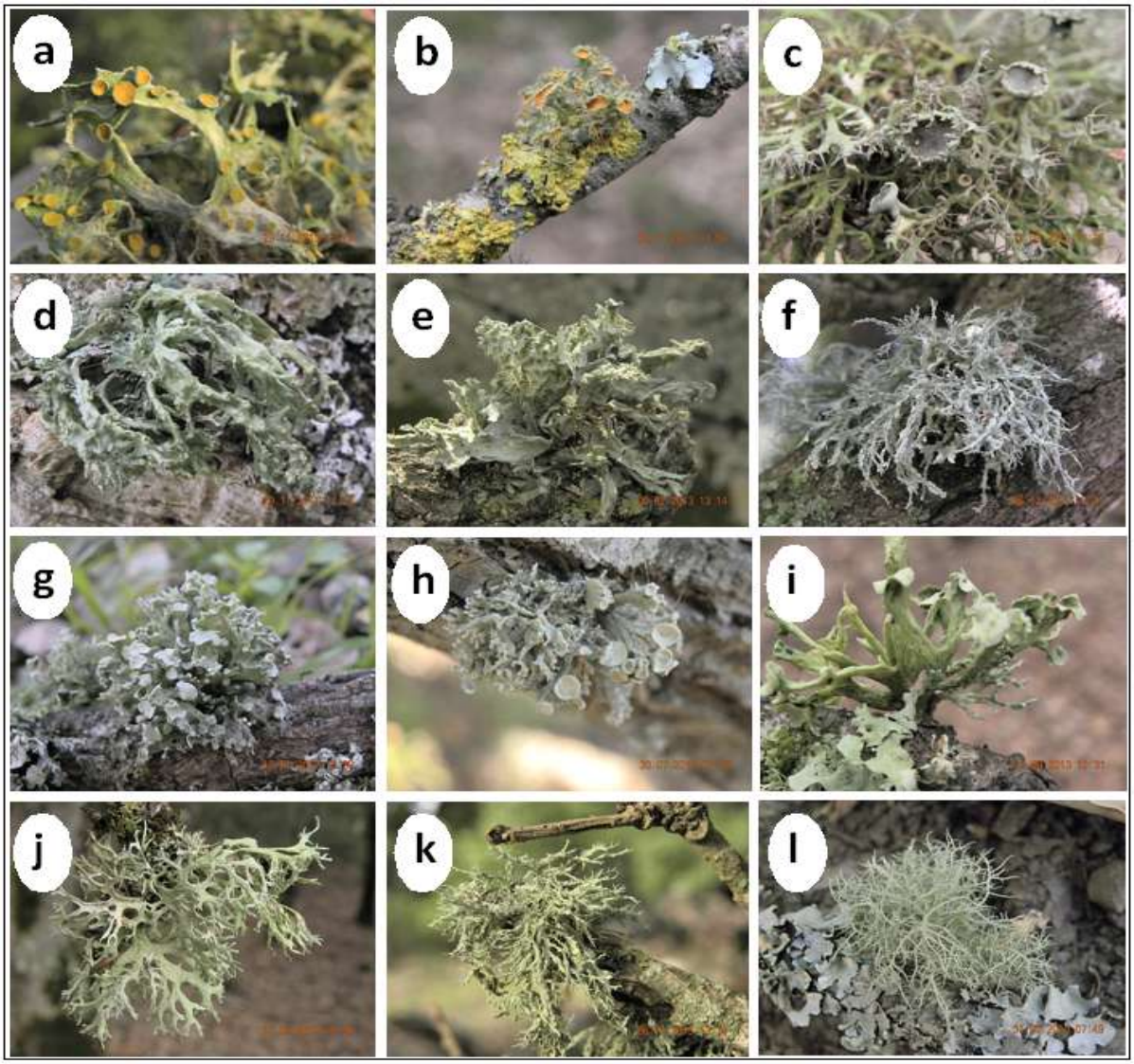

Fig. 6. Some fruticose lichens from oak mountains of Kroumiria, North Western of Tunisia: a. *Teloschistes villosus* (Ach.) Norman, b. *Teloschistes chrysophthalmus* (L.) Th. Fr., c. *Anaptychia ciliaris* (L.) Körb., d. *Ramalina fraxinea* (L.) Ach., e. *R. canariensis* J. Steiner, f. *R. siliquosa* (Huds.) A. L. Sm., g. *R. fastigiata* (Pers.) Ach., h. *Ramalina pollinaria* (Westr.) Ach.to the left and *R. fastigiata* (Pers.) Ach. to the wright, i. *R. calicaris* (L.) Fr., j. *Evernia prunastri* (L.) Ach., k. *Ramalina farinacea* (L.) Ach., l. *Usnea* cf. *barbata* (L.) F. H. Wigg (*U. hirta* (L.) Wigg. p.p.).

In general, patterns of abundance of different functional groups showed relatively small changes with stand age. One trend was that the relative abundance of the genera *Lobaria*, *Parmelia*, *Ramalina* increases with stand age and the fresh forest atmosphere. However, there was no relative increase of crustose lichens with stand age in this study.

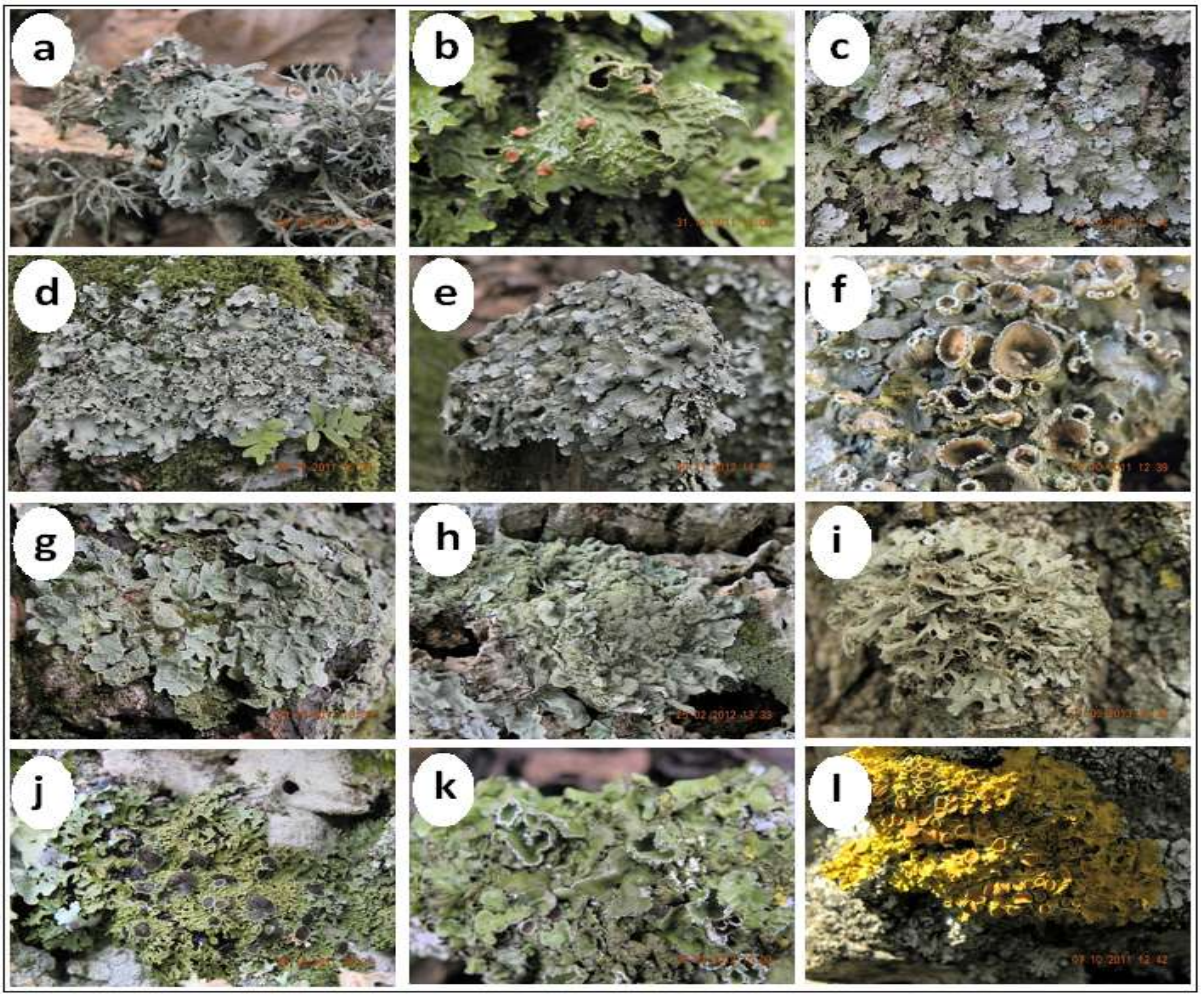

Fig 7. Some foliose lichens from oak mountains of Kroumiria, North Western of Tunisia: **a. *Hypogymnia*** *physodes* (L.) Nyl., b. *Lobaria pulmonaria* (L.) Hoffm., c. *L. amplissima* (Scop.) Forssell, d. *Parmotrema perlatum* (Huds.) M. Choisy, e. *Parmelia saxatilis* (L.) Ach. *s.l.*, f. anhydrous specimen of *Pleurosticta acetabulum* (Neck.) Elix et Lumbsch, g. *Parmelia sulcata* Taylor s.l., h. *Flavoparmelia soredians* (Nyl.) Hale, i. *Physcia adscendens* (Fr.) H. Olivier, j. *Physconia distorta* (With.) J. R. Laundon,, k. hydrous specimen of *Pleurosticta acetabulum* (Neck.) Elix et Lumbsch, l. *Xanthoria parietina* (L.) Th. Fr. *s.l.*

The presence of bioindicators species of air purity in this forest region does not deny sporadic occurrence of some visible injury and ultrastructural changes. In fact, bleaching of the thalli was observed for some species (Figure 10).

Holopainen and Karenlampi (1984), Pfeiffer and Barclay-Estrup (1992), Bruteig 1993, Jeran *et al.* (1993) then Egger *et al.* (1994) studied visible injury that occurred when specimens of *Hypogymnia physodes* L. were exposed to a range of SO_2 concentrations (140-2,860 µg m-3). Specimens were exposed in fumigation chambers for 5.5 to 8.0 h d-1 for 7 to 21 days. Visible injury, bleaching of the thalli of *H. physodes* was apparent after 4 days (22 h, fumigation at 2,860 µg m-3) with bleaching increasing as the length of exposure increased!

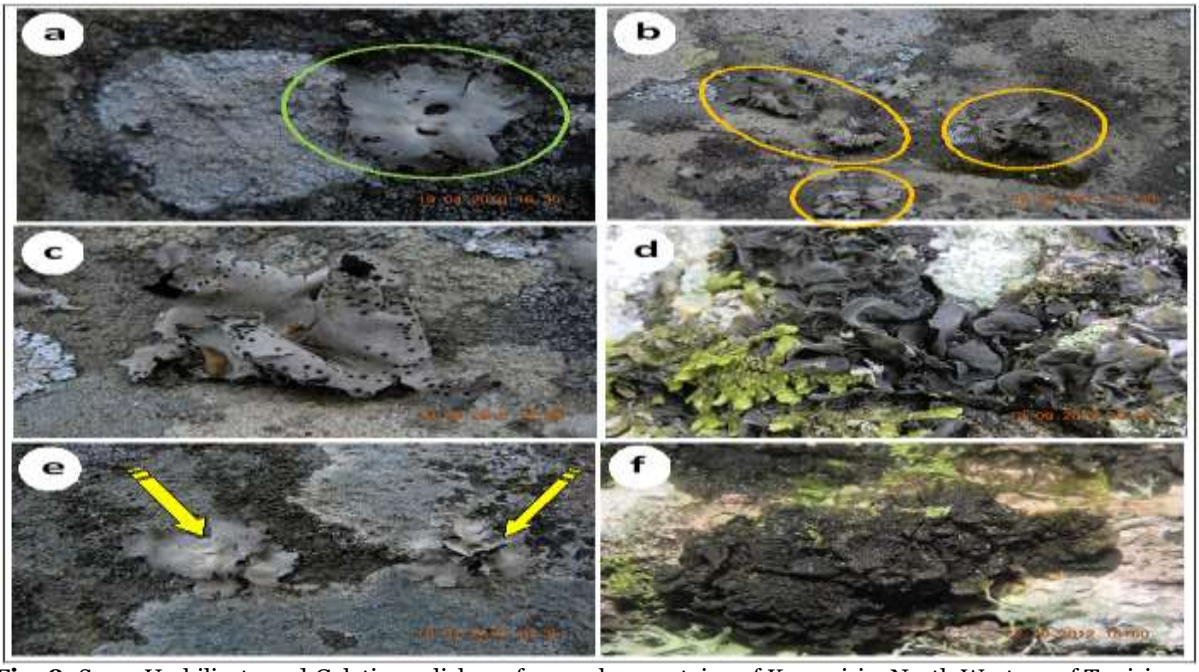

Fig. 8. Some Umbilicate and Gelatinose lichens from oak mountains of Kroumiria, North Western of Tunisia: a. *Umbilicaria* cf. *grisea* Hoffm., b. & e. *Umbilicaria hirsuta* (Sw. ex Westr.) Hoffm., c. *Umbilicaria crustulosa* (Ach.) Freye., d. *Collema* cf. *crispum* (Huds.) Weber ex F. H. Wigg, f. *Collema* cf. *flaccidum* (Ach.) Ach. Colored circles and arrows illustrate locality of thalli on huge rocks.

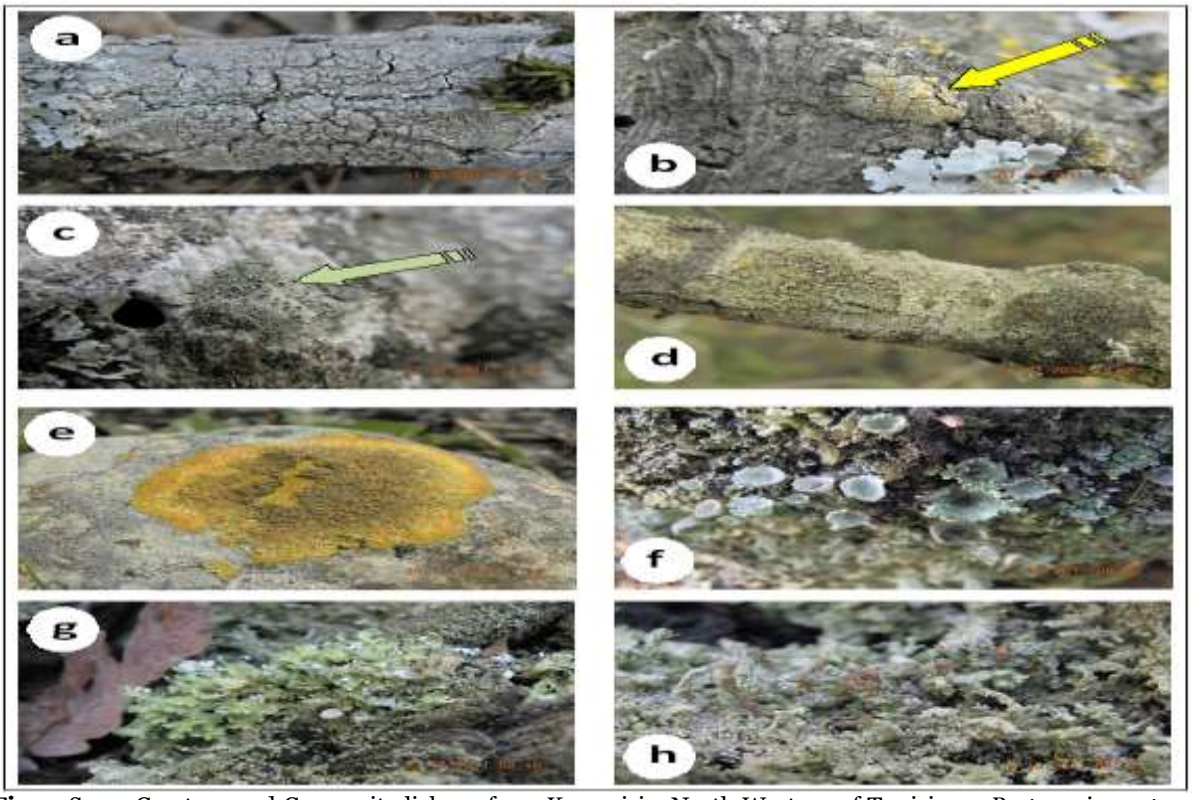

Fig 9. Some Crustose and Composite lichens from Kroumiria, North Western of Tunisia: a. *Pertusaria pertusa* (Weigel) Tuck., b. *Lecanora strobilina* (Spreng.) Kieff., c. *Lecanora hagenii* (Ach.) Ach., d. *Lecanora* spp., e. *Caloplaca flavescens* (Huds.) J. R. Laundon *s.l.*, f. *Cladonia* cf. *fimbriata* (L.) Fr., g. *Cladonia foliacea* (Huds.) Willd. *s.l.* h. *Cladonia squamosa* (Scop.) Hoffm. *s.l.*, Arrows illustrate locality of thalli on oak branches.

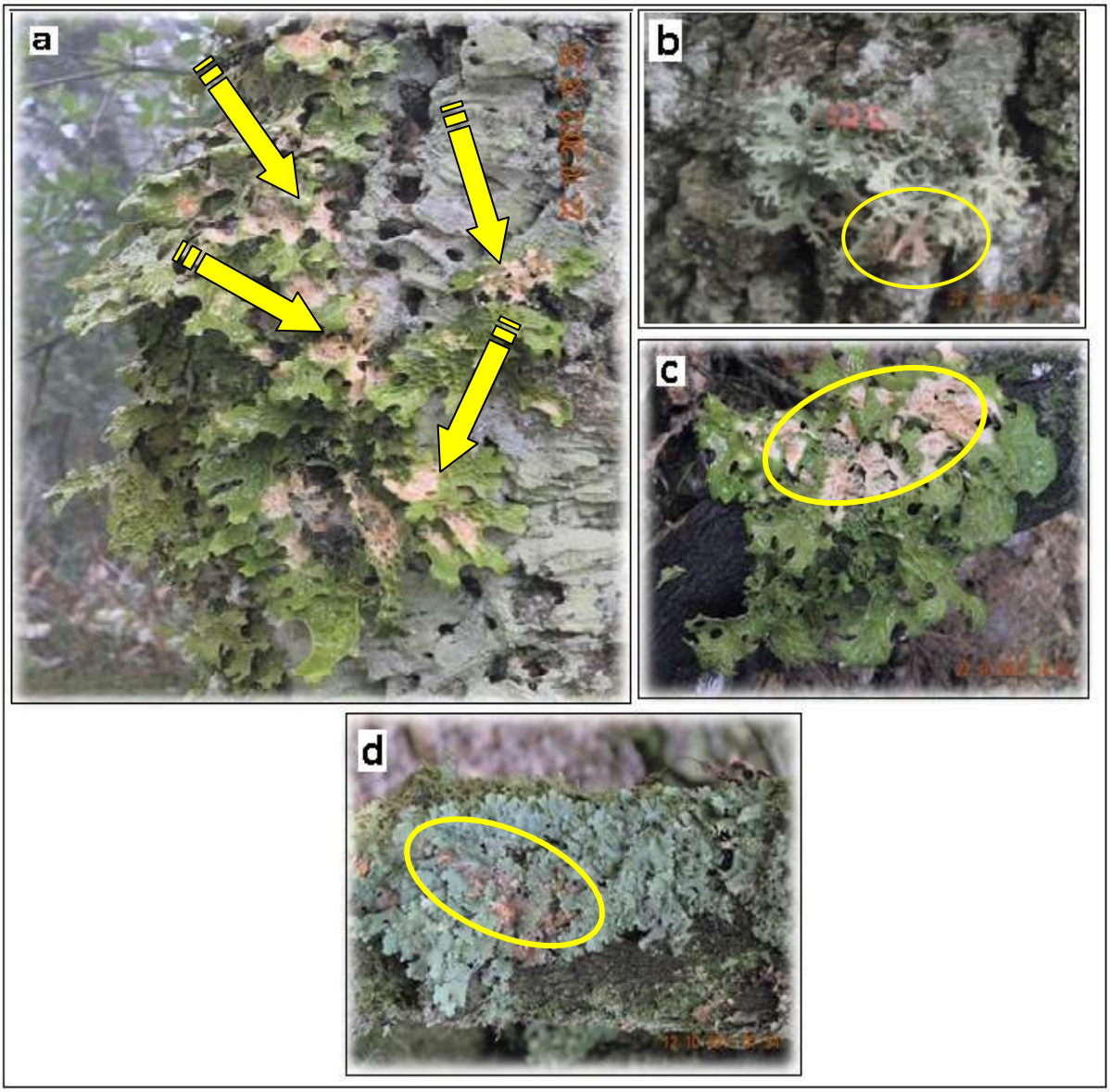

Fig. 10. Some injured specimens of lichens from Kroumiria, North-western of Tunisia: a. & c. bleaching thallus of *Lobaria pulmonaria* (L.) *Hoffm.*; c. *Evernia prunastri* (L.) Ach., d. *Parmelia sulcata* Taylor. Yellow circles and arrows illustrate the spots of discoloration and tendency towards bleaching of the thalli.

Conclusion

In this study a total of 211 species are reported, 115 of which are new records for Tunisia and 14 are very rare to vulnerable. The present research remains currently one the most detailed lichenological survey in recent times for diversity lichens for the oak forests of Kroumiria, and provides valuable data for Tunisian lichens Flora and its ecology. However, future studies should include deeper surveys on some complicated groups of the crustose component relying on more sophisticated keys of identification. Measurements of ambient sulphur dioxide and nitrogen oxides were not performed so the reduction in number of species, frequency of appearance at the different sites, and presence or abundance at each site could not be related to SO_2 and NO_X concentrations, only. More focus and special consideration could be given to species within the genus *Umbilicaria*, which is mentioned for the first time for Tunisia and which distribution area is very restricted to Kroumiria region.

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