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REVIEW

Lichens in the agricultural land of Poland – diversity, threats, and protection: a literature review

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Abstract

Agricultural landscapes provide interesting habitats and substrates occupied by lichens. Nevertheless, there are still gaps in knowledge about diversity of lichenized fungi in rural areas and factors that determine their occurrence, including anthropogenic impact. The review includes recognition of this topic in the regional context in Poland and presents literature data about species diversity and habitat groups. Human influences in terms of their significance for lichens disappearance as well as preservation of the lichen biota are analyzed. A list of threatened lichens found in rural areas as well as a proposal for protection of the lichen biota are given.

Keywords

lichenized fungi; rural areas; habitat groups; anthropogenic impact

Introduction

Although studies of lichens in the agricultural land of Poland are becoming increasingly important, diversity of lichenized fungi in rural areas and factors that determine their occurrence, including anthropogenic impact are still weakly recognized. There is a limited number of comprehensive investigations that focus on the lichen biota of rural areas. So far, this topic has been studied in detail during large-scale surveys in the Choszczno Lake District (NW Poland [1,2]) and the Sandr Nowotomyski (W Poland [3]). However, lichenological inventories of large areas in northern, i.e., the Kashuby Lake District [4] and the Polanowska Upland [5], northwestern, i.e., Western Pomerania [6], and northeastern Poland [7,8], also revealed the presence of many lichens species in agricultural lands. More interesting data concerning lichens in such landscape were also collected at particular locations, e.g., villages and their surroundings in some regions of Poland, especially Podlasie, Roztocze, and Lubelszczyzna (e.g., [9–35]). Several articles are devoted to the occurrence of lichenized fungi on bark of fruit trees, especially in orchards [3,36–44]. Lichenological studies in some protected areas, i.e., the Popradzki Landscape Park (S Poland [45]), the Wiśnicko-Lipnicki Landscape Park (S Poland [46]), the Chełmy Landscape Park (SW Poland [47]), the Pszczewski Landscape Park (W Poland [48]), the Wdzydzki Landscape Park (N Poland [49]), and the Suwalski Landscape Park (NE Poland [50]) also revealed taxa growing in rural areas. More interesting lichen taxa were found in the agricultural land in Gdańsk Pomerania [49,51–55]. Numerous papers contribute to understanding impacts of human activities on the lichen biota in the Polish countryside (e.g., [3,6–8,24,30,31,34,46,56,57]).

In this paper, the current knowledge about the lichenized fungi in the agricultural land and its importance for lichen diversity conservation in Poland is presented based on the literature survey. The article also revises threats to lichens and their protection in a man-transformed rural landscape.

Species diversity

Available data suggest a moderate level of species diversity of lichenized fungi in the agricultural land. In almost completely deforested areas in rural landscape of the Choszczno Lake District, 184 taxa were found [1,2], while 154 taxa were recorded in the agricultural landscape of the Sandr Nowotomyski [3]. In the Polanowska Upland 146 species were collected in open areas covered by meadows, pastures, bounds, fallow lands, and psamophilous grasslands, while in villages, settlements and gravel pits 116 species were observed [5]. The biota of particular villages and their surroundings is mainly represented by several dozen lichen species [23,24,26,29–34,44], rarely exceeding 100 taxa [27]. Species diversity is related to, among others, ecological factors of the sampling localities, including their climatic conditions, the availability of suitable habitats and substrates, but also to the land use. Adopted sampling strategies depending on research objectives also affect lichen diversity assessment.

Habitat groups of lichens

A high species richness of epiphytic lichens in the agricultural land is underlined in many papers. This habitat group comprises heliophilous, nitrophilous, and coniophilous lichens mainly from the genera *Physcia*, *Physconia*, *Ramalina*, and *Xanthoria* (e.g., [3,6,8,24–27,33,45,57–59]). Bark of roadside and free-standing trees, as well as phorophytes growing in mid-field afforestations and mid-field peat bogs, gardens, orchards, and country parks seem to create favorable habitats for many epiphytes in rural areas (e.g., [1–3,5,7,12,20,27,30–34,38–43,59–68]). The most frequently mentioned phorophytes in the literature are ash (*Fraxinus* sp.), willow (*Salix* sp.), poplar (*Populus* sp.), maple (*Acer* sp.), linden (*Tilia* sp.), and alder (*Alnus* sp.) [3,5,8,10,13,15,16,18,21,23,26,27,29,30–34,39,44,45,58,59,66,68–73].

Fruit trees are a special group of phorophytes in agricultural lands. The lichen biota of fruit trees of the Łącka Valley (S Poland) was already presented in the 1960s [36,37]. Afterwards, these data were supplemented by the information from the Bieszczady Mountains (S Poland [38,39,44]), Poręba Wielka in Gorce [64,65], the Wiśnickie Foothills (S Poland [46]), the commune of Sławno (central Poland [43]), the Nowotomyska Plain (W Poland [3,42]), and the Lower Vistula Valley (N Poland [40,41]). Numerous lichen species were found in orchards located in mountains and foothills [36,38,39], and they were sampled mainly on the bark of apple and pear trees [3,30,31,33,36,38–44,46,64]. More than 60% of threatened and protected species in vanished villages in the Bieszczady Mts were found on bark of fruit trees [44]. Specific microclimate conditions of phorophytes are thought to promote lichen growth in old orchards. Particularly, lichens are more abundant within and under tree crowns, where there is high air humidity and diffuse solar radiation [43]. On the other hand, diversity of trees and their age within an orchard, types and intensity of human activities in this agroecosystem and its surroundings, including levels of air pollution as well as general environmental conditions affect epiphytes. Apple orchards feature favorable light conditions, difficult access to the water on the trunk and higher pH of the bark of *Malus* sp. [36], and these allow for establishment and persistence of relatively rich and interesting lichen biota in nearly deforested countryside [42]. Some species of lichens were observed to grow preferentially on bark of apple trees [3,42,43]. For example, *Bacidia rubella* (Hoffm.) A. Massal. was sampled only [3,36,42] or mainly on this phorophyte [39] and it was relatively frequently observed in apple orchards [36,39,49,71]. This lichen species has also been recorded from bark of *Malus domestica* Borkh. in other studies dealing with rural areas [44,64,65,68]. Łubek [74] observed more diverse lichen biota associated with freestanding apple trees that grow at the edge of forests. Comparative data are found in reports which separately analyzed lichens growing on fruit tress (e.g., [9–11,13–15,17,24,30–32,34,37,46,50,58,59,64,65,68,71,72,74,75]); most of them were obtained during lichenological surveys in southeastern and southern part of Poland. More interesting species growing on bark of fruit trees, besides *B. rubella* (Hoffm.) A. Massal., are, among others, *Bacidia adastra* Sparrius & Aptroot, *B. subincompta* (Nyl.)

Arnold, *Bryoria fuscescens* (Gyeln.) Brodo & D. Hawksw., *B. implexa* (Hoffm.) Brodo & D. Hawksw., *Rinodina exigua* (Ach.) Gray, *Usnea hirta* (L.) Weber ex F.H. Wigg., and *U. subfloridana* Stirt. [24,36,39,41–43]. Wirth [76] included *Caloplaca cerina* (Hedw.) Th. Fr. into the group of typical and indicator species for i.a. orchards; its note is known from this type of agroecosystem in the Nowotomyska Plain [42]. This lichen species was frequently found in the association *Physcietum ascendentis* Ochsner 1928 occurring on roadside apple trees in Łącka valley and its surroundings [37].

Country parks constitute other important habitats that host interesting lichen biota [7,20,62–66,68]. Altogether the presence of 87 species was confirmed in rural parks that were investigated in northeastern part of Poland [20]. In the historical mansion park in Poręba Wielka (Gorce) 73 species were discovered, including threatened and rare lichens, e.g., *Bacidina egenula* (Nyl.) Arnold and *Sarcosagium campestre* (Fr.) Poetsch & Schied. [64,65]. Among 26 species known from the historical mansion park in Gogolewo village (S Wielkopolska region) the most interesting ones were *Chaenotheca brachypoda* (Ach.) Tibell and *C. trichialis* (Ach.) Hellb. [66]. The list of lichens of the manor park in Opiniogóra Górna (N Mazovia) consisted of 59 species and the role of this park as a refugium of forest lichens in the agricultural land was proposed [68].

Rural areas provide habitats that contribute to the expansion of many epixylous lichens. More than half of the species discovered in Narew village and its environs (NE Poland) were represented by epixylic lichens [29]. Timber constructions are common elements of regional architecture in some parts of Poland, e.g., Podlasie, and they are favored by lichens associated with dead and rotting wood [29]. Epixylous lichens are known to occupy fences, posts, bridges, and another man-made constructions [3,7–9,11,13–18,22,24,26,27,29–34,45,46,48,71,72,77–80]. Roadside wooden crosses, being a part of the regional cultural heritage in Polish rural areas, are atypical wooden substrates that are colonized by lichenized fungi [23,26,27,29]. They also grow on thatched roofs [1,9,81,82]; Lipnicki [1,81,82] found mainly common and widespread species. Some records of lichens are also known from similar anthropogenic substrates, i.e., wood shingles [17,18,79]. Diederich et al. [83] indicated the following species *Lecania cyrtella* (Ach.) Th. Fr., *Micarea denigrata* (Fr.) Hedl. and *Strangospora pinicola* (A. Massal.) Körb. as lichens associated with wood, which prefer open areas in rural environments and also habitats enriched with nitrogen compounds. All of them were observed on timber constructions in the countryside [3,26,27,29]. *Micarea denigrata* (Fr.) Hedl., as well as some other taxa found on wood in rural areas in Poland, i.e., *Carbonicola myrmecina* (Ach.) Bendiksby & Timdal, *Hypogymnia physodes* (L.) Nyl., *Imshaugia aleurites* (Ach.) S.L.F. Mey., *Lecanora conizaeoides* Nyl. ex Cromb., *L. saligna* (Schrad.) Zahlbr., *L. varia* (Hoffm.) Ach., and *Parmeliopsis ambigua* (Wulfen) Nyl. were included into the group consisting of species associated with wood in the agricultural landscape [84].

Epilythes colonize isolated blocks and stones in open areas, also when they are a part of man-made constructions [1–8,11,19–21,25,31,33,34,39,45,52,57,58,65,71,72,75,77,79,81,85–88]. Distribution of some epilithic lichens growing on isolated blocks were recognized in rural areas in the western foreland of the Białowieża Forest [20]. Many species recorded on similar substrates in open areas in the Trójmiejski Landscape Park and Kaszubski Landscape Park, i.e., fields, meadows, bounds, roadsides, included mostly calciphilous, nitrophilous, heliophilous, and coniophilous lichen species [88] and these information compiled data known earlier from the Kashuby Lake District [4]. Numerous lichens, also coniophilous and calciphilous species, were found on isolated blocks in open areas, i.e., field roads and mid-field afforestations in the surroundings of the "Długogóry" Nature reserve on the Myśliborskie Lakeland (N Poland [89]). Data about species growing on anthropogenic substrates rich in calcium carbonate (e.g., walls of farm buildings, wells, bridges, and posts) [1–5,7,8,11,18,21,23–26,30–34,39,45–48,59,62,66,70–72,75,77,78,81,87,90] indicate a positive effect of agricultural activities expanding potential habitats for lichenized fungi. Among them, calciphilous species or lichens that tolerate calcium carbonate, e.g., *Calogaya decipiens* (Arnold) Arup, Frödén & Søchting, *C. pusilla* (A. Massal.) Arup, Frödén & Søchting, *Lecanora albescens* (Hoffm.) Branth & Rostr., *L. dispersa* (Pers.) Röhl., *Xanthoria parietina* (L.) Th. Fr., as well as nitrophilous species from the family Physciaceae [e.g. *Phaeophyscia orbicularis* (Neck.) Moberg, *P. nigricans* (Flörke)

Moberg, *Physcia adscendens* (Fr.) H. Olivier, *P. caesia* (Hoffm.) Hampe ex Fürnr.] are frequently observed [23,26,27,29–32]. Some interesting records of lichens are known from gravestones and crosses, especially old and not renovated, and cemetery fences [2,7,19,20,23,26,27,32,46,80,90,91]. Old gravestones from the nineteenth century in the village of Bociek (NE Poland) have been colonized by 28 species [27]. The list of lichens found in the cemetery in Bogusław (W Poland) consisted of 41 epilythes [90], while the presence of 14 species was documented in the cemetery in Ugoszcz (Nadbużański Landscape Park, E Poland [80]). Other sacral objects also allow investigators to record numerous epilythes. One of them is the monastery complex of the Cistercians in Lubiąż (Lower Silesia, SW Poland); 57 species were found here, and among them the presence of very rare taxa in Poland, i.e., *Acarospora umbilicata* Bagl., *Diplotomma venustum* (Körb.) Körb., *Lecania rabenhorstii* (Hepp) Arnold, *Lecidea sarcogynoides* Körb., *Massjukiella nowakii* (S.Y. Kondr. & Bielczyk) S.Y. Kondr., Fedorenko, S. Stenroos, Kärnefelt, Elix, J.S. Hur & A., *Physcia dimidiata* (Arnold) Nyl., and *Xanthocarpia crenulatella* (Nyl.) Frödén, Arup & Søchting [92].

Terricolous lichens seem to play only a minor role among lichenized fungi growing in rural areas. There is a limited amount of information about their diversity or their occurrence in these places, and therefore it is difficult to find out species associated with the agricultural landscape. Available data suggest that the lichen biota occurring on soil is less diverse and interesting species are rarely found. It can be partially explained by the fact that a large part of rural areas is covered by fields and other agroecosystems which do not allow many species to survive. For example, land use activities can prevent terricolous lichens from a successful establishment due to ploughing, fertilization, etc. In the agricultural landscape more terricolous lichens grow in psamophilous grasslands, developed on the slopes of deforested dunes and fallow lands. Surveys in rural areas confirmed the presence of species mainly from the genera *Cetraria*, *Cladonia*, *Peltigera*, and *Trapeliopsis*; they were observed near roadsides, balks and fallow lands [3,11,14,19,27,70,78,81,85,93,94]. Some records of lichens are known from pastures [3,65,73,95] and mid-field peat bogs commonly referred as agricultural wasteland [67]. However, both trampling, grazing, as well as fertilization induce negative influence on habitat conditions and growth of terricolous lichens, especially on pastures [3]. Species from genus *Peltigera* were sampled in meadows [95], nevertheless high humidity of soil here is indicated as the factor that limits the abundance of terricolous lichens [85].

Among atypical substrates occupied by lichens in the agricultural land are, e.g., metal constructions of gates and fences, hydrants, eternity roof slates, papa, plate bitumine, plastic polyester, rubber [8,24,26,27,29–33]. Matwiejuk and Korobkiewicz [29] recorded *Candelariella aurella* (Hoffm.) Zahlbr., *Lecanora albescens* (Hoffm.) Branth & Rostr., *L. dispersa* (Pers.) Röhl., *Phaeophyscia orbicularis* (Neck.) Moberg, *Physcia caesia* (Hoffm.) Hampe ex Fürnr, *P. dubia* (Hoffm.) Lettau, and *Xanthoria parietina* (L.) Th. Fr. on old abandoned tyres. Some other taxa, i.e., *Athallia holocarpa* (Hoffm.) Arup, Frödén & Søchting, *Candelariella aurella* (Hoffm.) Zahlbr, *C. vitellina* (Hoffm.) Th. Fr., *Lecanora conizaeoides* Nyl. ex Cromb., *Massjukiella polycarpa* (Hoffm.) S.Y. Kondr., Fedorenko, S. Stenroos, Kärnefelt, Elix, J.S. Hur & A. Thell, *Physcia dubia* (Hoffm.) Lettau, *P. tenella* (Scop.) DC., and *Polycauliona candelaria* (L.) Frödén, Arup & Søchting were found on corroded metal parts of old farm machines [24].

Threats and protection

The intensive agricultural activity is indicated as one of the major threats to lichens in Poland [96]. Farmlands are sometimes described as "lichen desert", where lichenized fungi disappear due to application of mineral fertilizers and agrochemicals [2,6,84]. Destruction of habitats and substrates through, e.g., removal of old trees growing in orchards, roadsides or mid-field afforestations, timber constructions, isolated blocks, and smaller stones can also have negative effect on lichens and eliminate sensitive species [2,3,18,24,41,88,97]. Special attention should be paid to lichens that colonize bark of free-standing and old phorophytes. Nowadays, their well-preserved lichen biota with rare taxa persists in northern and northeastern part of Poland [4,7,20,97].

In the other part of the country epiphytes of free-standing trees are declining due to gradual removal of phorophytes [97]. Lichen diversity in orchards is related, among others, to type and intensity of human activities [41,42]. At present there is a trend toward denser and more intensive orchards and it poses growing threats for survival of the lichen biota in farmlands. Bleaching trunks of fruit trees and rubbing of tree bark by farm animals can result in a significant loss of epiphytes in the affected agroecosystem [41]. Studies conducted in the Bieszczady Mts revealed that localization of investigated orchards at less frequently visited areas and far away from main routes positively influences lichen diversity [39]. Similar observations in the same mountain range have been made in vanished villages; investigated anthropogenic habitats were indicated as important refuges of rare lichen species [44]. According to Zielińska [87], agricultural activities impoverish epilithic lichens communities on isolated blocks. Disappearance of some species that inhabit boulders in open areas is associated with, e.g., their dust impregnation, which enables for colonization by nitrophilous and coniophilous species such as *Acarospora fuscata* (Nyl.) Th. Fr., *Candelariella vitellina* (Hoffm.) Müll. Arg., *Lecanora alpigena* (Ach.) Cl. Roux., *Physcia adscendens* (Fr.) H. Olivier, and *P. dubia* (Hoffm.) Lettau [6,7]. Epilythes are negatively affected by cleaning and renovation of gravestones as well as other cemetery elements [35]. Air pollution, also generated by household fuel combustion is other important threat for the lichen biota [3,17,41,43].

Impacts of human activity in the agricultural land are also analyzed based on observations of lichens growing on anthropogenic substrates [3,6–8,24,30,31,34,46,56,57]. More than 60% of species recorded in Klewinowo and Hermanówka villages represented synanthropic lichens [31,34] according to Olech [98]. Providing new habitats, e.g., by planting trees near roads, houses, in gardens, orchards, cemeteries enables for expansion of heliophilous, nitrophilous, and coniophilous species in the agricultural land [6,7]. Many hemerophilous lichens are nitrophilous, e.g., from the genera *Physcia*, *Xanthoria*, and *Ramalina*, thus they commonly colonize habitats and substrates enriched with nitrogen compounds. Calciphilous lichens are other frequently recorded group in rural areas; they are found on the anthropogenic substrates that are rich in calcium carbonate, e.g., walls of farm buildings, wells, bridges, and posts.

The presence of many valuable and interesting taxa in the Polish countryside increases the conservation value of many areas. Studies devoted to protected and threatened lichens in the agricultural land of Podlasie were conducted by Matwiejuk [35], and among them epiphytes and terricolous species were more frequent. Their diversity was similar in forest and mid-field afforestations and near rivers. Also Kapek [44] paid special attention to threatened lichens during lichenological surveys in vanished villages in the Bieszczady Mts. Among 97 recognized taxa of epiphytes, 37% represented species that had been included into the red-listed categories in Poland [96]. Information about threatened lichens in rural areas can be also found in papers by, e.g., Lipnicki and Tobolewski [2], Zarabska [3], Kolanko and Matwiejuk [23], Szymczyk and Zalewska [24], Matwiejuk [26–28], Matwiejuk and Korobkiewicz [29], Kiercul [30,33], Łubek and Biskup [43], Kowalewska et al. [51], Kukwa [53–55], Kubiak et al. [68], and Popiel and Szczepańska [92]. Their records after publication of the current red list of lichens in Poland in 2006 are presented in Tab. 1. Most of them have been put on the red list of extinct and vulnerable lichens of Poland [96] in the endangered categories EN, NT, and VU.

Numerous studies conducted in the agricultural land revealed also protected species (e.g., [3,24,26–31,35,41,43,44,49,80]). Lichen conservation extends beyond species protection and it includes efforts to preserve ecosystems and landscapes at least in unimpaired conditions. Considering the presence of some rare species that required better protection in Jabłonka Stara, lichenologist postulated to include the village into the Pszczewski Landscape Park (W Poland) [48]. Records of interesting lichen species in the agricultural land in the central part of the Sandr Nowotomyski, especially in psamophilous grasslands in Nowy Tomyśl surroundings and the rich lichen biota on alders (*Alnus* sp.) and willows (*Salix* sp.), i.e., phorophytes that grow frequently in mid-field afforestations characteristic for the region, should support the establishment of the Sandr Nowotomyski Landscape Park [3].

Tab. 1 Bibliography of threatened lichens in Poland noted in the agricultural landscape after 2006 r.

Species	Category of threatenes	Source of literature data
Acarospora umbilicata Bagl.	NT	[92]
Acrocordia gemmata (Ach.) A. Massal.	VU	[44,68]
Alyxoria varia (Pers.) Ertz & Tehler	NT	[3,42,44,68]
Anaptychia ciliaris (L.) Körb. ex A. Massal.	EN	[24,27–29,31,68]
Arthonia vinosa Leight.	NT	[5]
Arthothelium ruanum (A. Massal.) Körb.	NT	[31,44]
Athallia cerinella (Nyl.) Arup, Frödén & Søchting	EN	[49]
Bacidia arnoldiana Körb.	NT	[92]
B. rubella (Hoffm.) A. Massal.	VU	[3,5,42,44,49,68]
B. subincompta (Nyl.) Arnold	EN	[44]
Biatora globulosa (Flörke) Fr.	VU	[5,49]
Bryoria fuscescens (Gyeln.) Brodo & D. Hawksw.	VU	[5,27,29,33,49]
B. implexa (Hoffm.) Brodo & D. Hawksw.	CR	[41]
Calicium abietinum Pers.	VU	[5]
C. adspersum Pers.	EN	[5]
C. glaucellum Ach.	VU	[44]
C. salicinum Pers.	VU	[5]
C. viride Pers.	VU	[5]
Caloplaca cerina (Hedw.) Th. Fr.	VU	[26,28,42]
C. obscurella (J. Lahm) Th. Fr.	NT	[24]
Catapyrenium squamulosum (Ach.) Breuss	NT	[26]
Cetraria ericetorum Opiz	NT	[5,28,49]
C. islandica (L.) Ach.	VU	[5,27,28,49]
C. sepincola (Ehrh.) Ach.	EN	[5,26,27]
Cetrelia olivetorum (Nyl.) W.L. Culb. & C.F. Culb.	EN	[44]
Chaenotheca brachypoda (Ach.) Tibell	EN	[5]
C. furfuracea (L.) Tibell	NT	[3,5]
C. phaeocephala (Turner) Th. Fr.	EN	[49,68]
C. stemonea (Ach.) Müll. Arg.	EN	[3]
C. trichialis (Ach.) Hellb.	NT	[3,5,24,68]
C. xyloxena Nádv.	VU	[49]
Chrysothrix candelaris (L.) J.R. Laundon	CR	[5]
Circinaria gibbosa (Ach.) A. Nordin, Savić & Tibell	EN	[28]
Dibaeis baeomyces (L. f.) Rambold & Hertel	NT	[5,28]

Tab. 1 Continued

Species	Category of threatenes	Source of literature data
Diplotomma alboatrum (Hoffm.) Flot.	VU	[92]
D. venustum (Körb.) Körb.	VU	[92]
Endocarpon pusillum Hedw.	VU	[26,28]
Evernia prunastri (L.) Ach.	NT	[3,5,24,26–35,41,43,44,49,68]
Flavoparmelia caperata (L.) Hale	EN	[3,44]
Graphis scripta (L.) Ach.	NT	[44]
Hypogymnia farinacea Zopf	VU	
H. tubulosa (Schaer.) Hav.	NT	[3,5,24,26,27,29,31,33–35,41,43, 44,49,68]
Hypotrachyna revoluta (Flörke) Hale	EN	[44]
Lecania rabenhorstii (Hepp) Arnold	DD	[92]
Lecanora argentata (Ach.) Röhl.	LC	[44]
L. intumescens (Rebent.) Rabenh.	EN	[5,44]
L. persimilis (Th. Fr.) Arnold	DD	[3,24,43,49,55]
L. subcarpinea Szatala	DD	[44]
Lecidea sarcogynoides Körb.	RE	[92]
Lecidella scabra (Taylor) Hertel & Leuckert	NT	[24,55]
Leimonis erratica (Körb.) R.C. Harris & Lendemer	NT	[49]
Melanelia subargentifera (Nyl.) Essl.	VU	[3,5,24,26–29,44,68]
Melanohalea elegantula (Zahlbr.) O. Blanco, A. Crespo, Divakar, Essl., D. Hawksw. & Lumbsch	VU	[5]
Myriolecis sambuci (Pers.) Clem.	DD	[3]
Normandina pulchella (Borrer) Nyl.	EN	[44]
Ochrolechia arborea (Kreyer) Almb.	VU	[44,49]
O. subviridis (Høeg) Erichsen	VU	[5,68]
Oxneria fallax (Arnold) S.Y. Kondr. & Kärnefelt	VU	[31,44]
Pachyphiale fagicola (Arnold) Zwackh	VU	[49]
Parmelina pastillifera (Harm.) Hale	DD	[44]
P. tiliacea (Hoffm.) Hale	VU	[3,24,27,29,31,32,68]
Peltigera canina (L.) Willd.	VU	[3,5,28,31]
P. hymenina (Ach.) Delise	DD	[5,49]
P. polydactylon (Neck.) Hoffm.	DD	[5]
P. praetextata (Flörke ex Sommerf.) Zopf	VU	[3,5,44]
Pertusaria coccodes (Ach.) Nyl.	NT	[5,49]
P. flavida (DC.) J.R. Laundon	EN	[5]
P. pertusa (L.) Tuck.	VU	[3,5]

Tab. 1 Continued

Species	Category of threatenes	Source of literature data
Phaeophyscia chloantha (Ach.) Moberg	VU	[44]
P. endophoenicea (Harm.) Moberg	EN	[44]
P. hirsuta (Mereschk.) Essl.	EN	[44]
P. sciastra (Ach.) Moberg	LC	[49]
Physcia aipolia (Ehrh. ex Humb.) Fürnr.	NT	[3,27,28,44,49]
P. dimidiata (Arnold) Nyl.	VU	[41,92]
Physconia distorta (With.) J.R. Laundon	EN	[5,41,44,49]
P. perisidiosa (Erichsen) Moberg	EN	[3,24,27,28,41,42,49,68]
Piccolia ochrophora (Nyl.) Hafellner	VU	[24,43]
Placynthium nigrum (Huds.) Gray	NT	[26]
Pleurosticta acetabulum (Neck.) Elix & Lumbsch	EN	[3,5,24,27–29,49,68]
Porpidia cinereoatra (Ach.) Hertel & Knoph	LC	[92]
P. macrocarpa (DC.) Hertel & A.J. Schwab	LC	[5]
Pseudoschismatomma rufescens (Pers.) Ertz & Tehler	VU	[44]
Psilolechia lucida (Ach.) M. Choisy	LC	[5,92]
Punctelia jeckeri (Roum.) Kalb	DD	[44]
P. subrudecta (Nyl.) Krog	VU	[44]
Ramalina farinacea (L.) Ach.	VU	[3,5,24,26–33,44,49,68]
R. fastigiata (Pers.) Ach.	EN	[5,24,26,27,29,44,68]
R. fraxinea (L.) Ach.	EN	[3,5,24,26–33,49,68]
R. pollinaria (Westr.) Ach.	VU	[5,26,27,29,30,44,92]
Rinodina exigua (Ach.) Gray	VU	[24,27]
Stereocaulon condensatum Hoffm.	VU	[5]
S. tomentosum Th. Fr.	EN	[5]
Strangospora pinicola (A. Massal.) Körb.	LC	[3,5,24,27,42,49,68]
Tuckermanopsis chlorophylla (Willd.) Hale	VU	[3,5,26–28,30,34,35,41,49]
Umbilicaria polyphylla (L.) Baumg.	LC	[5]
Usnea filipendula Stirt.	VU	[27,29,30,49]
U. hirta (L.) Weber ex F.H. Wigg.	VU	[3,5,26,27,29,30,32,34,35,49]
U. subfloridana Stirt.	EN	[3,5]
Varicellaria hemisphaerica (Flörke) I. Schmitt & Lumbsch	VU	[5]
Vulpicida pinastri (Scop.) J.-E. Mattsson & M.J. Lai	NT	[3,5,31,41]
Xanthoparmelia mougeotii (Schaer.) Hale	VU	[5]

Tab. 1 Continued

Species	Category of threatenes	Source of literature data
X. pulla (Ach.) O. Blanco, A. Crespo, Elix, D. Hawksw. & Lumbsch	NT	[26,27]
Xanthoria ulophyllodes Räsänen	VU	[44,49,55]

Category of threatens according to Cieśliński et al. [96]: CR – critically endangered; EN – endangered; VU – vulnerable; NT – near threatened; LC – least concern; DD – data deficient. Nomenclature was checked according to Index Fungorum [99].

The continuously increase in farming intensity can lead to the loss of habitats and substrates important for the persistence of lichenized fungi. Some proposals that could support protection of lichens in the agricultural landscape are given below:

- preservation of existing habitats which offer suitable growing conditions for lichens, restoration of degraded agroecosystems, and providing new substrates for expansions of potentially valuable and interesting species in rural areas, e.g., timber constructions, concrete, mortar and other anthropogenic substrates promoting the occurrence of epilithic lichens, especially calciphilous species, preservation of old trees in orchards, gardens, mid-field afforestations and roadsides [3,29–33];
- partial removal of shrubs growing around trees to increase light availability on trunks. Under favorable conditions heliophilous and xerophilous lichens should be observed [3];
- prevention of further losing of old traditional orchards and alleys with fruit trees. In the rural landscape old orchards must be conserved because they provide unique habitats for survival of many rare, protected, and threatened species [3,39–41,44]. Their role as local regulators of microclimatic conditions in deforested rural areas is also known [41]. Establishment of young plantations in environs of old ones could allow for expansions of epiphytic lichens growing on old fruit trees [3]. The lichen biota of old orchards could be a source of vegetative, symbiotic diaspores, or sexual ascospores that could develop into adults on bark of younger phorophytes;
- preservation of the cultural heritage which can be related, among others, with promotion of regional architecture. The significant use of wood for several purposes in the countryside could also provide potential habitats occupied by lichens. Every effort or task undertaken to maintaining timber constructions in the rural vicinity will allow for establishment and conservation of numerous epixylous lichens;
- the legal protection in the form of recognizing isolated blocks and old trees, also alleys of trees that host the rich lichen biota as natural monuments;
- education of local communities by, e.g., popular science articles, brochures, and easily accessible educational boards that promote the current state of knowledge about the lichen biota, its occurrence in the agricultural landscape and proposals of its protection;
- country parks and mid-field afforestations in nearly deforested rural areas enable for the presence of lichen associated with forest communities. Kubiak et al. [68] indicated the importance of older trees, the limited occurrence of acclimated tree species, diversification of habitat conditions and lack of larger industrial plants in the vicinity of study area for preservation of the lichen biota in the investigated manor park in Opiniogóra Górna (N Mazovia). They also suggested that introduction of new plantings into park tree stand should include phorophytes, e.g,. maple and ash that create favorable substrate conditions for lichens.

It should be underlined that strategies of protection in order to prevent biodiversity loss in rural areas are mainly adjusted to needs of particular groups of organisms, e.g., birds. In fact, these recommendations should be confronted with proposals of activities undertaken to preserve other groups of organisms, e.g., lichens. It will enable to develop a consistent and effective approach to solve the problems of protection, conservation, and restoration of the natural heritage. Regional differences in Poland are related, among others, to land history and use, as well as the intensity of

agricultural practices. The role of these factors on the lichen biota could be recognized through gathering data from different parts of the country. Improving the knowledge on lichens growing in agricultural landscapes should be pivotal for the establishment of conservation strategies.

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