

Lichens of Israel: diversity, ecology, and distribution

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Abstract

The biota of lichen-forming and lichenicolous fungi of different plant-geographical regions of Israel was analyzed. These areas differ in climatic conditions. A total of 350 species from 16 orders, 52 families, and 117 genera were recorded; among them 5% are endemic to the Levant. The highest species richness was found in the Mediterranean area. Species diversity of other areas with more arid climatic conditions were much poorer in comparison with species diversity found in the more humid and cooler Mediterranean region. Saxicolous lichens were the most common species. However, in the Sudanian penetration area, terricolous lichens dominated. Among phyto-geographic elements, temperate species were dominant. However, the Sudanian penetration area was characterized by the dominance of Mediterranean and sub-continental species. Most of the lichens studied were xerophytic and photophytic species. They dominated all plant-geographical areas of Israel. In the Mediterranean region, mesophytic lichens were also common.

Keywords

Ecology of lichens, lichen diversity, Israel, species composition

Introduction

The first lichens in the Mediterranean region were mentioned in the work of Müller Argo (1884). His paper included information on lichen species collected in the Negev desert. Later, lichenological investigations of this region were continued in the 1940s by I. Reichert, who published several papers on steppe and desert lichens (Reichert 1937a, b; 1940). He donated his unique lichen collection comprising specimens from Leba-

non, Syria, Jordan, Egypt, and Israel along with his lichenological library to the Department of Botany, Tel Aviv University. The collection and library served as the basis for lichenological studies of Israel, which were continued by M. Galun and her students.

Among Reichert's students, the famous lichenologist Margalith Galun can be rightly considered as the founder of a new era in the history of Israeli lichenology. In 1958 she, together with Reichert, published her first paper about the lichen flora on olive trees (Reichert & Galun 1958). In the 1960s she started thorough floristic studies of all regions of the country. Her well known handbook, "The Lichens of Israel" (Galun 1970), was the first summary of lichen floristic explorations in Israel, which stimulated further lichenological investigations in the country. Her extensive studies including lichen diversity, lichen biology, lichen ecology, and lichen systematics during a period of 40 years extended the body of knowledge available in many fields of lichenology not only in Israel, but world-wide.

From 1969 until 1995, many scientists contributed to the knowledge of Israeli lichens. Among these contributions are the experimental works on photosynthetic and respiratory activity of desert lichens in the central Negev by the German scientist O. Lange and his colleagues (Lange et al. 1977). Lange also was engaged by the lichenometric studies in the Negev desert (Lange 1990). A number of interesting studies on the influence of air pollution on various characteristics (ecological, physiological, heavy metal content, etc.) of different lichen species were made by J. Garti and his students and colleagues. In the 1980s and 1990s, many investigations were devoted to the question of biogenous weathering of rocks by lichens. They were carried out by Danin and other scientists. On the basis of these studies, Danin proposed to use the patterns of biogenic weathering as indicators of paleoclimates in Israel (Danin 1985, 1986).

Since 1996, intensive lichenological investigations have been carried out by the Institute of Evolution, University of Haifa, in collaboration with colleagues from other institutes in Israel and abroad. These investigations are based on past achievements and continue up to the present time. They touch on the different fields of lichenology including lichen biodiversity, taxonomy, ecology, biochemistry, genetics, etc.

The present study represents a short review of lichens collected in Israel up to 2008. The following characteristics of lichen biota were studied: Systematics, species richness, species composition in different regions of Israel, phytogeographical elements, and ecological peculiarities.

Materials and methods

The paper is based on the results of expeditions to various regions of Israel from 2000 to 2007, and data collated from literature sources (Galun 1970, Galun & Mukhtar 1996, Temina et al. 2005). Lichen specimens were identified in the Laboratory of Lichenology at the Institute of Evolution, University of Haifa (Israel), applying standard methods. The following references were used to identify the specimens: Galun 1970, Clauzade & Roux 1985, Purvis et al. 1992, Wirth 1995, Boqueras 2000, and

Temina et al. 2005. Lichen nomenclature follows Temina et al. (2005). Specimens were deposited in the herbaria of the Institute of Evolution, University of Haifa, Israel. To estimate similarity between lichen vegetations of different regions, the Sørensen index (Mueller-Dombois & Ellenberg 1974) was calculated. To analyze local community organization, complexes of lichen species were subdivided into groups based on phytogeographical and ecological characteristics for each species according to Wirth (1995), Temina et al. (2005), and Nimis & Martellos (2008). The contribution of each group to the local lichen community was estimated on the basis of relative frequency (Mueller-Dombois & Ellenberg 1974).

Results and discussion

Species diversity

The biota of lichen-forming and lichenicolous fungi of Israel includes 350 species from 16 orders, 52 families, and 117 genera (Table 1). Among the various families, the highest species diversity is represented by the Teloschistaceae (55 species), Physciaceae (36 species), Lecanoraceae (28 species), and Verrucariaceae (26 species). The dominance of these families in species diversity shows a similarity of Israeli lichenobiota and lichenobiotas of the Mediterranean and Irano-Turanian regions.

Table 1. Systematic diversity of lichen-forming and lichenicolous fungi of Israel.

| Order | Number of taxa | | |
|------------------|----------------|--------|---------|
| | Family | Genera | Species |
| Agyriales | 1 | 1 | 1 |
| Arthoniales | 3 | 8 | 24 |
| Capnodiales | 1 | 1 | 1 |
| Dothideales | 2 | 2 | 2 |
| Lecanorales | 20 | 53 | 175 |
| Lichinales | 4 | 10 | 23 |
| Ostropales | 3 | 3 | 10 |
| Peltigerales | 3 | 3 | 4 |
| Pertusariales | 1 | 2 | 8 |
| Phyllachorales | 1 | 1 | 1 |
| Pleosporales | 3 | 3 | 3 |
| Pyrenulales | 2 | 2 | 2 |
| Teloschistales | 2 | 5 | 56 |
| Trichotheliales | 1 | 1 | 3 |
| Verrucariales | 2 | 14 | 27 |
| Order uncertain | 3 | 4 | 6 |
| Mitosporic fungi | | 4 | 4 |
| Total | 52 | 117 | 350 |

Species composition of different regions of Israel

Israel is climatically and geographically very variable as indicated by the presence of 29 geo-climatic regions (Rubin & Pick 1994). This extensive climatic variability results from the presence of the mesic/desert border and from the widening of the Saharo-Syrian aridity belt (especially during the Pleistocene and Holocene, Tchernov 1975). Four plant-geographical regions are represented in Israel (Zohary 1973): The Mediterranean, the Irano-Turanian, the Saharo-Arabian, and the Sudanian penetration (Fig. 1). The climate in these regions varies from mesic in the Mediterranean area to semi-arid in the Irano-Turanian area, to arid in the Saharo-Arabian area and to extremely arid in the Sudanian penetration area.

The largest number of lichens occurred in the Mediterranean area (Fig. 2), which is not surprising, as this area is ecologically more heterogeneous, represents a spatio-temporally “broader niche” (Van Valen 1965) and has more habitat patches and subdivisions than other regions of Israel. Analysis of the Sørensen Indices of Similarity (Table 2) showed significant similarity between lichen biota of the Saharo-Arabian and the Irano-

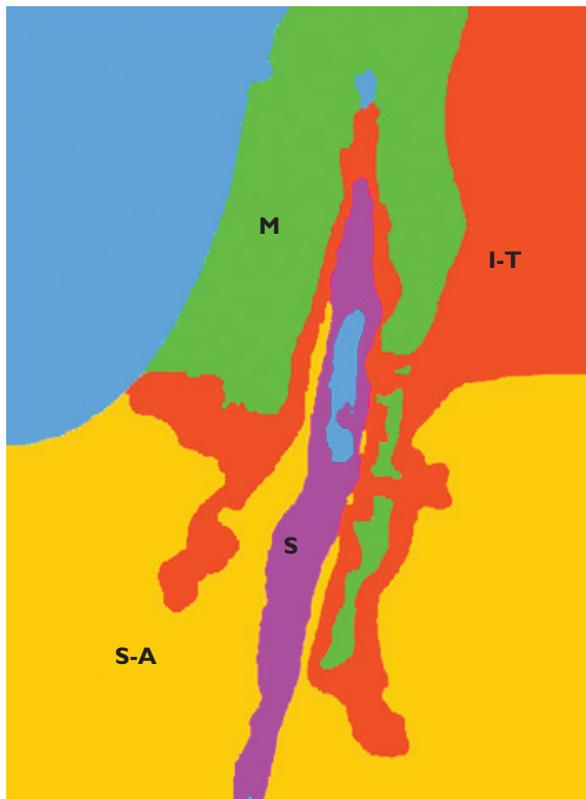


Figure 1. Plant-geographical regions of Israel. Abbreviations: **M** Mediterranean region **S-A** Saharo-Arabian region **I-T** Irano-Turanian region **S** Sudanian region.

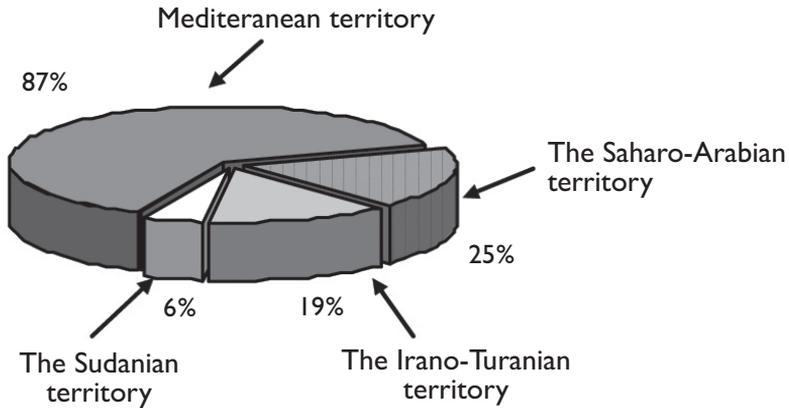


Figure 2. The species richness of lichens in different plant-geographical regions of Israel.

Turanian regions, apparently reflecting a relatively high degree of similarity of the climatic and biotic conditions of these regions. The frequencies of 60 basic species in the different plant-geographical regions are shown in Table 3. Only seven species were recorded in all regions. *Caloplaca aurantia*, *C. citrina*, *C. holocarpa*, *Placidium squamulosum*, *Psora decipiens*, and *Toninia sedifolia* are the most common lichens in Israel.

Substrates

Most lichens occurring in Israel are saxicolous species (Fig. 3A); among them, calcicolous lichens dominate. This may be attributed to the prevalence of limestone substrates in Israel. It is also possible to note the high presence of parasitic species in lichen biota. This is a characteristic feature of lichens of the Mediterranean region, which can perhaps be linked to the scarcity of free-living photobionts in this area.

The Mediterranean territory is characterized by the dominance of calcicolous and corticolous lichens (Fig. 3B). In the Irano-Turanian and Saharo-Arabian regions, calcicolous species prevail in lichen biota. The terricolous and substrate-indifferent lichens are the dominant species in the Sudanian penetration area, which probably reflects the lack of dew precipitation in this region.

Table 2. Sørensen index of similarity of lichen vegetation in different regions of Israel.

| | Mediterranean region | Saharo-Arabian region | Irano-Turanian region |
|-----------------------------|----------------------|-----------------------|-----------------------|
| Saharo-Arabian region | 26 | | |
| Irano-Turanian region | 21 | 83 | |
| Sudanian penetration region | 3 | 26 | 16 |

Table 3. The frequencies of basic lichen species in different plant-geographical regions of Israel; (vr - very rare; r - rare; rc - rather common; c - common; vc - very common).

| Species | Mediterranean region | Saharo-Arabian region | Irano-Turanian region | Sudanian penetration region |
|--------------------------------------------------------|--------------------------|-----------------------|-----------------------|-----------------------------|
| | Commonness-rarity status | | | |
| <i>Acarospora areolata</i> | - | c | rc | vr |
| <i>Aspicilia desertorum</i> | r | c | c | - |
| <i>Aspicilia calcarea</i> | c | r | r | - |
| <i>Aspicilia farinosa</i> | rc | rc | rc | - |
| <i>Bacidina phacodes</i> | rc | - | - | - |
| <i>Bagliettoa parmigera</i> | c | - | - | - |
| <i>Buellia solediosa</i> | r | rc | r | - |
| <i>Buellia subalbula</i> var. <i>fuscocapitellata</i> | - | rc | r | - |
| <i>Caloplaca alociza</i> | rc | c | rc | - |
| <i>Caloplaca arenaria</i> | rc | r | rc | - |
| <i>Caloplaca aurantia</i> | vc | c | c | - |
| <i>Caloplaca circumalbata</i> var. <i>bicolor</i> | - | c | c | - |
| <i>Caloplaca circumalbata</i> var. <i>circumalbata</i> | - | vc | c | - |
| <i>Caloplaca citrina</i> | vc | c | c | - |
| <i>Caloplaca erythrocarpa</i> | c | r | - | - |
| <i>Caloplaca holocarpa</i> | vc | c | c | - |
| <i>Caloplaca lactea</i> | c | r | r | - |
| <i>Caloplaca latzelii</i> | rc | - | - | - |
| <i>Caloplaca saxicola</i> | rc | - | - | - |
| <i>Caloplaca variabilis</i> | c | r | r | - |
| <i>Caloplaca velana</i> var. <i>velana</i> | c | - | - | - |
| <i>Candelariella minuta</i> | - | c | c | - |
| <i>Cladonia convoluta</i> | c | - | - | - |
| <i>Cladonia pocillum</i> | c | - | - | - |
| <i>Collema crispum</i> | rc | rc | rc | r |
| <i>Collema cristatum</i> | c | vr | r | - |
| <i>Collema tenax</i> | c | rc | rc | r |
| <i>Diploicia canescens</i> | rc | r | - | - |
| <i>Diploschistes candidissimus</i> | rc | rc | rc | - |
| <i>Diploschistes diacapsis</i> | - | rc | c | - |
| <i>Diplotomma epipolium</i> | r | c | c | - |
| <i>Diplotomma venustum</i> | - | rc | rc | - |
| <i>Lecania naegelii</i> | c | - | - | - |
| <i>Lecanora crenulata</i> | r | rc | rc | - |
| <i>Lecanora pruinosa</i> | c | r | r | - |
| <i>Lecidella euphorea</i> | c | - | - | - |

| Species | Mediterranean region | Saharo-Arabian region | Irano-Turanian region | Sudanian penetration region |
|---------------------------------------------------------|--------------------------|-----------------------|-----------------------|-----------------------------|
| | Commonness-rarity status | | | |
| <i>Lichinella sinaica</i> | - | r | - | c |
| <i>Lobothallia radiosa</i> | c | - | - | - |
| <i>Neofuscelia pulla</i> | rc | - | - | - |
| <i>Peltula obscurans</i> | - | r | - | c |
| <i>Peltula patellata</i> | - | r | - | c |
| <i>Physcia adscendens</i> | vc | - | - | - |
| <i>Physconia venusta</i> | rc | - | - | - |
| <i>Placidium squamulosum</i> | vc | c | c | r |
| <i>Psora decipiens</i> | c | c | c | r |
| <i>Ramalina lacera</i> | vc | - | r | - |
| <i>Ramalina maciformis</i> | vr | rc | rc | - |
| <i>Rinodina bischoffii</i> var. <i>aegyptiaca</i> | - | c | c | - |
| <i>Rinodina dubyana</i> | - | rc | r | - |
| <i>Squamarina cartilaginea</i> var. <i>cartilaginea</i> | vc | r | rc | - |
| <i>Squamarina cartilaginea</i> var. <i>pseudocrassa</i> | c | r | r | vr |
| <i>Squamarina lentigera</i> | vr | rc | c | vr |
| <i>Teloschistes lacunosus</i> | vr | rc | vc | - |
| <i>Toninia sedifolia</i> | c | rc | vc | vr |
| <i>Tornabea scutellifera</i> | rc | - | vr | - |
| <i>Verrucaria fuscella</i> | vc | - | - | - |
| <i>Verrucaria marmorea</i> | c | - | - | - |
| <i>Xanthoria calcicola</i> | rc | - | - | - |
| <i>Xanthoria mediterranea</i> | c | rc | rc | - |
| <i>Xanthoria parietina</i> | vc | r | r | - |

Geographic distribution

Most lichens recorded in Israel are globally widely distributed and occur in all or almost all continents. However, about one-third of them are rare in the rest of the world; among them, 5% are endemic to the Levant. Lichens found in Israel belong to eight phytogeographical categories: temperate, northern temperate, southern temperate, sub-oceanic, Mediterranean, subcontinental, arid, and endemic. The temperate species dominate in the lichens of Israel. The other phytogeographical elements are much less common than the temperate species. Widespread temperate species prevail in the Mediterranean, Irano-Turanian, and Saharo-Arabian regions. The Sudanian penetration area is characterized by the dominance of Mediterranean and sub-continental lichens. The high abundances of endemic species in the Irano-Turanian and Saharo-Arabian regions are noteworthy.

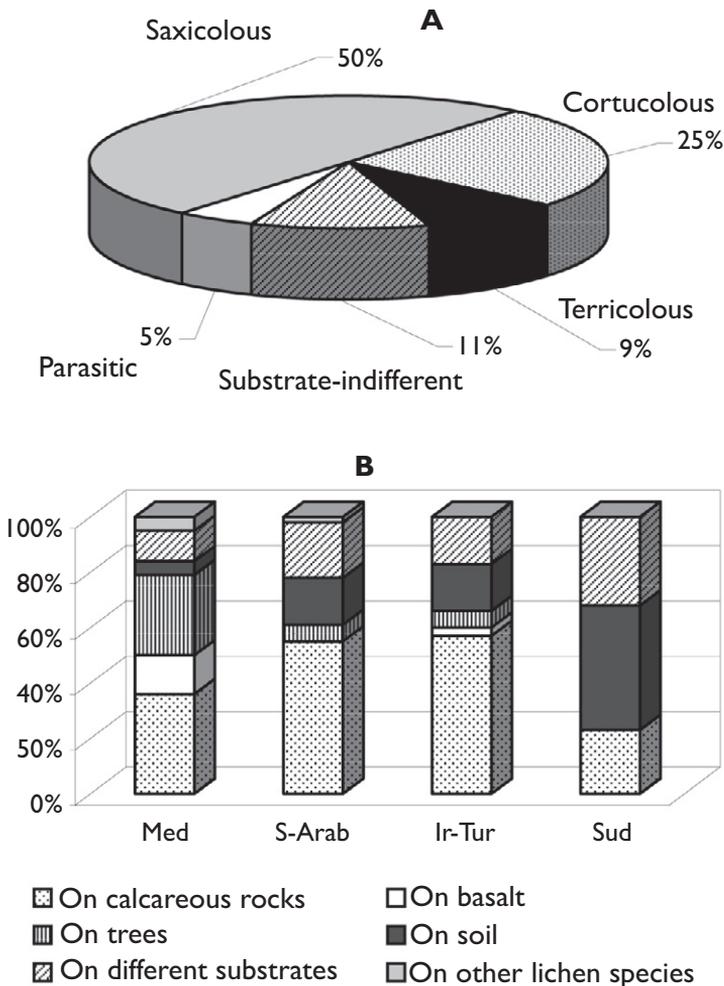


Figure 3. The frequencies of lichens on different substrates: A In all areas of Israel B in certain plant-geographical regions of Israel. Abbreviations: Med - Mediterranean region, S-Arab - Saharo-Arabian region, Ir-Tur - Irano-Turanian region, Sud - Sudanian region.

Ecology of the lichen species studied

The main factors influencing the distribution of lichens in arid areas are light and moisture conditions. As Fig. 4 shows, most lichens found in Israel represent xerophytic and photophytic species. The same groups of species dominate in all plant-geographical regions. However, in the Mediterranean region, high abundances of mesophytic and hygrophytic species were also observed. It is important to note that in this region the frequency of photophytic species is lower than the frequency of these species in other plant-geographical areas with higher solar radiation.

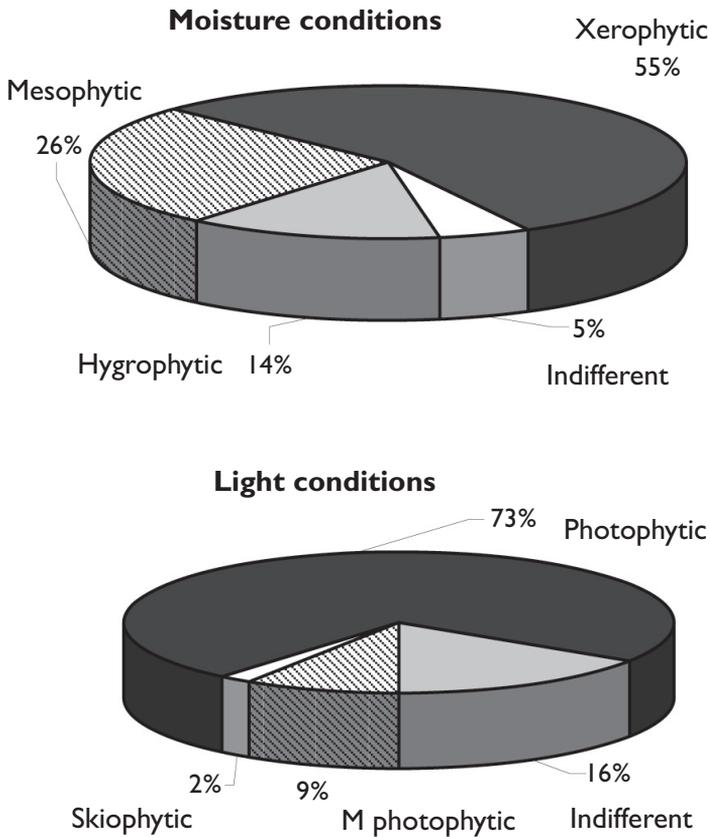


Figure 4. The ecological preferences of lichens found in Israel.

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