

management of agro-systems and forestry, in particular for their protection and for arthropod biodiversity conservation, and should be studied more deeply.

Many insects oviposit or pupate in bark cracks, thus finding protection for their vulnerable stages (Solomon *et al.* 1976; Poland & McCullough 2006; Suomi 2006; Jumean *et al.* 2009; Mudavanhu 2009). Oviposition-site choice is a major factor by which females can improve the survival of their offspring (Refsnider & Janzen 2010), and it is considered one of the most decisive aspects of habitat selection in insects (Higashiura 1989). Maximizing embryo survival has often been proposed to explain insects' choice of oviposition site. Insects tend to maximize egg survival by selecting sites that diminish predation risks and competition (Refsnider & Janzen 2010). Such sites perhaps may be situated under epiphytic lichen thallus.

Epiphytic foliose lichens often cover trees in forests in almost every biome. They create shelters for microfauna (Gerson & Seaward 1977; André 1985; Shorrocks *et al.* 1991; Messuti & Kun 2007), enhance the structural complexity of microhabitats for small animals living on the trees (Houston & O'Brien 1983; Gunnarson *et al.* 2004), and even have been proposed as surrogate organisms for rapid biodiversity assessment of microfauna (Wilkerson 2001). They also produce secondary metabolites that accumulate on the outer surface of the hyphae or diffuse into the environment (Molnár & Farkas 2010). Some have anti-insect activity (Cetin *et al.* 2008), while others are photo-protective against intensive radiation (Oksanen 2006), and thus are able to protect small arthropods or their eggs under the thallus from UV light. For example the golden shield lichen, *Xanthoria parietina* (L.) Th. Fr., produces parietin, a secondary product which protects the photosynthetic apparatus against damage by light (Solhaug & Gauslaa 1996). Previous research has shown that abundance and species richness of epiphytic lichens increase with tree age (Kantvilas & Minchin 1989; Boudreault *et al.* 2002; Johansson *et al.* 2007; Ranius *et al.* 2008; Nascimbene *et al.* 2009). Thus, epiphytic lichens may have a more important role in arthropod biodiversity protection in old forest stands. For the same reason, it is possible that the older parts of trees, like trunk and main branches, which are covered with more lichens than young branches (Esseen *et al.* 1996), may be inhabited by more arthropods finding protection under the lichen cover. Moreover, it is unknown if the arthropods use differently lichens located on different part of the trees.

To corroborate the hypothesis that epiphytic lichens on old parts of trees may protect more arthropods than young parts, we carried out a survey on trees growing in nature.

Material and methods

We removed pieces of bark of a surface of five cm² each, entirely covered by the epiphytic foliose lichen *X. parietina* from the trunk, main old and secondary young branches of each of 20 *Pistacia atlantica* trees, naturally growing along two paved roads in the northern region of Israel, for a total of 60 samples. Main old branches were large and directly connected to the trunk, while secondary young were smaller and developed on main branches. *Pistacia atlantica* trees serve as rootstock for grafting *Pistacia vera*, the pistachio tree, in the Mediterranean and Oriental regions (Barazani & Golan-Goldhirsh 2004), and surveying trees away from orchards and agricultural parcels enabled elimination of the effects of pesticides (Martinez & Mgocheki 2012). Each piece was entered in a marked and closed small plastic box for examination under stereo-microscope in the laboratory. We counted all the arthropods that found shelter in the lichen and classified them in three groups: mites, spiders and insects. Insects were identified to Order level. Eggs of arthropods were also recorded. The mean arthropod abundance in the lichen pieces was analyzed with a One Way ANOVA for each arthropod class and pooled, after square root transformation of the data

(Zar 2009) followed by “Least Significant Difference” (LSD) tests in order to compare the means and the relative magnitude of variance components. These tests served to compute a test of combined probabilities (Sokal & Rolf 2012). We compared the distribution of insects among the tree habitats (trunk, main old and secondary young branches) using a Log-likelihood ratio G test for each insect order. The analyses were carried out with the software Statistix (2008).

Results

We recorded more arthropods in lichen pieces from trunks than from branches (Fig. 1): mites ($F= 210.6$; d.f.= 1, 38; $P < 0.0001$), spiders ($F= 90.2$; d.f.= 2, 57; $P < 0.0001$), insects ($F= 98.2$; d.f.= 2, 57; $P < 0.0001$) and eggs ($F= 79$; d.f.= 2, 57; $P < 0.0001$). The result of a test of combined probabilities from the independent tests of significance of each group was significant too ($X^2= 73.7$, d.f.= 8, $P \ll 0.001$) indicating that this is a general trend. All arthropod class together, there were 10 ± 2.3 (average \pm S.E.) invertebrates present in each piece from the trunks, while only 2.1 ± 0.54 from the old branches and just 0.4 ± 0.13 from young ones: these results were statistically different ($F= 12.8$; d.f. = 2, 57; $P= 0.000026$). As a consequence, there were an average of 2000 arthropods in each meter square of lichens on trunks, 450 on old branches and only 80 on young ones. The insects found during this study appartained to five orders, among them four were not randomly distributed, but were also more recorded on trunks (Fig. 2): Coleoptera ($G= 43$; d.f. = 2; $P < 0.0001$), Hemiptera ($G= 9$; d.f. = 2; $P = 0.01$), Hymenoptera (mainly ants [Formicidae]: $G= 10$; d.f. = 2; $P = 0.02$) and Lepidoptera ($G= 43$; d.f. = 2; $P < 0.0001$). At the contrary the flies (Diptera) were more uniformly distributed among the three habitats ($G= 3.7$; d.f. = 2; $P = 0.2$)

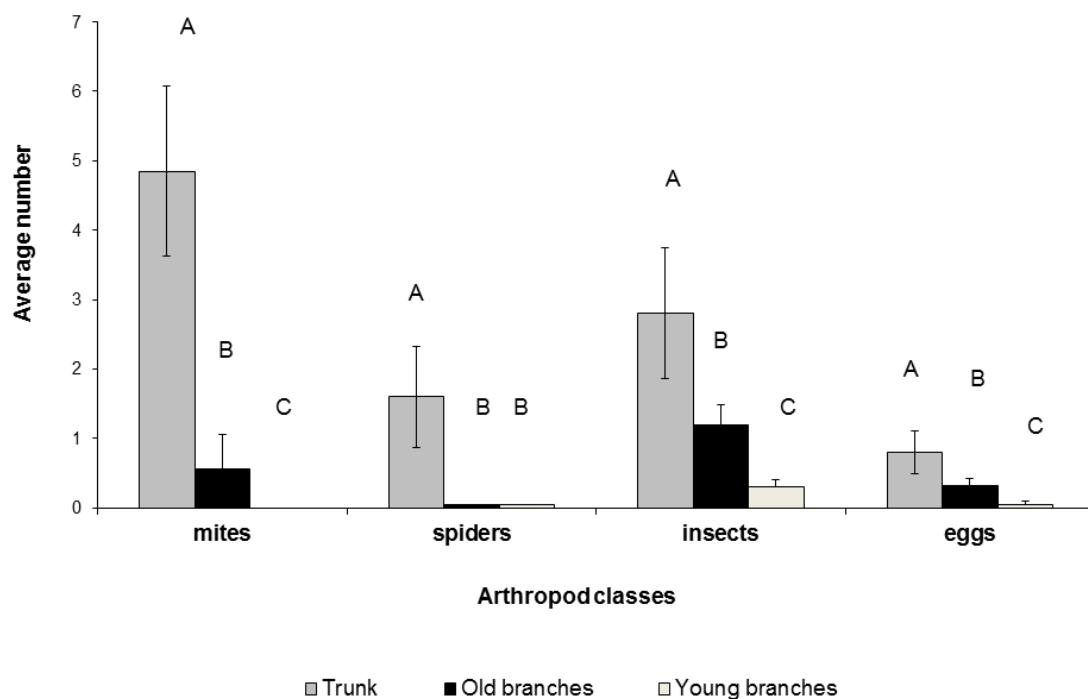


Figure 1. Mean number of arthropods (\pm S.E.) found in 60 pieces of bark covered with lichen. Each piece had a surface of 5 cm². In each of 20 trees a piece was cut from the trunk, another from a main old branch and a last from a secondary younger branch. The letters A, B and C symbolize differences in the means and the relative magnitude of variance components among the trunk, old and young branches following “Least Significant Difference” (LSD) tests for each arthropod class.

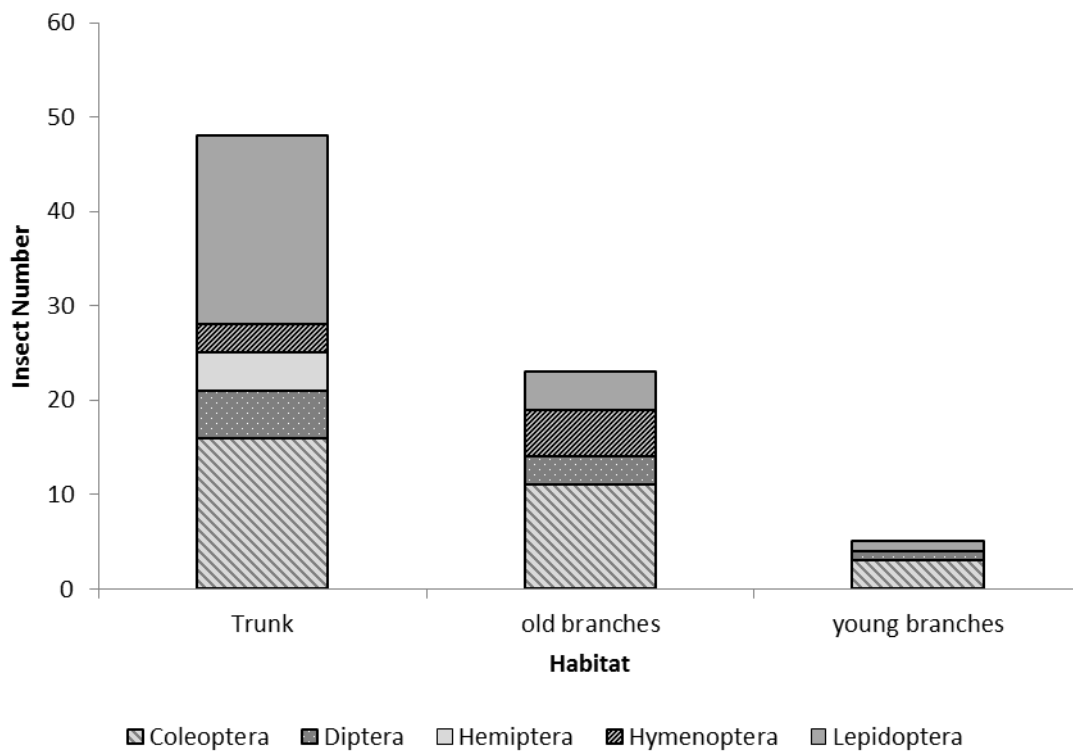


Figure 2. Total number of insect, following their taxonomy (Orders), found in 60 pieces of bark covered with lichen from trunks (5 orders), main old (4 orders) and secondary young branches (3 orders).

Discussion

We detected a higher arthropod density in lichen covering trunks than branches, indicating that the different value of lichen cover for these animals depends on location, and is not due only to its surface as indicated by Kantvilas & Minchin (1989), Boudreault *et al.* (2002) and others. It is probably due also to the ecology of these animals, some being located more on tree trunk than on branches (e.g. Stork *et al.* 2001).

It was not surprising that the mites were the greatest group, as numerous mites are known to be lichenivorous like Oribatids (Winchester *et al.* 2008). But it is possible that some species were predators like Mesostigmatid which live on tree trunks (Beaulieu *et al.* 2006) and may attack herbivorous like aphids. We counted high numbers of spiders under the lichens, especially on the trunk. These arthropods are predators and they may impact on the herbivore populations. Among the insects, some were herbivores (for example, aphids, flies and Lepidoptera) while others could serve as their natural enemies (for example coccinellids or ants). The presence of arthropod eggs demonstrated the possible role of lichen cover as oviposition site.

We showed that lichen cover on tree trunks can serve as shelter and/or oviposition site for more arthropods than lichen cover on branches. It is possible that this trend is widespread in insects using bark cracks as sheltering and oviposition sites: this is the case, for example, of the gall inducing aphids (Martinez *et al.* 2013). In economically important trees many pests oviposit or pupate in bark cracks (Jumean *et al.* 2009; Mudavanhu 2009). Researchers and managers should be concerned by the possibility that epiphytic lichen cover, in particular

on trunks, protects a high diversity of arthropods, giving a beneficial ecosystem service in natural and planted stands.

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