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Oribatid mites (Acari, Oribatida) of pine and cypress litter in selected habitats of Sicily (Italy)

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Abstract: Oribatid mites live in the soil or plant matter and usually feed on living and dead plant or fungal material, lichens, carrion, or some species are rarely predatory. Oribatid communities were investigated in litter under pine and cypress trees in selected locations in Sicily: Etna slopes (near Rifugio Sapienza and near Castiglione di Sicily), coastal town Giardini Naxos, Archaeological Museum in Agrigento, and Archaeological Park in Sagesta. The most abundant and diverse oribatid mites lived in cypress litter in Agrigento and on Etna slope. The lowest numbers of individuals and species were recorded in pine litter in Agrigento. In the oribatid mite communities, only 1–3 species were abundant, so the values of Shannon *H*' index, and Pielou E_{Pielou} and Hurlbert E_{Hurlbert} evenness indices were rather low. Their values were the highest in pine litter near Rifugio Sapienza, located nearest to the crater of Etna, while the lowest in pine litter in Agrigento. The former habitat was rich in oribatid mites and species, with a large participation of small species, like *Suctobelbella subcornigera*, *Brachychthonius impressus*, and *Liochthonius simplex*, which made up nearly 63% of the total number of oribatid mites within that habitat. In other habitats, usually *Oribatula propinqua* dominated, but in pine and cypress litter in Giardini Naxos, *Oppiella nova* and *Ramusella clavipectinata* were the most abundant, respectively. Among oribatid mites, adults usually dominated, but *Adrodamaeus femoratus*, *Aphelacarus acarinus*, *Brachychthonius impressus*, *Liochthonius simplex*, *Cosmochthonius reticulatus*, *Metabelba pulverulenta* and *Pilogalumna crassiclava* were rich in juveniles.

Keywords: Sicily, Mount Etna, habitats, oribatid mites, dominance and age structure

INTRODUCTION

Oribatid mites are important parts of ecosystems. They live mainly in the soil or plant matter and usually feed on living or dead plant or fungal material, lichens, carrion, and some species can be also predatory as egg-eaters. Hot and dry Sicilian summers limit the development of most oribatid species, which multiply mainly in winter (Stamou & Sgardelis 1989). However, some species are adapted to Medi-

terranean conditions and achieve in summer a high density and dominance index. Therefore, these habitats are interesting for research on oribatid mite communities, and their age structure. The oribatid mites of Sicily were earlier investigated mainly in zoogeographical and faunistic aspects (Berlese 1883, 1910; Arcidiacono 1975; Bernini et al. 1995).

In this paper we report on soil oribatid mite communities of litter under pine and cypress trees in selected parts of Sicily, with special attention to the age structure of some populations, which is rarely investigated in ecological papers.

STUDY AREA

Sicily in an interesting island to study because of Mount Etna – the highest, largest, and most active volcano in Europe. It reaches about 3330 m a.s.l., so during eruptions the emitted ashes and gases pollute a large area. Since the 5th century, 80 larger eruptions have been recorded, with the largest one in 1669, which damaged and covered by lava and ash almost the whole Catania. The last eruption of the volcano occurred on 13 January 2011.

Lower parts of Sicily are covered with typical Mediterranean vegetation. In coastal areas, with touristic cities and villages, typical plants include bitter orange (*Citrus* sp.), lemon (*Citrus limon* Burm.), cypress (*Cupressus* sp.), fig (*Ficus carica* L.), and jacaranda (*Jacaranda* sp.**)** trees. The lower slopes of Mount Etna offer fertile soils, so a dense human population lives there, despite the potential danger from volcano eruptions. Arable fields, vineyards, olive-tree (*Olea europaea* L.), orange, and other orchards cover the Etna slopes up to 800–900 m a.s.l. Higher parts, up to 3000 m a.s.l., are dominated by evergreen holm oak (*Quercus ilex* L.), beech (*Fagus sylvatica* L.), and chestnut (*Castanea sativa* Miller) forests, while the uppermost parts are covered by congealed lava and patches of grasses and herbs.

The Sicilian climate depends on altitude. The coastal parts represent a typical Mediterranean climate, with hot and dry summer (June–September, mean daily temperature 27–31°C, total precipitation about 85 mm) but mild and wet winter (October–May, mean daily temperature 15–24°C, total precipitation about 570 mm), with about 2500 sunny hours per year, while the climate of mountains is more continental.

MATERIAL AND METHODS

Samples of litter (500 cm^3 each) under pine trees (*Pinus heldreichii* H. Christ) and cypress trees (*Cupressus* sp.) were taken on 25–31 May of 2009, in 3 replicates, from the following locations and habitats:

(a) slopes of Etna – pine litter on the southern slope of Etna, near Rifugio Sapienza (37°41’N, 15°00’E; 1947 m a.s.l., slightly above the forest line), and cypress litter on the eastern slope of Etna, in Ravine Alacantara near Castiglione di Sicily (37°51’N, 15°12’E, 143 m a.s.l.), between Rifugio Sapienza and Giardini Naxos;

(b) coastal town Giardini Naxos (37°49’N, 15°15’E; 28 m a.s.l.);

(c) Archaeological Museum in Agrigento (37°18’N, 13°32’E, 234 m a.s.l.);

(d) Archaeological Park in Sagesta (37°56’N, 12°50’E, 283 m a.s.l.).

The mites were extracted in Tullgren funnels, conserved, and determined to species or genus level, including the juveniles. Names of oribatid species follow SUBÍAS (2004) and partly WEIGMANN (2006). Populations of oribatid species (18 139 mites in total) were characterized with abundance (*A*) and dominance (*D*) indices (ODUM 1971), while mite communities were compared with Shannon indices *H*', H_{min}, and H_{max} as well as Pielou (E_{Pielou}) and Hurlbert ($E_{Hurlbert}$) evenness indices (BEISEL et al. 2003).

RESULTS

The most abundant and diverse oribatid mite communities lived in cypress litter in Agrigento and on Etna slope, while the lowest numbers of individuals and species were recorded in pine litter in Agrigento (Table 1). Generally, cypress litter was richer in mite individuals than pine litter. In the oribatid mite communities, 1–3 species were abundant, so the Shannon index *H*' and Pielou E_{Pielou} and Hurlbert $E_{Hurlbert}$ evenness indices were rather low, with the highest value in pine litter on Etna slope, and the lowest value in pine litter in Agrigento.

Table 1. Mean density (individuals per sample, i.e. 500 cm^3, n = 3), number of species, and diversity indices (Shannon *H*', H_{min}, H_{max}, Pielou and Hurlbert evenness) of oribatid mite communities in selected habitats of Sicily. Pine = pine litter; Cyp. = cypress litter

Parameter	Etna slopes		Giardini Naxos		Agrigento		Segesta	
	Pine	Cyp.	Pine	Cyp.	Pine	Cyp.	Pine	Cyp.
Mean density of Oribatida	716.0	1 418.7	818.7	694.3	503.0	1 508.0	316.0	768.5
Mean density of juveniles	304.3	610.0	163.7	196.7	205.0	849.7	42.0	327.0
Number of species	19	31	28	22	9	28	22	18
Shannon index *H*'	2.09	1.93	1.71	1.74	0.69	1.05	1.75	1.56
Shannon index H_{min}	0.19	0.18	0.26	0.22	0.11	0.15	0.45	0.16
Shannon index H_{max}	2.94	3.43	3.33	3.09	2.20	3.33	3.09	2.89
Pielou evenness E_{Pielou}	0.71	0.58	0,51	0.56	0.31	0.32	0.57	0.64
Hurlbert evenness $E_{Hurlbert}$	0.69	0.54	0.47	0.53	0.28	0.28	0.49	0.55

Pine litter near Rifugio Sapienza, located nearest to the crater of Etna, was rich in oribatid mites and species. In this mite community, small species were abundant, like *Suctobelbella subcornigera* (Forsslund, 1941), *Brachychthonius impressus* Moritz, 1976, and *Liochthonius simplex* (Forsslund, 1942), which jointly made up nearly 63% of all oribatid mites (Table 2). Cypress litter near Castiglione di Sicilia was much richer in oribatid mites and species than pine litter near Rifugio Sapienza. In the former mite community, the most abundant was the medium-sized species *Oribatula propinqua* (Oudemans, 1900), which accounted for nearly 62% of total oribatid mites, while small mite species were not abundant there.

Table 2. Characteristics of oribatid species in selected habitats of Sicily: abundance (A = individuals per sample, i.e. 500 cm^3, n = 3) and dominance (D = % of the total number of oribatid mites in the mean sample). Pine = pine litter; Cyp. = cypress litter. Species with maximum $A \leq 10$ are listed below the table

Species name		Etna slopes		Giardini Naxos		Agrigento		Segesta	
		Pine	Cyp.	Pine	Cyp.	Pine	Cyp.	Pine	Cyp.
Adrodamaeus femoratus (C. L. Koch, 1839)	*A*	1.0	84.3	1.7	15.7	0	249.0	9.5	37.0
	D	0.1	5.9	0.2	2.3	0	16.5	3.0	4.8
Aphelacarus acarinus (Berlese, 1910)	*A*	0	0	4.7	0.3	30.0	57.0	22.5	0
	D	0	0	0.6	0.1	5.9	3.8	7.1	0
Brachychthonius impressus Moritz, 1976	*A*	156.3	1.3	29.3	1.7	0	7.0	0	3.0
	D	21.8	0.1	3.6	0.2	0	0.5	0	0.4
Cosmochthonius reticulatus Grandjean, 1947	*A*	0.7	24.0	12.0	42.3	5.0	6.7	3.5	56.0
	D	0.1	1.7	1.5	6.1	1.0	0.4	1.1	7.3
Haplochthonius simplex (Willmann, 1930)	*A*	2.0	10.0	5.0	94.7	13.0	57.7	1.0	183.0
	D	0.3	0.7	0.6	13.6	2.6	3.8	0.3	23.8
Licnodamaeus costula Grandjean, 1931	*A*	0	60.7	0	0	0	4.3	15.5	2.0
	D	0	4.3	0	0	0	0.3	4.9	0.3
Liochthonius simplex (Forsslund, 1942)	*A*	109.3	0	14.0	0	0	0	0	0
	D	15.3	0	1.7	0	0	0	0	0
Metabelba pulverulenta (C. L. Koch, 1839)	*A*	0	0.3	0	0	0	0	14.6	1.0
	D	0	<0.1	0	0	0	0	4.6	0.1
Oppiella nova (Oudemans, 1902)	*A*	23.0	1.3	383.0	0.3	0	1.0	0	0
	D	3.2	0.1	46.8	0.1	0	0.1	0	0
Oribatula propinqua (Oudemans, 1900)	*A*	87.3	879.0	36.0	101.0	416.0	1 076.3	159.5	389.5
	D	12.2	61.9	4.4	14.6	82.7	71.3	50.5	50.7
Pilogalumna crassiclava (Berlese, 1914)	*A*	60.7	15.00	99.3	70.3	0	6.3	0	49.5
	D	8.5	1.1	12.1	10.1	0	0.4	0	6.4
Punctoribates punctum (C. L. Koch, 1839)	*A*	0	0	1.3	0	<0.1	1.3	54.5	5.0
	D	0	0	0.2	0	0.1	0.1	17.3	0.7
Ramusella clavipectinata (Michael, 1885)	*A*	10.0	0	0.3	320.3	1.0	0.3	0	2.5
	D	1.4	0	<0.1	46.1	0.2	<0.1	0	0.3
Scheloribates laevigatus (C. L. Koch, 1835)	*A*	0.7	98.7	8.3	0.7	0	0	0.5	0
	D	0.1	6.9	1.0	0.1	0	0	0.2	0
Scheloribates pallidulus (C. L. Koch, 1841)	*A*	0	126.7	188.7	0	0	0.3	0	0
	D	0	8.9	23.1	0	0	<0.1	0	0
Suctobelbella subcornigera (Forsslund, 1941)	*A*	184.0	1.7	1.3	0.3	0	0	0	0
	D	25.7	0.1	0.2	0.1	0	0	0	0
Tectocepheus velatus (Michael 1880)	*A*	6.0	56.0	1.0	7.3	1.0	0	1.0	1.0
	D	0.8	3.9	0.1	1.1	0.2	0	0.3	0.1

Etna slope, pine litter: *Camisia segnis* (Hermann, 1804); *Damaeus* sp. 1; *Dissorhina ornata* (Oudemans, 1900); *Lohmannia paradoxa* (Haller, 1884); *Microtritia minima* (Berlese, 1904); *Oppiella translamellata* (Willmann, 1923); *Ramusella* sp. 1; Oribatida juv.
Etna slope, cypress litter: *Eueremaeus oblongus* (C. L. Koch, 1835); *Eulohmannia ribagai* (Berlese, 1910); *Eupelops* sp. 1; *Euzetes globulus* (Nicolet, 1855); *Fosseremus laciniatus* (Berlese, 1905); *Liochthonius* sp. 1; *Malaconothrus* sp. 1; *Nothrus anauniensis* Canestrini et Fanzago, 1876; *Oppia denticulata* (G. Canestrini et R. Canestrini, 1882); *Oppiella* sp. 1; *Oribatella superbula* (Berlese, 1904); *Phthiracarus* sp. 1; *Platynothrus peltifer* (C. L. Koch, 1839); *Protoribates* sp. 1; *Rhysotritia duplicata* (Grandjean, 1953); *Sphaerochthonius splendidus* (Berlese, 1904); *Tectocepheus velatus* (Michael, 1880); *Trimalaconothrus* sp. 1; Oribatida juv.
Giardini Naxos, pine litter: *Aphelacarus acarinus* (Berlese, 1910); *Damaeus* sp. 1; *Dorycranosus acutus* (Pschorn-Walcher, 1951); *Eueremaeus oblongus*; *Eupelops acromios* (Hermann, 1804); *Galumna* sp. 1; *Gustavia microcephala* (Nicolet, 1855); *Liacarus coracinus* (C. L. Koch, 1841); *Licnodamaeus costula* Grandjean, 1931; *Oppiella* sp. 2; *Oribatula* sp. 1; *Pasallozetes africanus* Grandjean, 1932; *Sphaerochthonius splendidus*.
Giardini Naxos, cypress litter: *Achipteria nitens* (Nicolet, 1855); *Aphelacarus acarinus*; *Dorycranosus acutus*; *Eupelops acromios*; *Eupelops* sp.1; *Liacarus coracinus*; *Oppiella* sp. 2, *Oribatula excavata* (Berlese, 1916); *Scheloribates latipes* (C. L. Koch, 1844); *Sphaerochthonius splendidus*; Oribatida juv.
Agrigento, pine litter: *Dorycranosus acutus*; *Tectocepheus velatus*; Oribatida juv.
Agrigento, cypress litter: *Achipteria nitens*; *Aphelacarus acarinus*; *Chamobates* sp. 1; *Damaeus* sp. 1; *Eueremaeus oblongus*; *Eupelops acromios*; *Galumna* sp. 1; *Jacotella reticulata* Ruiz, Kahwash et Subías, 1990; *Liacarus coracinus*; *Oribatula excavata*; *Passalozetes africanus*; *Ramusella* sp. 1; *Scheloribates latipes*; *Sphaerochthonius splendidus*; *Trimalaconothrus* sp. 1; *Xenillus tegeocranus* (Hermann, 1804); Oribatida juv.
Sagesta, pine litter: *Aphelacarus acarinus*; *Camisia segnis*; *Chamobates* sp.1; *Damaeus* sp. 1; *Dorycranosus acutus*; *Eueremaeus oblongus*; *Jacotella reticulata*; *Kunstidamaeus tecticola* (Michael, 1888); *Oppiella* sp. 2; *Passalozetes africanus*; *Scheloribates initialis* (Berlese, 1908), *Sphaerochthonius splendidus*.
Sagesta, cypress litter: *Aphelacarus acarinus*; *Nothrus anauniensis*; *Oppia* sp. 1; *Oppiella* sp. 2; *Oribatella quadricornuta* (Michael, 1882); *Sphaerochthonius splendidus*; *Zetorchestes falzonii* Coggi, 1898; Oribatida juv.

In the coastal town Giardini Naxos, pine litter was richer in oribatid mites and species than cypress litter, and in both habitats small oppioid species dominated: *Oppiella nova* (Oudemans, 1902) and *Ramusella clavipectinata* (Michael, 1885), respectively. In contrast, in pine and cypress litter in Agrigento and Segesta, *Oribatula propinqua* highly dominated, and cypress litter was richer in individuals than pine litter, especially in Agrigento. In the investigated habitats, relatively abundant were *Scheloribates latipes* (C. L. Koch, 1835) (pine litter, Giardini Naxos), *Haplochthonius simplex* (Willmann, 1930) (cypress litter, Giardini Naxos and Segesta), *Punctoribates punctum* (C. L. Koch, 1839) (pine litter, Segesta), and *Adrodamaeus femoratus* (C. L. Koch, 1839) (cypress litter, Agrigento).

In oribatid mite communities usually the adults dominated, except for cypress litter in Agrigento, where the juveniles were slightly more abundant than the adults. The age structure of species depended on their biology and kind of litter (Table 3). Several species, like *Adrodamaeus femoratus*, *Aphelacarus acarinus* (Berlese, 1910), *Brachychthonius impressus*, *Liochthonius simplex*, *Cosmochthonius reticulatus* Grandjean, 1947, *Metabelba pulverulenta* (C. L. Koch, 1839), and *P. crassiclava* (Berlese, 1914), were rich in juveniles, while *Haplochthonius simplex*, *Oppiella*

Table 3. Mean age structure of chosen oribatid species in selected habitats of Sicily

Species name	Habitat	Juveniles	Adults	Total
Aphelacarus acarinus	Agrigento, cypress litter	38.3	18.7	57.0
Adrodamaeus femoratus	Segesta, pine litter	148.7	100.3	249.0
	Etna slope, cypress litter	58.7	25.6	84.3
Brachychthonius impresus	Etna slope, pine litter	119.6	36.7	156.3
	Gardini Naxos, pine litter	17.7	11.6	29.3
Cosmochthonius reticulatus	Sagesta, cypress litter	31.0	25.0	56.0
	Gardini Naxos, cypress litter	38.6	3.7	42.3
	Etna slope, cypress litter	11.7	12.3	24.0
Haplochthonius simplex	Sagesta, cypress litter	2.5	180.5	183.0
	Gardini Naxos, cypress litter	7.7	87.0	94.7
	Agrigento, cypress litter	1.0	56.7	57.7
Liochthonius simplex	Etna slope, pine litter	98.7	10.6	109.3
Metabelba pulverulenta	Erice, cypress litter	36.0	23.0	59.0
Oppiella nova	Gardini Naxos, pine litter	71.0	312.0	383.0
Oribatula propinqua	Agrigento, cypress litter	640.3	436.0	1076.3
	Etna slope, cypress litter	451.7	427.3	879.6
	Agrigento, pine litter	153.0	263.0	416.0
	Sagesta, cypress litter	219.0	162.0	381.0
Pilogalumna crassiclava	Gardini Naxos, pine litter	45.0	54.3	99.3
	Gardini Naxos, cypress litter	51.7	18.7	70.3
Scheloribates latipes	Gardini Naxos, pine litter	1.0	187.7	188.7
S. laevigatus	Etna slope, cypress litter	19.0	79.7	98.7
	Etna slope, cypress litter	16.0	110.7	126.7
Tectocepheus velatus	Etna slope, cypress litter	19.0	37.0	56.0
	Etna slope, pine litter	4.0	2.0	6.0

nova, *Scheloribates laevigatus*, and *S. latipes* were represented mainly by adults. The age structure of *Oribatula propinqua* depended on locality: in pine litter in Agrigento the adults dominated, while in other habitats the juveniles were more abundant.

DISCUSSION

The investigated oribatid mite communities of Sicily are under a strong influence of the activity of Mount Etna, especially those located on higher slopes of this volcano. During volcano eruption a lot of ashes and gases are emitted, and they are finally partly deposited with rainfall also in leaf litter and affect the soil oribatid mites. The pine litter near Rifugio Sapienza, located nearest to the crater of volcano Etna, contains a lot of dark ash, but in spite of that it was rich in oribatid mites and species,

which are probably adapted to volcanic activity. This mite community was dominated by small species (like *Suctobelbella subcornigera*) and species of the genus *Brachychthonius*, with a short life cycle (Hågvar et al. 2009), and they are probably able to multiply quickly. The species of Brachychthoniidae are regarded as first colonizers on mine dumps (Skubała 2000) and in mine sedimentation tanks (Skubała 2002) in the post-industrial landscape of Silesia (SW Poland). These mites are also abundant in the first stage of primary succession of oribatid mites near the foreland of the Norwegian glacier in Finse, southern Norway (Hågvar et al. 2009).

In cypress litter near Castiglione di Sicilia, situated between Rifugio Sapienza and coastal Giardini Naxos, *Suctobelbella subcornigera* and *Brachychthonius* spp. were not abundant, but the larger species *Oribatula propinqua* dominated, which was also abundant in most of the other studied habitats and in pine and cypress litter in southern Italy (Seniczak & Seniczak 2012). Species of the family Oribatulidae are common in the Mediterranean region. They were the most diverse on Canary Islands, Spain (Moraza & Peña 2005a, b), and abundant in grass and cypress litter in Andalusia, Spain (Seniczak & Seniczak 2010), moss patches in Korčula, Croatia (Seniczak et al. 2012), and in steppe vegetation of Cape Tarkhankut, Crimea, Ukraine (Seniczak et al. 2009, 2011).

Oribatid mites in the investigated habitats of Sicily are more abundant and richer in species than those in Andalusia (Seniczak & Seniczak 2010), but are comparable with those found in yew and cypress litter in Caserta, Italy (Seniczak & Seniczak 2012), and in moss patches at the forest floor in Korčula, Croatia (Seniczak et al. 2012), probably due to higher fertility of soils in those habitats. However, high dominance indices of these species indicate in the light of Thienemann's principles (1939) a rather low soil fertility. Several species were rich in juveniles, which demonstrated that spring is a good season for their development. Most species listed in Table 2 were recorded in Sicily by Bernini et al. (1995), except for *Lohmannia paradoxa* (Haller, 1884), which is a new species for Sicily and Italy.

CONCLUSIONS

1. The most abundant oribatid mites and richest in species lived in cypress litter in the Archaeological Museum in Agrigento and on Etna slopes, while the poorest in individuals and species was pine litter in the Archaeological Museum in Agrigento. In oribatid mite communities, 1–3 species were abundant, so the Shannon index *H*' and Pielou and Hurlbert evenness indices (E_{Pielou} and E_{Hurlbert}) were generally low.
2. The pine litter located nearest to the crater of Etna was rich in oribatid mite individuals and species, especially in small mites (*Suctobelbella subcornigera*, *Brachychthonius impressus*, *Liochthonius simplex*), with a rather short life cycle. Other habitats were usually dominated by a medium-sized mite, *Oribatula propinqua*.
3. Among oribatid mites the adults usually dominated, but *Adrodamaeus femoratus*, *Aphelacarus acarinus*, *Brachychthonius impressus*, *Liochthonius simplex*, *Cosmochthonius reticulatus*, *Metabelba pulverulenta*, and *Pilogalumna crassiclava* were rich in juveniles.

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