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Responses of soil microarthropods to experimental short-term manipulations of soil moisture

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Abstract

In this study we experimentally manipulated the precipitation pattern (frequency and intensity) in a Mediterranean pine forest on Mt. Holomon (northern Greece) in order to investigate the response of soil microarthropods (Collembola and oribatid mites). Our experimental treatments included drought, frequent and infrequent irrigation and lasted for 4 months. The treatments affected soil water content, maximum soil temperature and diversity of soil microarthropods. Compared to the undisturbed surrounding area, drought decreased soil water content as well as microarthropod species richness and increased maximum soil temperature. Irrigation treatments increased soil water content and microarthropod species richness. Infrequent irrigation increased maximum soil temperature. Oribatid mites and Collembola responded differently to the irrigation treatments. The collembolan community showed higher species evenness and diversity in the frequently irrigated plots and the oribatid mite community in the infrequently irrigated ones. Our results indicate that irrigation pattern (and the corresponding changes in soil moisture) will have an impact on soil ecosystems in complicated non-linear ways.

Keywords: Collembola; Diversity profile; Drought and irrigation treatments; Mediterranean soil; Oribatid mites

1. Introduction

In many terrestrial ecosystems, soil is the most species rich component (Adams and Wall, 2000; André et al., 2002) and plays an important role in ecosystem functioning, affecting processes like decomposition and plant growth (Coleman and Hendrix, 2000). Collembola and oribatid mites constitute a diverse and numerically important part of the soil mesofauna (André et al., 2002) and have been proposed as bioindicators (Van Straalen et al., 1989). The distribution, abundance and life cycles of soil mesofauna are affected by soil temperature and moisture directly, e.g. through desiccation and indirectly, through changes in

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food resources and microhabitat modifications (Berg and Staaf, 1980; Stamou and Sgardelis, 1989; Setälä et al., 1995; Hasegawa and Takeda, 1996; Pflug and Wolters, 2001). Alterations of soil fauna regarding abundance, species composition and distribution through the soil profile, may have important implications for soil processes.

The response of soil fauna to microclimatic manipulations has been investigated in several studies and in a variety of ecosystems (e.g. Frampton et al., 2000a; Uvarov, 2003). According to the findings of most studies, irrigation and temperature manipulations have different levels of impact on different taxa and may affect abundance and species richness in contrasting ways. O'Lear and Blair (1999) found that in a tallgrass prairie the abundance of Acari decreased due to irrigation. In a transplant experiment carried out in the UK, Briones et al. (1997) found that some enchytraeid species were favored by temperature and others by soil moisture. Diptera were dependent on moisture and were reduced by increased temperature, while tartigrades survived adverse conditions by entering anhydrobiotic stages and recovered when climatic conditions improved. Frampton et al. (2000a), found that most species of Collembola increased in abundance in an irrigated agricultural field. Herbivorous, mycophagous, omnivorous and predatory epigeic arthropods were favored by irrigation in a spring-sown legume field (Frampton et al., 2000b). In a Norway spruce stand in Sweden, irrigation increased abundance and diversity of oribatid mites (Lindberg et al., 2002). Finally, modifications in soil moisture did not affect the structure of the nematode community in a Mediterranean grassland (Papatheodorou et al., 2004; Stamou et al., in press) or the abundance of soil microarthropods in a spruce forest in Germany (Taylor et al., 2004).

In contrast to irrigation, most studies recorded a negative effect of drought on various taxa of the soil fauna; on Collembola in a field of spring peas in the UK (Frampton et al., 2000a) and in a spruce forest in Germany (Pflug and Wolters, 2001), on herbivorous, mycophagus, omnivorous and predatory epigeic arthropods in a spring-sown legume field (Frampton et al., 2000b), on enchytraeids, mesostigmatid mites, macroarthropod predators, oribatid mites and on Collembola in a Norway spruce stand (Lindberg et al., 2002). So far there is limited knowledge of the response of soil mesofauna to moisture manipulations in Mediterranean ecosystems, where seasonal, inter-annual and diurnal fluctuations are characteristic of the climate and drought is a typical stage of the annual cycle.

This study examines the short-term effects of changes in the precipitation pattern (created by soil moisture manipulation) on diversity and abundance of soil microarthropods, namely Collembola and oribatid mites. More specifically, we experimentally manipulated soil moisture in a Mediterranean pine forest located in Mt. Holomon (northern Greece). The rationale for our irrigation manipulations is based on the climate change scenario of elongation of the dry period and increased frequency of extreme precipitation events coupled with decreased frequency of mild rains. Climate change models (like CSIRO9 and UKHI) have predicted that in middle latitudes there will be a shift in the precipitation pattern towards more intense convective events and fewer moderate or mild rains (Cubash et al., 1996; Hennessy et al., 1997). Another scenario prediction emphasizes that the seasonal cycle of precipitation will be enhanced, with increased precipitation during the winter and decreased precipitation during summer, with longer dry spells (Cubash et al., 2000; Raisanen et al., 2004). Drought is a known stress factor for soil communities, but occurs regularly in the Mediterranean region during summer. We included a drought treatment in our experiment starting at a dry month and continuing during the season with the highest precipitation of the year (i.e. prolonging the drought period). Also, we simulated infrequent precipitation (i.e. heavy irrigation every 5 weeks). Finally, we simulated frequent precipitation (i.e. irrigation every 3 days) to create stable conditions, which is actually unusual in the Mediterranean region and is not predicted by the Climate Change scenario. In the two irrigation treatments only irrigation pattern was manipulated since the overall amount of water used remained constant. Our initial hypothesis was that elongation of the dry season would decrease soil microarthropod species richness and abundance and that irrigation would have the opposite effect.

2. Materials and methods

2.1. Site description

The field experiment was carried out on Mt. Holomon at Taxiarhis, Halkidiki (40°26′N, 23°34′E), 64 km east of Thessaloniki, Greece. The site is a 40-year-old *Pinus brutea* L. plantation with *Quercus coccifera* L., *Q. conferta* L., *Juniperus oxycedrus* and *Erica* spp. understorey at an altitude of 470 m a.s.l. The soil is sandy clay (xeromoder) on mica shist with a moderate organic layer (pH 5.5). The climate is Mediterranean with mean annual temperature 10.9 °C and mean annual precipitation 745.3 mm. The dry period of the year is from July (61.8 mm) to September (27.8 mm), when the lowest precipitation occurs. The highest precipitation is observed in December (97.9 mm). Finally, the highest and the lowest mean monthly temperatures occur in July (20.9 °C) and January (1.7 °C) respectively (Data from Taxiarhis meteorological station 1974–2000).

2.2. Irrigation treatment and sampling

Roofs were used to intercept natural precipitation. The roofs (125 cm × 175 cm) consisted of a wooden frame covered with a 1 mm thick transparent PVC film. The frame was set with a small declination on four 80 cm wooden posts, which were driven into the ground. The rainwater collected on the surface of the roofs was channeled into 20 l containers through an attached funnel. Needles gathered on the roofs were brushed off frequently. The collected water (free of needles and other material) was stored in a dark and cool 500 l container and was used for irrigation.

A total of 21 roofs were placed at the study area. The soil moisture of the plots under the roofs was manipulated to create different moisture regimes as following:

- Seven plots were irrigated "frequently" [F] receiving 6 l m^{-2} every 3 days.
- Seven plots were irrigated "infrequently" [I] receiving 72 l m^{-2} every 5 weeks (irrigation took place over a period of 2 days, three times a day in order to avoid overflow).
- Seven plots were left "dry" [D] and were not irrigated at all.
- Seven plots without roof or irrigation were left undisturbed as control [C].

The experiment was conducted from September 1996 to January 1997. Temperature was measured daily with minimum–maximum thermometers placed between the Litter and F-layer of each plot. Soil water content (expressed as % of fresh weight) was measured by drying a sub sample of approximately 3 g fresh weight at 105 °C for 48 h. For microarthropod extraction, at each sampling and for each treatment five replicate soil cores were taken by a soil corer 8 cm in diameter. The samples were taken shortly before the irrigation of the [I] plots (i.e. on 13 October 1996, 17 November 1996, 22 December 1996, and 06 January 1997). The sample included L, F and H soil layers. The sampling sites were assigned a priori randomly to five out of the seven plots per treatment ensuring that at the end of the experiment all seven plots were equally sampled. On each occasion three further soil cores were extracted for water content estimation.

2.3. Soil microarthropods (abundance, diversity profiles)

Soil animals were extracted from samples by a modified Berlese–Tullgren apparatus and were collected in Gisin mixture (70% ethanol:glycerol, 20:1). Collembola were classified in most cases to species level by using the identification keys of Gisin (1960) and Fjellberg (1980). Collembolan nomenclature was updated where possible according to the "Checklist of the Collembola of the world" (Bellinger et al., 1996–2004). Oribatid mites were classified into morphospecies and identified to genus level. For oribatid mites the identification keys of Balogh (1972), Balogh and Balogh (1992), and Gilyarov and Krivolutsky (1975) were used; and especially for Oppioidea and for primitive Oribatei, Woas (1986) and Balogh and Mahunka (1983) were used, respectively.

2.4. Diversity profile

Abundance of the two microarthropod groups were estimated as individuals per m^2. For assessing the diversity of soil microarthropods in the different plots, we computed the Shannon and Simpson diversity indices, and we used also the method of diversity ordering (Renyi, 1961). We preferred this method of diversity ordering to any of the commonly used diversity indices, as it is a family of indices that includes the most widely used ones. Different indices emphasize different aspects of diversity producing inconsistent ordering of communities. These inconsistencies are unavoidable whenever one attempts to reduce a multidimensional concept, such as a community, to a single number. Renyi's parametric index of order a is an extension of Shannon's entropy metric and is given by the formula:

$$H_a = \begin{cases} \dfrac{\log \sum_{i=1}^{S} p_i^a}{1-a} & \text{for } a \neq 1 \\ -\sum_{i=1}^{S} p_i \log p_i & \text{for } a = 1 \end{cases}$$

where p_i is the fraction of the population abundance corresponding to species i, S the number of species or mophospecies and a the scale parameter, i.e. an arbitrary positive real number. The index shows varying sensitivity to the rare and abundant species of a community, as the scale parameter a changes (Ricotta, 2000). Plotting the value of the index against the scale parameter provides the diversity profile of a community. For $a = 0$, the index is equal to the logarithm of species number, i.e. all species contribute equally to the diversity of the community. For $a = 1$, the index equals Shannon's diversity index. For $a = 2$, the index equals Simpson's diversity index. For a tending to infinity, the index is most sensitive to the abundant species. Thus, when the curves of two diversity profiles differ in the range of low a values, this is due to the number of species. In the range of high a values, differences are due to the presence of abundant species. When two diversity profiles intersect, the two communities are considered incomparable, i.e. they may be ordered differently by different diversity indices. For the calculations we used the DivOrd program created by Tothmeresz (1995).

2.5. Statistical analysis

The differences of maximum and minimum temperatures among treatments were compared using the paired t-test with Bonferroni adjustment for multiple comparisons. Animal abundances were analyzed with repeated measures ANOVA for treatment effect. Animal abundances were log transformed prior to analysis. Bonferroni post hoc comparisons were used whenever ANOVA indicated significant differences. For t-test and ANOVA we used the SPSS (version 11) software package.

Community ordination was performed using redundancy analysis (RDA) of the Collembola and oribatid mites species abundances in relation to environmental variables. For this analysis we used the CANOCO (version 3.10) software package (Ter Braak, 1988). Environmental variables used in the analysis were: minimum and maximum temperature, soil water content and sampling date.

3. Results

3.1. Microclimatic conditions

Soil water content in our experimental plots is presented in Fig. 1. The average water content (± its range) of the control plots [C] was 34.6 (± 8.19%) without any specific trend. The minimum value of 22.4% observed at the second sampling was due to the preceding period of almost 1 month with low precipitation. The water content of the frequently irrigated plots [F] increased steadily and showed the highest values observed among treatments on all sampling occasions (on average 59.57 ± 11.7%). In the infrequently irrigated plots [I] water content increased gradually and showed the highest fluctuation observed among treatments (on average 43.11 ± 15.05%). As expected, the lowest water content values were measured in the dry plots [D] (on average 24.72 ± 5.61%). The relatively high value of water content for the [D] plots in the last sampling is due to snowfall. Snow covered the area, penetrated

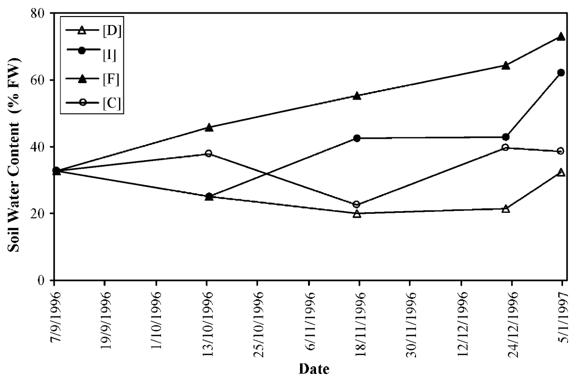

Fig. 1. Average soil water content (expressed as % fresh weight) of samples during the experiment: [D] dry plots; [I] infrequently irrigated plots; [F] frequently irrigated plots; [C] control plots.

Table 1
Paired *t*-test with Bonferroni adjustment for multiple comparisons between soil temperatures in experimental plots

Treatment	[F]	[I]	[D]	[C]
[F]		[I] > [F] (<**0.000**)	[D] > [F] (0.032)	[F] > [C] (0.144)
[I]	[I] > [F] (0.097)		[I] > [D] (0.083)	[I] > [C] (<**0.000**)
[D]	[D] > [F] (0.54)	[I] > [D] (0.248)		[D] > [C] (**0.001**)
[C]	[F] > [C] (0.894)	[I] > [C] (0.126)	[D] > [C] (0.53)	

The cells above the diagonal refer to the comparisons between maximum temperatures and cells below the diagonal refer to the comparisons between minimum temperatures. In each cell the comparison of the temperature values of experimental plots as well as the *P*-values are given (presented in bold if significant). [D] Dry plots, [I] infrequently irrigated plots, [F] frequently irrigated plots, and [C] control plots.

under the roofs and raised the water content of most of the plots.

Table 1 presents the results of statistical comparison of minimum and maximum temperatures between plots. Minimum temperatures displayed no differences between the experimental plots. Maximum soil temperature in the [I] plots was significantly higher than in the [F] and [C] plots, while maximum soil temperature in the [D] plots was significantly higher than in the [C] plots.

3.2. Soil microarthropods

Mean collembolan, oribatid mite and total microarthropod abundances for the study period are presented in Table 2. During the entire study period, the [D] plots were characterized by the lowest abundance for both Collembola and oribatid mites (52% and 55% lower than in the [C] plots, respectively). Maximum total microarthropod abundance was observed in the [F] plots. However, only the abundance of oribatid mites tended to increase under this regime (30% more than the [C] plots), while collembolan abundance tended to decrease (14% less than the [C] plots). In the [I] plots total microarthropod abundances were comparable to the [C] plots, but oribatid mites abundance was 13% higher, while collembolan abundance was 41% lower than in the [C] plots.

In Table 3 the results of repeated measures ANOVA for treatment effects on animal abundance as well as the Bonferroni post hoc comparisons are presented. Collembolan abundance was not affected by the treatments. Total microarthropod and oribatid mite abundances did not differ significantly between the [C] and the treatment plots; however the irrigated plots ([F] and [I]) had significantly greater abundances than the [D] plots. Of the most abundant collembolan species, only *Isotoma notabilis* was significantly affected, being more abundant in the [F] plots than in the [I] plots. Of the most abundant oribatid mites, *Oppiella ornata* was more abundant in the [C] and [F] plots than in the [D] plots, while *Zygoribatula cognata*

Table 2
Mean collembolan, oribatid mite and total microarthropod abundances (individuals per $m^2 \pm$ S.D.) during the study period

Treatment	Collembola	Oribatid mites	Total microarthropods
[D]	468 ± 326	674 ± 349	1142 ± 589
[I]	572 ± 338	1689 ± 703	2261 ± 952
[F]	839 ± 615	1948 ± 1244	2787 ± 1002
[C]	974 ± 772	1497 ± 1273	2472 ± 1769

[D] Dry plots, [I] infrequently irrigated plots, [F] frequently irrigated plots, and [C] control plots.

Table 3
Repeated measures ANOVA results for the abundance of microarthropods

	Treatments
Total microarthropods	[D] a, [C] ab, [I] b, [F] b ($P < 0.05$)
Collembola	NS
Oribatid mites	[D] a, [C] ab, [F] b, [I] b ($P < 0.05$)
Xenylla maritima	NS
Folsomia quadrioculata	NS
Isotoma notabilis	[I] a, [D] ab, [C] ab, [F] b ($P < 0.05$)
Oppiella ornata	[D] a, [I] ab, [C] b, [F] b ($P < 0.05$)
Belba sp2.	NS
Zygoribatula cognata	[D] a, [F] a, [I] b, [C] b ($P < 0.001$)

Animal abundances were log transformed prior to analysis. Treatments are ranked according to animal abundance from lowest to highest. Treatments with the same letter (a or b) are not significantly different according to Bonferroni post hoc comparison. [D] Dry plots, [I] infrequently irrigated plots, [F] frequently irrigated plots, and [C] control plots. NS, non-significant.

was more abundant in the [I] and [C] plots than in the [D] and [F] plots.

Total microarthropod and collembolan abundances varied significantly over the sampling period ($P = 0.001$), being greater in the first and fourth samplings than in the second and third. Some of the most abundant species had different patterns of abundances over time. *Belba* sp. was significantly more abundant on the third and fourth sampling dates than on the first. *Xenylla maritima* was most abundant on the first sampling date, and *Folsomia quadrioculata* on the fourth.

3.3. Community composition

Fig. 2 displays the results of the redundancy analysis for the collembolan community. The ordination is primarily affected by sampling date. The treatment effect is less obvious. *X. maritima* is ordinated close to the first sampling date, while *Isotomurus palustris* and *F. quadrioculata* are associated with the final sampling date. The ordination of the oribatid mites did not display any clear pattern in relation to sampling date or treatment and therefore it is not presented here. The ordination of all microarthropod species reflected the ordination of Collembola, affected mainly by sampling date.

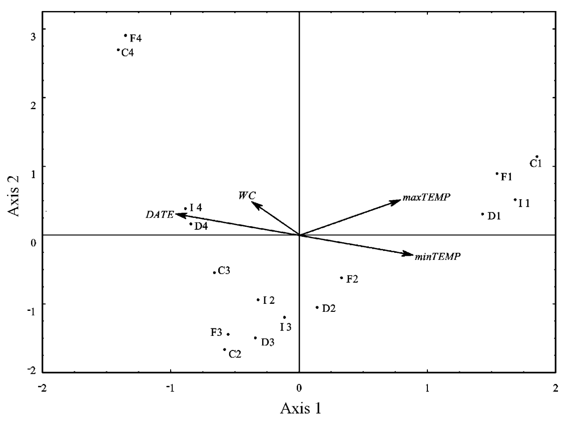

Fig. 2. Ordination of the environmental variables and the collembolan species assemblages (per treatment and sampling date) according to redundancy analysis. WC: soil water content, minTEMP: minimum temperature, maxTEMP: maximum temperature, DATE: sampling date. Individual samples are represented by a two letter code, the first for the treatment (D drought, I infrequent irrigation, F frequent irrigation, and C control) and the second for sampling date (1 October, 2 November, 3 December, and 4 January).

During the study period 20 species of Collembola and 37 species of oribatid mites were found. Most species (17 collembolan and 30 oribatid species) were found in the [F] plots, followed by the [I] plots (15 collembolan and 29 oribatid species) and the [C] plots (11 collembolan and 22 oribatid species). Finally in the [D] plots only 10 species of Collembola and 15 species of oribatid mites were found (Table 4). Their relative abundances over the entire study period, irrespective of treatment are presented in Table 5. A group of eight collembolan species and 13 oribatid species were present in all plots and were the most abundant species (Table 5, I). Three collembolan and five oribatid species were found in all but the [D] plots (Table 5, II). The irrigated plots (both [I] and [F]) were the most species rich because seven collembolan and 13 oribatid species were found only in them (Table 5, III).

3.4. Species diversity

Species richness, Shannon and Simpson diversity indices for Collembola and oribatid mites are presented in Table 4. Highest species richness was observed in the [F] plots followed by the [I] plots, while minimum species richness was observed in the [D] plots. For oribatid mites even though the [F] plots were characterized by maximum species richness they displayed the minimum values for Shannon's and Simpson's diversity indices.

This apparent contradiction highlights the need for a different approach to diversity estimation, such as the Renyi's parametric diversity index. Diversity profiles of Collembola and oribatid mites, based on this index, are presented in Fig. 3a and b. For Collembola (Fig. 3a) maximum and minimum diversity values at all scales were observed in the [F] and in the [D] plots respectively. The diversity profiles for the [C] and the [I] plots showed intermediate values and are intersecting. This indicates the incomparability of the two assemblages; the [I] plots were characterized by higher species richness and lower evenness compared to the [C] plots.

For oribatid mites (Fig. 3b), the [I] plots were characterized by maximum diversity (except species richness) compared to the other plots. The diversity

Table 4
Species richness and diversity indices of Collembola and oribatid mite assemblages

Treatment	Collembola			Oribatid mites		
	Species richness	Shannon's	Simpson's	Species richness	Shannon's	Simpson's
[F]	17	1.83	1.43	30	1.58	0.79
[I]	15	1.45	1.04	29	2.22	1.60
[C]	11	1.42	1.19	22	2.02	1.29
[D]	10	1.22	0.78	15	1.93	1.40

[D] Dry plots, [I] infrequently irrigated plots, [F] frequently irrigated plots, and [C] control plots.

profiles for the other plots are intersecting. As far as species richness was concerned the [F] plots were more diverse than the [C] plots, which in turn were more species rich than the [D] plots. However, evenness displayed the opposite pattern. The [D] plots exhibited higher value, followed by the [C] plots, while the [F] plots exhibited the lowest evenness value.

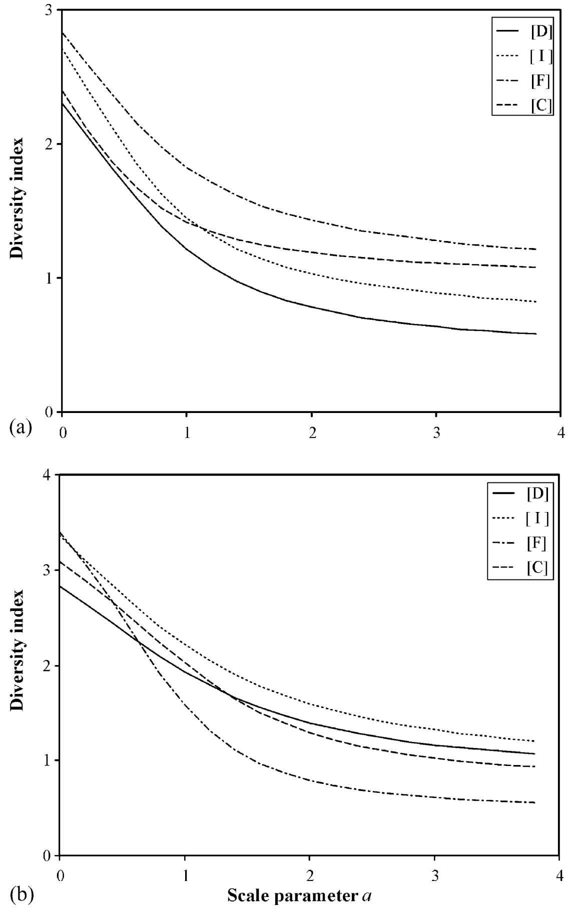

Fig. 3. Diversity profiles of soil microarthropod species assemblages per treatment (a) for Collembola and (b) for oribatid mites: [D] dry plots; [I] infrequently irrigated plots; [F] frequently irrigated plots; [C] control plots.

4. Discussion

The treatments (frequent or infrequent irrigation and drought) altered water content of the topsoil during the study period. As a side effect soil temperature was also affected. Maximum soil temperatures increased in dry [D] and irregularly irrigated [I] plots compared to control plots [C] while minimum temperatures remained rather unaffected in all treatments. Differences in the maximum soil temperature might be attributed to differences in evapotranspiration during the warmest periods of the day. Thus, the response of soil microarthropods to experimental treatments might be associated not only with soil moisture changes but with the changes in soil temperature as well. Uvarov (2003) has shown that fluctuation in soil temperature per se has a significant effect on both the survival and reproductive ability of oribatid mites.

The two irrigation and the drought treatments were applied for a short period. Furthermore, the treatments were applied on small isolated plots, where colonization by source populations from outside the treated plots was possible. Nevertheless, these short-term moisture manipulation treatments did produce distinct effects on species diversity and community composition of the two main microarthropod groups, namely oribatid mites and Collembola. Furthermore, even though total microarthropod and oribatid mite abundances in the experimentally manipulated plots did not differ from the control plots, the irrigated plots had significantly greater abundances than the dry

Table 5
List of collembolan and oribatid species found in the experimental plots and relative abundance (R.A. %) of each species

Collembola	R.A. (%)	Oribatid mites	R.A. (%)
(I) Species found in all plots			
Xenylla maritima (Tullberg, 1869)	45.57	*Oppiella ornata* (Oudemans, 1900)	52.72
Isotomurus palustris (Müller, 1776)	25.58	*Belba* sp1.	6.76
Folsomia quadrioculata (Tullberg, 1871)	14.21	*Belba* sp2.	5.96
Isotoma notabilis (Schäffer, 1896)	4.47	*Chamobates* sp.	5.46
Microgastrura duodecimoculata (Stach, 1922)	1.53	*Eremaeus* sp.	4.43
Ceratophysella bengtssoni (Ågren, 1904)	1.01	*Tectocepheus* sp.	3.07
Pseudosinella wahlgreni (Börner, 1907)	0.93	*Scheloribates* sp1.	2.51
Folsomia monoculata (Bagnall, 1949)	0.67	*Scheloribates* sp2.	2.31
		Camisia sp	1.75
		Unknown species	1.74
		Oppia sp2.	0.64
		Carabodes sp.	
		Quadroppia sp.	
(II) Species missing from the dry plots			
Ceratophysella succinea (Gisin, 1949)	1.48	*Zygoribatula cognata* (Oudemans, 1902)	4.17
Pseudachorutes sp.	1.22	*Damaeus* sp.	0.89
Isotoma antennalis (Bagnall, 1940)	0.56	*Achipteria* sp.	0.42
		Eupelops sp.	0.36
		Multoribates sp.	0.21
(III) Species found in only one or both the irrigated plots (in [ ] the plots where they were found)			
Micranurida pygmaea (Börner, 1901) [F]	0.84	*Lauroppia* sp. [I] [F]	2.61
Shaeridia pumilis (Krausbauer, 1898) [I] [F]	0.49	*Hermanniella* sp. [I] [F]	0.78
Onychiurus sp. [F]	0.37	*Sphaerochthonius* sp. [F]	0.24
Ceratophysella engadinensis (Gisin, 1949) [F]	0.19	*Suctobelba* sp. [I] [F]	0.22
Pseudosinella monoculata (Denis, 1938) [I]	0.15	*Tropacarus* sp. [F]	0.22
Orchesella cincta (Linné, 1758) [I]	0.10	*Scheloribates* sp3. [F]	0.20
Folsomia decopthalma (Steiner, 1958) [F]	0.10	*Galumna* sp. [I]	0.18
		Metabelba sp. [I] [F]	0.12
		Liebstadia sp. [F]	0.11
		Oppia sp1. [I] [F]	0.11
		Zygoribatula sp2. [I]	0.09
		Nanhermannia sp. [I]	0.05
		Micreremus sp. [I]	0.05
(IV) Other species (in [ ] the plots where they were found)			
Entomobrya nivalis (Linné, 1758) [D]	0.17	*Oppiella subpectinata* [F] [C] (Oudemans, 1901)	0.52
Pseudachorutes asigillatus (Börner, 1901) [I] [F] [D]	0.36	*Belba* sp3. [D] [F] [I]	0.40
		Eupelops sp2. [C]	0.37
		Oribatula sp. [D] [F]	0.13
		Joelia sp. [C]	0.12
		Unknown species [C] [I]	0.08

The species are grouped according to the treatment in which they were present and sorted by relative abundance within each group. [D] Dry plots, [I] infrequently irrigated plots, [F] frequently irrigated plots, and [C] control plots.

plots. It is likely that the effects of the treatments would be much greater if applied over a longer term and at a regional scale.

Under normal conditions the summer drought at the study site decreases soil water content to approximately 15%. The drought treatment applied in our experiment, which started on the driest month and extended the dry period of the year, and even though it was less intense than Mediterranean summer drought it negatively affected species richness of oribatid mites and marginally decreased species richness of Collembola. This result was in accordance with our hypothesis, because drought is a known stress factor and has, even in the short-term, an impact on soil microarthropods (Bengtsson, 1994). Collembola especially can be influenced by the occurence of drought. They are prone to desiccation as most species lack true tracheal systems and breathe through their integument. Humidity and temperature are known to be critical factors in collembolan distribution (Joosse and Groen, 1970; Verhoef, 1981; Verhoef and van Selm, 1983). However, the physiological resistance to desiccation varies between species (Joosse, 1981). Under dry conditions a few drought tolerant species are active. In the Mediterranean region, among Collembola, a well documented example is *X. maritima* (Gisin, 1960; Argyropoulou et al., 1993), which was the dominant species in our experimental plots. Many collembolan species can stop feeding and go into a dormant state in response to low humidity (Testerink, 1983). Alternatively, they can increase their locomotory activity as the saturation deficit of the surrounding air increases (Joosse and Groen, 1970) and escape dry conditions, i.e. some species might have left the dry plots. Drought seems to have similar effects on soil microarthropods in various types of climate. Its negative effect on collembolan abundance and species richness has been reported by Pflug and Wolters (2001) in a similar experiment. Lindberg et al. (2002), who applied summer drought treatment for 8 years, in a coniferous forest in Sweden reported negative effects on oribatid mite abundance and species diversity and collembolan abundance.

Both short-term irrigation treatments increased the species richness of Collembola as well as oribatid mites as we hypothesised. However, our hypothesis about irrigation increasing abundance compared to the control was not verified. The most abundant species of both taxa were abundant in all plots. The same trend has been reported in a 10 years study of collembolan dominance pattern, where species with high abundance did not become rare or vice versa (Wolters, 1998). The increase in species richness is mainly due to the presence of rare species that were not observed in the control plots. The presence of species only in the experimentally manipulated plots may be due to their extremely clumped distribution, or due to the vertical migration of these species from deeper unsampled layers, or due to the activation of senescent individuals. The short duration of our experiment did not allow for multiple generations of the soil microarthropods studied. Therefore, a rapid increase in their population size due to demographic response seems unlikely. However, since there is generally a positive correlation between habitat and microarthropod diversity (Anderson, 1978; Hansen and Coleman, 1998; Lindberg et al., 2002), in the long-term increased soil water content may lead to a decrease in microhabitat diversity and consequently to a decrease in soil arthropod diversity. So the short-term effect may be overturned in the long run. Generalizations about the effect of climate change on soil diversity should be made with caution, since the diversity profiles of the experimental plots indicate non-comparable species assemblages. Drought though, although annually occurring in Mediterranean ecosystems, produced similar effects on soil microarthropods as in other, temperate, ecosystems where drought is not regularly expected.

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