Geoderma 226–227 (2014) 47–53

Contents lists available at ScienceDirect

Geoderma

journal homepage: www.elsevier.com/locate/geoderma

Sampling season affects conclusions on soil arthropod community structure responses to metal pollution in Mediterranean urban soils

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ARTICLE INFO

Article history:
Received 16 November 2012
Received in revised form 19 November 2013
Accepted 2 February 2014
Available online 22 March 2014

Keywords:
Climatic conditions
Soil arthropod
Acarina
Collembola
Metal pollution

ABSTRACT

This study aimed to assess if the period of sampling affected conclusions on the responses of arthropod community structure to metal pollution in urban soils in the Mediterranean area. Higher temperature and lower precipitation were detected in autumn than in spring. In both samplings, the most abundant taxa were Acarina and Collembola, although their relative abundances were differently affected by seasonality and metal contamination. The relative abundance of Acarina was higher in autumn and positively related with soil total Cu, whereas Collembola abundance was higher in spring and correlated with water-extractable Cu. Arthropod community was heavily affected by seasonal variations in climatic conditions in high and low polluted soils, showing for the same soil different responses dependent on the sampling season. Sampling time therefore is a fundamental factor when assessing the effects of metal pollution on soil arthropod communities.

1. Introduction

Soils host the greater part of the terrestrial biosphere. Soil arthropod communities are extremely rich in species, comprising a high proportion of diversity, and contribute to fundamental services for terrestrial ecosystems (Brussaard et al., 1997; Chapman, 2012; Faber and van Wensem, 2012). Arthropods, in fact, play an important role in decomposition processes through litter breakdown and faecal production, and top-down control of decomposers (Sackett et al., 2010). Beside their fundamental role in nutrient cycling, arthropods contribute to the maintenance of good soil quality (Brussaard et al., 1997).

Mediterranean soils are the product of interactions between natural processes and human activities that have sometimes been beneficial but all too often have led to more or less advanced environmental degradation (De Franchis and Ibanez, 2003). Mediterranean arthropod distribution is strongly dependent on climatic conditions as the ecosystems in this area are characterized by large diurnal, seasonal, annual and inter-annual oscillations (Stamou et al., 2004).

Changes in climatic condition together with soil use can directly alter soil properties such as temperature, moisture content, chemical composition, and physical properties. These alterations consequently lead to a different soil arthropod community assemblage and, in turn, alter important ecosystem services such as litter decomposition and nutrient cycling (Castro et al., 2010; Kardol et al., 2010).

Many studies describe effects of climatic condition on soil fauna in Mediterranean forests or areas not impacted by human activities (Cortet and Poinsot-Balaguer, 1998; Doblas-Miranda et al., 2007; Gergócs et al., 2011; Stamou and Argyropoulou, 1995). These studies suggest that abundance and diversity of soil invertebrates may differ dependent on the season of sampling. In fact, different seasons are characterized by different climatic conditions as well as different parts of the life cycles of organisms. This may also affect the response of soil invertebrates to pollution. A previous study (Santorufo et al., 2012) highlighted variations in arthropod community structure in soils differently contaminated with metals. Despite the growing interest about, little is known on the effects of climatic conditions on soil invertebrates in metal polluted soils. The present study aimed at evaluating the structure of soil arthropod communities exposed to metal polluted soils in two different seasons, in autumn after a warm-dry summer period and in spring after a cold-humid winter period, in an urban Mediterranean area. In particular, this study tried to assess if conclusions on the response of the arthropod community structure to metal pollution can vary depending upon the season of sampling. Our hypothesis was that the long-term exposure has shaped the soil arthropod communities in metal-polluted field sites in such a way that differences would be clearly independent of the time of sampling.

2. Materials and methods

2.1. Soil sampling

Starting from the results obtained in a previous sampling (September 2010) and reported in Santorufo et al. (2012), further sampling was

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http://dx.doi.org/10.1016/j.geoderma.2014.02.001
0016-7061/

carried out at the same sites and in the same way in April 2011. All the sites are filling soils about 200 years old. RS1 and RS2 are gardens near a road side, MW1 and MW2 are gardens near a motorway, UP is a garden at the centre of an urban park. At each garden that was approximately 100 m^2, five samples were collected at 20 m apart.

2.2. Climatic conditions of the investigated area

Data on the climatic conditions of the investigated area from April 2010 to April 2011 were obtained from the web-site: http://www.ilmeteo.it. In particular, for downtown Naples, monthly rainfall and mean temperature were considered and reported in Fig. 1.

2.3. Physical and chemical analyses

The soils were characterized for pH, measured in a soil:distilled water suspension (1:2.5 = w:w) by electrometric method, for organic matter content, evaluated by loss of weight after ignition at 500 °C for 8 h, and water content, determined by gravimetric method after oven-drying to constant weight at 105 °C. These analyses were carried out following the methods reported by Allen (1989). The soil Cu and Pb concentrations were measured after sieving (2 mm) and oven drying (75 °C) the soil samples. To measure total metal concentrations, 0.1 g oven-dried soil samples were digested with 2 ml of a mixture (4:1 = v:v) of HNO_3 (65%, p.a., Riedel-deHaën, Seelze, Germany) and HCl (37%, p.a., Baker Philipsburg, NJ, USA) at 140 °C for 7 h in a macro-destruction oven. To measure water-extractable metal concentrations, an oven-dried soil:distilled water suspension (1:2.5 = w:w) was prepared, shaken for 2 h at 200 rpm and filtered over a 0.45 μm Whatman filter. Cu and Pb concentrations were measured by atomic absorption spectrometry equipped with a graphite furnace unit (Perkin-Elmer 5100). The quality of the analysis was checked using ISE sample 989 (International Soil-Analytical Exchange) certified by Wageningen Evaluating Programs for Analytical Laboratories as reference material. Recoveries of Cu and Pb were always within 10–15% of the certified concentrations. The metal concentrations were reported as μg g^{-1} dry weight (d.w.) and in order to have a summed measure of soil contamination, metal concentrations were also reported as the sum of toxic units (ΣTUs). TUs were calculated as the ratio between measured and background metal concentrations in the soils. The background levels of total (4.53 μg Cu g^{-1} d.w.; 18.7 μg Pb g^{-1} d.w.) and water-extractable metal concentrations (0.07 μg Cu g^{-1} d.w.; 0.02 μg Pb g^{-1} d.w.) were measured in the natural standard soil Lufa 2.2 (Speyer, Germany). For each site and sampling time, the chemical and physical analyses were performed in triplicate.

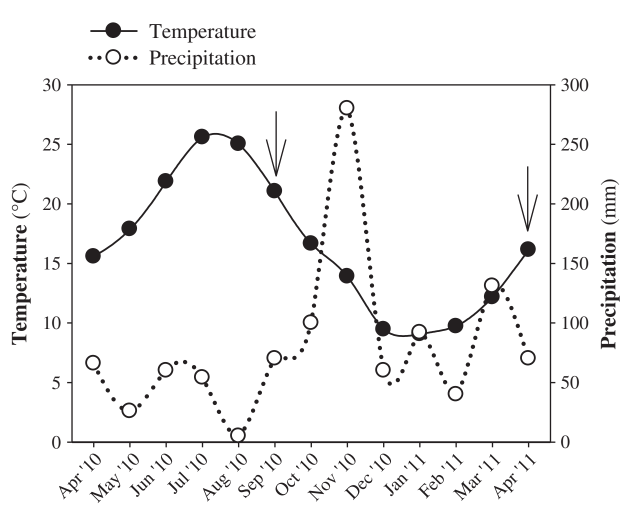

Fig. 1. Mean temperature (black line) and rainfall amount (dotted lines) in the investigated area of downtown Naples from April 2010 to April 2011; the arrows indicate the sampling times. Data were obtained from the web-site: http://www.ilmeteo.it/.

2.4. Arthropod community analyses

The analyses of the soil communities were performed on five subsamples collected at each site. To extract the arthropods, the soil samples were placed in a Tullgren apparatus at VU University (Amsterdam, The Netherlands) for 4 weeks following the method of Van Straalen and Rijninks (1982). The air temperature above the samples was 30 °C while the bottom of the samples was kept at 5 °C. The arthropods were collected in jars containing a 70% ethanol solution. In the final step, the animals were counted and identified according to the major taxonomic groups.

The results of the arthropod community analyses are reported as density (i.e. individual number/m^2 soil), richness (sum of different taxa in each soil) and relative abundance (i.e. individual number of each taxon/total number of organisms). In addition, for each sampling the Shannon (1948), Simpson (1949), Menhinick (1964), and Pielou (1969) indices, Acarina/Collembola ratios and the QBS index (Parisi et al., 2005) were calculated as reported in Santorufo et al. (2012).

2.5. Statistical analyses

The Kolmogorov–Smirnov test was applied to assess the normality of the distribution of the data sets. Pearson's regression test was performed to evaluate the correlations (considered significant when $P < 0.05$) between the parameters describing the community and the individual physical–chemical soil characteristics. One-way Analysis of Variance (ANOVA), with Holm–Sidak posthoc test, was performed to highlight differences (considered significant when $P < 0.05$) among the sites with respect to the parameters describing the community and soil metal concentrations. Student *t*-test was carried out to highlight differences in each investigated parameter between the samplings. Sigma-Plot 11.0 (Jandel Scientific, San Josè, USA) was used for all these analyses.

In order to test the direct relationships between biological parameters and the season or soil properties, a redundancy analysis (RDA), a canonical multivariate method, was carried out by the package Syntax 2000 (Australia). The RDA was carried out considering independent variables such as air temperature, soil water and organic matter content, soil total and water-extractable Cu and Pb, and dependent variables such as soil organism density, taxa richness, and relative abundance of Acarina and Collembola (the most abundant taxa). To further investigate the influence of abiotic factors identified by the RDA, some biological parameters (i.e. density, richness, Acarina and Collembola abundances, and QBS index) were related to soil organic matter content, ΣTUs, and Cu and Pb concentrations obtained at both sampling times.

3. Results

3.1. Climatic conditions and soil physical and chemical properties

Over the investigated period, the area showed a typical Mediterranean climate with a warm and dry summer, and a cold and rainy winter (Fig. 1). The mean temperature and total amount of rainfall in the last 3 months before the samplings in autumn (September 2010) and spring (April 2011) were 25 °C and 100 mm and 10 °C and 250 mm, respectively.

Soil pH-H_20 ranged between 5.45 and 7.33 (Table 1), and was lowest at RS1 compared to all other sites. The soil organic matter content was particularly high at RS2 and UP, for both the samplings, where also the highest water content was measured (Table 1). Soil pH and organic matter content did not differ between the samplings, whereas the mean soil moisture content was significantly ($P < 0.05$) higher in spring 2011 (water content 34.5 ± 5.77% d.w.) than in autumn 2010 (water content 15.1 ± 2.58% d.w.) (Table 1).