SOIL Discuss., 2, 67–84, 2015
www.soil-discuss.net/2/67/2015/
doi:10.5194/soild-2-67-2015


SOIL
Discussions
Open Access



# Study of microarthopod communities to assess soil quality in different managed vineyards

**E. Gagnarli[1], D. Goggioli[1], F. Tarchi[1], S. Guidi[1], R. Nannelli[1], N. Vignozzi[1], G. Valboa[1], M. R. Lottero[2], L. Corino[2], and S. Simoni[1]**

[1]CRA-ABP, Consiglio per Ricerca e Sperimentazione in Agricoltura – Research Centre for Agrobiology and Pedology, Firenze, Italy
[2]CRA-ENO, Consiglio per Ricerca e Sperimentazione in Agricoltura – Research Centre for Oenology, Asti, Italy

Received: 22 October 2014 – Accepted: 21 November 2014 – Published: 21 January 2015

Correspondence to: E. Gagnarli (elena.gagnarli@entecra.it)

Published by Copernicus Publications on behalf of the European Geosciences Union.

## Abstract

Land use influences the abundance and diversity of soil arthropods. The evaluation of the impact of different management strategies on soil quality is increasingly requested. The determination of communities' structures of edaphic fauna can represent an efficient tool. In this study, in some vineyards in Piedmont (Italy), the effects of two different management systems, organic and integrated pest management (IPM), on soil biota were evaluated. As microarthropods living in soil surface are an important component of soil ecosystem interacting with all the other system components, a multi disciplinary approach was adopted by characterizing also some soil physical and chemical characteristics (soil texture, soil pH, total organic carbon, total nitrogen, calcium carbonate).

Soil samplings were carried out on Winter 2011 and Spring 2012. All specimens were counted and determined up to the order level. The biological quality of the soil was defined through the determination of ecological indices, such as QBS-ar, species richness and indices of Shannon-Weaver, Pielou, Margalef and Simpson.

The mesofauna abundance was affected by both the type of management and the soil texture. The analysis of microarthropod communities by QBS-ar showed higher values in organic than in IPM managed vineyards; in particular, the values registered in organic vineyards were similar to those characteristic of preserved soils.


## 1 Introduction

The functioning of terrestrial ecosystems is dependent upon the relationships between above- and belowground food webs; transfers of biotic components of the decomposer subsystem to aboveground consumers connect the two subsystems (Kardol et al., 2011; Wardle, 2002).

Compared with forestry, there is generally less agreement about how the relationships between biodiversity and agriculture should be measured. Much of the emphasis – where it occurs at all – is put towards measuring detrimental impacts of agriculture on surrounding habitats (for instance through soil erosion or pollution run-off) rather than looking at biodiversity within agricultural systems (Dudley et al., 2005).

The abundance analysis of soil arthropods and the evaluation of biodiversity can represent an efficient tool in the evaluation of soil quality in agro-ecosystems (Cole et al., 2006; De Goede and Brussard, 2002; Duelli and Orbist, 2003; Van Straalen, 1998). The soil quality assessment is a complex issue depending on the combination of soil physical, chemical and biological properties.

A lot of methodologies are based on soil abiotic features, and particularly on physical and chemical parameters. In regard to use of soil biological indicators, less means are available with need of standardization and databases. Several studies have documented the importance of the soil biota for soil quality and vitality (Lavelle et al., 2006), and its potential for reflecting anthropogenic disturbances (Paoletti et al., 1991; Van Straalen, 1998). In this context, the determination of community structure of edaphic fauna adds significant information on the soil status. The population and taxa richness of soil micro-arthropods respond sensitively to agroecosystem managements and agronomic practices (Behan-Pelletier, 1999; Caruso and Migliorini, 2006; Gulvik et al., 2008; Menta et al., 2008; Parisi et al., 2005).

Furthermore, soil invertebrates affect the composition and structure of plant communities and influence rhizosphere microbial communities (Ladygina and Hedlund, 2010). Soil microarthropods, as litter transformers, improve soil quality and affect the structural properties of soils. A favourable soil structure ensures adequate nutrient retention, aeration, and water-holding capacity below ground, facilitates roots' penetration and prevents surface crusting and erosion of topsoil (Culliney, 2013). Therefore, the knowledge of interactions between the different groups of organisms and of mechanisms regulating soil food web is crucial to assess the sustainability of land use (Maraun and Scheu, 2000).

The main objective of this work was to assess the effect of crop managements (organic vs. Integrated Pest Management (IPM)) and of soil physical and chemical properties on microarthropod communities in different vineyards of Monferrato area (Piedmont, Italy).

## 2 Material and methods

### 2.1 Study area and soil sampling

The study was carried out on the wine growing hilly area of Monferrato (Piedmont, Italy), characterized by marls, clays and sands, and almost entirely devoted to the production of high quality wines, in particular Barbera. The area is located at 200–250 m a.s.l. altitude; the climate zone is typically of class E. In Table 1, the eleven study sites, seven organic and four IPM managed vineyards, located in the Costigliole d'Asti area (44°47′5″64 N 08°10′55″20 E) and surroundings, are reported. Samplings were carried out during the Winter 2011 and the Spring 2012.

The samples were collected using a cylindrical soil core sampler (3 cm diameter × 30 cm height): each sample was equally subdivided to study arthropod communities in three different depth ranges. The extraction of microarthropods was performed using the Berlese-Tullgren selector. All specimens were counted and determined up to the order level.

Additional core samples were collected and processed for the following soil physical and chemical properties: texture by the sedigraph method (Andrenelli et al., 2013); pH in a 1 : 2.5 soil/water suspension; total organic carbon (TOC) and total nitrogen (TN) by dry combustion (after 10 % HCl treatment for carbonate removal), using a Thermo Flash 2000 CN analyzer; total equivalent calcium carbonate ($CaCO_3$), calculated from the difference between the total carbon measured by dry combustion before and after the HCl treatment (Sequi and De Nobili, 2000).





SOILD
2, 67–84, 2015

## 2.2 Biodiversity analysis

Soil quality was defined through qualitative and quantitative biological indicators. Biological quality of soil was evaluated by QBS-ar index (Parisi, 2001), based on direct correlation between the quality of soil and the microarthropods adapted to the soil habitat. This index uses the biological form approach to separate the mesofauna specimens into morphological classes according to their levels of adaptation to the soil environment. Each form is eco-morphologically scored (EMI: Eco-Morphological Index) ranging from 1 to 20, on the basis of its edaphic adaptation level. The sum of EMIs gives the global value of QBS-ar index. The biological soil quality was characterized on the basis of D'Avino (2002) classification.

The ecological quali-quantitative indices adopted were: taxa richness; Shannon-Weaver diversity index ($H'$), measuring the commonness of species in a community; Margalef index ($d$), based on the number of species for a given number of individuals; Simpson index ($D$), indicating the probability of any two individuals drawn at random from an infinitely large community belonging to different species; Pielou's evenness index ($J$), expressing how evenly the individuals are distributed among the different species (Krebs, 1989).

## 2.3 Statistical analysis

The effects of soil properties and vineyard managements on the abundance of mesofauna were evaluated by means of Analysis of Variance (ANOVA). Soil QBS-ar data were analyzed using the Mann-Whitney rank test. All statistical analyses were performed by the SPSS statistical software (SPSS, 2004).





SOILD
2, 67–84, 2015

## 3 Results

### 3.1 Soil microarthropod abundance

On the whole, the microarthropods collected were 4322 showing a complex and well-structured community, more abundant in organic management (Table 3). The meso-fauna abundance was considerably affected by management: was higher in organic vineyards, with about 2 : 1 ratio ($t$ test: $t = 256$, $df = 196$, $P = 0.015$).

The distribution of the three main animal groups (Acari, Collembola, Other Arthropods) did not show any substantial difference depending on management (Fig. 1). The mites represented about 50 % of the total arthropodofauna recorded, collembolans about 30 %, and other microarthropods about 20 %. Among all taxa, seven were typically including eu-edaphic forms as Acari, Collembola, Diplura, Pauropoda, Protura, Pseudoscopionida, Symphyla (Fig. 1).

The overwhelming majority of the microarthropods abundance was nearly 80 % in the 0–10 cm depth layer ($F_{\text{depht}} = 71.80$, $P < 0.001$) (Fig. 2).

The soil characteristics of studied sites are reported in Table 2: textures ranged from Medium (loam and silt loam) to Moderately fine (clay-loam- and silty-clay-loam). Soil TOC content was generally medium, scarce in sites 9, 10 and very high in site 4. The highest value of TN content was in site 4. The soil pH ranged from slightly to moderately alkaline. Total $CaCO_3$ content showed wide variability, from extremely high (site 11) to low calcareous (site 6) (Costantini, 2009). The total abundance of the microartropods in the different seasons is reported in Table 3. The abundance of soil fauna was affected by TOC level (ANOVA, $F_{3,62} = 5.23$; Tukey test, $P < 0.05$) and by soil texture with higher abundance in the clay-loam soil than in silty-clay-loam, silt-loam and loam soils (Tukey test, $P < 0.05$).





SOILD
2, 67–84, 2015

## 3.2 Soil Microarthropods' biodiversity

The QBS-ar index was higher in the organic than in the IPM-managed vineyards in March (Mann–Whitney test: $U = 143.5$, $P = 0.04$) while there was no difference in May (Table 4).

In Fig. 3, the biodiversity indices, at the considered identification level under the different managements, are reported. No substantial difference between different crop managements was evidenced.

## 4 Discussion and conclusions

As regards species richness, generally, arthropods may represent up to 85 % of the soil fauna, mainly represented by Acari and Collembola followed by other Arthropods (Decaëns et al., 2006). In the vineyard soils studied, an analogous distribution was registered. Abundance and variety of niches occupied by arthropods assume considerable significance in this environment (Culliney, 2013). In this study, the highest microarthropod density was collected in the 0–10 cm depth range: the samplings at this level can be indicative for quantitative/qualitative analysis. However, the presence of some euedaphon groups (Protura, Diplura, and Pauropoda), even if less affecting the soil processes (Eisenbeis and Wichard, 1987), is highly respondent to stress condition and can be relevant for a biomonitoring purpose (Parisi et al., 2005). At the same time, it must be emphasized that, if a study aim is qualitatively focused on highlighting the presence of key species (i.e. sensitive to agricultural processing) well adapted to soil habitat, it is highly advisable the evaluation of euedaphic forms at deeper ranges.

Generally, soil mesofauna (collembolans and mites) is associated to TOC and can contribute to net nitrogen mineralization (Cortet et al., 2002); here, the distribution of soil fauna was significantly affected by TOC and by soil texture with the highest abundance on clay-loam soils. In particular, in Bricco vineyard (site 4), arthropod abundance was related to high values of TOC and TN (Table 2). As soil arthropods comprise a





SOILD
2, 67–84, 2015

large range of taxa with diverse patterns of response to different kind of anthropogenic perturbations (Decaëns et al., 2006), these communities may provide a wider view by integrating other parameters (e.g. soil physico-chemical conditions, bioavailability).

As expected, the total abundance of microarthopods and complexity of the population structure were higher in the organic managed vineyards than in the IPM ones. These soils can be ascribed to high biological classes (VI), similar to those registered in undisturbed and forestal soils (Parisi et al., 2005). This evidence is analogous to what observed by Miani et al. (2005): in organic vineyards, the QBS values were higher (about 20 %) than the values registered in the conventionally managed ones. In this study, the QBS-ar index returned quite efficient readings in such a way as to allow comparisons with other situations. However, the application of the ecological indices was not so effective: the criterion adopted was partly affected by the cut level of the biological form determination – up to the order level – adopted for QBS-ar.

By perspective, the attention should be moved from the monitoring method to evaluating at which extent the activity's processes determined by microarthropods can affect the plant's physiological and productive status.

The microarthropods have a role both as predator and as prey and are comprised in the important middle links of soil food webs, as they serve to channel energy from the soil microflora and microfauna to the macrofauna on higher trophic levels (Coleman et al., 2004).

These preliminary evidences suggest that study of food webs may be improved by addressing spatial and temporal partitioning, population dynamics, taxon-specific or functional groups.

Further researches are needed to establish more quantitative relationships between specific groups, especially among arthropods, and to better understand the roles of soil fauna in C and N cycles.





SOILD
2, 67–84, 2015

*Acknowledgements.* The authors would like to thank the vineryard farms – Az. Agr. Corino Lorenzo, Costigliole d'Asti (Asti); Az. Agr. Piana Antonio, Castelboglione (Asti); Tenuta Vitivinicola Bricco Boschis, Cavallotto, Castiglione Falletto (Cuneo) – for their receptiveness and kindness.

## References

Andrenelli, M. C., Fiori, V., and Pellegrini, S.: Soil particle-size analysis up to 250 micron by X-ray granulometer: device set-up and regressions for data conversion into pipette-equivalent values, Geoderma, 192, 380–393, 2013.

Behan-Pelletier, V. M.: Oribatid mites in agroecosystems: role for bioindication, Agr. Ecosyst. Environ., 74, 411–423, 1999.

Caruso, T. and Migliorini, M.: Micro-arthropod communities under human disturbance: is taxonomic aggregation a valuable tool for detecting multivariate change? Evidence from Mediterranean soil oribatid coenoses, Acta Oecol., 30, 46–53, 2006.

Cole, L., Bradford, M. A., Shaw, P. J. A., and Bardgett, R. D.: The abundance, richness and functional role of soil meso- and macrofauna in temperate grassland – A case study, Appl. Soil Ecol., 33, 186–198, 2006.

Coleman, D. C., Crossley, D. A., and Hendrix, P. F.: Fundamentals of Soil Ecology, 2nd Edn., Elsevier Inc., ISBN 0-12-179726-0, Athens, Georgia, 2004.

Cortet, J., Gillon, D., Joffre, R., Ourcival, J. M., and Poinsot-Balaguer, N.: Effects of pesticides on organic matter recycling and microarthropods in a maize field: use and discussion of the litter-bag methodology, Eur. J. Soil Biol., 38, 261–265, 2002.

Costantini, E. A. C.: Appendix: Soil Properties and Qualities, in: Manual of methods for soil and land evaluation, edited by: Costantini, E. A. C., Sience Publishers, Enfield, NH, USA, 529–539, 2009.

Culliney, T. W.: Role of Arthropods in Maintaining Soil Fertility, Agriculture, 3, 629–659, doi:10.3390/agriculture3040629, 2013.

D'Avino, L.: Esposizione del metodo di Vittorio Parisi per la valutazione della Qualità Biologica del Suolo (QBS) e proposta di standardizzazione delle procedure, CD ROM, Museo di Storia Naturale di Parma, Italy, 2002.





SOILD

2, 67–84, 2015

Study of microarthopod communities

E. Gagnarli et al.

Decaëns, T., Jiménez, J. J., Gioia, C., Measey, G. J., and Lavelle, P.: The values of soil animals for conservation biology, Eur. J. Soil Biol., 42, S23–S38, 2006.
De Goede, R. G. M. and Brussaard, L.: Soil zoology: an indispensable component of integrated ecosystem studies, Eur. J. Soil Biol., 38, 1–6, 2002.
Dudley, N., Baldock, D., Nasi, R., and Stolton, S.: Measuring biodiversity and sustainable management in forests and agricultural landscapes, Philos. T. Roy. Soc. B., 360, 457–470, 2005.
Duelli, P. and Obrist, M. K.: Biodiversity indicators: the choice of values and measures, Agr. Ecosyst. Environ., 98, 87–98, 2003.
Eisenbeis, G. and Wichard, W.: Atlas on the Biology of Soil Arthropods, Springer, Berlin, Heidelberg, New York, 437 pp., 1987.
Gulvik, M. E., Blozyk, J., Austad, I., Bajaczyk, R., and Piwczynski, D.: Abundance and diversity of soil microarthropod communities related to different land use regime in a traditional farm in Western Norway, Pol. J. Ecol., 56, 273–288, 2008.
Kardol, P., Reynolds, W. N., Norby, R. J., and Classen, A. T.: Climate change effects on soil microarthropod abundance and community structure, Appl. Soil Ecol., 47, 37–44, 2011.
Krebs, C. J.: Ecological Methodology, 1st Edn., Addison-Welsey, 654 pp., 1989.
Ladygina, N. and Hedlund, K.: Plant species influence microbial diversity and carbon allocation in the rhizosphere, Soil Biol. Biochem., 42, 162–168, 2010.
Lavelle, P., Decaens, T., Aubert, M., Barot, S., Blouin, M., Bureau, F., Margerie, P., Mora, P., and Rossi, J. P.: Soil invertebrates and ecosystem services, Eur. J. Soil Biol., 42, 3–15, 2006.
Miani, N., Skert, N., and Grahonja, R.: Biomonitoraggio sperimentale dell'inquinamento dei suoli agricoli della provincia di Trieste tramite il metodo QBS (Report), available at: http://www.tecpuntobio.it/Documenti/qbsinfvg.pdf (last access: May 2008), 2005.
Maraun, M. and Scheu, S.: The structure of oribatid mite communities (Acari, Oribatida): patterns, mechanisms and implications for future research, Ecography, 23, 374–383, 2000.
Menta, C., Leoni, A., Bardini, M., Gardi, C., and Gatti, F.: Nematode and microarthropod communities: comparative use of soil quality bioindicators in covered dump and natural soils, Environ. Bioind., 3, 35–46, 2008.
Paoletti, M., Favretto, M., Stinner, B., Purrington, F., and Bater, J.: Invertebrates as bioindicators of soil use, Agr. Ecosyst. Environ., 34, 341–362, 1991.
Parisi, V.: La qualità biologica del suolo. Un metodo basato sui microartropodi, Acta Naturalia de l'Ateneo Parmense, 37, 97–106, 2001.





SOILD
2, 67–84, 2015

Parisi, V., Menta, C., Gardi, C., Jacomini, C., and Mozzanica, E.: Microarthropod communities as a tool to assess soil quality and biodiversity: a new approach in Italy, Agr. Ecosyst. Environ., 105, 323–333, 2005.
Sequi, P. and De Nobili, M.: Carbonio organico, in: Metodi di Analisi Chimica del Suolo, edited by: Angeli, F., Ministero per le Politiche Agricole e Forestali, Osservatorio Nazionale Pedologico e per la Qualità del Suolo, VII.1, 1–13, 2000.
SPSS Inc.: SPSS ver. 13.0 – Advanced Model, SPSS Inc., Chicago, Illinois, 2004.
USDA: Soil Survey Division Staff, Soil survey manual, USDA Handbook No. 18, US Govt. Printing Office, Washington, DC, 1993.
Van Straalen, N. M.: Evaluation of bioindicator systems derived from soil arthropod communities, Appl. Soil Ecol., 9, 429–437, 1998.
Wardle, D. A.: Communities and Ecosystems: Linking the Aboveground and Belowground Components, Princeton Univertsity Press, New Jersey, 408 pp., 2002.





SOILD
2, 67–84, 2015

**Table 1.** Vineyard sampling sites.

| Site no. | Sampling site (farm/vineyard, location) | Vine variety | Crop management |
|---|---|---|---|
| 1 | Villa Achille, Costigliole D'asti (Asti) | Nebbiolo | organic |
| 2 | Villa Achille, Costigliole D'asti (Asti) | Nebbiolo | organic |
| 3 | Villa Achille, Costigliole D'asti (Asti) | Nebbiolo | organic |
| 4 | Vigna Bricco, Costigliole D'asti (Asti) | Barbera | organic |
| 5 | Isola Villa, Mongardino (Asti) | Barbera | organic |
| 6 | La Barla, Mongardino (Asti) | Barbera | organic |
| 7 | La Barla, Mongardino (Asti) | Barbera | organic |
| 8 | Az. Piana, Castelboglione (Asti) | Barbera | IPM |
| 9 | Az. Piana, Castelboglione (Asti) | Barbera | IPM |
| 10 | Cavallotto, Castiglione Falletto, (Cuneo) | Barbera | IPM |
| 11 | Cavallotto, Castiglione Falletto (Cuneo) | Nebbiolo | IPM |





SOILD
2, 67–84, 2015



E. Gagnarli et al.

**Table 2.** Mean values of soil characteristics in sampling sites.

| Site no. | Soil Texture (USDA, 1993) | TOC (%) | TN (%) | C / N | pH | CaCO3 (%) |
|---|---|---|---|---|---|---|
| 1 | loam | 0.95 | 0.10 | 9.5 | 7.4 | 30.5 |
| 2 | silty-clay-loam | 1.14 | 0.13 | 9.0 | 7.9 | 18.5 |
| 3 | silty-clay-loam | 1.12 | 0.12 | 9.7 | 7.9 | 25.5 |
| 4 | clay-loam | 1.90 | 0.19 | 10.3 | 7.9 | 24.1 |
| 5 | silty-clay-loam | 0.96 | 0.10 | 9.2 | 7.9 | 12.9 |
| 6 | silt-loam | 1.36 | 0.13 | 10.2 | 7.8 | 4.4 |
| 7 | silt-loam | 1.08 | 0.12 | 9.3 | 7.8 | 5.3 |
| 8 | silty-clay-loam | 1.08 | 0.13 | 8.7 | 7.9 | 26.7 |
| 9 | silty-clay-loam | 0.74 | 0.10 | 7.5 | 7.9 | 29.1 |
| 10 | clay-loam | 0.82 | 0.10 | 8.2 | 7.9 | 26.8 |
| 11 | loam | 0.94 | 0.10 | 9.0 | 7.9 | 52.2 |





SOILD
2, 67–84, 2015

**Table 3.** Abundance of the microarthropod groups in the eleven vineyard sites.

| | Abundance (N) in the organic managed vineyards | | | | | | | | Abundance (N) in the IPM vineyards | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| March 2011 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Total abundance (N) | 8 | 9 | 10 | 11 | Total abundance (N) |
| Acari | 98 | 88 | 61 | 115 | 85 | 68 | 52 | 567 | 32 | 22 | 38 | 28 | 120 |
| Collembola | 63 | 31 | 39 | 33 | 84 | 31 | 24 | 305 | 51 | 6 | 28 | 7 | 92 |
| Geophilomorpha | | | 1 | 1 | 1 | | 2 | 5 | 1 | | | | 1 |
| Coleoptera | | 1 | 2 | 1 | | | | 4 | | | | 1 | 1 |
| Diplura | | | | | 1 | 1 | 1 | 3 | | | | | |
| Diptera *larvae* | 2 | 3 | 1 | 4 | 1 | | 2 | 13 | | | 2 | 1 | 3 |
| Diptera | 1 | 4 | 3 | 4 | 2 | 4 | 1 | 19 | 5 | 2 | 1 | 8 | 16 |
| Rhynchota | | | | | 1 | 1 | | 2 | | | | | |
| Hymenoptera | | 17 | | | 44 | 1 | | 62 | | 23 | | | 23 |
| Olometabolic *larvae* | 7 | 5 | | 3 | 5 | | | 20 | 1 | 3 | 1 | | 5 |
| Homoptera | 1 | | | | | | | 1 | | | | | |
| Pauropoda | | 1 | 7 | 1 | 5 | 4 | | 18 | | | | | |
| Protura | 1 | 1 | 4 | 4 | 2 | 4 | | 16 | | | | | |
| Pseudoscorpionida | | 3 | 1 | | 1 | | | 5 | | | | | |
| Symphyla | 3 | 9 | 8 | | 13 | 1 | | 34 | 1 | | | 3 | 4 |
| Thysanoptera | 1 | 6 | 1 | | 3 | | | 11 | | | 1 | | 1 |
| May 2012 | | | | | | | | | | | | | |
| Blattodea | | | | | | 1 | | 1 | | | | | |
| Geophilomorpha | | 2 | | | | | | 2 | | | 2 | 2 | 4 |
| Coleoptera | | | | | | 1 | | 1 | | | 1 | 3 | 4 |
| Julida | | | | | 1 | | | 1 | 1 | | | | 1 |
| Diplura | | | 3 | | 4 | 1 | 3 | 11 | | | | 3 | 3 |
| Diptera *larvae* | | 1 | | 2 | 2 | 1 | 1 | 7 | | | | | |
| Diptera | | 1 | | 11 | 2 | 1 | | 15 | | | | | |
| Rhynchota | | | | 2 | 3 | 3 | 2 | 10 | 3 | 24 | 10 | | 37 |
| Hymenoptera | 2 | 1 | | 11 | 4 | 11 | 2 | 31 | 1 | 12 | | 1 | 14 |
| Isopoda | | | | | | | | | 1 | | | | 1 |
| Olometabolic *larvae* | | 7 | | 9 | 7 | 2 | 2 | 27 | | | 39 | 2 | 41 |
| Lepidoptera | | | | | | 1 | | 1 | | | | | |
| Homoptera | | | | 4 | | 2 | | 6 | | 1 | | | 1 |
| Pauropoda | 1 | 6 | 6 | 5 | 3 | 2 | | 23 | 4 | | 2 | 1 | 7 |
| Protura | | | | | | 1 | | 1 | | | | 1 | 1 |
| Pseudoscorpionida | | 7 | 2 | | | 7 | | 16 | | 1 | | | 1 |
| Psocoptera | | | | 2 | | | | 2 | 1 | | | | 1 |
| Symphyla | 1 | 4 | 7 | 4 | 10 | 6 | 16 | 48 | 3 | | | 2 | 5 |
| Thysanoptera | 3 | | 2 | 1 | | 1 | | 7 | 1 | | 1 | | 2 |
| Acari | 103 | 157 | 133 | 320 | 183 | 169 | 161 | 1226 | 124 | 150 | 83 | 79 | 436 |
| Collembola | 46 | 112 | 102 | 199 | 63 | 57 | 123 | 702 | 67 | 53 | 69 | 44 | 233 |





SOILD
2, 67–84, 2015

**Table 4.** Soil microarthropod taxa, Ecomorphological Index (EMI) and QBS-ar values for each sampling time and management. Values with different letters within each row were significantly different (Mann–Whitney $U$ test, $p < 0.05$).

| | March | | May | |
|---|---|---|---|---|
| | Organic | IPM | Organic | IPM |
| Acari | 20 | 20 | 20 | 20 |
| Collembola | 20 | 20 | 20 | 20 |
| Blattaria | | | 5 | |
| Chilopoda | 10 | 10 | 10 | 20 |
| Coleoptera | 20 | 1 | 1 | 1 |
| Diplopoda | | | 10 | |
| Diplura | 20 | | 20 | 20 |
| Diptera (l.) | 10 | 10 | 10 | |
| Diptera | 1 | 1 | 1 | |
| Rhynchota | 1 | | 1 | 1 |
| Hymenoptera | 5 | 5 | 5 | 5 |
| Isopoda | | | | |
| Olometabola (l.) | 10 | 10 | 10 | 10 |
| Olometabola | | | 1 | |
| Homoptera | 1 | | 5 | 5 |
| Pauropoda | 20 | | 20 | 20 |
| Protura | 20 | | 20 | 20 |
| Pseudoscopionida | 20 | | 20 | 20 |
| Psocoptera | | | 5 | 5 |
| Simphyla | 20 | 20 | 20 | 20 |
| Tisanoptera | 1 | 1 | 1 | 1 |
| QBS-ar | 199a | 98b | 205a | 188a |
| Taxa richness | 16 | 10 | 20 | 17 |
| QBS-ar classes | VI | IV | VII | VI |





SOILD
2, 67–84, 2015

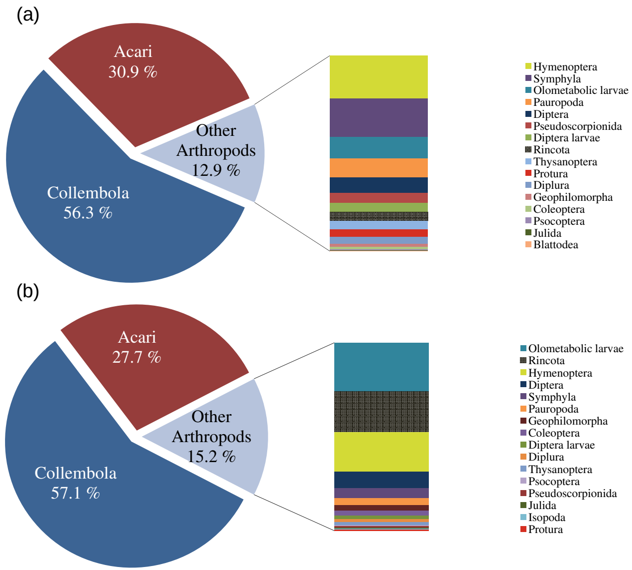


**Figure 1.** Community structure of three main soil microarthropod groups (Acari, Collembola, Other Artropods) in the different agronomic management, **(a)** Organic, **(b)** IPM. The composition of the "Other Artropods" group is detailed: epiedaphic (Rincota, Thysanoptera, Diptera, Psocoptera, Blattoidea), emiedaphic (Hymenoptera, olometabolic larvae, Diptera larvae, Geophilomorpha, Julida, Isopoda, Homoptera) and euedaphic forms (Symphyla, Pauropoda, Pseudoscorpionida, Coleoptera, Protura, Diplura).





SOILD
2, 67–84, 2015
Study of microarthropod communities
E. Gagnarli et al.

Title Page
Abstract Introduction
Conclusions References
Tables Figures
◂ ▸
Back Close
Full Screen / Esc
Printer-friendly Version
Interactive Discussion

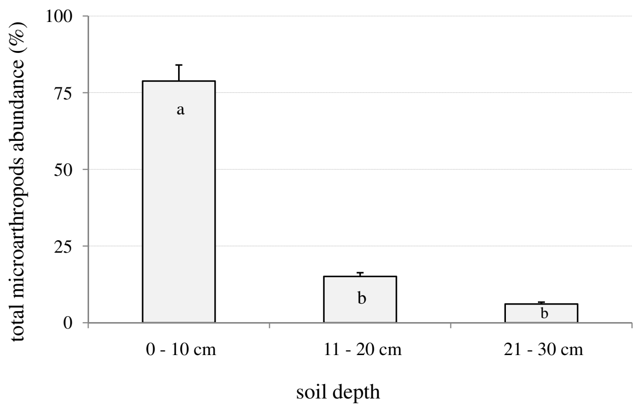


**Figure 2.** Microarthropod total abundance at three soil sampling depths (ANOVA, Tukey test, $P < 0.001$).

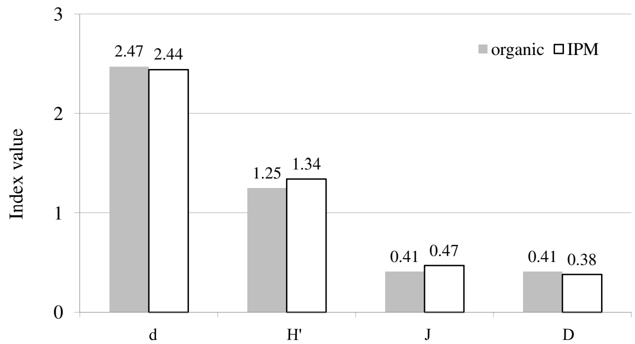


**Figure 3.** Biodiversity indices under the different vineyard managements: Margalef index ($d$), Shannon-Weaver ($H'$), Pielou index ($J$), Simpson index ($D$).





SOILD
2, 67–84, 2015

Study of microarthropod communities

E. Gagnarli et al.