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

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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 and the determination of community structures of edaphic fauna can represent an efficient tool. In Langhe area (Piedmont, Italy), eight vineyards characterized for physical and chemical characteristics (soil texture, soil pH, total organic carbon, total nitrogen, calcium carbonate) were selected. We evaluated the effect of crop managements, organic and integrated-pest management (IPM), on abundance and biodiversity of microarthropods living at the soil surface. Soil samplings were carried out in winter 2011 and spring 2012. All specimens were counted and determined up to the order level. The biodiversity analysis was determined by ecological indexes (Taxa richness, Dominance, Shannon-Wiener, Buzas and Gibson's evenness, Margalef, Equitability, Berger-Parker). The biological soil quality was assessed by BSQar index.

The mesofauna abundance was affected by both the type of management and sampling time. On the whole, a higher abundance was in organic vineyards (N=1981) than in IPM ones (N=1062). The analysis performed by ecological indexes showed a quite high level of biodiversity in this environment, particularly on May 2012. The BSQar values registered were similar to those obtained in preserved soils and on step with animal.

Key words: BSQ-ar, diversity indices, mesofauna, organic viticulture, IPM vineyard.

1 Introduction

The functioning of terrestrial ecosystems depends on the relationships between above- and belowground food webs, and on transfers of biotic components of the decomposer subsystem to aboveground consumers connect the two subsystems (Kardol et al., 2011; Wardle et al., 2004).

Soil quality characteristics such as stability, resilience to disturbance or stress and biodiversity (van Bruggen and Semenov, 2000) are directly influenced by land use and management practices (DeFries et al., 2004). The soil quality assessment is a complex issue depending on the combination of all physical, chemical and biological properties.

The capability of a soil to sustain biological productivity meanwhile maintaining environmental equilibrium, cannot be directly measured; however, it can be assessed through indicators based on biological components of soil that need of standardization and suitable databases. Compared with forestry, there is generally less agreement about how the relationship 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 development of agroecological technologies and systems which emphasize the conservation/regeneration of biodiversity, soil, water and other resources, is urgently needed to meet the growing array of socioeconomic and environmental challenges (Altieri, 1999; Lavelle, 2000). European politics for sustainable agronomic managements have been implemented but they need to be evaluated for their efficiency (Chikoski et al, 2006; Herzog, 2005).

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 an agricultural context, the combination of productive goals and sustainable land uses protecting both soil and biodiversity, is essential in order to prevent the decline of soil fauna communities (Menta et al., 2011). Enhancing biodiversity in agroecosystems is a key ecological strategy to make sustainable productions.

Farming practices such as ploughing, chemical fertilisation and pesticide application can affect soil quality by modifying soil characteristics (Mazzoncini et al., 2010). Therefore, soil quality can be assessed by physical, chemical and microbiological properties of soil together with the abundance and diversity of edaphic fauna (nematodes, Acari, Collembola, Symphyla, Chilopoda, Pauropoda, enchytraeids, earthworms); furthermore, the determination of community structure adds significant informations on the soil status (Cole et al., 2006; De Goede and Brussard, 2002; Duelli and Orbist, 2003; Menta et al., 2008; van Straalen, 1998; Yan et al., 2012). In a well-balanced soil, mesofauna is highly biodiversified and occupy all trophic levels within the soil food webs (Ruf et al., 2006). Therefore, the loss of mesofauna diversity is a negative consequence on soil biota, since it is involved in fundamental ecosystem services as nutrient cyclings (Gardi et al. 2008; Narula et al., 1996). 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 but need further studies (Maraun and Scheu, 2000).

Soil microarthropods, as litter transformers, improve soil quality and affect the soil structural properties (porosity, aeration, infiltration and distribution of organic matter in soil horizons) (Bird et al. 2004; Culliney, 2013). They are concentrated in the litter layers and upper horizons of the soil and their abundance and distribution are highly dependent on individual tolerance limits to environmental conditions (Chikoski et al., 2006; Faber and Verhoef, 1991). Microarthopods are useful models as they are both taxonomically and ecologically highly diversified; particularly, euedaphic forms are unable to survive abrupt variations due to the disturbances caused, for example, by agricultural cultivation and trampling (Parisi et al., 2005; Menta, 2012).

The literature suggests that organically managed fields contain a greater abundance and diversity of arthropods than conventionally managed fields (Berry et al., 1996; Hole et al., 2005; Pimentel et al., 2005; Reddersen, 1997) and that changing from conventional to organic farming leads to a gradual increase in biodiversity (van Diepeningen et al., 2005).

The aim of this study was to determine the effect of management practices in experimental vineyards, by comparing organic and IPM managements, on soil microarthopods community structure and composition before and after treatments. We hypothesized that management may affect the abundance (total numbers of individuals), richness (total numbers of taxa (eco-morphological group), diversity and quality indexes of all soil microarthropods.

2 Material and methods

2.1 Study sites' description

The study was carried out in the North-West of Italy, in Piedmont, in Central Tanaro river area (Table 1A). This hilly area is characterized by marls, clays and sands, and almost entirely devoted to the production of high quality wines, in particular Barbera. The sampled vineyards are located in a triangle area with 20 km maximum distance between the vineyards' locations. According to the georeferenced soil database for Europe, the climatic classification of this area is Mediterranean suboceanic to subcontinental (TM3) (Costantini et al., 2013): this is characterized by a degree of continentality - a rather high temperature difference between summer and winter and a quite regular precipitation pattern - typifying Po Plain and adjacent low hills relatively warmer than the other climates of northern Italy. On the whole, although the various micro-climates determined by the hills and valleys of the Langhe are influenced by the continental climate of the entire area, the values of the average annual temperature of all places lowland (below 300 m above sea level) are similar (see Table 1B), in the 12-14°C range (CREST, 2006). The relatively warm temperature and the rainfall pattern enhance weathering of the soil parent materials; therefore, on stable morphological positions, neogenetic clay can accumulate in depth and Luvisols dominate the soilscape (Costantini et al., 2013). In this area, eight vineyards were selected, four under organic management for ten years and four under Integrated Pest Management (IPM), respectively. All the vineyards were selected in areas characterized by the similar range of soil texture features (loam, silty-clay-loam and clay-loam) on the basis of previous soil analysis (personal communication by farms' owners). Furthermore, other chemical/ physical properties were determined (Table 2). The considered vineyards were a few kilometres distant from each other and were similar in accordance with the major physiographic characteristics (slope, orientation, approximate size, soil type). The organic vineyards selected were cultivated without herbicide and synthetic pesticides; they were treated with tribasic copper sulphate (15.2%), pure sulfur (wettable powder). Sulfur (powder) was widely used to control powdery mildew on grapes. In each organic farm, agronomic practices were no-tillage, yearly spadework intra-row and mowing of grass.

Integrated Pest Management vineyards were treated with: anti-downy mildew fungicides as Metiram (three times), Metiram plus Systemic (three times), Copper hydroxide and Bordeaux mixture (Copper Sulphate and Lime) (four times); anti-powdery mildew fungicides including Sulfur (powder), Tebuconazole (twice) and wettable powder sulfur; with anti-botritys fungicides as a formulation with cyprodinil (37.5%) and fludioxonil (25%); with insecticides as clorpyriphos-methil (twice) and Pyrethroids. On soil along the row, as herbicide, glyphosate was used (once a year); in 2012, the second year of study, no herbicide was applied in CSF_i3 and CSF_i4. Agricultural machinery and minimum tillage were also applied.

2.2 Soil sampling and processing

Soil samples for the study of microarthropods were carried out in late winter 2011 and spring 2012. In each site, one plot (10m x 25m) was selected in the inner area of the vineyard to minimize edge effects. Three samples per plot were collected along a linear transect between rows at about 40 cm from the plant. Sample cores were obtained using a drill corer (3 cm diameter, 30 cm depth). Close to these samples for the study of mesofauna, equivalent soil cores were taken for chemical analysis in 2011. The samples for microarthropods extraction were air-dried and, then, sieved (2 mm mesh size) in the Berlese-Tullgren funnels. All specimens were counted and determined up to the order level.

The samples collected for determination of abiotic parameters were homogeneized for each vineyard. Soil texture was determined by the X-ray attenuation method according to the procedure described by Andrenelli et al. (2013), using a Micromeritics SediGraph apparatus. The procedure provides pipette-equivalent results. Soil pH was determined potentiometrically, in a 1:2.5 soil:water suspension. Soil total organic carbon (TOC) and total nitrogen (TN) were determined by dry combustion, using a Thermo Flash 2000 CN analyzer. Each soil sample was analyzed two times separately: 60–70 mg soil were weighed into Sn capsules and analyzed for total C (organic + mineral C) and total N contents; 20–30 mg soil were weighed into Ag capsules, treated with 10 % HCl until complete removal of carbonates and then analyzed for total C content (organic C). The difference in the C content between the untreated and the HCl-treated soil was used to assess the total equivalent CaCO3 content (Sequi and De Nobili, 2000).

2.3 Data and biodiversity analysis

The influence of management and soil sampling was evaluated on the density of mesofauna by means of Analysis of Variance (ANOVA). In the present study, the biological soil quality was defined through qualitative and quantitative indices. The ecological quali-quantitative indices, calculated for each management in spring and autumn samples, were the following (see Harper, 1999; Krebs, 1989): Taxa richness (*S*), Abundance (*N*), Dominance (D) (Dominance=1-Simpson index), ranging from 0 (all taxa are equally present) to 1 (one taxon dominates the community completely); *H*: Shannon-Wiener index taking into account the number of individuals as well as number of taxa, varying from 0 for communities with only a single taxon to high values for communities with many taxa, each with few individuals; *E*: Buzas and Gibson's index measuring the evenness in the communities; I_{Marg} : Margalef index that measures number of species present for a given number of individuals; J: Equitability index measuring the evenness with which individuals are divided among the taxa present; d: Berger-Parker, dominance indicating the number of individuals in the dominant taxon.

Biological quality of soil was evaluated by BSQ-ar index (Parisi, 2001). The BSQ-ar index is based on direct correlation between the quality of soil and the number of microarthropods adapted to the soil habitat. It 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-Morphologically Index) ranging from 1 to 20, on the basis of its edaphic adaptation level. The sum of EMIs gives the global value of BSQ-ar index. The biological soil quality was characterized on the basis of D'Avino (2002) classification and the values were compared by the Mann-Whitney test.

The statistics concerning the calculation and comparisons of the biodiversity indexes were performed by PAST (2013) Program (Hammer et al., 2001). All the other statistical analysis were performed by the SPSS statistical program (SPSS, 2004).

3 Results

3.1 Soil microarthropods' abundance

The climate data for air temperature and rainfall registered in the three locations for 120 days before the samplings are reported in Figure 1. During the considered periods, the daily mean temperatures were quite similar in the different localities with values around 3°C in the period December 2010 - March 2011 and around 10°C in the period January – May 2012. Regarding rainfall, on the whole, very similar values were registered in 2010-2011, with a cumulative rainfall of about 300 mm; in 2012, the cumulative rainfall registered was less homogeneous and the highest amount was registered in the CSB area.

The soil characteristics of studied sites are reported in Table 2. The different vineyard soils had quite homogeneous texture, ranging from medium (loam) to moderately fine (clay loam and silty clay loam). Soil TOC content was generally medium, scarce in CSB_i2, CSF_i3 and high in CSA_o3. TN content was the highest in CSA_o3. Soil pH ranged from slightly to moderately alkaline. Total $CaCO_3$ content showed wide variability, from extremely calcareous (CSF_i4) to weakly calcareous (CSA_o4) (Costantini, 2009).

On the whole, the abundance of microarthropods was higher in the organic vineyards than in IPM ones, with about 2:1 ratio and the mesofauna density was considerably affected by both sampling time ($F_{1,45}$ = 15.02; P=0.000) and management ($F_{1,45}$ = 11.01; P=0.002). The density of microarthropods registered in May 2012 was higher than that registered in March 2011 (t-test = 3.51, df = 46, P=0.001). Overall, the organically managed vineyards had a higher density than the IPM ones (t-test = 2.91, df = 46, P=0.006).

The figure 2 shows the total soil microarthropods' density registered in the different samplings. In 2011, a higher density was registered in the organic vineyards (t-test = 4.38, df = 22, P=0.000). In 2012, no difference was in density (t-test = 1.79, df = 22, P=0.09).

The community structure of the soil microartropods in the different seasons is reported in Table 3. The distribution of the three main animal groups (Acari, Collembola, Other Arthropods) did not show any substantial difference depending on management. The mites represented about 50% of the total arthropodofauna recorded, collembolans about 30%, and other microarthropods about 20%. The group of the other arthropods was represented by epiedaphic (Rincota, Thysanoptera, Diptera, Psocoptera, Blattoidea), hemiedaphic (Hymenoptera, olometabolic larvae, Diptera larvae, Geophilomorpha, Julida, Isopoda, Homoptera) and euedaphic forms (Symphyla, Pauropoda, Pseudoscorpionida, Coleoptera, Protura, Diplura).

3.2 Soil Microarthropods' biodiversity

The biodiversity indexes and their comparisons are reported in Table 4. In March 2011, the Taxa richness was higher in the organically managed vineyards; the Margalef index denoted a higher variation in soil samples from the organic vineyards while a higher Evennes (E= 0.39) was registered in the IPM vineyards. In May 2012, the same numbers of Taxa was registered in organic and in IPM vineyards but Dominance (D=0.45) was higher in organic ones: this was due to the presence of one or two groups mainly represented in the community of arthropods; a different and quite homogeneous distribution in the structure of population from IPM vineyards determined higher values of Shannon-Wiener (H=1.27) and Equitability index (J = 0.44);

The BSQ-ar index was higher in the organic than in the IPM managed vineyards in March 2011 (Mann-Whitney, U=1332 P=0.000) (Table 5); there was no difference in May 2012, (Mann-Whitney, U=2721 P=0.6).

In Figure 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

On the whole, several studies report about comparison in biodiversity between organic and -conventional fields/crops by indicating a greater abundance and diversity of arthropods in organic ones (e.g. Hole et al., 2005; Kromp, 1990; Liebig et al., 1999; Reddersen, 1997). Less data and evidences are available in the evaluation of the artropod biodiversity to compare organic and IPM managements (Landi et al., 2014; Todd et al., 2015). The organic and integrated systems showed higher soil quality and potentially lower negative environmental impact than the conventional system (Mazzoncini et al., 2010; Reganold et al., 2001).

In the present study case, in vineyard, the effect of organic and IPM managements on soil quality was evaluated through the characterization of the entire microarthropod community living on soil surface. The total abundance and biodiversity of microarthopods were higher in the organically managed vineyards than the IPM ones only in March 2011. Some factors may have contributed to this evidence. Compared to the organic management, which was based on no-tillage allowing natural grass to cover the vineyard floor over the whole year, IPM may have resulted in higher soil disturbance due to the tillage treatment performed at the beginning of Winter, which can explain the lower collembolan population (Heisler, 1991).

The aereal treatments applied on vine plants in the different managed vineyards, did not seem to affect the soil mesofauna as registered by Iannotta et al. (2005) on olive groves. On the contrary, the suppression of the herbicide (glyphosate formulations) application, in IPM fields in 2012, appeared to benefit the organisms living in the topsoil; this was observed by Gomez and Sagardoy (1985) and by Renaud et al. (2004) on springtails.

In addition, the difference registered in 2011 and 2012 in the total abundance could be affected by climatic data registered in the previous sampling periods and natural seasonal fluctuations in soil microarthropods (Culliney, 2013; Narula et al. 1996). In 2011, after a general stability of the first two months, March was very rainy. As example, the number of springtails is affected by optimal habitat and their populations arise after rainfalls (Badejo et al.,1998; Costantini et al., 2015; Schaefer, 1995).

The 2012 was the third warmest year of the last 55 years, but in the first half of February, Piedmont was affected by an exceptional cold spell while an average deficit of 8% the rainfall was observed with (ARPA Piemonte 2012).

Concerning the biodiversity analysis, the higher dominance in May 2012 in organic vineyards than IPM ones was due to mite and springtail populations: these groups represented 91% of the total microarthropods collected. On the whole, within Acari, the oribatid mites were the most represented with about 2:1 ratio (Organic *vs* IPM). This evidence seems according to those registered by several authors that consider the Oribatid mites as good bioindicator as their community structure can be significantly affected by several levels of disturbance (Behan-Pelletier, 1999; Caruso and Migliorini, 2006)

The biodiversity indexes registered in 2011, in particular the Margalef Index, were affected by the difference in Taxa richness. In organic vineyards, there was registered a conspicuous presence of euedaphic groups such as pseudoscorpions, Protura, Diplura, springtails, mites, small myriapods (Pauropoda and Symphyla). In 2012, it was registered the same number of Taxa Richness in the different managements. However, the relative frequency in each taxon determined higher values in Shannon-Wiener and Equitability indexes in IPM vineyards.

The BSQar values were consistent with the total microarthropod abundance.

The biological quality of the soil was very high in the organic vineyards of Costigliole d'Asti area. These soils can be ascribed to high biological classes (VI), similar to those registered in undisturbed and forestal soils (Parisi et al., 2005). Miani et al. (2005) found similar evidences with BSQar values higher (about 20%) in organic vineyards than the values registered in conventionally managed ones.

In this case study, IPM management seemed to have no long lasting effect on the soil biota: in a short time scale, high BSQar indexes were registered by denoting that these soils are still resilient and show quick microarthropod recolonization. Biodiversity plays a fundamental role in the capacity of the soil to recover its initial situation after a natural or human perturbation (Spratt, 1997). The presence of some euedaphic 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).

The BSQar index confirmed to return quite efficient reading to allow comparisons with other situations and it was in step with the information acquired from the study on abundance. 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/works) well adapted to soil habitat, is highly advisable the evaluation of euedaphic forms present at deeper sampling range or by studying the vertical migration of microarthropods.

By perspective, the attention should be moved from the monitoring method to the evaluation at which extent the processes determined by microarthropods can affect the plant's physiological and productive status. The effects of soil biodiversity on vegetation dynamics operate through a variety of biotic interactions, among them the changing interactions between plants and their below- and above-ground multitrophic communities (Bardgett and van der Putten, 2014).

These kinds of evidences can be integrated in the microarthropods'studies addressing spatial and temporal partitioning, population dynamics, taxon-specific or functional groups. As soil arthropods include a wide 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 close integrating other parameters (e.g. soil physic-chemical conditions, bioavailability).

Further researches are needed to establish more quantitative relationships between specific groups, especially among arthropods, to better understand the roles of soil fauna in C and N cycles and crucially developing such ecological–economic links to assess the effects of agricultural systems on specific, measurable properties that are important indicators of sustainability.

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Table 1. A) Vineyard sampling sites' description. B) Yearly mean temperature and rain registered in the three vineyards' sites.

A)

Sampling site (farm/ vineyard, site, province)	**Abbreviation**	**GPS coordinates**	**Vine variety**	**Agricultural management**
Villa Achille, Costigliole d'Asti (Asti)	CSA_o1	44° 47' 21.757" N 8° 9' 51.651" E	Nebbiolo	organic
Villa Achille, Costigliole d'Asti (Asti)	CSA_o2	44° 47' 22.031" N 8° 9' 53.505" E	Nebbiolo	organic
Vigna Bricco, Costigliole d'Asti (Asti)	CSA_o3	44° 47' 12.157" N 8° 11' 12.134" E	Barbera	organic
Isola Villa, Mongardino (Asti)	CSA_o4	44° 49' 59.306" N 8° 11' 24.362" E	Barbera	organic
Az. Piana, Castelboglione (Asti)	CSB_i1	44° 43' 24.912" N 8° 22' 39.950" E	Barbera	IPM
Az. Piana, Castelboglione (Asti)	CSB_i2	44° 43' 25.241" N 8° 22' 38.212" E	Barbera	IPM
Cavallotto, Castiglion Falletto, (Cuneo)	CSF_i3	44° 37' 14.514" N 7° 58' 40.544" E	Barbera	IPM
Cavallotto, Castiglion Falletto (Cuneo)	CSF_i4	44° 37' 17.262" N 7° 58' 40.814" E	Nebbiolo	IPM

B)

		Costigliole d'Asti (CSA)	Castelboglione (CSB)	Castiglion Falletto (CSF)
Temperature (°C)	2010	12.5	12.4	12.2
	2011	13.7	14.4	13.9
	2012	13.3	11.6	13.8
Cumulative rain (mm)	2010	881.7	715.8	757.0
	2011	540.0	733.4	506.0
	2012	589.0	448.8	543.2

Table 2. Soil physical and chemical parameters of the investigated vineyard sites (March 2011)

	Textural class (USDA,1993)	TOC (%)	TN (%)	C/N	pH	$CaCO_3$ (%)
CSA_o1	Loam (L)	0.95	0.10	9.5	7.4	30.5
CSA_o2	silty clay loam (SCL)	1.12	0.12	9.7	7.9	25.5
CSA_o3	clay loam (CL)	1.90	0.19	10.3	7.9	24.1
CSA_o4	silty clay loam (SCL)	0.96	0.10	9.2	7.9	12.9
CSB_i1	silty clay loam (SCL)	1.08	0.13	8.7	7.9	26.7
CSB_i2	silty clay loam (SCL)	0.74	0.10	7.5	7.9	29.1
CSF_i3	clay loam (CL)	0.82	0.10	8.2	7.9	26.8
CSF_i4	Loam (L)	0.94	0.10	9.0	7.9	52.2

Table 3 - Community structure of the soil microarthropods (N) (biological forms as morpho-types adapted to soil) (Parisi et al., 2005) at different sampling times and in the eight vineyard sites.

March 2011	CSA_o1	CSA_o2	CSA_o3	CSA_o4	Organic	CSB_i1	CSB_i2	CSF_i3	CSF_i4	IPM	Total Abundance (N)
Acari	98	61	115	85	359	32	22	38	28	120	479
Collembola	63	39	33	84	219	51	6	28	7	92	311
Chilopoda		1	1	1	3	1				1	4
Coleoptera		2	1		3				1	1	4
Diplura				1	1					0	1
Diptera larvae	2	1	4	1	8			2	1	3	11
Diptera	1	3	4	2	10	5	2	1	8	16	26
Rincota				1	1					0	1
Hymenoptera				44	44		23			23	67
Coleoptera larvae	7		3	5	15	1	3	1		5	20
Homoptera	1				1					0	1
Pauropoda		7	1	5	13					0	13
Protura	1	4	4	2	11					0	11
Pseudoscopionida		1		1	2					0	2
Symphyla	3	8		13	24	1			3	4	33
Thysanoptera	1	1		3	5			1		1	6
Total (N)	177	128	166	248	719	91	56	71	48	266	985

May 2012	CSA_o1	CSA_o2	CSA_o3	CSA_o4	Organic	CSB_i1	CSB_i2	CSB_i3	CSB_i4	IPM	Total Abundance (N)
Acari	103	133	320	183	739	124	103	133	79	439	1178
Collembola	46	102	199	63	410	67	30	93	44	234	644
Chilopoda					0			2	2	4	4
Coleoptera			1		1			1	3	4	5
Diplopoda				1	1	1				1	2
Diplura		3		4	7				3	3	10
Diptera larvae			2	2	4					0	4
Diptera			11	2	13					0	13
Rincota			1	2	3	3	24	10		37	40
Hymenoptera	2		11	3	16	1	12		1	14	30
Isopoda				1	1	1				1	2
Coleoptera larvae			9	7	16			39	2	41	57
Homoptera			5		5		1			1	6
Pauropoda		6	5	3	14	4		2	1	7	21
Protura					0				1	1	1
Pseudoscopionida		2			2		1			1	3
Psocoptera			2		2	1				1	3
Symphyla	1	7	4	10	22	3			2	5	27
Thysanoptera	3	2	1		6	1		1		2	8
Total (N)	155	255	571	281	1262	206	171	281	138	796	2058

Table 4. Taxa richness (*S*), Abundance (*N*), and biodiversity index values (*D*: Dominance; *H*: Shannon-Wiener; *E*: Buzas and Gibson's evenness; I_{Marg}: Margalef; *J*: Equitability; *d*: Berger-Parker) for each management in spring and autumn samples.

	March 2011			May 2012		
	Organic	IPM	Boot p(eq)	Organic	IPM	Boot p(eq)
S	16	10	0.02*	17	17	1
N	719	266	0	1262	796	0
D	0.35	0.34	0.58	0.45	0.40	<0.01**
H	1.44	1.36	0.33	1.10	1.27	<0.01**
E	0.26	0.39	0.04*	0.18	0.21	0.22
I_{Marg}	2.28	1.62	0.02*	2.24	2.34	0.49
J	0.52	0.59	0.13	0.39	0.44	0.01**
d	0.49	0.45	0.15	0.59	0.55	0.13

Table 5. Soil microarthropods taxa, Eco-morphological Index (EMI) and QBS-ar values for each sampling time and management. Values with different letters within each row were different (Mann-Whitney *U* test, *P*<0.05).

	March 2011										May 2012									
	Organic					IPM					Organic					IPM				
	CSA_o1	CSA_o2	CSA_o3	CSA_o4	EMI value	CSB_i1	CSB_i2	CSF_i3	CSF_i4	EMI value	CSA_o1	CSA_o2	CSA_o3	CSA_o4	EMI value	CSB_i1	CSB_i2	CSF_i3	CSF_i4	EMI value
Acari	20	20	20	20	**20**	20	20	20	20	**20**	20	20	20	20	**20**	20	20	20	20	**20**
Collembola	20	20	20	20	**20**	20	20	20	20	**20**	20	20	20	20	**20**	20	20	20	20	**20**
Chilopoda		10	10	10	**10**	10				**10**								10	10	**10**
Coleoptera		20	6		**20**				1	**1**			20		**20**			1	1	**1**
Diplopoda														10	**10**	10				**10**
Diplura				20	**20**							20		20	**20**				20	**20**
Diptera larvae	10	10	10	10	**10**			10	10	**10**			10	10	**10**					
Diptera	1	1	1	1	**1**	1	1	1	1	**1**			1	1	**1**					
Rincota				1	**1**								1	1	**1**	1	1	1		**1**
Hymenoptera				5	**5**		5			**5**	5		5	5	**5**	5	5		5	**5**
Isopoda														10	**10**	10				**10**
Coleoptera larvae	10	10	10	10	**10**	10	10	10		**10**			10	10	**10**			10	10	**10**
Homoptera	5				**5**								5		**5**		1			**1**
Pauropoda		20	20	20	**20**							20	20	20	**20**	20		20	20	**20**
Protura	20	20	20	20	**20**														20	**20**
Pseudoscopionida		20		20	**20**							20			**20**		20			**20**
Psocoptera													1		**1**	1				**1**
Symphyla	20	20		20	**20**	20			20	**20**	20	20	20	20	**20**	20			20	**20**
Thysanoptera	1	1		1	**1**			1		**1**	1	1	1		**1**	1		1		**1**
QBS	107	172	117	178	**203a**	81	56	62	72	**98b**	66	121	134	147	**194a**	108	67	83	146	**190a**
n taxa	9	12	9	14	**16**	6	5	6	6	**10**	5	7	13	12	**17**	10	6	8	10	**17**
Class	VI	VI	VI	VI	**VII**	IV	III	III	IV	**IV**	IV	VI	VI	VI	**VI**	VI	IV	IV	VI	**VI**

m

Figure 1 - Temperature (lines) and rainfall (bars) measured in the three vineyards' sites (CSA, CSB, CSF) for 120 days before the soil sampings in 2010-2011 (A) and 2012 (B) in .

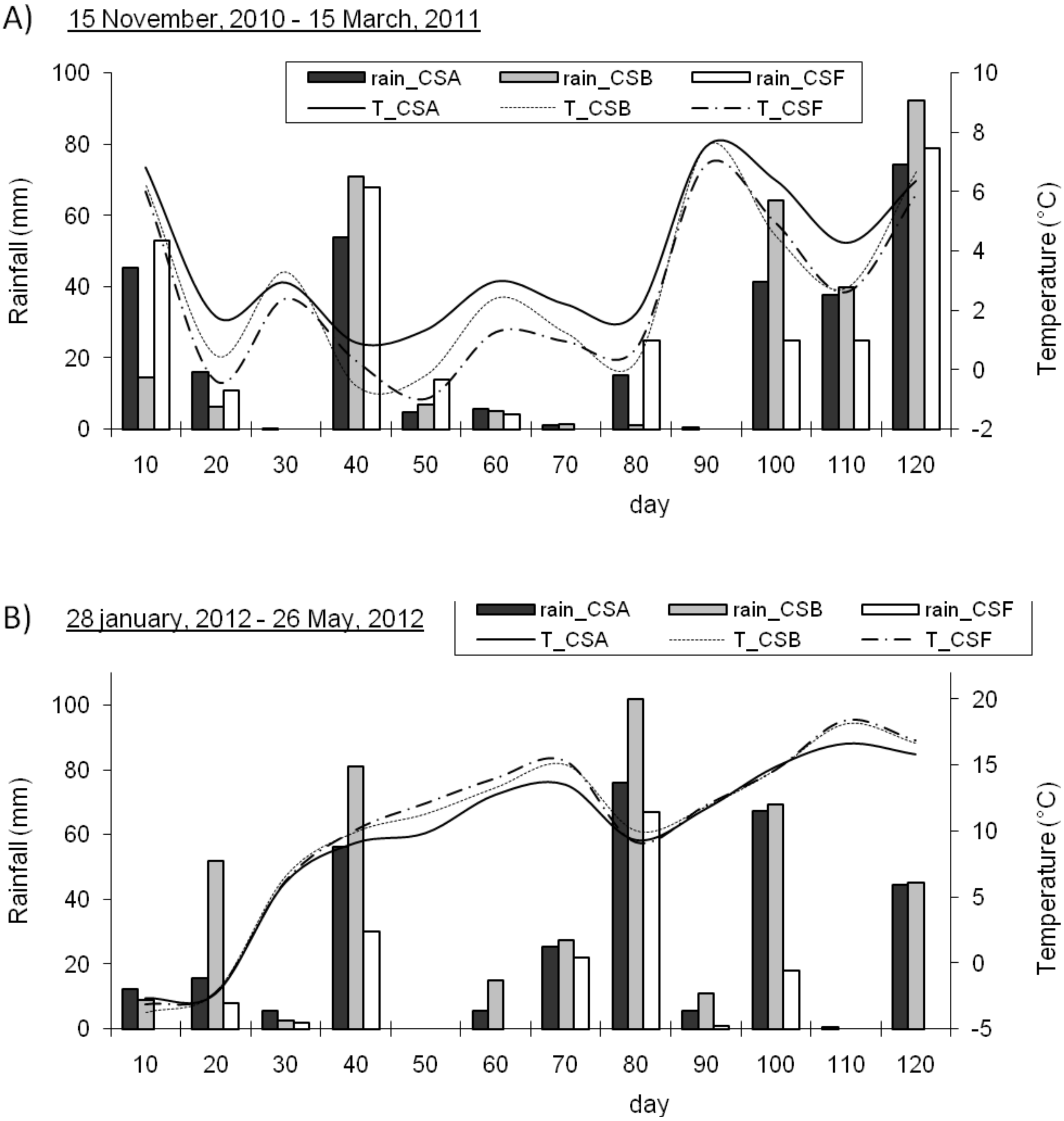

Figure 2 – Density of soil microarthropods measured as means (± SE) of individuals, (N)/ 1 dm^3 soil volume, determined for management and data sampling. Within the year, different letters indicate significance in the values‘ comparison (t-test, P<0.05)