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Does green manuring positively affect the soil macro-invertebrates in vineyards? A case study from Kaltern/ Caldaro (South Tyrol, Italy)

Abstract

In the last decades, low permanent cover crops were established in vineyard alleyways to facilitate management. However, a consequence was the decline of flora and fauna diversity. Green manuring by seeding flowering plants and mulching them into the soil represents an alternative. Here we hypothesize that green manuring positively affects the soil macro-invertebrate communities.

The vineyard alleyways were managed with following four treatments: permanent cover crop (PCC) and green manuring as control (GMC), as well as activated (cow horn manure, GMA), and with slurry (GMS). Soil macro-invertebrates were obtained from pitfall traps and soil core samples. Additionally, 11 soil properties were measured.

The treatments differ only in two soil properties (i.e. potassium and ammonia). However, we found significant differences in the soil macro-invertebrate communities, with GM treatments harbouring more rare and unique Araneae and Coleoptera species which represent 45.07 % of all taxa (vs. 18.75 % in PCC).

Here we present one of few existing studies investigating soil macro-invertebrates in vineyards. We were able to record and confirm rare Araneae and Coleoptera species, with two new Coleoptera species records for South Tyrol. Green manuring seems to considerably increase the biodiversity of ground-living invertebrates, and even facilitates the preservation of soil fertility. Finally, we assume that a certain amount of plant-associated species such as phytophagous Coleoptera was not covered by our sampling methods.

Keywords: vineyard alleyways, soil macrofauna, new records, Coleoptera, Araneae

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Introduction

In grapevine research cover crops and mulching has recently been studied more intensively than soil cultivation and herbicide use (Guerra & Steenwerth 2012). This fact highlights the trend towards grape growing without herbicides and adopting more sustainable production techniques. Cultivating cover crops in vineyards is practiced in areas with sufficient rainfall to prevent excessive water supply and nitrogen availability to the vines (Pou et al. 2011, Rotaru et al. 2011).

In South Tyrol, the northernmost province of Italy, with a yearly mean rainfall of 810 mm, a common practise over the last 40 years has been to apply mixtures of low growing perennial grass species in the alleyways adapted to mulching and chemical weed control in the under-vine area. These mechanical and chemical measurements severely reduced the diversity of the vineyard inhabiting plants, since only species not affected by frequent mulching survive in the alleyways between the vine rows (Bruggisser et al. 2013). Reduced mineral fertilization as well as enforcement of herbicide bans in many wineries during the last years have led to an increased competition between mulch adapted crops and grapevines. To avoid negative effects of the increased nutrient and water competition, an alternative solution would be to grow cover crops in the form

of green manure. These crops, consisting mainly in a mix of cereals and legumes, are sown after the grape harvest in late autumn and germinate in spring, when grapevines are still dormant. Before grape water stress occurs during summer time, the manure crops are ploughed or mulched (Haas et al. 2015). The green manure cover crops allow repopulation of the alleyways with wild plant species after the cultivated cover crops have finished their winter-spring life cycle. The possibility for alternative plant species to colonize the bare soil after the yearly ploughing might increase plant diversity and offer habitats for more above- and below-ground macro-invertebrate species.
The present study analyses the effects of green manure soil management versus the traditional mulching techniques on the soil macro-invertebrate diversity. We hypothesize that green manuring positively affects the soil macro-invertebrate diversity due to a more heterogeneous vegetation and an improved soil structure.

Material & Methods

Site description

The soil amelioration experiment was carried out from 2009 to 2017 in a vineyard located at Kaltern/Caldaro, South Tyrol, Italy (latitude 46.40416° N and longitude 11.25184° E) at 323 m a.s.l. as explained in Haas et al. (2015). The horizontally terraced vineyard is east-exposed and generally very dry. It is located in the humid continental climate zone and has an average inclination of 8°. However, the area of the South Tyrolean Unterland can be considered as dry region: in 2017 the mean annual temperature and precipitation close to the vineyard was 12.2°C and only 360 mm, respectively (OpenDataSüdtirol 2018). In alternating parcels of six to 12 metres, one of four different treatments was applied on the alleyways. The permanent cover crop treatment (PCC, serving as control plots) was mowed two to three times a year. For the green manure treatments superficial soil tillage of the central 60 cm of each alleyway was performed after harvest with a spading machine at 10 cm depth for seed bed preparation and incorporation of the green manure residues. A mixture of *Secale cereale* L., *Vicia villosa* subsp. *villosa* L., *Onobrychis viciifolia* Scop., *Lotus corniculatus* L., *Melilotus albus* Medik., and *Vicia faba* L. (in order of importance in the seed mixture) was sown for green manure control (GMC), green manure activated (GMA), and the green manure slurry (GMS) treatments. Three times a year the soil of GMA was treated with cow horn manure (biodynamic preparation 500) following the biodynamic farm protocol. At the beginning of April a fertilization of 0.7 kg/m^2 of slurry (fermented liquid manure corresponding to about 30 kg/ha N) was applied to GMS.

Soil properties

Soil chemical and physical properties were determined in 2017, after eight years of treatment application. Soil samples were obtained from a depth of 0–30 cm and 31–60 cm. For each sample 10 to 15 insertions were done in the middle of the alleyway in order to get a representative sample of both soil depths. Soil analyses were performed at the Laboratory of Agricultural Chemistry at Laimburg Research Centre following VDLUFA methods (i.e. Verein Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten, VDLUFA 2018). This includes the following parameters: Humus content (i.e. in percentage as soil organic carbon multiplied by 1.72), pH (in $CaCl_2$ solution), phosphorus (P expressed as P_2O_5 from CAL extract), bor (B), manganese (Mn), copper (Cu), zinc (Zn), dry mass (soil weight after 6-15 h at 105 °C), and ammonia (i.e. NH_4^+ as kg/ha).

Macro-invertebrate sampling

Simultaneously to the soil sampling, we took eight soil core samples (20 × 20 cm, 15 cm depth) and installed six pitfall traps (Ø 8.5 cm) per treatment at the end of May 2017. The soil core samples were heat-extracted for 12 days in a modified Kempson apparatus (Kempson et al. 1963) in the laboratory of the Institute for Alpine Environment of Eurac Research, Bozen/Bolzano, Italy. The pitfall traps were kept in the field for 31 days (i.e. two periods, 14 and 17 days) with propylene glycol as preservation liquid. The soil macro-invertebrates were stored in 75% ethanol solution until identification to family, and were possible, to genus or species level under a stereo microscope. Staphylinidae were identified to species level following Pace (1978) and Assing & Wunderle (2008). Additionally, for all Coleoptera the keys of Freude et al. (1971, 1974) and Assing & Schülke (2012) were used. Araneae were identified following Nentwig et al. (2018) and Roberts (2001). Taxa such as adult Diptera, Lepidoptera, Formicidae, and Hemiptera, as well as soil mesofauna (i.e. Acari, Collembola) were defined as bycatch and therefore excluded from analyses.

Statistics

One-way Analyses of Variance (ANOVA) of soil properties and soil macro-invertebrate communities were performed using IBM SPSS Statistics 25 (version 25.0.0.1, Armonk, New York). Constrained Redundancy Analyses (RDA) of log-transformed taxa data from pitfall traps and environmental data (i.e. soil parameter) was performed using the software Canoco 5 (version 5.10, Ter Braak & Šmilauer 2012).

Results

Soil properties

The treatments differed significantly only in two soil parameters (i.e. K and NH_4^+, Table 1). The amount of P, K, and NH_4^+ was highest in GMS, while the PCC treatment showed the highest Cu content with 283.44 mg/kg. Generally, the soils contained low percentages of organic material expressed here in humus content, with GMS showing a slightly higher value.

Tab. 1: Mean and standard deviation of soil parameters from differently managed vineyard alleyways. Significant differences at $P < 0.05$ and Tukey's HSD post-hoc test are given for K and NH_4^+ (marked with *). Soil properties: DM... dry mass, NH_4^+... ammonia. Treatments: PCC... permanent cover crop, GMC... green manure control, GMA... green manure activated, GMS... green manure slurry. n = 16 for PCC, n = 8 for the green manuring treatments.

	Humus [%]	pH	P [mg/100 g]	K * [mg/100 g]	Mg [mg/100 g]	B [mg/kg]	Mn [mg/kg]	Cu [mg/kg]	Zn [mg/kg]	DM [%]	NH_4^+ * [kg/ha]
PCC	**3.02** (0.22)	**7.30** (0.02)	**30.69** (1.85)	**15.63** (0.54) [ab]	**40.13** (2.09)	**0.60** (0.04)	**87.50** (8.61)	**283.44** (22.14)	**24.19** (1.64)	**87.44** (0.27)	**4.06** (0.32) [a]
GMC	**2.81** (0.13)	**7.38** (0.03)	**29.63** (2.90)	**14.13** (1.49) [a]	**37.63** (3.16)	**0.56** (0.06)	**80.13** (17.71)	**252.63** (30.67)	**22.00** (1.86)	**87.88** (0.35)	**2.63** (0.26) [ab]
GMA	**2.73** (0.31)	**7.38** (0.04)	**28.50** (2.46)	**13.63** (0.93) [a]	**34.63** (3.86)	**0.50** (0.08)	**67.75** (16.14)	**229.25** (39.14)	**21.00** (2.54)	**87.88** (0.13)	**2.50** (0.46) [b]
GMS	**3.21** (0.25)	**7.34** (0.04)	**35.75** (3.42)	**20.00** (2.54) [b]	**37.50** (3.49)	**0.61** (0.07)	**71.25** (11.80)	**236.38** (38.68)	**23.00** (1.48)	**87.13** (0.23)	**4.25** (0.59) [a]

Abundance and species assemblage

In total, 537 and 321 individuals of soil macro-invertebrates were obtained from pitfall traps and soil core samples, respectively. Generally, the abundance of most taxa was very low with only one to three specimens per sample, which was also reflected by their low activity (i.e. individuals per sampling day) and density (i.e. mean individuals per square metre, Table 2). On the other hand, taxa such as Symphyla, Chilopoda and Nematocera larvae were abundant and reached on average more than 80 ind./m^2 in three of four treatments. Araneae and Coleoptera were also frequent (in total 226 and 287 individuals, respectively), and were present in every single pitfall trap sample. When looking at the overall species composition in the individual green manuring treatments, we found no significant differences (Fig. 1). Nonetheless, the soil macro-invertebrate communities from the pitfall traps samples showed two nearly separated clusters in the RDA plot with the green manuring treatments on the bottom and PCC on the top (Fig. 1).

Biodiversity

Overall, we were able to identify 80 soil macro-invertebrate taxa (Table 2). Regarding the biodiversity, GMA and PCC had the highest while GMS and GMC had the lowest taxonomic richness (49, 48, 42 and 37 taxa, respectively). The treatments PCC and GMA had the highest proportion of unique taxa (i.e. 9 and 8 taxa, respectively), while 16 taxa were present in all four treatments. Again, no differences of the three green manuring treatments were found regarding the biodiversity. Further, in GMS we found the lowest proportion of unique taxa with five taxa out of 28 total unique taxa. However, by comparing PCC with all green manuring treatments taken together, a clearer picture was found with the latter having a much higher percentage of unique taxa (i.e. 45.07 % in GM vs. 18.75 % in PCC). A large proportion of these unique taxa in GM were Coleoptera and Araneae species that were identified to species level, with 17 out of 40 and 7 out of 21 species, respectively.

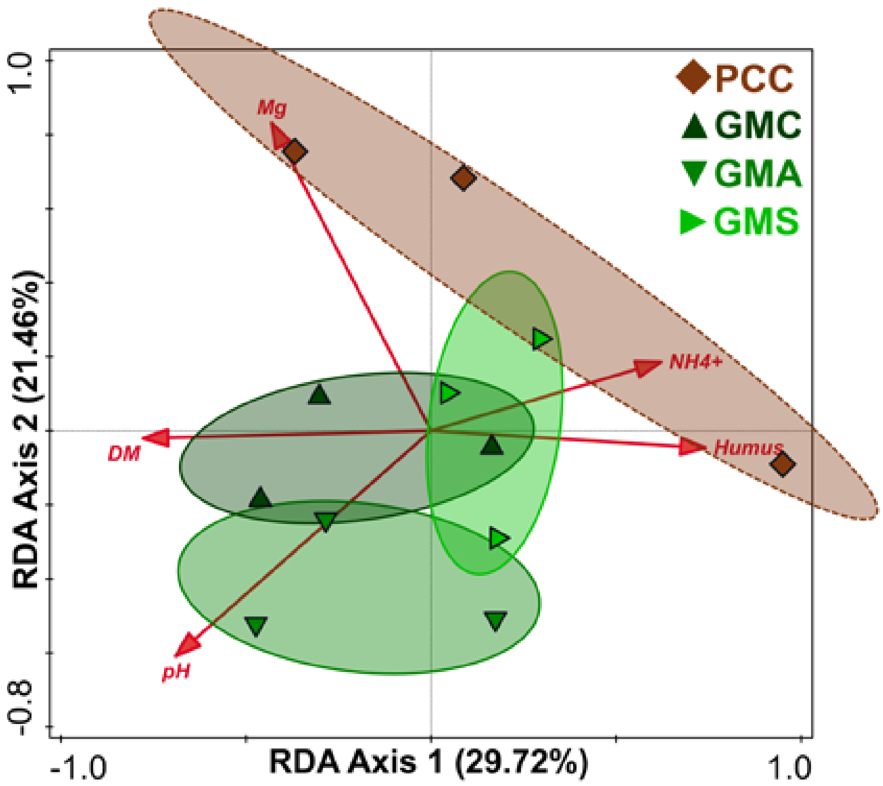

Fig. 1: Plot from constrained Redundancy Analysis (RDA) of soil macro-invertebrate communities from pitfall traps and soil properties in differently treated vineyard alleyways. Taxa data were log-transformed. Soil properties not mentioned were excluded from analyses as they showed high autocorrelation and redundancy. Soil properties: DM... dry mass, NH4+... ammonia. Treatments: PCC... permanent cover crop, GMC... green manure control, GMA... green manure activated, GMS... green manure slurry. n = 3.

Discussion

Here we present one of few existing studies about soil macro-invertebrate communities from vineyards (but see Thomson & Hoffmann 2007, Reinecke et al. 2008, Bruggisser et al. 2013, Faber et al. 2017). Knowledge on the invertebrate biodiversity is of current interest due to the increasing pressure of ongoing management intensification of vineyards and the generally observed massive decline of insect abundance and biodiversity (Hallmann et al. 2017). In this study, we investigated the effect of green manure versus permanent crop treatment on above- and below-ground soil invertebrate diversity and found significant differences in community composition. Even if our sampling approach represents only a snapshot in assessing the soil macro-invertebrate community of vineyard alleyways, we were able to distinguish between permanent cover crop and green manuring managements, with the latter harbouring more rare taxa.

Species assemblage and treatments

By comparing the soil macro-invertebrate communities from pitfall traps and soil core samples, we generally found only few animals compared to other dry habitats in South Tyrol (Steinwandter & Seeber 2017). Exceptionally hot weather periods before and during sampling might have reduced the abundance of several taxa, especially those relying on humid soil conditions such as earthworms. Further, the soil types in the vineyard were characterized as loamy sand and therefore not ideal for below-ground taxa.
In this study, we could find well separable soil macro-invertebrate communities in the four differently treated vineyard alleyways, despite their spatial proximity (Fig. 1). PCC plots showed a high number of taxa, but the lowest amount of rare and unique species compared with the pooled green manuring treatment data. The PCC treatment can be seen as intensive management with cuttings two to three times a year, and was established some decades ago to facilitate the handling of vine stocks. In vineyards in Switzerland, Bruggisser et al. (2010) showed no differences in plant and soil macro-invertebrate biodiversity between conventional (i.e. intensive) and organic (i.e. extensive) management. However, here we show that the consequences of removing flowering plants from alleyways in PCC reduced soil macro-invertebrate biodiversity, and contrarily, green manuring (considered as extensive management) can considerably increase biodiversity of soil macro-invertebrates, particularly of taxa associated with those plants. Therefore, our results are in line with a recent worldwide comparison of vegetation management in vineyards where extensive practices showed increased above- and below-ground biodiversity and ecosystem service provision (Winter et al. 2018). Further, the alleyway vegetation did not impair the management effort of the farmers. In fact, this kind of soil preparation even facilitated the preservation of soil fertility of the vineyard. The seeded flowering plants increased soil organic matter content and nitrogen availability for vines in deeper soil layers through deep rooting, better ensuring their nutritional supply compared to the PCC treatment (Haas & Niedrist 2015).

Findings of rare species and faunistic novelties

In this sampling approach, we were able to find several rare Coleoptera and Araneae species, with two new Coleoptera findings for South Tyrol. The first new record, the Staphylinidae *Allotyphlus pacei* Coiffait, 1973 is a very small species with reduced eyes and wings. Its distribution is described as the area between Vicenza, Verona and Lake Garda, and was probably introduced to South Tyrol with the plantation of new vinestocks, as has happened with other Leptotyphlinae species (Degasperi 2014). Other rare Staphylinidae include (i) *Alevonota gracilenta* (Erichson, 1839) which lives underground in burrows of mammals (Assing & Wunderle 2008), (ii) *Bryaxis lagari* (Halbherr, 1890) that was found close to the Sigmundskron Castle and Neumarkt/Egna (Schatz 2005) and reaches its northern distribution limits (Schülke & Smetana 2015), (iii) *Aleochara spissicornis* Erichson, 1839 that was found near Brixen/Bressanone in 1934, 1950, 1951, and 1964 (Peez & Kahlen 1977), but was recently recorded in sparse numbers (Schatz 2008) and shows a relict distribution in the Southern Alps (Zanetti & Manfrin 2004),

and (iv) *Tachyporus transpadanus* Schülke, 2006, an adventive species that was recorded several times since its first finding in 2004 (Kahlen 2018). Further, we found the Ptiliidae *Ptinella mekula* Kubota, 1943 for the second time in South Tyrol after 2010 (project "SoilDiv", Peham & Meyer 2014). This species might be quite frequent, but has presumably been overlooked due to its hidden life style. All these species are thermophilic and prefer sandy, dry and warm habitats such as vineyards.
The second new record, the Curculionidae *Gymnetron rotundicolle* Gyllenhal, 1838 was found in dry grasslands of Bohemia (Czech Republic, Strejcek 2007), Burgenland (Austria), and recently also in the bordering regions of Veneto and Friuli (both Italy, Caldara 2008), Switzerland (Germann et al. 2013), Slowakia (Kratky 2013), often associated with *Veronica* spp. herbs. Further, we could sample the thermophilic and rare *Stenocarus cardui* (Herbst, 1784) that had no recent record since 1955 and is known for North Tyrol (Austria), but also from Bozen/Bolzano, Meran/Merano, and Eppan/Appiano (Kahlen 2018). The Silphidae *Nicrophorus interruptus* Stephens, 1830 is quite common but has been recorded only four times in South Tyrol so far: Brixen/Bressanone, Ritten/Renon, and Martelltal/Val Martello (Peez & Kahlen 1977). Additionally, we sampled the Latridiidae *Corticarina cavicollis* (Mannerheim, 1844), an adventive species from North and Central America that was first recorded in Italy in 1998 and 1999 (Rücker 2003). It was found in Friuli at the Tagliamento river in 2016, and at Gmund/Monte 5 km from the sampled vineyard (Kahlen 2018). It appears to be spreading in South Tyrol.
For ground-living Araneae, the two Gnaphosidae *Drassyllus praeficus* (L. Koch, 1866) and *D. pusillus* (C. L. Koch, 1839) represent rare findings, as few and mostly older records are known so far (FloraFaunaSüdtirol 2018). Similar to the former, only few findings are known for the Salticidae *Attulus penicillatus* (Simon 1875) (eight records in FloraFaunaSüdtirol 2018). Except for *Drassyllus pusillus,* which can be found in a variety of habitats such as forests and meadows, the preferred habitat of these species are sandy, warm and open habitats (Nentwig et al. 2018).

Conclusion
Green manuring practices improve the soils (e.g. by increasing the soil organic matter; Haas et al. 2015) and provide more niches for soil macro-invertebrates in vineyards. Further, green manuring does not impair the handling of vines. However, yearly mulching processes could hamper and/or slow down the development of stable populations, as this implies a severe disturbance of the upper soil layers and its inhabitants.
Overall, our results were promising as new and rare species could be found and/or confirmed for the first time after decades. We assume that extensively managed vineyards can positively contribute to the conservation of fauna and flora (cf. Nascimbene et al. 2016). Seeding flowering plants in alleyways seems to benefit both the soil organisms and the soil as its soil organic matter and humus content increases compared to permanent cover crop treatments. This encourages us to keep investigating vineyards with green manuring, especially as we expect to find further interesting species above-ground such as phytophagous Coleoptera that were not covered by our sampling methods.

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Appendix

Tab. 2: Abundance and density of soil macro-invertebrates from differently managed vineyard alleyways. The abundance from pitfall traps are given as individuals per sampling day (ind/d), the density from soil core samples as mean and standard deviation of individuals per square metre (ind/m² and (sd), respectively). Some taxa such as Hemiptera, Formicidae, and adult Diptera were excluded from the list. Table (a) includes all soil macro-invertebrates except adult Coleoptera, Table (b) adult Coleoptera. Juvenile Araneae are not listed but were included at family level. For each treatment: n (pitfall traps) = 6, n (soil core samples) = 8. Treatments: PCC… permanent cover crop, GMC… green manure control, GMA… green manure activated, GMS… green manure slurry. Species: *… rare findings, **… new records for South Tyrol

a	PCC			GMC			GMA			GMS		
	ind/d	ind/m²	(sd)	ind/d	ind/m²	(sd)	ind/d	ind/m²	(sd)	ind/d	ind/m²	(sd)
GASTROPODA	**0.26**	**9.38**	**(18.60)**	**–**	**3.13**	**(8.84)**	**0.06**	**–**	**–**	**–**	**–**	**–**
LUMBRICIDAE	**–**	**3.13**	**(8.84)**	**–**	**–**	**–**	**0.03**	**21.88**	**(61.87)**	**–**	**–**	**–**
ARANEAE	**1.90**	**6.25**	**(11.57)**	**1.97**	**3.13**	**(8.84)**	**1.65**	**–**	**–**	**1.77**	**6.25**	**(17.68)**
Theriidae: *Asagena phalerata* (Panzer, 1801)	0.16	–	–	0.10	–	–	0.03	–	–	0.03	–	–
Linyphiidae	0.39	3.13	(8.84)	0.42	–	–	0.35	–	–	0.48	6.25	(17.68)
Agyneta fuscipalpa (C. L. Koch, 1836)	*0.35*	–	–	*0.32*	–	–	*0.26*	–	–	*0.42*	–	–
Diplostyla concolor (Wider, 1834)	*0.03*	–	–	–	–	–	–	–	–	–	–	–
Mermessus trilobatus (Emerton, 1882)	–	–	–	*0.06*	–	–	*0.03*	–	–	*0.03*	–	–
Palliduphantes pallidus (O. P.-Cambridge, 1871)	–	–	–	–	–	–	–	–	–	*0.03*	–	–
Tetragnathidae: *Pachygnatha degeeri* Sundevall, 1830	0.03	–	–	–	–	–	0.03	–	–	–	–	–
Lycosidae	0.77	3.13	(8.84)	0.29	–	–	0.42	–	–	0.26	–	–
Trochosa hispanica Simon, 1870	*0.19*	–	–	*0.26*	–	–	*0.35*	–	–	*0.03*	–	–
Xerolycosa miniata (C. L. Koch, 1834)	*0.58*	–	–	*0.03*	–	–	*0.06*	–	–	*0.19*	–	–
Pisauridae: *Pisaura mirabilis* (Clerck, 1757)	–	–	–	0.03	–	–	–	–	–	–	–	–
Agelenidae: *Tegenaria sp.*	–	–	–	–	–	–	–	–	–	0.03	–	–
Clubionidae: *Clubiona sp.*	0.06	–	–	–	–	–	–	–	–	0.03	–	–
Zodariidae: *Zodarion rubidum* Simon, 1914	0.10	–	–	0.74	–	–	0.39	–	–	0.52	–	–
Gnaphosidae	0.13	–	–	0.10	–	–	0.26	–	–	0.32	–	–
Drassyllus praeficus (L. Koch, 1866) *	*0.06*	–	–	*0.06*	–	–	*0.13*	–	–	*0.13*	–	–
Drassyllus pusillus (C. L. Koch, 1839) *	–	–	–	*0.03*	–	–	*0.03*	–	–	–	–	–
Haplodrassus signifer (C. L. Koch, 1839)	*0.03*	–	–	–	–	–	–	–	–	*0.06*	–	–
Micaria pulicaria (Sundevall, 1831)	*0.03*	–	–	–	–	–	*0.10*	–	–	*0.13*	–	–
Phrurolithidae: *Phrurolithus festivus* (C. L. Koch, 1835)	0.16	–	–	0.16	–	–	0.10	–	–	0.13	–	–
Thomisidae: *Xysticus kochi* Thorell, 1872	0.03	–	–	0.03	3.13	(8.81)	–	–	–	–	–	–
Salticidae	0.03	–	–	0.10	–	–	0.06	–	–	–	–	–
Attulus penicillatus (Simon, 1875) *	*0.03*	–	–	*0.03*	–	–	*0.03*	–	–	–	–	–
Phlegra fasciata (Hahn, 1826)	–	–	–	*0.03*	–	–	–	–	–	–	–	–
Talavera aequipes (O. P.-Cambridge, 1871)	–	–	–	*0.03*	–	–	*0.03*	–	–	–	–	–
OPILIONES	**–**	**–**	**–**	**0.06**	**–**	**–**	**0.03**	**–**	**–**	**–**	**–**	**–**
CHILOPODA	**–**	**71.88**	**(74.93)**	**0.03**	**12.50**	**(18.90)**	**–**	**18.75**	**(29.12)**	**–**	**40.63**	**(79.69)**
Geophilidae	–	46.88	(66.06)	–	12.50	(18.90)	–	18.75	(29.12)	–	34.38	(78.99)
Lithobiidae	–	25.00	(44.32)	0.03	–	–	–	–	–	–	6.25	(11.57)
SYMPHYLA	**–**	**121.88**	**(80.66)**	**–**	**81.25**	**(98.88)**	**–**	**115.63**	**(151.15)**	**–**	**43.75**	**(78.77)**
COLEOPTERA LARVAE	**0.16**	**50.00**	**(53.45)**	**0.06**	**6.25**	**(11.57)**	**0.10**	**34.38**	**(77.85)**	**0.03**	**9.38**	**18.60**
Carabidae larvae	–	6.25	(11.57)	–	–	–	–	–	–	–	–	–
Staphylinidae larvae	–	21.88	(28.15)	–	3.13	(8.84)	–	–	–	–	–	–
Elateridae larvae	–	15.63	(26.52)	–	–	–	–	6.25	(11.57)	–	–	–

a	PCC			GMC			GMA			GMS		
	ind/d	ind/m²	(sd)	ind/d	ind/m²	(sd)	ind/d	ind/m²	(sd)	ind/d	ind/m²	(sd)
Coccinellidae larvae	0.16	6.25	(17.68)	0.06	–	–	0.10	–	–	0.03	–	–
Chrysomelidae larvae	–	–	–	–	–	–	–	–	–	–	3.13	(8.84)
Curculionidae larvae	–	–	–	–	3.13	(8.84)	–	28.13	79.55	–	6.25	(11.57)
NEMATOCERA LARVAE	**–**	**18.75**	**(25.88)**	**–**	**–**	**–**	**–**	**84.38**	**(201.31)**	**–**	**6.25**	**(17.68)**
Chironomidae larvae	–	9.38	(18.60)	–	–	–	–	–	–	–	–	–
Cecidomyiidae larvae	–	9.38	(12.94)	–	–	–	–	–	–	–	3.13	(8.84)
Sciaridae larvae	–	–	–	–	–	–	–	71.88	(203.29)	–	–	–
Scatopsidae larvae	–	–	–	–	–	–	–	12.50	(35.36)	–	3.13	(8.84)
BRACHYCERA LARVAE	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**6.25**	**(11.57)**	**–**	**15.63**	**(22.90)**
Dolichopodidae larvae	–	–	–	–	–	–	–	3.13	(8.84)	–	6.25	(11.57)
Stratiomyidae larvae	–	–	–	–	–	–	–	3.13	(8.84)	–	9.38	(18.60)

b	PCC			GMC			GMA			GMS		
	ind/d	ind/m²	(sd)	ind/d	ind/m²	(sd)	ind/d	ind/m²	(sd)	ind/d	ind/m²	(sd)
COLEOPTERA	**2.58**	**46.88**	**(54.18)**	**1.81**	**65.63**	**(55.00)**	**2.42**	**43.75**	**(60.87)**	**2.45**	**28.13**	**(31.16)**
Carabidae	1.55	6.25	(11.57)	1.03	6.25	(11.57)	1.29	6.25	(17.68)	1.35	–	–
Amara aenea De Geer, 1774	*0.26*	–	–	*0.13*	–	–	*0.23*	–	–	*0.23*	–	–
Amara bifrons (Gyllenhal, 1810)	–	*3.13*	*(8.84)*	–	–	–	–	–	–	–	–	–
Badister bullatus (Schrank, 1798)	–	–	–	*0.03*	–	–	–	–	–	–	–	–
Calathus fuscipes (Goeze, 1777)	*0.10*	–	–	*0.06*	–	–	*0.10*	–	–	*0.10*	–	–
Harpalus affinis (Schrank, 1781)	*0.26*	–	–	*0.29*	*6.25*	*(11.57)*	*0.32*	*6.25*	*(17.68)*	*0.68*	–	–
Harpalus anxius (Duftschmid, 1812)	*0.52*	–	–	–	–	–	*0.03*	–	–	*0.03*	–	–
Harpalus dimidiatus (P. Rossi, 1790)	*0.06*	–	–	–	–	–	*0.19*	–	–	–	–	–
Harpalus distinguendus (Duftschmid, 1812)	–	–	–	*0.06*	–	–	–	–	–	*0.03*	–	–
Harpalus pumilus Sturm, 1818	*0.10*	–	–	*0.03*	–	–	–	–	–	–	–	–
Harpalus rubripes (Duftschmid, 1812)	*0.03*	*3.13*	*(8.84)*	*0.03*	–	–	–	–	–	*0.06*	–	–
Harpalus signaticornis (Duftschmid, 1812)	–	–	–	–	–	–	–	–	–	*0.03*	–	–
Harpalus tardus (Panzer, 1797)	*0.23*	–	–	*0.13*	–	–	*0.06*	–	–	*0.13*	–	–
Ophonus azureus (Fabricius, 1775)	–	–	–	*0.26*	–	–	*0.32*	–	–	*0.06*	–	–
Pseudoophonus rufipes (De Geer, 1774)	–	–	–	–	–	–	*0.03*	–	–	–	–	–
Histeridae: *Margarinotus purpurascens* (Herbst, 1792)	–	–	–	–	–	–	0.03	–	–	–	–	–
Ptiliidae: *Ptinella mekula* Kubota, 1943 *	–	–	–	–	18.75	(43.81)	–	–	–	–	–	–
Silphidae: *Nicrophorus interruptus* Stephens, 1830 *	–	–	–	–	–	–	0.03	–	–	–	–	–
Staphylinidae	0.29	25.00	(51.75)	0.06	28.13	(50.78)	0.35	15.63	(35.20)	0.35	25.00	32.73
Aleochara spissicornis Erichson, 1839 *	*0.13*	–	–	–	–	–	*0.03*	–	–	–	*6.25*	*(17.68)*
Alevonota gracilenta (Erichson, 1839)	–	–	–	–	–	–	–	–	–	–	*3.13*	*(8.84)*
Allotyphlus pacei Coiffait, 1973 **	–	*15.63*	*(35.20)*	–	–	–	–	*3.13*	*(8.84)*	–	–	–
Amischa analis (Gravenhorst, 1802)	–	–	–	–	*3.13*	*(8.84)*	–	–	–	–	–	–
Anotylus hamatus (Fairmaire & Laboulbene, 1856)	–	–	–	–	–	–	*0.23*	–	–	*0.26*	–	–
Atheta fungi (Gravenhorst, 1806)	–	*3.13*	*(8.84)*	*0.06*	–	–	–	–	–	*0.03*	–	–
Bryaxis lagari (Halbherr, 1890) *	–	–	–	–	–	–	–	*3.13*	*(8.84)*	–	–	–
Meotica marchia Benick, 1954	–	–	–	–	*6.25*	*(11.57)*	–	*6.25*	*(17.68)*	–	*9.38*	*(12.94)*
Philonthus lepidus (Gravenhorst, 1802)	*0.13*	–	–	–	–	–	*0.03*	–	–	*0.06*	–	–
Philonthus succicola Thomson, 1860	–	–	–	–	–	–	*0.03*	–	–	–	–	–
Scopaeus minutus Erichson, 1840	–	–	–	–	–	–	–	*3.13*	*(8.84)*	–	*6.25*	*(17.68)*
Tachyporus transpadanus Schülke, 2006 *	–	*3.13*	*(8.84)*	–	–	–	*0.03*	–	–	–	–	–
Xantholinus laevigatus Jacobsen, 1849	–	*3.13*	*(8.84)*	–	–	–	–	–	–	–	–	–
Xantholinus linearis (Olivier, 1795)	*0.03*	–	–	–	–	–	–	–	–	–	–	–
Elateridae: *Melanotus tenebrosus* (Erichson, 1841)	0.03	–	–	–	–	–	–	–	–	–	–	–
Scarabaeidae: *Maladera holosericea* (Scopoli, 1772)	–	–	–	0.03	–	–	–	–	–	–	–	–
Chrysomelidae	0.55	6.25	(11.57)	0.55	–	–	0.58	–	–	0.42	–	–
Chrysolina rossia (Illiger, 1802)	*0.03*	–	–	–	–	–	–	–	–	–	–	–
Galeruca tanaceti (Linnaeus, 1758)	*0.52*	*6.25*	*(11.57)*	*0.55*	–	–	*0.58*	–	–	*0.42*	–	–
Latridiidae: *Corticarina cavicollis* (Mannerheim, 1844)	0.06	–	–	–	–	–	0.03	–	–	0.03	–	–
Curculionidae	0.13	9.38	(12.94)	0.13	31.25	(39.53)	0.10	21.88	(28.15)	0.29	3.13	(8.84)
Gymnetron rotundicolle Gyllenhal, 1838 **	*0.03*	–	–	–	–	–	–	–	–	–	–	–
Sitona hispidulus (Fabricius, 1776)	–	*3.13*	*(8.84)*	–	–	–	*0.06*	–	–	–	–	–
Sitona macularius (Marsham, 1802)	*0.06*	*6.25*	*(11.57)*	*0.10*	*28.13*	*(38.82)*	*0.03*	*15.63*	*(26.52)*	*0.29*	–	–
Stenocarus cardui (Herbst, 1784) *	*0.03*	–	–	*0.03*	*3.13*	*(8.84)*	–	*6.25*	*(17.68)*	–	*3.13*	*(8.84)*