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True bugs (Heteroptera) assemblage and diversity in the ecological infrastructures around the Mediterranean vineyards

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Abstract

One of the main tools in Integrated Pest Management (IPM) is habitat management known as ecological infrastructure. Ecological infrastructures play an important role in enhancing biodiversity in perennial plantations such as vineyards. Moreover, elements of ecological infrastructure such as weeds and flowering plants enhance the population of beneficial insects, in particular, natural enemies of vineyard pests. The study was carried out during three consecutive years in three different models (extensive, integrated and organic) in Zadar county (Croatia). The main objective of this research was to assess the effects of three types of ecological infrastructures (weed margins, wildflower strips, and Mediterranean dry pastures) on true bugs (Heteroptera) composition and diversity. During the study period from May to October for three consecutive years (2010-2012), 4158 individuals belonging to 14 families, 30 genera and 58 species were recorded. Species richness and abundance were higher in both weedy margins and wildflower strips. The highest number of species was found in ecological infrastructures associated with integrated vineyard. *Nysius graminicola graminicola* (Kolenati) was considered as the dominant species within the whole study. The most abundant predators were *Macrolophus melanotoma* (Costa) and *Orius niger* (Wolff). Unlike Mediterranean dry pastures, the population of beneficial species was also more abundant and diverse in weedy margins and wildflower strips. Our results emphasize the need for maintaining ecological infrastructures in order to enhance the biodiversity of true bugs and overall arthropod biodiversity in vineyard landscapes. Moreover, weed margins and wildflower strips seem to have an influence on attracting and conserving the beneficial Heteroptera in agroecosystems. This results could help to improve conservative biological control as a part of IPM in vineyards.

Key words: biodiversity, ecological infrastructure, true bugs, vineyards, weeds.

Introduction

Integrated Pest Management (IPM) practices refer to ecologically-based pest control (Wilson and Daane, 2017). According to Naranjo *et al*. (2014), biological control is a key ecosystem service of IPM. Moreover, conservation biological control as a part of IPM strategy is a sustainable approach to pest management, which can contribute to reduction in pesticide use (Altieri 1999; Begg *et al*., 2017). Snyder (2019) showed that conservation biological control techniques may support natural enemy biodiversity. Furthermore, IPM promotes and preserves biodiversity and establishes a more sustainable agroecosystem. One of the main problems related to vineyard pests seems to be monoculture production. Moreover, intensified farming practices lead to a loss of species biodiversity (Attwood *et al*., 2008). Among different management regimes, organic vineyards favour a range of taxa (Hole *et al*., 2005). For instance, Froidevaux *et al*. (2017) found that abundance of arachnids in Mediterranean vineyards was positively associated with vegetation cover. According to Wilson and Daane (2017), non-crop species can attract and maintain beneficial insects in agricultural settings and increase agrobiodiversity. Lososová *et al*. (2003) noticed that European vineyards offer a high range of plants, especially weeds around and between rows. Surrounding vegetation, meadows, weeds, and wildflower strips are components of ecological infrastructure which provide shelter to beneficial arthropods. Insectary plants also known as flowering plants within and around vineyards enhance the activity and density of natural enemies (Landis *et al*., 2005; Wong and Frank, 2013; Lu *et al*., 2014). Weeds can also serve as a habitat for insect pests, thus their presence may suppress pest transition into the vineyard. Ecological infrastructures do not only serve as a source of natural enemies, but it can also reduce soil erosion and conserve water in the soil.

True bugs are an ecologically very diverse group of insects (Lundgren, 2011). Their sensitivity to ecological factors and side effects of pesticide treatments make them good indicators of ecological change (Fauvel, 1999). Orabi *et al*. (2010) in their study confirmed Heteroptera as bioindicators of environmental conditions and change. All developmental stages of these insects live in the same environment (Fauvel, 1999). According to Gilbert *et al*. (2015), some Heteroptera are sensitive to habitat changes which makes them good indicators of habitat quality. True bugs are an important group of insects in vineyard production, such as phytophagous insects but in particular as natural enemies. Some authors agree that sometimes certain species of these insects can cause damage to grapes (Arzone *et al*., 1990; Paoletti, 1999; Schaefer and Panizzi, 2000; Leskey *et al*., 2012). For instance, species belonging to the genus *Lygus* (Miridae), *Piesma* (Piesmatidae) and *Nysius* (Lygaeidae) were found as vectors of some important pathogens (Mitchell, 2004). Orságova *et al*. (2011) reported that *Lygus rugulipennis* Poppius act as a vector of some grape viruses. Except from true bug phytophagous species in vineyards, some authors mentioned beneficial Heteroptera species as well (Lozzia *et al*., 2000; Rogé *et al*., 2009). For instance, predatory species from the genus *Orius* (Anthocoridae), *Nabis* (Nabidae) and *Geocoris* (Lygaeidae) are important predators of leafhoppers, spider mites, including lepidopteran and hemipteran eggs (Costello and Daane, 1999). Some Heteroptera (Anthocoridae, Miridae, Nabidae and Reduviidae) are involved in biological control of grape moths (Thiéry *et al*., 2018). *Malacocoris chlorizans* (Panzer) is known as a predator of red mites (Chuche and Thiéry, 2014). The predatory species *Nabis americoferus* Carayon and *Zelus renardii* Kolenati also inhabit vineyards (Costello and Daane, 1999). According to the data of Schuman *et al*. (2013), some *Geocoris* species feed on *Empoasca* spp. Besides this, true bugs serve as an important food source for many insectivorous animals and therefore contribute to greater agrobiodiversity (Gilbert *et al*., 2015). Zurbrüg and Frank (2006) noticed that vegetational structure and flower abundance are key factors in Heteroptera richness and community structure.

The first objective of this research was to address what type of ecological infrastructure provides the best conditions for Heteroptera biodiversity, in particular, predatory species. Moreover, we wanted to select plants (habitat) which could encourage beneficial organisms to provide natural control of vineyard pests.

Materials and methods

Study sites

The experiment was conducted in Zadar county (Croatia). According to the Köppen climate classification, the study sites belonged to the Mediterranean climate types (Csa) characterized by wet and mild winters and hot, dry summers (Bolle, 2003). Mean annual temperature was 25 °C and precipitation was 85.3 mm. Ecological infrastructures around three vineyards (each with a different type of farming system; integrated, extensive and organic) were chosen. In the integrated vineyard (I) (44°09'25.6"N 15°26'12.6"E) synthetic insecticides and fungicides were used. The ground cover between rows was mowed several times during the growing season. Within-row weeds were controlled using herbicides (glyphosate). The extensive vineyard (E) (44°08'01.8"N 15°15'15.0"E) as a part of small family fields (vineyards, olive orchards, vegetable fields) was surrounded by elements of ecological infrastructures (weed margins, wildflower strips, natural hedges, bushes and typical Mediterranean dry stone walls). In this vineyard fungicides (copper) were used when necessary. In the organic vineyard (O) (44°15'09.8"N 15°25'54.0"E) only copper and sulphur fungicides were allowed as well as botanical insecticides extracted from common nettle (*Urtica dioica* L.) and field horsetail (*Equisetum arvense* L.). Weeds were controlled by mechanical methods. At each site, three different types of ecological infrastructures were delimited due to the distance from the vineyard and vegetation structure (number of plant species). According to the preliminary observations, we presumed that sites with poorer vegetational structure (a lower number of species or sites dominated by several species with high occurrence) will be less attractive to Heteroptera, particularly beneficial species. The ecological infrastructure types were: (1) weedy margins (WM) within the vineyards as a board margin situated along the vineyard rows, characterized by typical weed plants, dominated mostly by annual and biennial dicotyledonous species and about 2 m width. The ground vegetation was mowed once in April, (2) wildflower strips (WFS) associated with a board vegetation of field paths with a distance of at least 10 to 20 m from the edge of the vineyard, and (3) Mediterranean dry pastures (MDP) used for extensive livestock (sheep and goats) grazing and dominated mostly by Poaceae. MDP were about 30 to 50 m away from the vineyards.

Insect sampling and determination

Sampling took place from the beginning of May to the beginning of October during three consecutive years (2010-2012). Samples were taken every fifteen days using a sweep net during sunny and calm weather, between 10:00 a.m. and 4:00 p.m. A sweep sample consisted of 50 sweeps with a 40 cm diameter entomological net. Sampled bugs were stored in ethanol (70%) until the determination. Identification was done using entomological publications (Stichel, 1955; Wagner and Weber, 1964; Wagner, 1971; Péricart, 1987; 1998; Derjanschi and Péricart, 2006). All collected Heteroptera adults were sorted according to species level while nymphs were identified at a family level.

Vegetation sampling

All vascular plant species were recorded once per site during each growing season. Plant identification was carried out using the Croatian Flora (Rogošić, 2011). In order to determine the relative species abundance and plant richness, the phytosociological Braun-Blanquet method was used (Poore, 1995). The standard plot size for sampling that was used was approximately 30-50 m^2. Three transects were made for each site. In each area, all the plants were identified and for each species a code was assigned based on its contribution (% of coverage) to the area. An additional 9 plants as follows (*Anthemis arvensis* L., *Daucus carota* L., *Ditrichia viscosa* (L.) Greuter, *Euphorbia* spp., *Hedera helix* L., *Plantago lanceolata* L., *Rubus* spp., *Trifolium pratense* L. and *Trifolium repens* L.) were selected during the growing season and from which insects were collected. These particular plants were identified as a possible habitat for beneficials according to the literature data but also by our own preliminary observations.

Statistical analyses

Correspondence analysis (CA) was performed to ordinate the ecological infrastructures on the basis of the abundance of predatory species. Data for this method were presented in a two-way table, with the rows corresponding to predatory species and columns to ecological infrastructures. This method was calculated on a matrix $p \times n$, where p presented predatory species and n the ecological infrastructures (Manly and Navarro, 2017). In order to provide information on arthropod biodiversity and richness several indices were calculated (Shannon-Wiener Diversity Index, Simpson Diversity index, and Sörensen Index) (Magurran, 2004). Diversity indices were statistically compared using the Tukey's Test. Dominance values of true bugs community were calculated according to Tischler (1949) as follows; eudominant (>10%), dominant (5-10%), subdominant (2-5%), recedent (1-2%), and subrecedent (<1%). All the statistical tests were performed in the XLStat 2011 software (Addinsoft, Paris, France) and MS Excel 2010.

Table 1. Composition of plants species in ecological infrastructures. Integrated (I), extensive (E), organic vineyard (O).

Family	Species	I	E	O
Alliaceae	*Allium* spp.	-	+	-
Apiaceae	*Daucus carota* L.	+	+	+
	Foeniculum vulgare L.	+	+	-
Amaranthaceae	*Amaranthus retroflexus* L.	-	+	-
Asteraceae	*Achillea millefolium* L.	+	-	-
	Anthemis arvensis L	+	+	-
	Artemisia absinthium L.	+	+	-
	Calendula arvensis L.	-	+	+
	Centaurea cyanus L.	+	-	-
	Cichorium intybus L.	+	+	+
	Cirsium arvense L.	+	+	-
	Dittrichia viscosa (L.) Greuter	-	+	+
	Erigeron annus L.	+	-	-
	Onopordum illyricum L	-	+	-
	Scolymus hispanicus L	-	-	+
	Senecio vulgaris L.	-	+	-
	Sonchus spp.	+	-	+
Brassicaceae	*Bunias erucago* L.	-	+	-
	Capsela bursa pastoris (L.) Medik	+	-	-
	Sisymbrium officinale (L.) Scop.	-	+	-
Chenopodiaceae	*Chenopodium album* L.	-	+	-
Convolvulaceae	*Convolvulus arvensis* L.	+	+	+
Euphorbiaceae	*Euphorbia* spp.	+	-	-
	Mercurialis annua L.	-	+	-
Fabaceae	*Dorycnium hirsutum* (L.) Ser.	+	+	+
	Lotus spp.	+	+	+
	Melilotus officinalis (L.) Lam.	-	+	-
	Securigera spp.	-	+	-
	Trifolium repens L.	+	-	+
	Trifolium pratense L.	+	-	-
	Vicia spp.	+	+	+
Hypericaceae	*Hypericum perforatum* (L.) Lam.	-	-	+
Lamiaceae	*Lamium amplexicaule* L.	-	+	-
Papaveraceae	*Fumaria officinalis* L.	-	+	-
	Papaver rhoeas L.	-	+	-
Plantaginaceae	*Plantago lanceolata* L.	+	-	-
Poaceae	*Avena fatua* L.	-	-	+
	Avena sterilis L.	+	+	+
	Aegilops neglecta Req. ex Bertol	-	-	+
	Briza maxima L.	-	-	+
	Bromus racemosus L.	+	+	-
	Chrysopogon gryllus (L.) Trin.	-	-	+
	Cynodon dactylon (L.) Pers.	+	+	+
	Dactylis glomerata L. subsp. *hispanica* (Roth.) Nyman	+	+	+
	Hordeum murinum L.	-	+	+
	Koeleria spp.	-	-	+
	Setaria viridis (L.) P. Beauv.	+	+	-
	Sorghum bicolor (L.) Moench	-	+	-
Polygonaceae	*Rumex* spp.	+	-	+
Portulacaceae	*Portulaca oleracea* L.	-	+	-
Rubiaceae	*Galium* spp.	-	+	-
Solanaceae	*Datura stramonium* L.	-	-	+

Table 2. Families and species of true bugs (Heteroptera) collected in ecological infrastructures. Integrated (I), extensive (E), organic vineyard (O). Food preferences: Phy, phytophagous; Zoo, zoophagous.

Family	Species	I	O	E	Food preferences
Alydidae	*Camptopus lateralis* (Germar 1817)	+	+	+	Phy
Anthocoridae	*Orius niger* (Wolff 1811)	+	+	+	Zoo
Berytidae	*Neides* spp.	-	-	+	Phy
Coreidae	*Centrocoris variegatus* Kolenati 1845	+	+	+	Phy
	Coreus marginatus marginatus (L. 1758)	+	+	+	Phy
	Coriomeris spp.	+	-	+	Phy
	Gonocerus acuteangulatus (Goeze 1778)	-	-	+	Phy
Lygaeidae	*Geocoris ater* (F. 1787)	+	-	-	Zoo
	Geocoris erythrocephalus (Lepeletier et Serville 1825)	+	+	+	Zoo
	Geocoris megacephalus (Rossi 1790)	+	-	+	Zoo
	Geocoris pallidipennis pallidipennis (A. Costa 1843)	+	-	-	Zoo
	Beosus maritimus (Scopoli 1763)	+	-	-	Phy
	Lygaeus equestris (L. 1758)	+	-	+	Phy
	Spilostethus saxatilis (Scopoli 1763)	+	-	-	Phy
	Metopoplax ditomoides (A. Costa 1847)	+	-	-	Phy
	Nysius graminicola graminicola (Kolenati 1845)	+	+	+	Phy
	Paromius gracilis (Rambur 1839)	+	+	+	Phy
	Raglius alboacuminatus alboacuminatus (Goeze 1778)	+	-	-	Phy
Miridae	*Adelphocoris lineolatus* (Goeze 1778)	+	+	+	Phy
	Deraeocoris schach (F. 1781)	-	-	+	Zoo
	Deraeocoris serenus (Douglas et Scott 1868)	+	-	+	Zoo
	Dicyphus globulifer (Fallen 1829)	-	-	+	Zoo-Phy
	Lopus decolor (Fallen 1807)	+	-	+	Phy
	Lygus pratensis (L. 1758)	+	+	+	Phy
	Macrolophus melanotoma (A. Costa 1853)	-	+	+	Zoo-Phy
	Macrotylus atricapillus (Scott 1872)	+	+	+	Phy
	Notostira elongata (Geoffroy 1785)	+	-	-	Phy
	Taylorilygus apicalis (Fieber 1861)	+	-	-	Phy
	Trigonotylus ruficornis (Geoffroy 1785)	+	+	+	Phy
Nabidae	*Nabis punctatus punctatus* A. Costa 1847	-	+	-	Zoo
	Nabis pseudoferus pseudoferus Remane 1949	+	-	+	Zoo
Pentatomidae	*Aelia rostrata* (Boheman 1852)	+	-	+	Phy
	Ancyrosoma leucogrammes (Gmelin 1790)	+	+	+	Phy
	Carpocoris fuscipinus Boheman 1851	+	+	+	Phy
	Carpocoris purpureipennis De Geer 1773	+	-	-	Phy
	Dolycoris baccarum (L. 1758)	+	+	+	Phy
	Eurydema ventralis Kolenati 1846	+	-	+	Phy
	Eysarcoris ventralis (Westwood 1837)	+	+	+	Phy
	Graphosoma lineatum (L. 1758)	+	-	+	Phy
	Nezara viridula (L. 1758)	+	+	+	Phy
	Rhaphigaster nebulosa (Poda 1761)	+	+	-	Phy
	Staria lunata (Hahn 1835)	+	+	+	Phy
Plataspidae	*Coptosoma scutellatum* (Geoffroy 1785)	+	-	+	Phy
Reduviidae	*Rhynocoris rubricus* (Germar 1814)	+	+	+	Zoo
Rhopalidae	*Chorosoma schillingi* (Schilling 1829)	-	+	+	Phy
	Corizus hyoscyami hyoscyami (L. 1758)	+	+	+	Phy
	Liorhyssus hyalinus (F. 1794)	+	+	-	Phy
	Maccevethus spp.	-	-	+	Phy
	Rhopalus parumpunctatus Schilling 1829	+	-	+	Phy
	Rhopalus subrufus (Gmelin 1790)	+	+	+	Phy
	Stictopleurus abutilon (Rossi 1790)	+	+	+	Phy
	Stictopleurus punctatonervosus (Goeze 1778)	+	+	+	Phy
Scutelleridae	*Eurygaster maura* (L. 1758)	+	+	+	Phy
	Odontotarsus purpureolineatus (Rossi 1790)	+	-	-	Phy
	Odontotarsus robustus Jakovlev 1884	+	+	+	Phy
Stenocephalidae	*Dicranocephalus agilis* (Scopoli 1763)	+	-	-	Phy
Tingidae	*Kalama tricornis* (Schrank 1801)	-	+	-	Phy
	Tingis grisea Germar 1835	-	+	+	Phy

Results

Plants

In total, 50 vascular plant species belonging to 13 families were identified in this study (see appendix). The families with the most species richness were Asteraceae (14 species), Poaceae (12 species) and Fabaceae (7 species) (table 1). Few species (*Cynodon dactylon* L., *A. arvensis* and *Avena sterilis* L.) often occurred in WM, until *D. carota* was highly associated with WFS and MDP of all sites. Species richness in the integrated site ranged between 19 (WM) and 7 (MDP). In WM plants that exhibited the highest abundance were *A. sterilis*, *Bromus racemosus* L., *P. lanceolata* and *Dorycnium hirsutum* (L.) Ser., while in WFS *D. carota*, *Foeniculum vulgare* L., and *T. repens* dominated. In the MDP of this site *D. carota* was considered as the most common species. The number of taxa recorded was 35 in the ecological infrastructure of the extensive vineyard. Among all identified species, 26 occurred in WM. The most abundant plants were *A. arvensis*, *C. dactylon*, *Amaranthus retroflexus* L. and *Chenopodium album* L. In WFS *A. sterilis*, *B. racemosus*, *D. carota*, *D. viscosa* and *Dactylis glomerata* L. dominated. The plant community cover in the extensive site decreased from 26 species in WM to 9 species in MDP. The dominant plant in MDP was *A. sterilis*. In the organic vineyard, 23 plant species were found (among them 19 in WM, 14 in WFS and 11 in MDP). Dominant species in WM were *C. dactylo*n, *D. hirsutum* and *D. viscosa*. In WFS *D. viscosa*, *Briza maxima* L. and *D. hirsutum* were considered as dominant species. The most common species within the MDP were *Aegilops neglecta* Req. ex Bertol, *A. sterilis* and *D. carota*.

True bugs

During this research, a total of 4158 individuals belonging to 14 families, 30 genera, and 58 species were found. All Heteroptera species are listed in table 2. The most common was *Nysius graminicola graminicola* (Kolenati) with 1014 individuals, comprised about 25% of total capture. The highest number of collected species was found in WM associated with the integrated vineyard. On the other hand, in MDP, around the organic vineyard the number of species showed the lowest value. Tables 3, 4 and 5 illustrate the Heteroptera composition (percentage of individuals) in different ecological infrastructures. Species represented below 2% were considered to be recedents or subrecents and are not shown in the results. The community structure of the ecological infrastructures around the integrated vineyard was dominated by *N. graminicola graminicola* (35.29%), *Camptotus lateralis* (Germar) (8.8%) and *Orius niger* (Wolff) (6.9%) (table 3). In ecological infrastructures of the extensive vineyard, *N. graminicola graminicola* was also found as a dominant species (43.18 %), followed by *Macrotylus atricapillus* (Scott) (13.5%) and *Macrolophus melanotoma* (Costa) (5.35%) (table 4). The most abundant species in the ecological infrastructures of the organic vineyard were *M. atricapillus* (58.0%), *N. graminicola graminicola* (9.2%), *M. melanotoma* (7.79%) and *Lygus pratensis* (L.) (5.35%) (table 5). The Simpson Diversity Index differed significantly (I: F = 8.491; df = 2; p = 0.018, O: F = 5.415; df = 2; p = 0.045) between ecological infrastructures associated with integrated and organic sites (figure 1).

Table 3. Heteroptera composition (%) collected in ecological infrastructures around integrated vineyard.

Species	%
Camptopus lateralis	8.77*
Orius niger	6.87*
Centrocoris variegatus	0.27
Coreus marginatus marginatus	0.90
Coriomeris spp.	0.27
Beosus maritimus	0.54
Geocoris ater	0.72
Geocoris erythrocephalus	1.71
Geocoris megacephalus	0.09
Geocoris pallidipennis pallidipennis	0.36
Lygaeus eqestris	0.45
Metapoplax ditomoides	0.09
Nysius graminicola graminicola	35.29*
Paromius gracilis	0.63
Raglius alboacuminatus alboacuminatus	0.36
Spilostethus saxatilis	0.09
Adelphocoris lineolatus	1.09
Deraeocoris serenus	3.98
Lopus decolor	0.36
Lygus pratensis	4.79
Macrotylus atricapillus	1.80
Notostira elongata	0.18
Taylorilygus apicalis	1.99
Trigonotylus ruficornis	6.24*
Nabis pseudoferus pseudoferus	2.98
Aelia rostrata	0.18
Ancyrosoma leucogrammes	1.08
Carpocoris fuscispinus	1.99
Carpocoris purpureipeniis	0.09
Dolycoris baccarum	1.62
Eurydema ventralis	0.09
Eysarcoris ventralis	0.72
Graphosoma lineatum	0.54
Nezara viridula	0.54
Rhaphigaster nebulosa	0.09
Staria lunata	0.27
Captosoma scutellatum	0.09
Rhynocoris rubricus	0.54
Corizus hyoscyami hyoscyami	0.63
Liorhyssus hyalinus	2.62
Rhopalus parumpuctatus	0.18
Rhopalus subrufus	1.53
Stictopleurus abutilon	2.17
Stictopleurus punctatonervosus	1.99
Eurygaster maura	0.36
Odontotarsus purpureolineatus	0.09
Odontotarsus robustus	0.72
Dicranocephalus agilis	0.09

* highest values.

The Shannon-Wiener Diversity Index showed significant diversity (F = 7.522; df = 2; p = 0.023) between the ecological infrastructures associated with organic vineyard (figure 2) with the greatest diversity in ecological infrastructures within the integrated site. The highest similarity between ecological infrastructures (Sörensen Index) occurred with integrated and extensive site (0.78) (table 6).

Table 4. Heteropotera composition (%) collected in ecological infrastructures around extensive vineyard.

Species	%
Camptopus lateralis	1.68
Orius niger	1.68
Neides spp.	0.04
Centrocoris variegatus	1.13
Coreus marginatus marginatus	0.99
Coriomeris spp.	0.24
Gonocerus acuteangulatus	0.24
Geocoris erythrocephalus	0.94
Geocoris megacephalus	0.34
Spilostethus saxatilis	0.14
Nysius graminicola graminicola	43.18*
Paromius gracilis	0.09
Raglius alboacuminatus alboacuminatus	0.19
Adelphocoris lineolatus	0.29
Deraeocoris schach	0.04
Deraeocoris serenus	1.48
Dicyphus globulifer	1.83
Lopus decolor	0.24
Lygus pratensis	0.29
Macrolophus melanotoma	5.35*
Macrotylus atricapillus	13.5*
Trigonotylus ruficornis	0.24
Nabis pseudoferus pseudoferus	0.14
Aelia rostrata	0.54
Ancyrosoma leucogrammes	0.74
Carpocoris fuscispinus	0.19
Dolycoris baccarum	1.18
Eurydema ventralis	0.39
Eysarcoris ventralis	0.49
Graphosoma lineatum	0.09
Nezara viridula	0.29
Staria lunata	0.74
Captosoma scutellatum	0.44
Rhynocoris rubricus	0.14
Chorosoma schillingi	0.19
Corizus hyoscyami hyoscyami	0.19
Maccevethus spp.	0.04
Rhopalus parumpuctatus	0.34
Rhopalus subrufus	0.59
Stictopleurus abutilon	0.34
Stictopleurus punctatonervosus	0.39
Eurygaster maura	0.59
Odontotarsus robustus	0.24
Tingis grisea	0.14

* highest values.

Beneficial species

Results of CA showed that ecological infrastructures affected the abundance of predatory species (figure 3). For each type of ecological infrastructures the number of species was calculated. The highest abundance of beneficial species was associated within the WM and WFS unlike the MDP. Weedy margin (WM) closer to the extensive site was highly correlated with beneficials. On the other hand, the MDP around organic site displayed a low number of species (figure 4). The higher number of species was recorded in ecological infrastructures associated with extensive and integrated vineyards. In ecological infrastructures of integrated vineyards eight beneficial species were found. Among them were as follows: *O. niger* (15.3%), *Deraeocoris serenus* (Douglas et Scott) (8.8%) and *Nabis pseudoferus pseudoferus* Remane (6.6%) dominated in WM, whereas, *Geocoris erythrocephalus* (Lepeletier et Serville) (5.8%) was more abundant in WFS. The most abundant species associated with ecological infrastructures of the extensive vineyard were *M. melanotoma* (21.8%) and *Dicyphus globulifer* (Fallen) (7.4%). Species *O. niger* (4.8%) and *G. erytrocephalus* (3.42%) occurred with higher number in WM and WFS. Few individuals of *Deraeocoris schach* (F.) (0.04%) and *Rhynocoris rubricus* (Germar) (0.4%) were found around this vineyard. Only *M. melanotoma* was considered as a dominant species (16.61%) in the surrounding landscape of the organic vineyard with higher abundance in WM and WFS, unlike MDP (table 7). All other species occurred with less than 1%.

Table 5. Heteropotera composition (%) collected in ecological infrastructures around organic vineyard.

Species	%
Camptopus lateralis	0.93
Orius niger	0.28
Centrocoris variegatus	0.93
Coreus marginatus marginatus	0.85
Geocoris erythrocephalus	0.18
Nysius graminicola graminicola	9.20*
Paromius gracilis	0.09
Adelphocoris lineolatus	0.56
Lopus decolor	2.91
Macrolophus melanotoma	7.79*
Macrotylus atricapillus	58.02*
Lygus pratensis	5.35*
Trigonotylus ruficornis	4.13
Nabis punctatus punctatus	0.37
Ancyrosoma leucogrammes	0.18
Carpocoris fuscispinus	0.84
Dolycoris baccarum	0.28
Eysarcoris ventralis	1.03
Nezara viridula	0.18
Rhaphigaster nebulosa	0.28
Staria lunata	0.18
Rhynocoris rubricus	0.09
Chorosoma schillingi	0.18
Corizus hyoscyami hyoscyami	0.28
Liorhyssus hyalinus	0.46
Rophalus subrufus	1.40
Stictopleurus abutilon	0.46
Stictopleurus punctatonervosus	0.65
Eurygaster maura	0.93
Odontotarsus robustus	0.46
Tingis grisea	0.09
Kalama tricornis	0.18

* highest values.

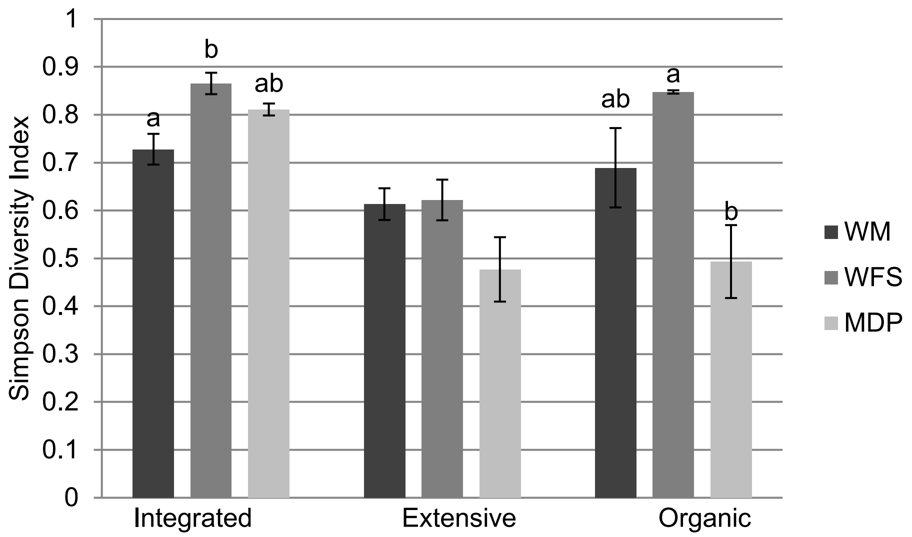

Figure 1. Simpson Diversity Index. Different letters above the bars indicate significant differences ($p < 0.05$).

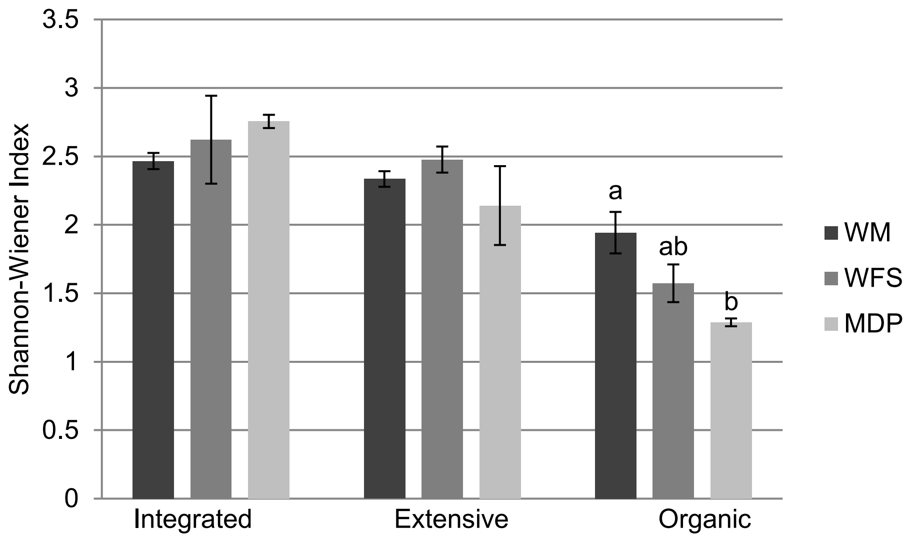

Figure 2. Shannon Wiener Diversity Index. Different letters above the bars indicate significant differences ($p < 0.05$).

Table 6. Sörensen Index of Similarity. Integrated vineyard (I), extensive vineyard (E), organic vineyard (O).

Locality	I	E	O
I	1	0.782	0.683
E	0.782	1	0.746
O	0.683	0.746	1

Plant species associated with true bugs

A total of 270 individuals were recorded on 9 selected plants (figure 5). Species *M. melanotoma* (42 individuals) was highly associated with *D. viscosa*. Between beneficial species, *O. niger* was found on four out of nine selected plants. This insect dominated over *P. lanceolata* (16 individuals), until seven specimens were recorded on *D. carota,* and five on *H. helix.* Only four specimens were found on *D. viscosa*. Order *Geocoris* showed preference on *D. carota* (19 individuals) and *T. pratense* (9). Fifteen specimens of *R. rubricus* occured on *A. arvensis* and eight on *Rubus* spp. Other Heteroptera collected on these plants were phytophagous. Among them *M. atricapillus* (73 individuals) on *D. viscosa*, while on *T. pratense* 11 individuals of *Dicranocephalus agilis* (Scopoli) were found. The highest number of *N. graminicola graminicola* was recorded on *Sonchus* spp. (29) while 10 individuals were found on *A. arvensis*.

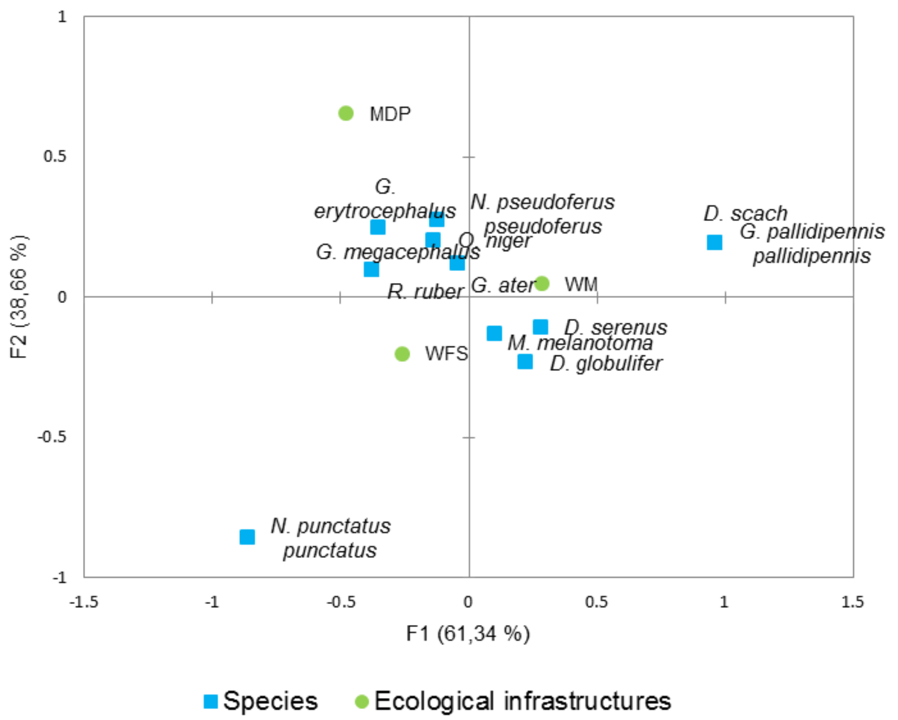

Figure 3. Correspondence analysis (CA) performed on the abundance of beneficial species associated with different ecological infrastructures.

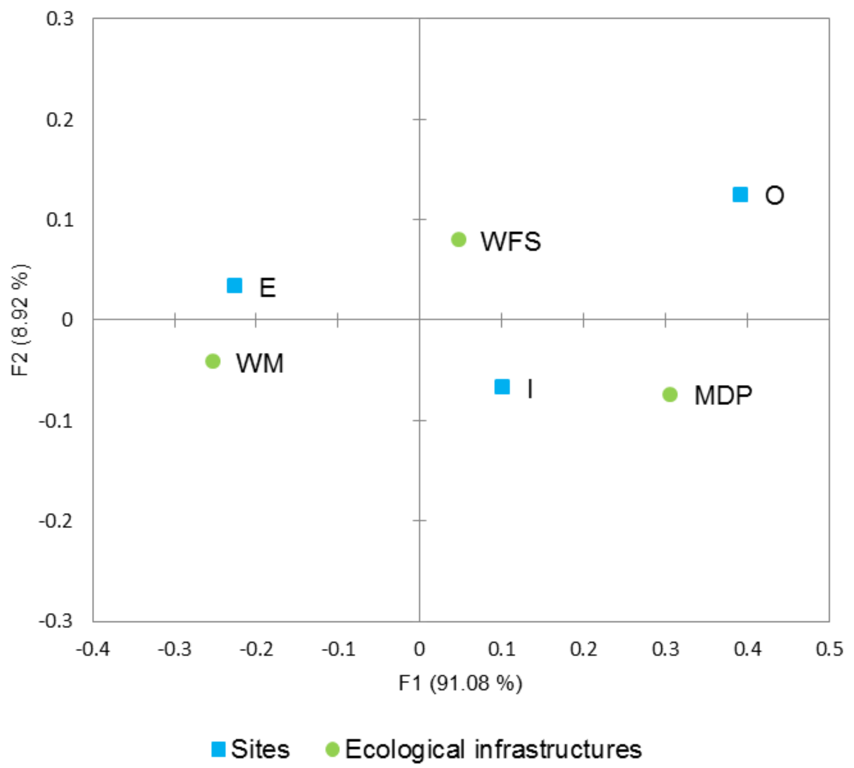

Figure 4. Correspondence analysis (CA) applied to the abundance of beneficial species in ecological infrastructures related to the sites of research.

Table 7. Percentage composition of predaceous species in ecological infrastructure around integrated, extensive and organic vineyards. Weedy margins (WM), wildflower strips (WFS), Mediterranean dry pastures (MDP).

Species	Integrated			Extensive			Organic		
	WM	WFS	MDP	WM	WFS	MDP	WM	WFS	MDP
D. globulifer	0	0	0	4.44	3	0	0	0	0
D. scach	0	0	0	0.04	0	0	0	0	0
D. serenus	5.65	3	0.2	0.48	0	0	0	0	0
G. ater	0.8	0.6	0.2	0.4	0.6	0	0	0	0
G. erytrocephalus	2.2	2.42	1.21	1.4	2.02	0.4	0	0	0.4
G. megacephalus	0	0	0.2	0.4	0.6	0	0	0	0
G. pallidipennis pallidipennis	0.36	0	0	0	0	0	0	0	0
M. melanotoma	0	0	0	14.9	6.4	0.4	3.2	5.3	1.21
N. pseudoferus pseudoferus	3.43	1.81	1.41	0.4	0.2	0	0	0	0
N. punctatus punctatus	0	0	0	0	0	0	0	0.8	0
O. niger	8.4	4.24	2.62	2.02	3.83	1	0	0.6	0
R. rubricus	0.4	0.2	0	0	0.4	0	0	0	0

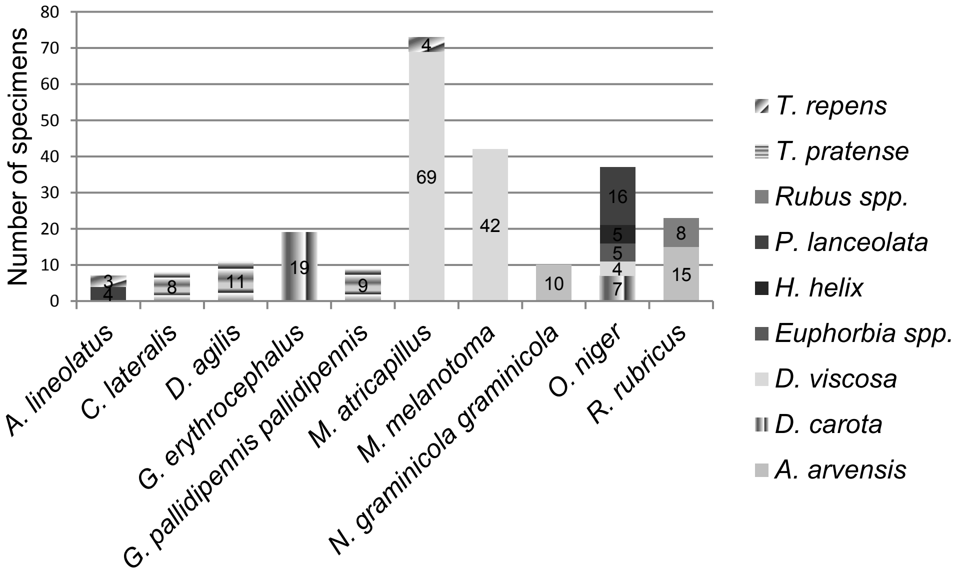

Figure 5. Number of the true bugs occurred on plants.

Discussion

The present study demonstrated the effect of different types of ecological infrastructures (WM, WFS and MDP) on Heteroptera composition and diversity. According to Gessé *et al*. (2014), Heteroptera composition could be specifically related to the plant community in which these insects live. Results of our research are in line with the findings of other authors (Zurbrüg and Frank, 2006; Gilbert *et al*., 2015; Mateos *et al*., 2018) specifying that floristic composition and vegetation structure influence Heteroptera species assemblage. The majority of true bugs found during this research fed on plants. Among phytophagous the most abundant were *N. graminicola graminicola* and *L. pratensis*. In this research *Nysius* mainly occurred on Asteraceae (*A. arvensis* and *Sonchus* spp.). According to Eyes and Malipatil (2010) these insects seems to prefer Asteraceae in particular *Sonchus*. Although Arzone *et al*. (1990) reported *Nysius* as potential pests in vineyards, during this research, no damage was observed on the grape. Besides them in ecological infrastructures, another phytophagous Heteroptera *M. atricapillus* was found as a dominant species around organic site comprising more than 50% of all capture. One of the key factors that influenced high abundance of *M. atricapillus* might be *D. viscosa* on which this insect was found in high numbers. Beneficial *M. melanotoma* was also associated with *D. viscosa*. Pollen and nectar of this plant contains high concentration of sugars and therefore makes *D. viscosa* a considerable source of food for natural enemies (Alcalá Herrera *et al*., 2019). Additionally, *D. viscosa* is a perennial plant with deeply spread roots and can survive a long months of drought. Long flowering stage, stretched from August to November (Kovačić *et al*., 2008) makes this plant an appropriate element of ecological infrastructures (food source, shelter and oviposition sites), in dry Mediterranean conditions particularly at the end of the vegetation period. It is interesting to note that within the ecological infrastructures where *D. viscosa* was not present, no specimens of *M. melanotoma* were registered. Another beneficial species *O. niger* belongs to Anthocoridae, that is an important family of natural enemies concerning vineyards (Judt *et al*., 2019). For instance, Morandin *et al*. (2011) reported *Orius* as a predator of the *Lygus* species. Duso and Girolami (1983) showed Anthocoridae as biological agents controlling *Panonychus ulmi* (Koch) in vineyards. In addition, *Orius* has been considered as a natural enemy of *Colomerus vitis* (Pagenstecher) (Sáenz-Romo *et al*., 2019). In our research, *Orius* was observed in WM and WFS, therefore these elements of ecological infrastructures might serve as a suitable habitat for these insects. Atakan and Pelivan (2019) reported *Vicia villosa* as a bank plant for some *Orius* species. Elimem *et al*. (2018) confirmed *Chrysanthemum coronarium* as a host plants on which several species of *Orius* were found. For instance, Honěk *et al*. (2013) reported the *Taraxacum officinale* was frequently colonized by Anthocoridae. According to Pelivan and Atakan (2019) *Orius* was recorded on *Sinapis arvensis*. Species from the families Asteraceae, Apiaceae, Fabaceae seem to be most appropriate hosts for natural enemies, especially the genus *Orius* and *Nabis* (Limonta *et al*., 2003; Altieri *et al*., 2005). For instance, a high abundance of, *M. melanotoma* was related to *D. viscosa*. On the other hand, *G. erytrocephalus* was found on *D. carota* as well as *O. niger.* This Anthocoridae was also associated with *P. lanceolata*. However, we assume that the reason of the appearance of a higher population of *O. niger* in the present study might also be the proximity of peach and apple orchards in integrated site bordering with WM as well as natural hedges (Atanassov *et al*., 2003; Morandin *et al*., 2011; Wan *et al*., 2011). Furthermore, within WM several host plants which attract aphids (*Rumex* spp., *P. lanceolata* and *D. carota*) were found. According to Wang *et al*. (2014), *Orius* has been recorded as an efficient predator of numerous aphid species. It has been widely known that a large group of arthropods are attracted by extrafloral nectaries (Guillermo-Ferreira *et al*., 2012; Portillo *et al*., 2012; Stefani *et al*., 2019). Extrafloral nectar seems to indicate the presence of prey on the plants and attract predators (Jones *et al*., 2016; Stefani *et al*., 2019). Nectar-rich flowers of particular weed species are known to promote survival and fecundity of natural enemies (Herz *et al*., 2019). A large number of studies reported the effects of nectar and pollen on beneficial insects fitness (Lundgreen, 2011; Portillo *et al*., 2012), but on the other hand very little is known about the effects of plant-derived sugars on predatory Heteroptera in general. For instance, pollen enhances fecundity of *Macrolophus pygmaeus* (Rambur) (Vandekerkhove and De Clercq, 2010). Revel *et al*. (2010) frequently observed *Zelus annulosus* (Stal) (Reduviidae) on plants in search for extrafloral nectar. Some Reduviids collect nectar and honeydew from certain plants in order to coat their legs with sticky substances facilitating prey capture (Revel *et al*., 2010). According to Guillermo-Ferreira *et al*. (2012), the diet of *Atopozelus opsimus* Elkins (Reduviidae) both instars and adults consisted mostly of extrafloral nectar. Besides that, Avila-Núñez *et al*. (2016) found reduvid *Heniartes stali* Wygodzinsky collecting sticky fluid from trichomes of Andean blackberry. This fact might be the reason why in our study *R. rubricus* was related to *Rubus* spp. Gil-Santana and Alves (2011) found *Zelus versicolor* (Herrich-Schaffer) on Asteraceae known as the plant family that synthetizes a variety of chemical compounds including sterols which may be important for their development. From our results, it is clear that Reduviidae was associated specifically with WM and WFS that contain plants from the family Asteraceae (for instance *A. arvensis*). One of the aims of this study was to select a particular species of spontaneous flora to be the habitat for feeding or a reproduction site for natural enemies. The families that dominated in WM and WFS were Asteraceae, Apiaceae and Fabaceae (complex plant architecture, compound flower structure, high pollen producers). Few works (Fauvel, 1999; Morris, 2000; Haddad *et al*., 2001) emphasized the impact of richly structured habitats (denser and higher vegetation, high pollen producers) as well as plant species with attractive flowers on beneficial insects. Both WFS and WM showed greater abundance of predatory Heteroptera as well as a higher number of species compared to MDP. Moreover, higher biodiversity indices were related to WM and WFS where Dicotyledonae prevailed. The number of plant species in MDP was also lower than in WM and WFS. A lower number of the Heteroptera species within MDP in our case can be associated with lower diversity of plants and the higher disturbance by livestock grazing. Therefore, due to the fact that non-crop habitats provide food, prey, and refuge and harboured a number of beneficials, presence of such plants in or around the vineyards could increase the occurrence of natural enemies (Judt *et al*., 2019). Unlike crop or vegetable production, weeds are not a considerable problem within vineyards particularly in the Mediterranean region. Moreover, weeds show some kind of synchronicity in flowering and are present in vineyards during the whole vegetation season. However, our results suggest that WM and WFS may contribute to the conservation of the true bugs biodiversity within and around vineyards. In regards to WFS special emphasis should be placed on perennial plants. Flower rich boundaries seems to be important for beneficial species that depend on pollen or nectar and in that sense, creating and maintaining ecological infrastructures as the part of landscape should be taken into account when planning a conservation biological control program. In general, the heteropteran community structure depends on various factors as well as on the abundance of plants, their structure, richness and diversity (Gilbert *et al*., 2015). Furthermore, our results agreed with Froidevaux *et al*. (2017) that landscape characteristics (ecological infrastructures) are more important for insect composition than exclusively vineyard management. These areas might serve as a source of predators and ensure their migrations from surrounding landscape into the vineyard. For instance, *Macrolophus* and *Dyciphus* can colonize crop plants from the semi-natural habitats (Aviron *et al*., 2016). The influence of landscape effects on the possibility of natural enemies to migrate from ecological infrastructures into agricultural areas depends on taxon-specific mobility and dispersal capacity (Rusch *et al*., 2011). Therefore, beneficial insects could be filtered out from the ecological infrastructures into the vineyard due to their colonization potential. True bugs show great flight potential, thus can be able to exceed long distances (Lu *et al*., 2007, Fu *et al*., 2014). However, surrounding landscape of vineyards including weedy margins and perennial wildflower strips seems to be an appropriate habitat for beneficial Heteroptera, so their presence in ecological infrastructures contribute to the insect composition and diversity.

Conclusions

Our results correspond with earlier studies that emphasized the influence of ecological infrastructures on Heteroptera assemblage and diversity. In this study, Heteroptera biodiversity reached a higher level in weedy borders and wildflower strips, unlike Mediterranean dry pastures. Although weed cover and wildflower strips can harbour a lot of phytophagous, these bugs usually serve as food not only for beneficial Heteroptera but for other groups of predatory insects, parasites as well as for spiders. These findings highlight the importance of conserving spontaneous flora in vineyard surrounding landscape to improve better conditions for true bugs. Results of this research suggest that vineyard adjacent areas such as wildflower strips, and in particular weedy margins contribute to promoting agrobiodiversity. Future research should be devoted to systematically exploring the role of spontaneous plants on the beneficial Heteroptera community. Special attention should be given to plants such as *A. arvensis*, *D. carota*, *D. viscosa*, *P. lanceolata* and *Rubus* spp., which could act as good candidates in attracting the predatory species. Furthermore, it could be interesting to identify which phenophases of non-crop plants support higher numbers of predators. That data might help in preventing this vegetation from being mowed or destroyed in particular phenophases. Finally, this research could help with the better understanding of the role of ecological infrastructures as a valuable conservation measure in IPM.

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References

ALCALÁ HERRERA R., CASTRO-RODRÍGUEZ J., FERNÁNDEZ-SIERRA M. L., CAMPOS M., 2019.- *Dittrichia viscosa* (Asterales: Asteraceae) as an arthropod reservoir in olive groves.- *Frontiers in Sustainable Food systems*, 3 (64): 1-8.

ALTIERI M. A., 1999.- The ecological role of biodiversity in agroecosystems.- *Agriculture, Ecosystem and Environment*, 74: 19-31.

ALTIERI M. A., PONTI L., NICHOLLS C. I., 2005.- Manipulating vineyard biodiversity for improved insect pest management: case studies from northern California.- *International Journal of Biodiversity Science and Management*, 1: 1-13.

ARZONE A., VIDANO C., ALMA A., 1990.- Vineyard agro-ecosystem Heteroptera in the Mediterranean Region.- *Scopolia*, 1: 101-107.

ATAKAN E., PEHLIVAN S., 2020.- Influence of weed management on the abundance of thrips species (Thysanoptera) and the predatory bug, *Orius niger* (Hemiptera: Anthocoridae) in citrus mandarin.- *Applied Entomology and Zoology*, 55: 71-81.

ATANASSOV A., SHEARER P. W., HAMILTON G. C., 2003.- Peach pest management programs impact beneficial fauna abundance and *Grapholita molesta* (Lepidoptera: Tortricidae) egg parasitism and predation.- *Environmental Entomology*, 32 (4): 780-788.

ATTWOOD S. J., MARON M., HOUSE A. P. N., ZAMMIT C., 2008.- Do arthropod assemblages display globally consistent response to intensified agricultural land use and management?- *Global Ecology and Biogeography*, 17 (5): 585-599.

AVILA-NÚÑEZ J. L., NAYA M., OTERO L. D., ALONSO AMELOT M. E., 2016.- A resin bugs (Reduviidae: Harpactorinae: Apiomerini) harvesting the trichome secretion from an Andean blackberry.- *Neotropical Biodiversity*, 2 (1): 151-158.

AVIRON S., POGGI S., VARENNES Y. D., LEFÈVRE D., 2016.- Local landscape heterogeneity affects crop colonization by natural enemies of pests in protected horticultural cropping systems.- *Agriculture Ecosystems and Environment*, 227: 1-10.

BEGG G. S., COOK S. M., DYE R., FERRANTE M., FRANCK P., LAVIGNE C., LÖVEI G. L., MANSION-VAQUIE A., PELL J. K., PETIT S., QUESADA N., RICCI B., WRATTEN S. D., BIRCH A. N. E., 2017.- A functional overview of conservation biological control.- *Crop Protection*, 97: 145-158.

BOLLE H. J., 2003.- *Mediterranean climate - variability and trends*.- Springer-Verlag, Berlin Heidelberg, Germany.

CHUCHE J., THIÉRY D., 2014.- Biology and ecology of the flavescence dorée vector *Scaphoideus titanus*: a review.- *Agronomy for Sustainable Development*, 34: 381-403.

COSTELLO M. J., DAANE K. M., 1999.- Abundance of spiders and insects predators on grapes in central California.- *Journal of Arachnology*, 27: 531-538.

DERJANSCHI V., PERICART J., 2006.- *Hémiptères Pentatomoidea Euro-Méditerranéens. Volume I.* Faune de France.- Fédération Française des Sociétés de Sciences Naturelles, Paris, France.

DUSO C., GIROLAMI V., 1983.- Ruolo degli Antocoridi nel controllo del *Panonychus ulmi* Koch nei vigneti.- *Bollettino dell'Istituto di Entomologia della Università degli Studi di Bologna*, 37: 157-169.

ELIMEM M., LIMEM-SELLEMI E., HAFSI A., BEN OTHMEN S., CHERMITI B., 2018.- The genus *Orius* Wolf (Insecta; Heteroptera; Anthocoridae) in the Tunisian coastal region: biodiveristy and distribution.- *Journal of New Sciences*, *Sustainable Livestock Management*, 5 (2): 91-99.

EYES A. C., MALIPATIL M. B., 2010.- *Nysius caledoniae* Distant, 1920 (Hemiptera: Heteroptera: Orsillidae) a recent introduction into New Zealand, and keys to the species *Nysius*, and genera of *Orsillidae* in New Zealand.- *Zootaxa*, 2484: 45-52.

FAUVEL G., 1999.- Diversity of Heteroptera in agroecosystems: role of sustainability and bioindication.- *Agriculture Ecosystem and Environment*, 74: 257-303.

FROIDEVAUX J. S. P., LOUBOUTIN B., JONES G., 2017.- Does organic farming enhance biodiversity in Mediterranean vineyards? A case study with bats and arachnids.- *Agriculture Ecosystem and Environment*, 249: 112-122.

FU X., LIU Y., LI C., LU Y., LI Y., WU K., 2014.- Seasonal migration of *Apolygus lucorum* (Hemiptera: Miridae) over the Bohai Sea in northern China.- *Journal of Economic Entomology*, 107 (4): 1399-1410.

GESSÉ F., MONLEÓN-GETINO T., GOULA M., 2014.- Biodiversity analysis of true bug assemblages (Hemiptera, Heteroptera) in four habitats in the Garraf Natural Park (Barcelona, Spain).- *Journal of Insect Science*, 14 (1): 283.

GIL-SANTANA H. R., ALVES R. J. V., 2011.- Association between *Zelus versicolor* (Herrich-Schäffer) (Hemiptera, Reduviidae, Harpactorinae) and *Bidens rubifolia* Kunth (Asterales, Asteraceae).- *EntomoBrasilis*, 4 (1): 30-32.

GILBERT S., NORRDAHL K., TUOMISTO H., SÖDERMAN G., RINNE V., HUUSELA-VEISTOLA E., 2015.- Reverse influence of riparian buffer width on herbivorous and predatory Hemiptera.- *Journal of Applied Entomology*, 139: 539-552.

GUILLERMO-FERREIRA R., CARDOSO-LEITE R., GANDOLFO R., 2012.- First observation of alternative food usage (extrafloral nectar) by the assassin bug *Atopozelus opsimus* (Hemiptera, Reduviidae).- *Revista Brasileira de Entomologia*, 56 (4): 489-491.

HADDAD N. M., TILMAN D., HAARSTAD J., RITCHIE M., KNOPS J. M. N., 2001.- Contrasting effects of plant richness and composition on insect communities: a field experiment.- *American Naturalist*, 158 (1): 17-35.

HERZ A., CAHENZLI F., PENVERN S., PFIFFNER L., TASIN M., SIGSGAARD L., 2019.- Managing floral resources in apple orchards for pest control: ideas, experiences and future directions.- *Insects*, 10 (8): 247.

HOLE D. G., PERKINS A. J., WILSON J. D., ALEXANDER I. H., GRICE P. V., EVANS A. D., 2005.- Does organic farming benefit biodiversity?- *Biological Conservation*, 122 (1): 113-130.

HONĚK A., ŠTYS P., MARTINKOVÁ Z., 2013.- Arthropod community of dandelion (*Taraxacum officinale*) capitula during seed dispersal.- *Biologia*, 68 (2): 330-336.

JONES I. M., KOPTUR S., VON WETTBERG E. J., 2016.- The use of extrafloral nectar in pest management: overcoming context dependence.- *Journal of Applied Ecology*, 54 (2): 489-499.

JUDT C., GUZMÁN G., GÓMEZ J. A., CABEZAS J. M., ENTRENAS J. A., WINTER S., ZALLER J. G., PAREDES D., 2019.- Diverging effects of landscape factors and inter-row management on the abundance of beneficial and herbivorous arthropods in Andalusian vineyards (Spain).- *Insects*, 10 (10): 320.

KOVAČIĆ S., NIKOLIĆ T., RUŠČIĆ M., MILOVIĆ M., STAMENKOVIĆ V., MIHELJ D., JASPRICA N., BOGDNOVIĆ S., TOPIĆ J., 2008.- *Flora jadranske obale i otoka 250 najčešćih vrsta*.- Školska knjiga, Zagreb, Croatia.

LANDIS D. A., MENALLED F., COSTAMAGNA A. C., 2005.- Manipulating plant resources to enhance beneficial arthropods in agricultural landscapes.- *Weed Science*, 53: 902-908.

LESKEY T. C., HAMILTON G. C., NIELSEN A. L., POLK D. F., RODRIGUEZ-SAONA C., BERGH J. C., HERBERT D. A., KUHAR T. P., PFEIFFER D., DIVELY G. P., HOOKS C. R. R. RAUPP M., SHREWSBURY P., KRAWCZYK G., SHEARER P. W., WHALEN J., KOPLINKA-LOEHR C., MYERS E., 2012.- Pests status of the brown marmorated stink bug, *Halyomorpha halys* in the USA.- *Outlooks on Pest Management*, 23 (5): 218-226.

LIMONTA L., DIOLI P., DENTI A., 2003.- Heteroptera present in two different plant mixtures.- *Bollettino di Zoologia Agraria e di Bachicoltura*, 35 (1): 55-65.

LOSOSOVÁ Z., DANIHELKA J., CHYTRY M., 2003.- Seasonal dynamics and diversity of weed vegetation in tilled and mulched vineyards.- *Biologia*, 58 (1): 49-57.

LOZZIA G. C., DIOLI P., MANACHINI B., RIGAMONTI I. E., SALVETI M., 2000.- Effects of soil management on biodiversity of Hemiptera, Heteroptera in vineyards of Valtellina (Northern Italy).- *Bollettino di Zoologia Agraria e di Bachicoltura*, 32 (2): 141-155.

LU Y., WU K., GUO Y., 2007.- Flight potential of *Lygus lucorum* (Meyer-Dür) (Heteroptera: Miridae).- *Environmental Entomology*, 36 (5): 1007-1013.

LU Z. X., ZHU P. H., GURR G. M., ZHENG X. S., READ D. M., HEONG K. L., YANG Y. J., XU H. X., 2014.- Mechanisms for flowering plants to benefit arthropod natural enemies of insect pests: prospects for enhanced use in agriculture.- *Insect Science*, 21 (1): 1-12.

LUNDGREN J. G., 2011.- Reproductive ecology of predaceous Heteroptera.- *Biological Control*, 59 (1): 37-52.

MAGURRAN A. E., 2004.- *Ecological diversity and its measurement*.- Chapman and Hall, London, UK.

MANLY B. F. J., NAVARRO A. J. A., 2017.- *Multivariate statistical methods-A primer*. Fourth edition.- Taylor & Francis, New York, USA.

MATEOS E., GOULA M., SAURAS T., SANTOS X., 2018.- Habitat structures and host plant specialization drive taxonomic and functional composition of Heteroptera in postfire successional habitats.- *Turkish Journal of Zoology*, 42: 449-463.

MITCHELL P. L., 2004.- Heteroptera as vectors of plant pathogens.- *Neotropical Entomology*, 33 (5): 519-545.

MORANDIN L., LONG R. F., PEASE C., KREMEN C., 2011.- Hedgerows enhance beneficial insects on farms in California's Central Valley.- *California Agriculture*, 65 (4): 197-201.

MORRIS M. G., 2000.- The effects of structure and its dynamics on the ecology and conservation of arthropods in British grasslands.- *Biological Conservation*, 95: 129-142.

NARANJO S. E., ELLSWORTH P. C., FRISVOLD G. B., 2014.- Economic value of biological control in integrated pest management of managed plant systems.- *Annual Review of Entomology*, 60: 621-645.

ORABI G., MOIR M. L., MAJER J. D., 2010.- Assessing the success of mine restoration using Hemiptera as indicators.- *Australian Journal of Zoology*, 58 (4): 243-249.

ORSÁGOVÁ H., BŘEZÍKOVÁ M., SCHLESINGEROVÁ G., 2011.- Presence of phytplasmas in hemipterans in Czech vineyards.- *Bulletin of Insectology*, 64 (Supplement): S119-S120.

PAOLETTI M. G., 1999.- *Intervebrate biodiversity as bioindicators of sustainable landscape*es. *Practical use of invertebrates to asses sustainable land use*.- Elsevier, Amsterdam, The Netherlands.

PEHLIVAN S., ATAKAN E., 2020.- Distribution and seasonal abundance of predatory bugs, *Orius* spp. (Hemiptera: Anthocoridae) in Adana Province, Turkey.- *Turkish Journal of Entomology*, 44 (1): 57-69.

PÉRICART J., 1987.- *Hémiptères Nabidae d'Europe occidentale et du Maghreb*.- Faune de France, Fédération Française des Sociétés de Sciences Naturelles, Paris, France.

PÉRICART J., 1998.- *Hémiptères Lygaeidae Euro-Méditerranées*.- Faune de France. Fédération Française des Sociétés de Sciences Naturelles, Paris, France.

POORE M. E. D., 1995.- The use of phytosociological methods in ecological investigations: I. The Braun_Blanquet system.- *Journal of Ecology*, 43 (1): 226-244.

PORTILLO N., ALOMAR O., WÄCKERS F., 2012.- Nectarivory by the plant-tissue feeding predator *Macrolophus pygmaeus* Rambur (Heteroptera: Miridae): nutritional redundancy or nutritional benefit.- *Journal of Insect Physiology*, 58 (3): 397-401.

REVEL M., DEJEAN A., CÉRÉGHINO R., ROUX O., 2010.- An assassin among predators: the relationship between plant-ants, their host Myrmecophytes and the Reduviidae *Zelus annulosus*.- *PLoS ONE*, 5 (10): e13110.

ROGÉ P., VIELI L., MILES A., WILSON H., 2009.- Effect of landscape structure on biological control of vineyard pests in Northern California.- *Revista Brasileira de Agroecologia*, 4 (2): 3128-3132.

ROGOŠIĆ J., 2011.- *Bilinar cvjetnjača hrvatske flore s ključem za određivanje bilja*. Vol. 1 and 2.- Sveučilište u Zadru, Zadar, Croatia.

RUSCH A., VALANTIN-MORISON M., SARTHOU J-P., ROGER-ESTRADE J., 2011.- Effect of crop management and landscape context on insect pest populations and crop damage.- *Agriculture Ecosystems & Environment*, 166: 118-125.
SÁENZ-ROMO M. G., VEAS-BERNAL A., MARTÍNEZ-GARCÍA H., IBÁÑEZ-PASCUAL S., MARTÍNEZ-VILLAR E., CAMPOS-HERRERA R., MARCO-MANCEBÓN V. S., 2019.- Effects of ground cover management on insect predators and pests in a Mediterranean Vineyard.- *Insects*, 10 (12): 421-437.
SCHAEFER C. W., PANIZZI A. R., 2000.- *Heteroptera of economic importance*. 1st ed.- CRC Press, Boca Raton, Florida, USA.
SCHUMAN M. C., KESSLER D., BALDWIN I. T., 2013.- Ecological observations of native *Geocoris pallens* and *G. punctipes* populations in the great basin desert of Southwestern Utah.- *Journal of Entomology*, 6: 1-11.
SNYDER W. E., 2019.- Give predators a compliment: conserving natural enemy biodiversity to improve biocontrol.- *Biological Control*, 135: 73-82.
STEFANI V., NUNES ALVES V., LANGE D., 2019.- Induced indirect defence in a spider-plant system mediated by pericarpial nectaries.- *Austral Ecology*, 44 (6): 1005-1012.
STICHEL W., 1955.- *Illustrierte Bestimmungstabellen der Wanzen*.- Stichel, Berlin- Hermsdorf, Germany.
THIÉRY D., LOUÂPRE P., MUNERET L., RUSCH A., SENTENAC G., VOGELWEIGHT F., ILTIS C., MOREAU J., 2018.- Biological protection against grape berry moths. A review.- *Agronomy for Sustainable Development*, 38: 15.
VANDEKERKHOVE B., DE CLERCQ P., 2010.- Pollen as an alternative or supplementary food for the mirid predator *Macrolophus pygmaeus*.- *Biological Control*, 53: 238-242.
WAGNER E., WEBER H. H., 1964.- *Hétéroptères Miridae*. Faune de France Vol. 67.- Fédération Française des Sociétés de Sciences Naturelles, Paris, France.
WAGNER E., 1971.- *Die Miridae (Heteroptera) des Mittelmeerraumes*. Teil 1.- Akademische Verlagsgesellschaft Geest & Portig, Leipzig-Dresden, Germany.
WAN N-F., JI X-Y., JIANG J-X., DAN J-G., 2011.- Effects of ground cover on the niches of main insect pests and their natural enemies in peach orchard.- *Chinese Journal of Ecology*, 30 (2): 30-39.
WANG S., MICHAUD J. P., TAN X-L., HANG F., 2014.- Comparative suitability of aphids, thrips and mites as prey for the flower bug *Orius sauteri* (Hemiptera: Anthocoridae).- *European Journal of Entomology*, 111 (2): 221-226.
WILSON H., DAANE K. M., 2017.- Review of ecologically-based pest management in California vineyards.- *Insects*, 8 (4): 108.
WONG S. K., FRANK S. D., 2013.- Pollen increases fitness and abundance of *Orius insidiosus* Say (Heteroptera: Anthocoridae) on banker plants.- *Biological Control*, 64 (1): 45-50.
ZURBRÜG C., FRANK T., 2006.- Factors influencing bug diversity (Insecta: Heteroptera) in semi-natural habitats.- *Biodiversity and Conservation*, 15: 275-294.

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Appendix

Braun-Blanquet cover abundance in ecological infrastructures associated with organic, extensive and integrated vineyard. Weedy margins (WM), wildflower strips (WFS), Mediterranean dry pastures (MDP).

Integrated vineyard		
Weedy margins (WM)	Wildflower strips (WFS)	Mediterranean dry pastures (MDP)
1.1 *Avena sterilis* L. +.1 *Dactylis glomerata* L. subsp. *hispanica* (Roth.) Nyman +.1 *Cirsium arvense* L. +.1 *Euphorbia* spp. 1.1 *Bromus racemosus* L. +.2 *Dorycnium hirsutum* (L.) Ser. +.1 *Cichorium intybus* L 1.1 *Daucus carota* L. +.1 *Vicia* spp. 1.2 *Trifolium repens* L. +.2 *Trifolium pratense* L. 1.1 *Plantago lanceolata* L. +.1 *Capsella bursa pastoris* (L.) Medik +.1 *Sonchus* spp. +.1 *Lothus* spp. +.1 *Centaurea cyanus* L. +.1 *Rumex* spp. +.2 *Anthemis arvensis* L. +.1 *Convolvulus arvensis* L.	+.1 *Cynodon dactylon* L. 1.2 *Foeniculum vulgare* L. 2.2 *Daucus carota* L. 1.1 *Dactylis glomerata* L. subsp. *hispanica* (Roth.) Nyman +.1 *Achillea millefolium* L. 1.2 *Trifolium repens* L. r.1 *Euphorbia* spp. +.1 *Convolvulus arvensis* L. +.1 *Artemisia absinthium* L. +.1 *Avena sterilis* L. +.1 *Cirsium arvense* L.	2.2 *Daucus carota* L. +.1 *Rumex* spp. 1.2 *Cynodon dactylon* L. 1.2. *Bromus racemosus* L. +.1 *Erigeron annus* L. +.1 *Convolvulus arvensis* L. 1.1 *Setaria viridis* (L.) Beauv

Appendix continued

Appendix continued

Extensive vineyard		
Weedy margins (WM)	Wildflower strips (WFS)	Mediterranean dry pastures (MDP)
2.2 *Anthemis arvensis* L. 1.2 *Cynodon dactylon* L. 1.1 *Avena sterilis* L. 1.1 *Sorghum bicolor* (L.) Moench +.1 *Amaranthus retroflexus* L. +.2 *Bromus racemosus* L. +.2 *Chenopodium album* L. +.1 *Mercurialis annua* L. +.1 *Cichorium intybus* L. +.1 *Hordeum murinum* L. +.1 *Papaver rhoeas* L. +.1 *Sonchus* spp. +.1 *Artemisia absinthium* L. +.1*Fumaria officinalis* L. +.1 *Senecio vulgaris* L. +.1 *Convolvulus arvensis* L. +.1 *Lamium amplexicaule* L. +.1 *Foeniculum vulgare* L. +.1 *Dactylis glomerata* L. subsp. *hispanica* (Roth.) Nyman +.1 *Setaria viridis* (L.) Beauv. +.1 *Bunias erucago* L. +.1 *Calendula arvensis* L. +.1 *Cirsium arvense* L. r.1 *Allium* spp. r.1 *Melilotus officinalis* (L.) Lam. +.1 *Portulaca oleracea* L.	1.1 *Avena sterilis* L. 1.1 *Bromus racemosus* L. 1.1 *Hordeum murinum* L. +.1 *Galium* spp. +.1 *Lotus cornicolatus* L. 1.1 *Daucus carota* L. 1.1 *Dactylis glomerata* L. subsp. *hispanica* (Roth.) Nyman 1.1 *Vicia* spp. 1.2 *Dittrichia viscosa* (L.) Greuter +.1 *Securidera* spp. +.1 *Setaria viridis* (L.) P. Beauv. +.1 *Dorycnium hirsutum* (L.) Ser. +.1 *Onopordum illyricum* L. +.1 *Sisymbrium officinale* (L.) Scop.	2.1 *Avena sterilis* L. 1.2 *Dactylis glomerata* L. subsp. *hispanica* (Roth.) Nyman 1.1 *Daucus carota* L. 1.1 *Dittrichia viscosa* (L.) Greuter 1.1 *Doricnium hirsutum* (L.) Ser. 1.1 *Hordeum murinum* L. 1.1 *Vicia* spp. +.1 *Lotus corniculatus* L. +.1 *Foeniculum vulgare* L.
Organic vineyard		
Weedy margins (WM)	Wildflower strips (WFS)	Mediterranean dry pastures (MDP)
3.2 *Cynodon dactylon* (L.) Pers. 2.2 *Dorycnium hirsutum* (L.) Ser. 1.1 *Dittrichia viscosa* (L.) Greuter +.1 *Centaurea cyanus* L. +.2 *Aegilops neglecta* Req. ex Bertol 1.1 *Daucus carota* L. +.1 *Avena fatua* L. +.1 *Briza maxima* L. +.1 *Vicia* spp. +.1 *Hordeum murinum* L. +.1 *Cichorium intybus* L. +.1 *Scolymus hispanicus* L. r.1 *Datura stramonium* L. +.1 *Chrysopogon gryllus* (L.) Trin. +.1 *Sonchus* spp. +.1 *Rumex* spp. +.1 *Convolvulus arvensis* L. +.2 *Lotus* spp. +.1 *Onopordum illyricum* L.	1.1 *Dittrichia viscosa* (L.) Greuter +.1 *Aegilops neglecta* Req. ex Bertol +.1 *Daucus carota* L. +.1 *Avena sterilis* L. 2.1 *Briza maxima* L. +.1 *Vicia* spp. +.1 *Hordeum murinum* L. +.1 *Cichorium intybus* L. +.1 *Scolymus hispanicus* L. 2.2 *Dorycnium hirsutum* (L.) Ser. +.1 *Chrysopogon gryllus* (L.) Trin. +.1 *Sonchus* spp. +.1 *Dactylis glomerata* L. subsp. *hispanica* (Roth.) Nyman 1.1 *Trifolium repens* L.	1.1 *Aegilops neglecta* Req. ex. Bertol. 1.1 *Avena sterilis* L. +.1 *Dittrichia viscosa* (L.) Greuter +.1 *Hypericum perforatum* (L.) Lam. +.1 *Convolvulus arvensis* L. +.1 *Cichorium intybus* L. 2.1 *Daucus carota* L. 1.1 *Vicia* spp. 1.1 *Rumex* spp. 1.2 *Trifolium repens* L. 1.2 *Koeleria* spp.