FAUNA OF LADYBUGS (COLEOPTERA: COCCINELLIDAE) IN THE VINEYARD AGROECOSYSTEM

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Components of ecological infrastructure in vineyard agroecosystems such as wildflower strips, vineyard edges, vegetation between rows and weed margins in fields play an important role in organic plant production. The composition of weeds (as elements of the ecological infrastructure) and their influence on abundance and biodiversity of ladybugs was researched in this paper. The present study was conducted from May to October (2011–2012) in the vineyard region of Zadar (Northern Dalmatia – Croatia). Ladybugs (Coleoptera: Coccinellidae) were sampled by the sweep net method and visual inspection of plants. A total of 180 individuals of ladybugs were collected during this research. The most abundant species appearing in all localities were *Hippodamia variegata* (Goeze, 1777) (41.1 %) and *Scymnus spp.* (23.8 %). Other Coccinellids included *Coccinella septempunctata* (Linnaeus, 1758), *Psyllobora vigintiduopunctata* (Linnaeus, 1758) and *Stethorus punctilum* (Weise, 1891) but were less presented. Diversity indices varied between sites. The highest value was recorded at the locality Bokanjac (2.41), whereas the lowest was seen at the site Posedarje (1.00). The maximum similarity index (0.90) was recorded between Bokanjac and Suhovare, while the minimum was (0.60) between Bokanjac and Posedarje. Among plants the main weed species hosting ladybugs were *Anthemis arvensis*(Linnaeus, 1753), *Daucus carota* (Linnaeus, 1753), *Dittrichia viscose* (Greuter, 1973) and *Chenopodium album* (Linnaeus, 1753).

Key words: vineyard, ladybugs, ecological infrastructure, weeds

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Sastavni elementi ekološke infrastrukture kao što su cvjetne trake, zatravljena površina unutar vinograda te korovima obrasli rubni dijelovi polja i vinograda imaju važnu ulogu u ekološkoj proizvodnji. Ovaj rad prikazuje rezultate istraživanja utjecaja korova na brojnost i bioraznolikost božjih ovčica. Istraživanje je obavljeno u periodu od svibnja do listopada (2011.–2012.) u vinogradima u okolici Zadra (Sjeverna Dalmacija – Hrvatska). Božje ovčice (Coleoptera: Coccinellidae) sakupljane su metodom košnje entomološkom mrežom i vizualnim pregledom biljaka. Tijekom ovog istraživanja sakupljeno je sveukupno 180 jedinki božjih ovčica. Vrste *Hippodamia variegata* (Goeze, 1777.) (41,1 %) i *Scymnus spp.* (23,8 %) u najvećem su broju zabilježene na svim lokalitetima. *Coccinella septempunctata* (Linnaeus, 1758), *Stethorus punctilum* (Linnaeus, 1758) i *Stethorus punctilum*(Weise, 1891) manje su prisutne. Indeks raznolikosti varirao je između lokaliteta. Najveća vrijednost je zabilježena na lokalitetu Bokanjac (2,41), dok je najniža u Posedarju (1,00). Najveći indeks sličnosti zabilježen je između Bokanjca i Suhovara (0,90), a najniži između Bokanjca i Posedarja (0.60). Među biljkama kao dominantne korovne vrste koje privlače bubamare navedene su: *Anthemis arvensis* (Linnaeus, 1753), *Daucus carota* (Linnaeus, 1753), *Dittrichia viscosa* (Greuter, 1973) i *Chenopodium album* (Linnaeus, 1753).

Ključne riječi: vinograd, božje ovčice, ekološka infrastruktura, korovi

Introduction

The great anthropogenic impact on viticulture ecosystems has led to the disturbance of biodiversity (Vaduvoiu & Mitrea, 2013). Vineyards in many parts of the world can be regarded as monocultures with little remaining native vegetation, particularly because of chemical weed treatments (Carlos et al., 2012). According to Norris & Kogan (2005) weeds in agricultural production can indirectly serve carnivorous (beneficial) arthropods by providing food and shelter for their prey but also as alternative hosts for beneficial arthropods when their preferred plant host is absent. There are many ways in which increased plant biodiversity can contribute to the design of pest-stable agroecosystems (Altieri et al., 2005). Some authors (Nicholls et al., 2008; Ruby et al., 2011) reported that weed borders play an important role in attracting beneficial insects. Among insect predators, the ladybugs (Coleoptera: Coccinellidae) include major predators of harmful arthropods in agriculture (Joshi et al., 2012). As Akhavan et al. (2013) reported, ladybugs are of great economic importance in both their larval and adult stages as predators on various important pests such as aphids, coccids and other soft bodied insects. In their investigation of scale insects in Croatia Milek et al. (2009) found 12 species of ladybugs. Jelovčan et al. (2007) cit. Jelovčan (2005) gave a check list of the 73 species ever found in Croatia. The most recent research into ladybug fauna in Croatia brought results of 78 determined species (Koren et al., 2012). The main goal of this paper was to research the ladybugs complex in vineyard weedy margins and field patches near vineyards, likewise the influence of some plants (mainly weed) species on ladybug fauna.

Materials and Methods

The study took place in the northern Dalmatia region of Croatia (near the town of Zadar), from May to October 2011 and 2012. According to the Köppen climate classification the climate is Mediterranean (Csa), with cool to mild and wet winters and dry and hot summers (Bolle, 2003). The ecological infrastructure of three vineyards, each in different type of production system (two in Organic and one in Integrated Pest Management) was sampled. The Bokanjac organic vineyard, BO (N 44°08′01.8′′; E 15°15′15.0′′), near the town of Zadar lies among small fields, enclosed mainly with perennial plantations such as vineyards and olive orchards. The Posedarje vineyard, PO (N 44°15′09.8′′; E 15°25′54.0′′), is surrounded with hedge-rows, mixed hedgerows with trees, meadows and abandoned arable land where the closest cultivated area is about 500m away. The third, Suhovare, SIPM (N 44°09′25.6′′; E 15°26′12.6′′), is sited in a large agricultural area surrounded with other vineyards, stone fruit orchards (peach and sour cherry) and vegetable fields. The ecological infrastructure of the researched vineyards is composed of weedy margins, hedgerows, wildflower strips, meadows, non-cultivated fields and field patches. At site SIPM chemical control (selective pesticides) was allowed, whereas in BO and PO the use of synthetic pesticide was proscribed, except sulphur and copper fungicides if necessary. In each site, two zones, vineyard margins (a) and field patches (b), were chosen to collect the insects from. Ladybugs were collected by the sweep net method (2 transects of 50 strikes) and also by visual inspection of plants (Baggiolini, 1965), fortnightly during the vegetation season (May-October). Captured insects were killed immediately with diethyl ether and conserved in 70 % ethyl alcohol. All collected individuals were determined with the help of entomological keys and sorted to genus and species level when possible. For identifying ladybug species the following key (Freude et al. 1967) was used. An inventory of plant communities was taken once during 2011 in vineyard edges and field patches near vineyards. In each zone three sampling points, with a surface of about 1 m^2 each, were chosen (a total of 18 sample stations) and the plants were counted. The identification of plants was made using the »Bilinar of Croatian Flora« (Rogošić, 2011).

The insect data were analyzed and summarized to calculate dominance, diversity, abundance and similarity of species in different sampling areas. Biodiversity between sites was measured using the Shannon Wiener Diversity Index (H), while similarity of Coccinellidae among sites was evaluated using the Sörrenson Index of Similarity (Sørensen, 1948) cit. Maguran (1988). To check for dominant groups we used the scale proposed by Tischler (1949) (Table 1.) and completed by Heydemann (1955) (Tischler, 1949) cit.Holecováet al. (2005).

$$D_1 = \frac{a_1}{\sum_{i=1}^{n} a_1} 100\,(\%) \tag{1}$$

where:

D_1 = dominance of the species number 1 in percentage

a_1 = number of adult of the species 1 on one site

$\sum_{i=1}^{n} a_1$ = total number of adults of all species on one site

Table 1. Tischler's scale for a species dominance (Tischler, 1949):

Tischler's scale for a species dominance (Tischler, 1949):		
E	eudominant	10 % – 100 %
D	dominant	5 % – 10 %
Sd	subdominant	2 % – 5 %
R	recent	1 % – 2 %
Sr	subrecent	< 1 %

As a measure of diversity the **Shannon Wiener Index (H)** was used

$$\mathrm{H} = -\sum_{i=1}^{n} p_{\mathrm{i}} \ln p_{\mathrm{i}} \qquad (2)$$

where

S = species richness (number of species) in one locality, p_i = proportion of species i, n_i = abundance of species i, N = the total abundance in sample. The index values are among 0.0 and 5.0. In the majority of cases the calculated values range from 1 to 3.5. The values above 3.0 indicate that the habitat is stable, whereas all values below 1.0 indicate a degraded or polluted habitat structure (Magurran, 1988).

As a measure of similarity the **Sørensen Index (SQ)** was used

SQ = 2J/(a+b)

where:

J = number of similar species in both communities; a = total number of species in community A, b = total number of species in community B. The value of SQ ranges from 0 to 1. Within this index, 0 represents no similarity and 1 complete similarity: the bigger the value the higher the similarity (Southwood & Henderson, 2000).

Results

Ladybugs

A total of 180 individuals belonging to 3 subfamilies, 5 tribes, and 7 species were collected during period of research (Table 2).

H. variegate was the most abundant coccinellid species (41.1 %) found in two investigated sites (SIPM and BO) as eudominant, followed by *Scymnus spp.* (23.8 %) *and Scymnus frontalis* (Fabricius, 1787) (14.4 %). Except *H. variegata* and *P. vigintiduopunctata* other species were represented in all investigated localities. The lowest abundance was shown by *Exochomus nigromaculatus* (Goeze, 1777) with only five specimens found (2.77 %). Dominance between sites and zones was estimated, showing high values for *H. variegata* in BO whereas *E. nigromaculatus* in the same site was established as subrecent (Table 2). Among other species *S. punctilum* was found as recent in all sites. Only in site PO was *P. vigintiduopunctata* not found,

Table 2. List of total number of ladybugs sampled in ecological infrastructure of vineyard

Subfamily	Tribe	Ladybug species	Total number	Percentage (%)
Coccinellinae	Coccinelini	*Coccinella septempunctata*	16	8.88
		Hipodamia variegata	74	41.1
	Psyllioborini	*Psyllobora vigintiduopunctata*	8	4.44
Chilocorinae	Chilocorini	*Exochomus nigromaculatus*	5	2.77
Scyminae	Scymnini	*Scymnus frontalis*	26	14.4
		Scymnus spp.	43	23.88
	Stethorini	*Stethorus punctilum*	8	4.44

Table 3. The dominance of coccinellids in researched localities

No.	Ladybug species	Dominance (%)			Results		
		SIPM	BO	PO	SIPM	BO	PO
1.	*Coccinella septempunctata*	2.7	4.4	1.6	Sd	Sd	R
2.	*Exochomus nigromaculatus*	1.1	0.5	1.1	R	Sr	R
3.	*Hipodamia variegata*	13.8	27.2	0	E	E	R
4.	*Psyllobora vigintiduopunctata*	2.2	2.2	0	Sd	Sd	R
5.	*Scymnus frontalis*	4.4	6.6	3.3	Sd	D	Sd
6.	*Scymnus spp.*	12.2	4.4	7.2	E	Sd	D
7.	*Stethorus punctilum*	1.6	1.1	1.6	R	R	R

Table 4. Shannon Wiener Diversity Index (H)

	sites/zones	SIPMa	SIPMb	BOa	BOb	POa	POb
2011	Shannon Wiener Index (H′)	2.22	2.12	1.96	1.74	1.49	1.73
	No. species	6	6	5	4	3	4
	No. specimens	16	48	46	17	7	17
2012	sites/zones	SIPMa	SIPMb	BOa	BOb	POa	POb
	Shannon Wiener Index (H′)	1.84	1.52	2.41*	1.50	–	1.00*
	No. species	4	3	6	3	1	2
	No. specimens	7	5	18	4	1	2

* maximum and minimum values

whereas in this site *E. nigromaculatus* was presented with two individuals, one at the vineyard edge and one on field path. *C. septempunctata* was found at vineyard edges as well as at field patches of all localities. In site PO 5 out 7 species were noticed as recent, one as subrecent and one as dominant. Samples taken from grape vine (branch shaking) showed only few individuals of *Psyllobora* and *Coccinella*, and consequently we did not put the data into the table. Diversity indices of all researched sites are reported in Table 4. The highest value (H) was recorded in BOa (2.41) and the lowest in POb (1.00). In 2011 similar results showed sites BOb (1.74) and POb (1.73), while POa showed no results overall. The maximum value of similarity (SQ) index was noticed in a comparison of SIPM and BO (0.90) while the minimum (0.60) was that between BO and PO (Table 5).

Table 5. Sörenson Index of Similarity (SQ)

	Sites of research	SIPM	BO	PO
2011	SIPM	1	0.90	0.72
	BO	0.90*	1	0.60*
	PO	0.72	0.60	1
	Sites of research	**SIPM**	**BO**	**PO**
2012	SIPM	1	0.83	0.75
	BO	0.83	1	0.60*
	PO	0.75	0.60	1

* maximum and minimum values

Flora

During this research altogether 32 plant species from 13 families were identified. In vineyard margins (BOa) we found 16 species belonging to 10 families. The most species-rich families were Asteraceae (37.5 %), Apiaceae (12.5 %) and Cichoriaceae (12.5 %). Floral composition at site (SIPMa) was represented by 16 species belonging to 9 families such as Fabaceae (37.5 %) and Asteraceae (17 %), while the percentage contribution of other families showed low results (1 % severally). The site poorest in plants (POa) was presented by only 8 species belonging to 5 families. The plant composition of field patches was less diverse than in vineyard weedy margins. Zones (SIPMb) and (BOb) were represented by families Fabaceae (28.6 %) and Poaceae (42.8 %) while the third site (POb) showed a high abundance of family Poaceae species (57 %). Other plants belonged mainly to the families Chenopodiaceae, Brassicaceae, Poligonaceae and Plantaginaceae. However, the species richness at the vineyards margins was higher than that in the field patches.

Discussion

The total number of ladybugs in 2011 was higher than in 2012. This result could be explained by the impact of climatic factors. High temperatures and lack of rainfall during the period of research in 2012 (Croatian Meteorological and Hydrological Service) made the vegetation dry, which reduced food sources, habitat and possibility of surviving. The highest abundance was shown by *H. variegata*. Grez et al. (2010) found this species in fields next to vineyards, representing more the 62 % of total coccinellids captured. Grez et al. (2013) also reported *Hippodamia spp*. as the most abundant species in agricultural land mostly composed of vineyards, grain growing and horticultural areas . In our research, adults of *H. variegata* were found on *D. carota*, *D. viscosa* and *Cirsium spp.*, while *Chenopodium album* hosted all development stages of this ladybug (Table 6). *D. carota* harboured a lot of *Hippodamia* coccinellids, for two reasons. Flowers of the wild carrot serve as shelter for this insect until pollen presents a secondary food, particularly in late summer (Burgio, et al. 2004). Like Burgio et al. (2004) we found *P. vigintiduopunctata* on *Cirsium spp*. Ladybug *Scymnus spp*. was found in all sites. Daane et al. (2008) reported the genus *Scymnus* as the most abundant mealybug predator in California vineyards. According to (Biddinger, et al., 2009; Biswas et al., 2007) *Stethorus spp.* is an important natural enemy of spider mites. The lower individual number of *S. punctilum* might be explained by prey scarcity. We found three specimens of this ladybug only at site SIPM which is bordered with apple and peach orchards and in site PO (near hedgerows) as well as on *Anthemis arvensis* (BO). This result confirmed the data of Burgio et al. (2006) who found this coccinellid on shrubs and trees. In their research Leather et al. (1999) found *C. septempunctata* on *Cirsium spp*. and on grasses. Syed et al. (2012) reported finding this species on *Cynodon dactylon* (L.) Pers (1805). That could explain presence of this species at all localities,

Table 6. Ladybugs found on plants by visual inspections

PLANTS		LADYBUGS						
Families	**Species**	**CS**	**SP**	**SF**	**HV**	**EN**	**PV**	**SP**
Apiaceae	*Daucus carota*	+	–	–	+	–	–	–
	Foeniculum vulgare	+	–	–	–	–	–	–
Asteraceae	*Anthemis arvensis*	–	–	–	+	+	+	+
	Cirsium spp.	+	–	–	+	–	+	–
	Dittrichia viscosa	–	+	+	+	–	–	–
Chenopodiaceae	*Chenopodium album*	+	–	–	+	–	–	–
Fabaceae	*Dorycnium hirsutum*	–	+	+	–	–	–	–
	Trifolium pratense	–	+	+	–	–	–	–
Plantaginaceae	*Plantago spp.*	–	+	–	–	–	–	–

CS = *Coccinella septempunctata*, SP = *Scymnus spp.*, SF = *Scymnus frontalis*, HV = *Hippodamia variegata*, EN = *Exochomus nigromaculatus*, PV = *Psyllobora vigintiduopunctata*, SP = *Stethorus punctilum* even in POb where high abundance of Poaceae were recorded. The higher number of coccinellids in weedy margins as opposed to field patches could be explained by higher diversity of weed species. The Shannon Wiener Diversity Index showed higher values in zones SIPMa and Boa, where Asteraceae, Apiaceae and Fabaceae dominated. Zone (b), except at PO showed lower values. As Iperti (1999) claimed, predaceous role of Coccinellids benefits from the maintenance of field diversity. We also suggest that weed margins diversity can support the abundance of ladybugs.

Conclusions

During this research (2011–2012) a total number of 180 ladybugs belonging to 7 species were captured. In general *H. variegata* was the most abundant coccinellid, while *E. nigromaculatus* was rare with only two specimens found. Differences between localities and zones were noticed. Higher values of diversity indices were given by weedy margins in vineyards while in field patches, except zone OPb, diversity is lower. According to results obtained we could conclude that despite the farming mode, inborn plants, and in particular weed composition, play an important role in attracting and harbouring ladybugs. This inventory of ladybugs in horticultural areas could help in the better management of the ecological infrastructure in vineyard ecosystems and reduce insecticide usage.

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