Spanish Journal of Agricultural Research
14(1), e0303, 10 pages (2016)
eISSN: 2171-9292
http://dx.doi.org/10.5424/sjar/2016141-7371
Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)

RESEARCH ARTICLE

OPEN ACCESS

The role of ecological infrastructure on beneficial arthropods in vineyards

Kristijan Franin[1], Božena Barić[2] and Gabrijela Kuštera[1]

[1] *University of Zadar, Dept. of Ecology, Agronomy and Aquaculture. Mihovila Pavlinovića b.b., 23 000 Zadar, Croatia* [2] *University of Zagreb, Faculty of Agriculture, Dept. of Agricultural Zoology. Svetošimunska cesta 25, 10 000 Zagreb, Croatia*

Abstract

Weeds and non-cultivated plants have a great impact on abundance and diversity of beneficial arthropods in agriculture. The main aim of this work was to study the influence of the ecological infrastructure (meadows and weedy margins) on the arthropod composition in vineyard surrounding landscape. Research was carried out from May to October during three years. Sampling took place in the ecological infrastructure of three differently managed vineyards (organic, integrated and extensive). Three zones were chosen in each vineyard (3 m, 10 m, and 30 m from the edge of the vineyard). Samples were taken using a standardised sweep net method. In total, we captured 6032 spiders and 1309 insects belonging to 4 orders and 10 families. Arthropod fauna was numerically dominated by Aranea (82.1%); among insects, Coleoptera was the most abundant taxonomic group (10.6%); Neuroptera showed the lowest value (0.88%). Significant differences were found between sites and zones. Organic vineyard showed the highest abundance of arthropods (92.41% were spiders) and in the integrated vineyard there was a 23% of insects. Both the highest abundance of arthropods and the highest Shannon Index value (2.46) was found 3 m away from the edge of the vineyard. Results showed that spiders were the dominant arthropods and ladybugs the dominant insects. Weedy strips near the edge of the vineyard contained a high number of insects and spiders. Our results support the importance of weedy margins in enhancing the population of arthropods as well as in biodiversity promotion. Well-managed field margins could play important role in biological control of vineyard pests.

Additional key words: spiders; beneficial insects; diversity; weeds

Abbreviations used: ED (extensive vineyard); H' (Shannon Diversity Index); IB (integrated vineyard); OP (organic vineyard)

Citation: Franin, K.; Barić, B.; Kuštera, G. (2016). The role of ecological infrastructure on beneficial arthropods in vineyards. Spanish Journal of Agricultural Research, Volume 14, Issue 1, e0303. http://dx.doi.org/10.5424/sjar/2016141-7371.

Received: 13 Jan 2015. **Accepted**: 11 Feb 2016.

Funding: The authors received no specific funding for this work

Competing interests: The authors have declared that no competing interests exist.

Correspondence should be addressed to Kristijan Franin**:** kfranin@unizd.hr

Introduction

Intensification of agriculture results in habitat destruction and has a negative effect on biodiversity. According to Pérez-Bote & Romero (2012), biodiversity in agricultural habitats is influenced by the surrounding landscape. A diverse plant community can influence beneficial arthropod populations by providing food or habitat resources that might not be found in a simple plant comunity (Costello & Daane, 1998). Clough *et al*. (2007) found that in arable land, biodiversity depends on recolonization from surrounding perennial habitats, which serve as overwintering habitats and contain alternative resources for arthropods. Beneficial organisms that are not resident in vineyards all year round must recolonize on a seasonal basis, most likely from natural vegetation in the surrounding landscape (Duelli & Obrist, 2003). Flowering plants provide nectar and pollen resources to insects during the growing season (Ambrosino *et al*., 2006; Blaauw & Isaacs, 2012). Roschewitz *et al*. (2005) and Gardiner *et al*. (2009) reported that vegetational diversity can also provide support for insect biological control at the local and landscape levels. Weeds play an important role in enhancing the abundance and diversity of arthropod predators and serve as a source of increased diversity in agroecosystems. In most agroecosystems, weeds are ever-present biological components within and around fields, adding to the complexity of interacing trophic levels which mediate a number of crop insect interactions with major effects on final yields (Nicholls & Altieri, 2012). However, weeds are traditionally viewed as plants that reduce yields by competing with crops or by harbouring pests and plant pathogens (Penagos *et al*., 2003). Increased diversity has been the rationale for enhancing biological control of arthropod pests through habitat management (Norris & Kogan, 2005). The same authors (Norris & Kogan, 2000) indicated that weed cover enhances the number and activity of spiders and ground beetles. In their research on dicotyledonous weeds, Wilson & Aebisher (1995) reported that the density of most arthropod species decreased significantly as distance from crop edge increased from 0 to 128 m. Some authors (Winkler, 2005; Bàrberi *et al*., 2010) have reviewed the importance of vegetation diversity for enhancing populations of beneficial arthropods in cropland. Wyss (1996), Simon *et al*. (2010) and Song *et al*. (2010) reported a positive effect of plant comunity diversification on beneficial arthropods in orchards. Non-crop habitats bordering agricultural fields in Europe have been found to have a favourable effect on a number of beneficials as spiders, ladybugs, and syrphids (Hillocks, 1998; Ernoult *et al*., 2013). Woodcock *et al*. (2008) showed the positive effects of composition and diversity of plants around the field margins on ground beetle diversity. Fields with a dense weed cover and high diversity usually have more predaceous and parasitic arthropods than weed-free fields (Speight & Lawton, 1976). Even now a lot of grape producers destroy weeds not only in fields but also in the surrounding landscape, such as field margins, field patches and non-cultivated areas. In the Zadar County (Croatia) vineyards, typical grape production is organized in monoculture, what leads to landscape simplification and decrease of predatory arthropod population. Vegetation surrounding the fields has a great impact on predator abundance in the vineyards. The main goal of this paper was to examine the influence of vegetation (weed) structure on predatory insects and spiders of three vineyards.

Material and methods

Study area

Field work was carried out in the Ravni Kotari area, near Zadar (Croatia, Northern Dalmatia). Climate is Mediterranean (Csa type) with temperate and wet winters and dry and hot summers (Bolle, 2003). Three different sites (organic vineyard, vineyard in extensive management, and vineyard in integrated management) were researched between 2010 and 2012. Mean temperatures and rainfall during the years of research were, respectively, 14.07°C, 1130.9 mm/yr (2010), 15.02°C, 420.7 mm/yr (2011) and 14.96°C, 798.8 mm/yr (2012).

The first site, Posedarje OP (44.2032 °N, 15.4319 °E) was an organic vineyard (0.5 ha) surrounded with meadows and low intensity grasslands. In this vineyard the soil was tilled and was managed without pesticides or syntetic fertilizers. The second vineyard (5 ha), Bastica IB (44.1582 °N, 15.4362 °E) had the soil surface covered mainly with weed plants, was not tilled, and was mowed several times during the growing season. This site was situated in a large agricultural area, and was mostly surrounded with vineyards, orchards and arable land under vegetable production. Organic fertilizers were used every three years, whereas syntetic fertilizers were used each year. Copper and sulphur as well as some pesticides (folpet, dimetomorph, probineb and tiamethoxam) were applied against major grape pests. The third site, Dolac ED (44.1343 °N, 15.2528 °E) had 0.2 ha, and represented an extensive system of grape production. The soil was tilled once during vegetational season. Fertilizers and pesticides were used. The vineyard was part of a landscape consisting of small vineyards, olive orchards and vegetable gardens (mosaic of small fields).

In each site, plant and arthropod communities were analyzed at 3 m (zone A), 10 m (zone B) and 30 m (zone C) from the edge of the vineyard (Fig. 1). Zone A, the vineyard edge, consisted mostly of weeds. Zones B and C consisted of meadows and field paths. Field margins and meadows were mowed twice during vegetational season (May and July). In order to maintain the ecological infrastructure fertilizers or pesticides were not used.

Plant comunities

Plant comunities were estimated using the phytosociological method of Braun-Blanquet (1965). Samples

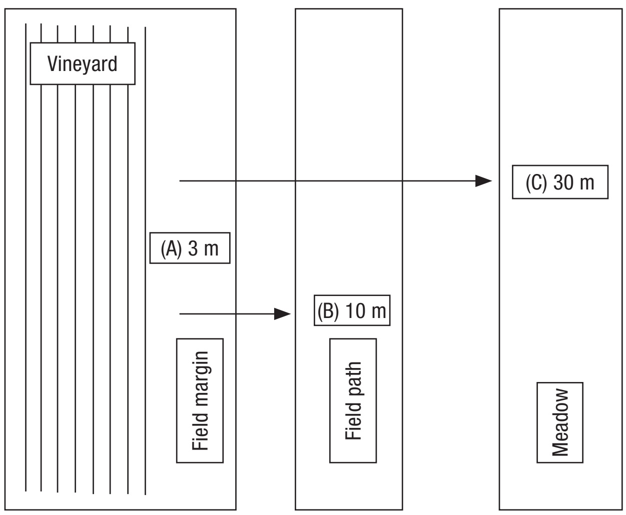

Figure 1. Map of the study site with zones A, B and C.

were collected in June and September. In each zone, three plots of 1 m^2 were chosen randomly, avoiding the edges and their proximities. Plant species were identified using the Croatian Flora (Rogosic, 2011). The abundance of weeds in the sample plot was recorded. All the records were tabulated for each site for further analysis of data and to discover relationships between insects and the vegetational structure of ecological compensation areas.

Sampling methods and arthropod identification

Arthropod samples were collected every two weeks between the beginning of the May and the beginning of October. All samples from areas surrounding the vineyards (ecological infrastructure) were taken when weather conditions were appropriate (sunny weather, dry vegetation, day period between 9.30 am and 12.00 pm) using a standardised sweep net method. The sweep net was applied in a standard way, taking 50 sweeps at each weed transect. The sweep net had a diameter of 40 cm, fitted with a heavy cloth suitable for use in dense vegetation (Zurbrügg & Frank, 2006). Samples were collected and examined in the laboratory. Arthropods were stored in 70% ethanol until identification. Adult insects were identificated with help of entomological handbooks and publications. Larva were counted and determined to family lavel. Spiders were only counted.

Data analyses

Nonparametric (Kruskal-Wallis ANOVA, Spearman Rank Correlation), one-way ANOVA method was used to compare number and composition of arthropods between localities and years of research (Statistica 6.1, StatSoft Inc., 2003). Biodiversity among sites and zones was compared using Shannon diversity index (H'), which is based on the number of individuals at the family level (Magurran, 1988).

Results

Arthropod composition and abundance

Altogether 7341 arthropods were collected and classified into Arachnida (Aranea) and Insecta during the three years of research. The number of arthropods across the years of the study was significantly different (Kruskal-Wallis test, H=18.97, df=2, $p<0.001$). The highest number was recorded in 2011 and the lowest in 2012 (Table 1). The lowest number of arthropods in 2012 probably was because of dryness and reduced vegetation cover (36.19 mm of rainfall between 6 July and12 September). We also found significant differences in arthropod abundance among sites (Kruskal-Wallis test, H=27.01, df=2, $p<0.001$). Arthropods were more abundant in the ecological infrastructure of the integrated and extensive vineyards than in the organic vineyard. Site IB showed the greatest number of individuals in comparison with other sites (Table 2). Arthropod abundance also varied (Kruskal-Wallis test, H=47.39, df=8, $p<0.001$) among zones. The highest abundance was recorded in zone A of all localities (Table 3). Arthropod fauna was dominated by spiders (82.10%). The highest number of spiders were found in OP followed by ED and IB (Table 4). A total of 1309 insects representing four orders (Coleoptera, Diptera, Heteroptera and Neuroptera) and 10 families were collected (Table 4). Insect composition was dominated by Coccinellidae (9.13%) whereas Reduviidae were rare, representing 0.13% of the total of arthropods. Comparisons of abundances showed differences among arthropods (Kruskal-Wallis test, H=1710.20, df=10, $p<0.001$) for Aranea, Coccinellidae, Syrphidae and Reduviidae, whereas for Anthocoridae, Chrysopidae, Cantharidae, Carabidae, Geocoridae, Miridae and Nabidae significant differences were not found (Table 5). In Heteroptera composition Miridae dominated (2.31%), followed by Anthocoridae (1.39%). Geo-

Table 1. Comparison of captures within years of research.

Years	2010	2011	2012
Min.	0	0	0
Max.	114	70	151
Mean (±SE)	2.024 (0.215)[ab]	3.023 (0.281)[a]	1.663 (0.223)[b]
Med.	0	0	0
Quartile1	0	0	0
Quartile3	0	1	0

Means followed by different letters are significantly different ($p<0.001$).

Table 2. Arthropod abundance within sites of research.

Sites	IB	ED	OP
Min.	0	0	0
Max.	60	114	151
Mean (±SE)	2.068 (0.199)[b]	1.975 (0.219)[ab]	2.671 (0.297)[a]
Med.	0	0	0
Quartile1	0	0	0
Quartile3	1	0	0

IB (integrated vineyard); ED (extensive vineyard); OP (organic vineyard). Means followed by different letters are significantly different ($p<0.001$).

Table 3. Comparison of captures within sites and zones.

Zones	Min.	Max.	Mean (SE)	Med.	Quartile1	Quartile3
OP(A)	0	70	2.22 (0.40)[a]	0	0	0
OP(B)	0	151	3.31 (0.65)[a]	0	0	0
OP(C)	0	61	2.46 (0.44)[a]	0	0	0
ED(A)	0	114	2.36 (0.47)[ab]	0	0	1
ED(B)	0	50	2.11 (0.35)[ab]	0	0	0
ED(C)	0	63	1.44 (0.27)[ab]	0	0	0
IB(A)	0	53	2.56 (0.37)[b]	0	0	1
IB(B)	0	60	1.96 (0.35)[ab]	0	0	0
IB(C)	0	56	1.57 (0.27)[ab]	0	0	0.5

OP (organic vineyard); ED (extensive vineyard); IB (integrated vineyard). Means followed by different letters are significantly different (p<0.001).

Table 4. Arthropod abundance in ecological infrastructure of vineyard.

Order	Family	OP	IB	ED	Total	Percentage
Aranea	−	2682	1627	1696	6005	82.10
Diptera	Syrphidae	10	59	38	107	1.46
Coleoptera	Cantharidae	10	19	10	39	0.53
	Carabidae	16	32	22	70	0.95
	Coccinellidae	116	344	208	668	9.13
Heteroptera	Anthocoridae	2	80	20	102	1.39
	Geocoridae	6	27	21	54	0.73
	Miridae	56	0	113	169	2.31
	Nabidae	4	17	4	25	0.34
	Reduviidae	3	1	6	10	0.13
Neuroptera	Chrysopidae	4	46	15	65	0.88

OP (organic vineyard); IB (integrated vineyard); ED (extensive vineyard).

Table 5. Comparison among arthropod orders and insect families.

Arthropods	Min.	Max.	Mean (SE)	Med.	Quartile1	Quartile3
Aranea	0	151	20.21 (1.02)[a]	15.00	8	28
Cantharidae	0	6	0.13 (0.03)[b]	0.00	0	0
Carabidae	0	11	0.23 (0.06)[b]	0.00	0	0
Coccinellidae	0	31	2.24 (0.25)[c]	1.00	0	2
Syrphidae	0	8	0.36 (0.05)[bd]	0.00	0	0
Chrysopidae	0	5	0.21 (0.04)[b]	0.00	0	0
Anthocoridae	0	8	0.24 (0.05)[b]	0.00	0	0
Geocoridae	0	3	0.18 (0.02)[b]	0.00	0	0
Miridae	0	24	0.51 (0.19)[b]	0.00	0	0
Nabidae	0	10	0.12 (0.04)[b]	0.00	0	0
Reduviidae	0	2	0.03 (0.01)[bd]	0.00	0	0

Means followed by different letters are significantly different (p<0.05).

coridae, Nabidae and Reduvidae collectivly accounted for 1.2%. The number of Anthocoridae was significantly different among sites (Kruskal-Wallis test, H=46.07, df=2, p<0.001), with higher abundance in IB (78.43%) than in the other sites. In OP only 2 individuals were recorded. Miridae showed significant difference (Kruskal-Wallis test, H=17.11, df=2, p<0.001) between localities with 113 specimens collected in ED and 56 in OP. Miridae were not present in IB (Fig. 2). Geocoridae and Nabidae showed no significant differences. The number of Coleoptera, except Coccinellidae (Kruskal-Wallis test, H=8.46, df=2, p<0.001), showed no significant differences between sites. Abundance of Chrysopidae (Kruskal-Wallis test, H=25.83, df=2, p<0.001) and Syrphidae (Kruskal-Wallis test, H=17.93, df=2, p<0.001) also differed among sites with the highest number recorded in IB (Fig. 2). The H' varied among sites and zones (Fig. 3b). The higher arthropod abundance was associated with greater compositional and structural diversity of veg-

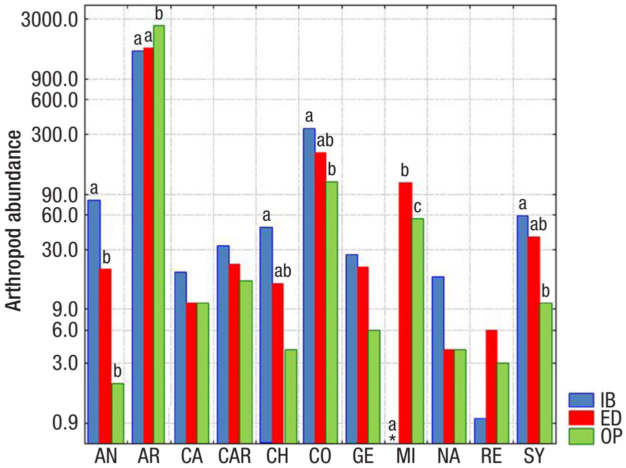

Figure 2. Arthropod (spiders and predaceous insects) abundance among sites of research (IB, ED, OP, see text). AN: Anthocoridae, AR: Aranea, CA: Cantharidae, CAR: Carabidae, CH: Chrysopidae, CO: Coccinellidae, GE: Geocoridae, MI: Miridae, NA: Nabida, RE: Reduviidae, SY: Syrphidae.[a,b]: values with different superscripts within a group are significantly different ($p<0.001$), *: no Miridae was found in IB.

etation, which was particularly linked with weeds. The highest diversity was noticed in zone A of all sites (Fig. 3a). To compare the number of plant species and the arthropod abundance Spearman rank order correlation was used. Although there was no statistically significant correlation between the number of plant species and the arthropod abundance, regression analysis showed a positive trend (Fig. 4).

Plant comunities

Altogether, 41 plant species belonging to 13 families (Table 6) were identified. Site ED showed the highest number of species, followed by IB and OP. In IB and ED the highest percentage (39.0%) of plant species was in the zone A (vineyard edge) as opposed in OP, where only eight species (19.5%) were found. These plants mostly belong to the weed flora. Among families Poaceae showed the highest abundance (22.2%), followed by Asteraceae (18.3%), Fabaceae (14.3%), Apiaceae (9.1%) and Cichoriaceae (7.9%). The most abundant plant species among all localities was *Avena fatua*. The lowest abundance was recorded in OP (zone B) represented by only four species (*Briza maxima* L., *Dorycnium herbaceum* Vill, *Dittrichia viscosa* L. and *Aegilops* spp.). Our analysis showed that flora in zone A was predominantly composed of dicotyledones (Asteraceae, Fabaceae, Apiaceae). Zones B and C also comprised species from these families except OP (B and C), where Poaceae dominated.

Discussion

This work explored the influence of ecological infrastructure and plant composition on arthropod population and diversity. Arthropod communities clearly differed between sites and were dominated by Aranea. In agricultural landscapes, spiders are generally most diverse in semi-natural habitat (Duelli *et al*., 1999). In this research, spiders were most abundant at the site OP, especially in zone C (pastures and meadows at wood vicinity) as suggested by Isaia *et al*. (2006). Bruggisser *et al*. (2010) reported that spider and plant richness was not higher in organic compared to conventional farming. The main reason for spider dominance is probably their broader diet and their ability to survive a long period without prey (Costello & Daane, 1999). Spiders also may benefit from higher weed populations (especially ED and BI sites), which provide higher structural complexity and potentially increase the availability of herbivore prey (Schmidt *et al*., 2005; Woodcock *et al*., 2013). We noticed that dry vegetation also affected to a high number of spiders and predaceous insects. Among Coleoptera the most abundant family was Coccinellidae presented mostly by *Hippodamia* spp. particularly in zone IB(C), possibly as a result of presence of their prey on plants such as *Dau-*

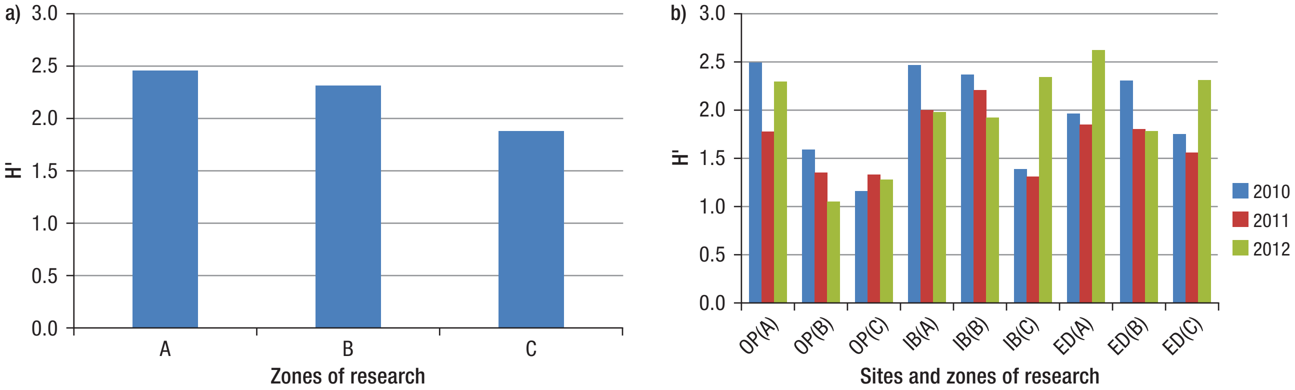

Figure 3. Shannon diversity index (H') in the sites and zones of research.

Table 6. Plant communities in zones (percentage of species).

Plant community	OP			ED			IB		
	A	B	C	A	B	C	A	B	C
Aegilops spp.	17	20	11						
Amaranthus retroflexus L.				7					
Ammi majus L.							3		
Anthemis arvensis L.				40					
Artemisia vulgaris L.				3		3			
Avena fatua L.			13		15	44	10	30	5
Briza maxima L.	8	40	15						
Bromus spp.							12	30	
Centaurea cyanus L.	5					3	2		
Chenopodium album L.				4			10		
Cichorium intybus L.	6				3	4			7
Cirsium arvense (L.) Scop.	7			2			2	1	3
Crepis spp.				3					
Cynodon dactylon Pers.							1		30
Dactylis glomerata L.						7	5	2	
Datura stramonium L.	1								
Daucus carota L.			10	9	5	12			42
Dittrichia viscosa (L.) Greuter	2	5	9		10				
Dorycnium herbaceum Vill	29	35	35				5		
Erigeron spp.				4					
Euphorbia spp.							3		
Foeniculum vulgare Miller				1	25	7			
Hordeum murinum L.					7	20			
Hypericum perforatum L.							4	3	
Lathyrus spp.							2		
Lathyrus pratensis L.							5		
Lotus corniculatus L.	10						10	5	
Medicago falcata L.					30			5	
Medicago sativa L.							5		
Papaver rhoeas L.				2					
Plantago lanceolata L.							3	2	
Plantago spp.							3		
Polygonum spp.							2		
Rumex crispus L.				3			3		10
Rumex spp.	10								
Senecio vulgaris L.				3					
Sinapis arvensis L.				2					
Sonchus spp.				2					
Sorghum halepense (L.) Pers				8					
Trifolium pratense L.								20	
Vicia spp.	5		7	7	5		10	2	3
Total	100	100	100	100	100	100	100	100	100

cus carota (Burgio *et al*., 2006). In California vineyards, Daane *et al*. (2008) also found *Hippodamia* spp. and *Scymnus* spp. as important predators of mealbugs. Kopta *et al*. (2012) reported that plants like *Amaranthus retroflexus* L., *Centaurea cyanus* L. *Daucus carotta* L., and *Foeniculum vulgare* L. were present in almost all sites where ladybugs were found in high number. These plants provide alternative food sources such as pollen and nectar from extrafloral nectaries. As Raymond *et al*. (2000), we also found ladybugs (all developmental stages) on *Chenopodium* spp. Gaigher & Samways (2010) indicated that abundance of carabids was higher in organic than in the integrated vineyard. O'Rourke *et al*. (2008) and Eyre *et al*. (2012) reported that crop rotation and diverse crop habitats increased Carabidae activity, density and diversity. Their conclusions correspond with our results. The highest abundance of Carabidae found at site IB may lay in the fact that integrated vineyard was surrounded with arable land producing grains and vegetables with a lot of weed strips. Management of weed strips appears to increase the availability of food for carabids and results in enhanced reproduction (Zangger, 1994; Zangger *et al*., 1994). The other reason probably lays in the fact that

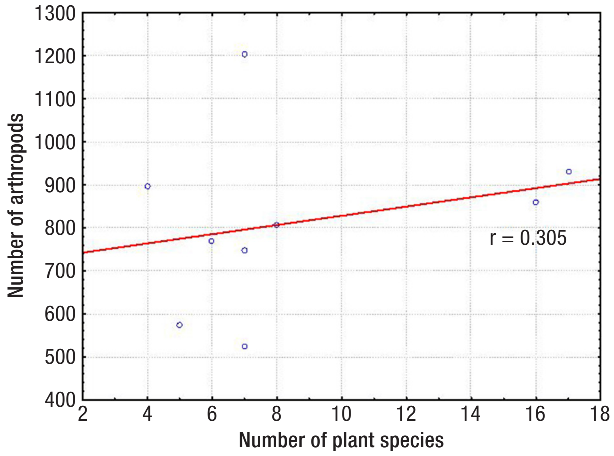

Figure 4. Relationship between the number of plant species and the number of arthropods.

ground surface of this vineyard (IB) was managed with cover crops and mulched several times during the vegetational period (Thomson & Hoffmann, 2007). As Burgio *et al*. (2006) reported, sampling by sweep net is able to collect only terrestial Carabidae present in the weed canopy, and not those on the soil. Green lacewing (Chrysopidae) showed preference to weed margins where plants such as *Chenopodium album* L., *Convolvulus arvensis* L. and *Anthemis arvensis* L. are found (Ruby *et al*., 2011). Beside, as food source, some weeds as *Trifolium pratense* L., *Centaurea cyanus* L., *Papaver rhoeas* L. and *Vicia* spp. seem suitable for lacewings as oviposition site. Our data agree with those reported by Eichenberger (1991), who also found lacewings on the plants above mentioned. Diptera from family Syrphidae were always more abundant in zone A of all sites where Apiaceae and Asteraceae dominated (Tooker *et al*., 2006). Syrphidae prefer grassy strips based on total botanical diversity (Speight, 2008). Plants from these families (Apiaceae and Asteraceae) are known as nectar and pollen producers in great amounts so they play an important role in Syrphidae attraction (Branquart & Hemptinne, 2000; Rebek *et al*., 2005; Morales & Kohler, 2008; van Rijn & Wäckers, 2010). As expected, the low number of syrphids at OP could be due to the low presence of flowering weeds. Costello & Daane (1999), Nicholls *et al*. (2000, 2008) and Altieri *et al*. (2005) also reported several dominant Heteroptera predators such as *Nabis* spp., *Orius* spp. and *Geocoris* spp. in the ecological infrastructure of vineyards. Insect predators such as Anthocoridae and Geocoridae prefer thrips, aphids, lepidopteran and hemipteran eggs and spider mites. High number of Anthocoridae was found at site IB (A) at the vicinity of apple orchard. One potential explanation is that these predators are strongly associated with aphids, mites and thrips which are always present in apple orchards (Rieux *et al*., 1999; Burgio *at al*., 2006; Gadino *et al*., 2012). Prischmann *et al*. (2005) found no significant differences in Heteroptera abundance between commercially managed and unmanaged vineyards. Daane *et al*. (2008) also found these bugs as not commonly present in large numbers in vineyards. Miridae were represented by *Macrolophus* spp. and *Dicyphus* spp. We noticed a relationship between *Macrolophus* spp. and the plant *Ditrichia viscosa* (L.). Greuter (Asteracea) as has also been documented in Greece (Perdikis *et al*., 2007). That can explain a higher number of these bugs in DE and OP, while in site IB *D. viscosa* was not present.

This study shows that 'plant rich' weedy margins (zone A) can enhance the abundance of some predators. Our results agree with some other studies showing that the introduction of flowering plants into agricultural settings leads to increased arthropod abundance (Rebek *et al*., 2005; Walton & Isaacs, 2011). Higher arthropod diversity was associated with greater compositional diversity of weed cover (Benton *et al*., 2003; Gaigher & Samways, 2010). Our results showed that the number of total insects was lower in meadows and pastures than in wildflower strips of field paths and weedy areas, what is similar to the results of Zurbrügg & Frank (2006). In almost all localities, vegetation structure was the best explanatory factor for insect distribution, abundance, and species richness. Our results are similar to the results reported in other studies of arthropods in organic and intergrated vineyards (Gaigher & Samways, 2010). The best plant families for preserving predators (Coccinellidae, Syrphidae and Chrysopidae) are Apiaceae, Asteraceae and Chenopodiaceae (Fiedler *et al*., 2008; Bertolaccini *et al*., 2011). Some studies also showed that organic management systems increased the arthropod abundance and richness but not the diversity (Clark, 1999). Overall, these results suggest that despite the assertion that organic fields contribute to increase biodiversity, arthropod abundance and diversity also depend on plant composition. Sites and zones with higher number of weed plants species especially those with attractive flowers obviously provide favourable conditions for natural enemies. Conservation and attendance of ecological infrastructure such as weedy margin can serve as habitat for beneficial fauna. Therefore it can play an important role in increasing the vineyard production quality.

In summary, this study shows the importance of noncultivated areas on the abundance of predatory arthropods. Ecological infrastructure, especially weed margins, field paths and sorrounding wildflower areas, are important components of the vineyard sistem as they enhance the plant abundance and diversity. Despite the vineyard management, our conclusion is that plant community plays an important role in attracting and maintaining populations of arthropods. Regular approach to weed management in vineyards can increase biodiversity of beneficial organisms and achieve a more sustainable agroecosytem.

References

Altieri MA, Ponti L, Nichols CI, 2005. Manipulating vineyard biodiversity for improved insect pest management: case studies from northern California. Int J Biodivers Sci Manage 1: 1-13. http://dx.doi.org/10.1080/17451590509618092

Ambrosino MD, Luna JM, Jepson PC, Wratten SD, 2006. Relative frequencies of visits to selected insectary plants by predatory hoverflies (Diptera: Hoverflies), other beneficial insects and herbivores. Environ Entomol 35: 394-400. http://dx.doi.org/10.1603/0046-225X-35.2.394

Bàrberi P, Burgio G, Dinelli G, Moonen AC, Otto S, Vazzana C, Zanin G, 2010. Functional biodiversity in the agricultural landscape: relationships between weeds and arthropod fauna. Weed Res 50 (5): 388-401. http://dx.doi.org/10.1111/j.1365-3180.2010.00798.x

Benton TG, Vickery JA, Wilson JD, 2003. Farmland biodiversity: is habitat heterogeneity the key? Trends Ecol Evol 18: 182-188. http://dx.doi.org/10.1016/S0169-5347(03)00011-9

Bertolaccini I, Pérez EN, Tizado EJ, 2011. Alternative plant hosts of legume aphids and predators in the province of León, Spain. Cien Inv Agr 38 (2): 233-242. http://dx.doi.org/10.4067/S0718-16202011000200009

Blaauw BR, Isaacs R, 2012. Larger wildflower planting increas natural enemy density, diversity, and biological control of sentinel prey, without herbivore density. Ecol Entomol 37 (5): 386-394. http://dx.doi.org/10.1111/j.1365-2311.2012.01376.x

Bolle HJ, 2003. Mediterranean climate – Variability and trends, 372 pp. Springer, Berlin. http://dx.doi.org/10.1007/978-3-642-55657-9

Branquart E, Hemptinne JL, 2000. Selectivity in the exploitation of floral resources by hoverflies (Diptera: Syrphinae). Ecography 23: 732-742. http://dx.doi.org/10.1111/j.1600-0587.2000.tb00316.x

Braun-Blanquet J, 1965. Plant sociology: the study of plant communities. Hafner, London.

Bruggisser OT, Schmidt-Entling MH, Bacher S, 2010. Effects of vineyard management on biodiversity at three tropic levels. Biol Conserv 143: 1521-1528. http://dx.doi.org/10.1016/j.biocon.2010.03.034

Burgio G, Ferrari R, Boriani L, Pozzati M, van Lenteren J, 2006. The role of ecological infrastructures on Coccinellidae (Coleoptera) and other predators in weedy field margins within northern Italy agroecosystems. Bull Insectol 59 (1): 59-67.

Clark MS, 1999. Ground beetle abundance and community composition in conventional and organic tomato systems of California's Central Valley. Appl Soil Ecol 11: 199-206. http://dx.doi.org/10.1016/S0929-1393(98)00138-3

Clough Y, Kruess A, Tscharntke T, 2007. Local and landscape factors in differently managed arable fields affect the insect herbivore community of a non-crop plant species. J Appl Ecol 44: 22-28. http://dx.doi.org/10.1111/j.1365-2664.2006.01239.x

Costello MJ, Daane KM, 1998. Influence of ground cover on spider populations in a table grape vineyard. Ecol Entomol 23 (1): 33-40. http://dx.doi.org/10.1046/j.1365-2311.1998.00108.x

Costello MJ, Daane KM, 1999. Abundance of spiders and insect predators on grapes in central California. J Arachnol 27: 531-538.

Daane KM, Cooper ML, Triapitsyn SV, Walton VM, Yokota GY, Haviland DR, Bentley WJ, Godfrey KE, Wunderlich LR, 2008. Vineyard managers and researchers seek sustainable solutions for mealybugs, a changing pest complex. Calif Agr 62(4): 167-176. http://dx.doi.org/10.3733/ca.v062n04p167

Duelli P, Obrist MK, Schmatz DR, 1999. Biodiversity evaluation in agricultural landscapes: above-ground insects. Agr Ecosyst Environ 74: 33-64. http://dx.doi.org/10.1016/S0167-8809(99)00029-8

Duelli P, Obrist MK, 2003. Biodiversity indicators: the choice of values and measures. Agr Ecosyst Environ 98: 87-98. http://dx.doi.org/10.1016/S0167-8809(03)00072-0

Eichenberger J, 1991. Zur Eiablage von *Chrysoperla carnea* Stephens Planipennia, Chrysopidae an verschiedenen Ackerunkräutern inWahlversuchen im Labor. Diploma thesis, University of Bern, Switzerland.

Ernoult A, Vialatte A, Butet A, Michaela N, Rantier Y, Jambon O, Burel F, 2013. Grassy strips in their landscape contex, their role as new habitat for biodiversity. Agr Ecosyst Environ 199: 15-27. http://dx.doi.org/10.1016/j.agee.2012.07.004

Eyre MD, Luff ML, Atlihan R, Leifert C, 2012. Ground beetle species *(Carabidae, Coleoptera)* activity and richness in relation to crop type, fertility management and crop protection in a farm management comparision trial. Ann Appl Biol 161 (2): 169-179. http://dx.doi.org/10.1111/j.1744-7348.2012.00562.x

Fiedler AK, Landis DA, Wratten SD, 2008. Maximizing ecosystem services from conservation biological control: The role of habitat management. Biol Control 45: 254-271. http://dx.doi.org/10.1016/j.biocontrol.2007.12.009

Gadino AN, Walton VM, Lee JC, 2012. Evaluation of methyl salycilate lures on populations of *Typhlodromus pyri* (Acari: Phytoseiidae) and other natural enemies in western Oregon vineyards. Biol Control 63: 48-55. http://dx.doi.org/10.1016/j.biocontrol.2012.06.006

Gaigher R, Samways MJ, 2010. Surface active arthropods in organic vineyards, integrated vineyards and natural habitat in the Cape Floristic Region. J Insect Conserv 14: 595-605. http://dx.doi.org/10.1007/s10841-010-9286-2

Gardiner MM, Landis DL, Gratton C, DiFonzo CD, O'Neal M, Chacon JM, Wayo MT, Schmidt NP, Mueller EE, Heimpel GE, 2009. Landscape diversity enhances biological control of an introduced crop pest in the North-Central USA. Ecol Appl 19: 143-154. http://dx.doi.org/10.1890/07-1265.1

Hillocks RJ, 1998. The potential benefits of weeds with reference to a small holder agriculture in Africa. Integr Pest Manage Rev 3: 155-167. http://dx.doi.org/10.1023/A:1009698717015

Isaia M, Bona F, Badino G, 2006. Influence of landscape diversity and agricultural practices on spider assemblage in Italian vineyards of Langa Astigiana (Northwest Italy). Environ Entomol 35 (2): 297-307. http://dx.doi.org/10.1603/0046-225X-35.2.297

Kopta T, Pokluda R, Psota V, 2012. Attractiveness of flowering plants for natural enemies. Hort Sci 39 (2): 89-96.

Magurran AE, 1988. Ecological diversity and its measurement. In: Diversity indices and species abundance models. pp: 7-45. Springer, Netherlands. http://dx.doi.org/10.1007/978-94-015-7358-0

Morales MN, Köhler A, 2008. Syrphidae community: diversity and floral preferences in Green Belt (Santa Cruz do Sul, RS, Brazil). Rev Bras Entomol 52 (1): 41-49. http://dx.doi.org/10.1590/S0085-56262008000100008

Nicholls CI, Parella MP, Altieri MA, 2000. Reducing the abundance of leafhoppers and thrips in a northern California organic vineyard through maintenace of full season floral diversity with summer cover crops. Agr Forest Entomol 2: 107-113. http://dx.doi.org/10.1046/j.1461-9563.2000.00054.x

Nicholls CI, Altieri MA, Ponti L, 2008. Enhancing plant diversity for improved insect pest management in northern california organic vineyards. Acta Hort 785: 263-278. http://dx.doi.org/10.17660/ActaHortic.2008.785.32

Nicholls CI, Altieri MA, 2012. Plant biodiversity enhances bees and other insect pollinators in agroecosystems. A review. Agron Sustain Dev 33 (2): 257-274. http://dx.doi.org/10.1007/s13593-012-0092-y

Norris RF, Kogan M, 2000. Interactions between weeds, arthropod pests, and natural enemies in managed ecosystems. Weed Sci 48: 94-158. http://dx.doi.org/10.1614/0043-1745(2000)048[0094:IBWAPA]2.0.CO;2

Norris RF, Kogan M, 2005. Ecology of interactions between weeds and arthropods. Annu Rev Entomol 50: 479-503. http://dx.doi.org/10.1146/annurev.ento.49.061802.123218

O'Rourke ME, Liebman M, Rice ME, 2008. Ground beetle (Coleoptera: Carabidae) assemblages in convential and diversified crop rotation systems. Environ Entomol 37(1): 121-130. http://dx.doi.org/10.1603/0046-225X(2008)37[121:GBCCAI]2.0.CO;2

Penagos DI, Magallanes R, Valle J, Cisneros J, Martínez AM, Goulson D, Champan JW, Caballero P, Cave RD, Williams T, 2003. Effect of weeds on insect pest of maize and their natural enemies in Southern Mexico. Int J Pest Manage 49(2): 155-161. http://dx.doi.org/10.1080/0967087021000043111

Perdikis D, Favas C, Lykouressis D, Fantinou A, 2007. Ecological relationships between non-cultivated plants and insects predators in agroecosystems: the case of *Dittrichia viscosa* (Asteraceae) and *Macrolophus melanotoma* (Hemiptera: Miridae). Acta Oecol 31 (3): 299-306. http://dx.doi.org/10.1016/j.actao.2006.12.005

Pérez-Bote JL, Romero AJ, 2012. Epigeic soil arthropod under different agricultural land uses. Span J Agric Res 10 (1): 55-61. http://dx.doi.org/10.5424/sjar/2012101-202-11

Prischmann DA, James DG, Gringras SN, Snyder WE, 2005. Diversity and abundance of insects and spiders on managed and unmanaged grapevines in south-central Washington State. Pan-Pac Entomol 81: 131-144.

Raymond B, Darby AC, Douglas AE, 2000. Intraguild predators and the spatial distribution of a parasitoid. Oecologia 124: 367-372. http://dx.doi.org/10.1007/s004420000396

Rebek EJ, Sadof CS, Hanks LM, 2005. Manipulating the abundance of natural enemies in ornamental landscapes with floral resource plants. Biol Control 33: 203-216. http://dx.doi.org/10.1016/j.biocontrol.2005.02.011

Rieux R, Simon S, Defrance H, 1999. Role of hedgerows and ground cover management on arthropod populations in pear orchards. Agr Ecosyst Environ 73: 119-127. http://dx.doi.org/10.1016/S0167-8809(99)00021-3

Rogosic J, 2011. Bilinar cvjetnjaca hrvatske flore s kljucem za odredivanje bilja. Vol. 1 (537 pp) and Vol. 2 (571 pp). University of Zadar, Croatia.

Roschewitz I, Hucker M, Tscharntke T, Thies C, 2005. The influence of landscape contex and farming practices on parasitism of cereal aphids. Agr Ecosyst Environ 108: 218-227. http://dx.doi.org/10.1016/j.agee.2005.02.005

Ruby T, Rana SA, Rana N, Inayat TP, Siddiqui MJI, Khan NA, 2011. Weeds as viable habitat for arthropod species in croplands of central Punjab. Pak J Agri Sci 48(2): 145-152.

Schmidt MH, Roschewitz I, Thies C, Tscharntke T, 2005. Differential effects of landscape and management on diversity and density of ground-dwelling farmland spiders. J Appl Ecol 42(2): 281-287. http://dx.doi.org/10.1111/j.1365-2664.2005.01014.x

Simon S, Bouvier JC, Debras JF, Sauphanor B, 2010. Biodiversity and pest management in orchard systems. A review. Agron Sustain Dev 30: 139-152. http://dx.doi.org/10.1051/agro/2009013

Song BZ, Wu HY, Kong Y, Zhang J, Du YL, Hu JH, Yao CY, 2010. Effects of intercropping with aromatic plants on the diversity and structure of an arthropod community in a pear orchard. Biocontrol 55: 741-751. http://dx.doi.org/10.1007/s10526-010-9301-2

Speight MCD, 2008. Species accounts of European Syrphidae (Diptera). In: Syrph the Net, the database of European Syrphidae, Vol. 56, 66 pp. Syrph the Net Publications, Dublin.

Speight MR, Lawton JH, 1976. The influence of weed-cover on the mortality imposed on artificial prey by predatory groune beetles in cereal fields. Oecologia 23: 211-233. http://dx.doi.org/10.1007/BF00361237

Thomson LJ, Hoffman AA, 2007. Effects of groundcover (straw and compost) on the abundance of natural enemies and soil macro invertebrates in vineyards. Agric For Entomol 9 (3): 173-179. http://dx.doi.org/10.1111/j.1461-9563.2007.00322.x

Tooker JF, Hauser M, Hanks LM, 2006. Floral host plants of Syrphidae and Tachinidae (Diptera) of Central Illinois. Ann Entomol Soc Am 99 (1): 96-112. http://dx.doi.org/10.1603/0013-8746(2006)099[0096:FHPOSA]2.0.CO;2

van Rijn PCJ, Wäckers FL, 2010. The suitability of field margin flowers as food source for zoophagous hoverflies. IOBC/WPRS Bull 56: 125-128.

Walton NJ, Isaacs R, 2011. Influence of native flowering plant strips on natural enemies and herbivores in adjacent blueberry fields. Environ Entomol 40 (3):697-705. http://dx.doi.org/10.1603/EN10288

Wilson PJ, Aebischer NJ, 1995. The distribution of dicotyledonous arable weeds in relation to distance from the field edge. J App Ecol 32: 295-310. http://dx.doi.org/10.2307/2405097

Winkler K, 2005. Assesing the risk and benefits of flowering field edges. Strategic use of nectar sources to boost biological control. Ph.D. Tesis, Wageningen University, Holland.

Woodcock BA, Westbury DB, Tscheulin T, Harrison-Cripps J, Harris SJ, Ramsey AJ, Brown VK, Potts SG, 2008. Effects of seed mixture and management on beetle assemblages of arable field margins. Agr Ecosyst Environ 125: 246-254. http://dx.doi.org/10.1016/j.agee.2008.01.004

Woodcock BA, Savage J, Bullock JM, Nowakowski M, Orr R, Tallowin JRB, 2013. Enhancing beetle and spider communities in agricultural grasslands: The role of seed addition and habitat management. Agr Ecosyst Environ 167: 79-85. http://dx.doi.org/10.1016/j.agee.2013.01.009

Wyss E, 1996. The effect of artificial weed strips on diversity and abundance of the arthropod fauna in a Swiss experimental apple orchard. Agr Ecosyst Environ 60: 47-59. http://dx.doi.org/10.1016/S0167-8809(96)01060-2

Zangger A, 1994. The positive influence of strip-management on carabid beetles in a cereal field: accessibility of food and reproduction in *Poecilus cupreus*. Ser Entomol 51: 469-472. http://ecol.iee.unibe.ch/content/uploads/pdf/iee/1994/zanggereae1994.pdf.

Zangger A, Lys NA, Nentwig W, 1994. Increasing the availability of food and the reproduction of *Poecilus cupreus* in a cereal field by strip-management. Entomol Exp Appl 71: 111-120. http://dx.doi.org/10.1111/j.1570-7458.1994.tb01777.x