Boll. Zool. agr. Bachic.
Ser. II, 32 (2): 141-155

30 September 2000

G.C. LOZZIA, P. DIOLI, B. MANACHINI, I.E. RIGAMONTI, M. SALVETTI

Effects of soil management on biodiversity of Hemiptera, Heteroptera in vineyards of Valtellina (Northern Italy)

Abstract - Research on the biodiversity of Hemiptera was carried out in 1997-1999 in two viticultural areas of Valtellina. The first site in Postalesio is situated in the vicinity of a forest and has a humid microclimate, while the other site in Sassella is located in a simpler environment with a dry microclimate. In both areas two vineyards were selected: one that was full of weeds and a second one without weeds. In the Postalesio area the development of weeds was observed for many years, its composition is diversified and weeding is accurate, while in the Sassella area the growth of weeds is more recent with a more trivial composition. Different biodiversity indexes (Index of Shannon-Weaver H', the Hill's numbers: N_0, N_1, D, N_2, N_{inf}, Index of Pielou J') and of similarity (Sörensen's index QS) have been applied to the data. On the whole 59 species of Heteroptera were collected belonging to 12 families. The highest number of species and indexes of biodiversity were found in the vineyard in Postalesio with weeds in 1997; the presence of the forest and the diverse flora have favoured the biocenosis of Hemiptera. In the Sassella vineyard with weeds, whose vegetation has become richer during the study, the indices of biodiversity have shown a constant increase from '97 to '99. In the same area the flora that has taken over in the weed-free vineyard has led to a biodiversity comparable to the one with weeds during the first year, while after two years the situation worsened. In the other weed-free vineyard no Heteroptera have been found.

Riassunto - *Effetti della gestione del suolo sulla biodiversità degli Emitteri Eterotteri (Hemiptera Heteroptera) in vigneti valtellinesi.*

Nel corso delle annate dal 1997 al 1999 è stata svolta una ricerca sulla biodiversità degli Eterotteri in due aree coltivate a vite della Valtellina: la prima, in località Postalesio, è affiancata ad un bosco ed ha microclima umido, l'altra, in località Sassella, è in un ambiente più semplificato e con microclima secco. In ogni zona sono stati considerati un vigneto inerbito e uno diserbato. Nella prima località l'inerbimento è pluriennale e diversificato e il diserbo molto accurato, nella seconda l'inerbimento è più recente e semplificato e nel diserbato si ha presenza di una flora di sostituzione. I dati sono stati elaborati utilizzando diversi indici di biodiversità (Indice di Shannon-Weaver H', numeri di Hill N_0, N_1, D, N_2, N_{inf}, Indice di Pielou J') e di somiglianza (Indice di Sörensen QS). In tutto sono state

raccolte 59 specie appartenenti a 12 famiglie. Il numero di specie e gli indici di biodiversità più elevati sono stati riscontrati nel vigneto Postalesio inerbito nel 1997; la presenza del bosco e la flora diversificata hanno favorito la biocenosi degli Eterotteri. Nel vigneto inerbito di Sassella, la cui copertura vegetale da semplice è divenuta via via più complessa, gli indici di biodiversità hanno mostrato un progressivo aumento dal '97 al '99 (H' = 0,58 nel 1997, H' = 1,187 nel 1999; J' = 0,426 nel 1997, J' = 0,898 nel 1999). Nella medesima località la flora di sostituzione presente nel vigneto diserbato ha permesso nel primo anno l'affermazione di una biodiversità paragonabile a quella dell'inerbito (H'= 0,838, J' = 0,67) mentre dopo due anni la situazione è peggiorata (H' = 0,6778 nel 1999, con sole 5 specie). Nell'altro diserbato non si sono trovati Eterotteri.

Key words: Heteroptera, biodiversity, vineyards, Valtellina.

INTRODUCTION

The intensification of cultivation practices, the massive use of synthetic pesticides, the simplification of the agroecosystems with the removal of hedges and other natural elements, and the prevailing objective of maximising production have all together led to an impoverishment of the landscape and to the reduction of the biodiversity. As a consequence the agroecosystems have become less stable and more susceptible to attacks by phytophagous insects. This in turn has led to a further increase of the use of chemical control in order to reduce the damages caused by harmful organisms. In particular weed-control, eliminating the spontaneous flora, has had a heavy impact on the arthropod communities (Lozzia e Rigamonti, 1994; Boller, 1995).

To prevent these problems, in the last decade the phytosanitary management of the vineyard has evolved moving from the blind chemical control, through the stage of guided control, to integrated agricultural production, valorising and integrating all the positive factors of the agroecosystem. In particular the growth of weeds as a new concept of soil management favouring the augmentation of numerous arthropod species has found widespread acceptance. (Remund *et al.*, 1992; Lozzia *et al.*, 1996; Boller *et al.,* 1997).

Favretto *et al.* (1988) and Maudsley *et al.* (1997), claimed that Hemiptera and Heteroptera, especially those belonging to the families of Anthocoridae, Reduviidae and Nabidae, are exhibiting continuous movements between forests, natural vegetation along the hedges and agricultural crops. The type of weeds and the botanical composition seem to influence the abundance of different heteropteran species. In vineyards, the low layers of grass are apparently favourable for the economically important zoophagous or zoophytophagous species such as Anthocoridae, especially those belonging to the genus *Orius*, including predators of Tetranychid mites, and Nabidae predators of microlepidopteran larvae. The *Rhynocoris iracundus* (Poda) and *R. rubricus* (Germar), also predators, seem to prefer the larger umbellifers even if they can feed on soil micro arthropods (Dioli, 1990). Some species are found only occa-

sionally in agricultural environments, as they are typical of moors marsh and grazing land with gramineae (Dioli, 1980); among these *Stenodema calcaratum* (Fallèn), *Peritrechus gracilicornis* Puton, *Stictopleurus punctatonervosus* (Goeze).

The main aim of this investigation was to compare the abundance of different arthropod families present in a perennial agricultural environment (vineyard) and the possibility of their interaction with the surrounding environment (forest and annual crops). Our attention was focussed on Heteroptera of which some species are mainly linked to the agricultural environment, while others mainly to the surrounding environment, and only a few utilise both environments. For example, *Liocoris tripustulatus* F. was found in the vineyard but not in the forest or in the agricultural areas (Favretto *et al.,* 1988). *Deraeocoris punctulatus* Douglas & Scott on the other hand seems to favour the mulberry tree and was not found in the vineyard. *Dicyphus errans* (Wolff) has shown to be polyphagous as it was captured both on the grapevine and on the natural vegetation present in the vineyard such as *Geranium* sp., *Stachys* sp., *Salvia* sp., *Cucumpelus* sp., *Ononis matrix* L., *Solanum nigrum* L., *Lycopersicon esculentum* Mill., *Nicotiana tabacum* L..

The weeds have also been observed to reduce the potential danger of phytophagous Heteroptera to agricultural crops. Tavella *et al.* (1996) have reported that in apple orchards with weed-covered soil *Lygus rugulipennis* Poppius greatly reduced its migrations towards the apple trees, finding better nutritional conditions on the herbaceous weed species. The work reported here is a contribution to the knowledge of the role played by weeds on the biodiversity of Hemiptera Heteroptera in vineyards with differents soil managements, in particular in the two types of vineyards with and without weed-covered soil.

MATERIALS AND METHODS

The environments of the experiment were chosen in two viticultural areas in the province of Sondrio (North Italy) that differ in their microclimatic and pedological characteristics. In each locality a vineyard without weed and one with weed was chosen. In all vineyards the Chiavennasca variety of grapes was cultivated in the Valtellina arch style. The insect pest control was carried out using *Bacillus thuringiensis* Berliner and against the diseases fungicides were applied that exhibited a high selectivity towards the Rhynchota. The characteristics of the experimental situations are summarised in Table 1.

For the collection of the insects a entomological net (diameter = 40 cm) and a motor aspirator (type D-VAC) were used. The surveys were carried out in different points of each vineyard: on the grass, on individual flowers, near herbaceous plants along the margin and walls. The aspiration was carried out above the spontaneous grass but also near dry walls and on the bare ground. The aspirations lasted 15 minutes for each vineyard. The collections were carried out every 15 days from June 1997 to September 1999.

Table 1 - General characteristics of the experimental environments.

Localities	Sassella		Postalesio	
Characteristics	Exposition South with strong inclination. Sandy and acid soil. Microclimate dry. Forest as elements of ecological compensation.		Exposition South, South-East with slow slope. Sandy and acid soil. Microclimate humid. Presence of woods as element of natural compensation.	
Vineyards	with weeds	without weeds	with weeds	without weeds
Characteristics	The weed cover is recent, the plants are rare and mainly high herbs.	The soil is not completely without weeds. There are some colonizing botanical species.	The green cover is many years old. The weeds are composed mainly of herbaceous species.	The soil is completely without weeds.
Altitude	320 m	320 m	230 m	230 m

In addition, a study of the botanical composition of the vineyards with weeds was carried out, following the Daget and Poissonet method (1969).

The data of the collections of Hemiptera has been analysed using biodiversity and similarity indices: the Shannon-Weaver index $H' = \sum Pi \text{ Log } Pi$ where Pi = relative frequency of the single species; the numbers of Hill (1979): N_0 = number of species, $N_1 = e^{(H' \times \ln 2)}$ where H' = index of Shannon-Weaver, $N_2 = 1/\sum (Pi)^2$, $N_{inf} = 1/P$ max where P max = absolute frequency of the most representative species, index of equitability of Pielou (1996) J' = H'/Log No; index of similarity of Sörensen QS = 2c x 100/(a+b) where a and b are the number of species found respectively in the environments A and B while c is the number of those common to both biotopes.

The cumulative percentage curves were also calculated to make a better graph of the distribution of individuals for each species of Heteroptera in the different communities studied.

RESULTS AND DISCUSSION

Study of the weed

Tables 2 and 3 show the botanical composition of the vineyard with weeds in Postalesio. Evident is a dominance of Gramineae, Poligonaceae and Leguminosae. In 1997 *Setaria viridis* L. was the most abundant species, followed by *Lolium perenne* L. and *Convolvulus arvensis* L.. On the whole 33 plant species were found. In 1998 the most common species was still *S. viridis* followed by *L. perenne* and *Poa annua* L.. This type of vegetation is basically comparable to a frequently mowed meadow with the plants constituting a thick carpet characterised by a low botanical diversity.

The weed community in the Sassella area (Table 4) is more recent, as the weed-cover was established the same year as the start of the experiment. 23 plants pecies were collected and at the time of the first survey (1997) 3 annual species prevailed:

Table 2 - Composition of the herbaceous cover; Postalesio 1997.

Species	n	%	% cumulative
Setaria viridis L.	70	11.48	11.48
Lolium perenne L.	59	9.67	21.15
Convolvulus arvensis L.	57	9.34	30.49
Rumex acetosella L.	55	9.02	39.51
Veronica persica Poir. C.	43	7.05	46.56
Potentilla reptans L.	42	6.89	53.44
Holcus lanatus L.	41	6.72	60.16
Equisetum arvense L.	38	6.23	66.39
Silene vulgaris L.	26	4.26	70.66
Digitaria sanguinalis L.	23	3.77	74.43
Trifolium repens L.	22	3.61	78.03
Cynodon dactylon Pers.	20	3.28	81.31
Sonchus arvensis L.	16	2.62	83.93
Setaria glauca P.B.	11	1.80	85.74
Polygonum persicaria L.	11	1.80	87.54
Geranium molle L.	11	1.80	89.34
Erigeron canadensis L.	9	1.48	90.82
Other species	56	9.18	100.00
Total	610	100.00	100.00

Amaranthus retroflexus L., *Solanum nigrum* L. and *Chenopodium album* L., suitable for growth even in arid environments like those of terraced vineyards, to be followed and replaced later by other species sporadically present. This was the composition in the first year of weed growth after numerous years of weed control, and is considered as a "colonizing flora" made up of survivors of the herbicide treatments. As the action of the herbicide did not exist any longer in the second year of research (Table 5) there was a natural evolution of the vegetation with a reduction of dominant weeds in 1997 and the appearance of other species such as: *Orlaya grandiflora* Hoffm., *Silene armeria* L. and *Lactuca sp.*, which are typical of screes and arid areas. In the two Sassella vineyards the weed cover was similar, because they are close and seem a single unity, remaining unchanged also during the other years of study.

Study of the Hemiptera and Heteroptera communities

In the three years of study a total of 663 specimens was collected, belonging to 59 species and 12 families (Table 6). There are species belonging to the families of Miridae, Lygeidae, Rhopalidae, Pentatomidae, Coreidae, Pyrrhocoridae, Reduviidae, Tingidae, Nabidae, Cydnidae, Thyreocoridae and Alydidae. They are phytophagous

Table 3 - Composition of the herbaceous cover; Postalesio 1998.

Species	n	%	% cumulative
Setaria viridis L	70	12.86	12.86
Lolium perenne L.	59	10.84	23.71
Poa annua L.	56	10.29	34.01
Rumex acetosella L.	55	10.11	44.12
Potentilla reptans L.	42	7.72	51.84
Holcus lanatus L.	41	7.53	59.37
Equisetum arvense L.	38	6.98	66.36
Silene vulgaris L.	26	4.77	71.14
Digitaria sanguinalis L.	23	4.23	75.37
Trifolium repens L.	22	4.04	79.41
Cynodon dactylon Pers.	20	3.67	83.08
Calystegia sepium L.	18	3.31	86.39
Polygonum bistorta L.	17	3.12	89.52
Sonchus arvensis L.	16	2.94	92.46
Hypochoeris radicata L.	11	2.02	94.48
Geranium molle L.	11	2.02	96.51
Dactilis glomerata L.	10	1.83	98.34
Erigeron canadensis L.	9	1.65	100.00
Total	544	100	100.00

species and detritivoures with some important predators belonging especially to the families of Miridae, Reduviidae and Nabidae. The sucking phytophagous species collected are indifferent to the vine, only living on spontaneous plants. The entomophagous predators are also rather indifferent to the phytophagous pests of the vine as they eat other Heteroptera, Homoptera and insects that mainly live on the grass.

In the weed-free Postalesio vineyard no Heteroptera were found while 82 specimens were captured in the vineyard with weed-cover. In 1997 the total number of Heteroptera collected in the vineyards of Sassella with weeds was 247 and 65 in the weed-free vineyard, respectively.

In 1998 in the vineyards of Sassella there was a considerable reduction of the number of specimens captured; 42 in the vineyard with weeds and 21 in the weed-free one. In the Postalesio vineyard instead there was an increase of captures with 110 specimens. In 1999, 60 specimens were found in the Sassella vineyard with weeds, 6 in the weed-free Sassella vineyard and 30 in the Postalesio vineyard with weeds. The data collected was analysed with the indices mentioned above and the results have been summarised in Tables 7 and 8.

It is evident that for all the vineyards the biodiversity was rather low, if compared to the high values that can be found in natural ecosystems: the index of Shannon-

Table 4 - Composition of the herbaceous cover; Sassella 1997.

Species	n	%	% cumulative
Amaranthus retroflexus L.	67	35.45	35.45
Solanum nigrum L.	25	13.23	48.68
Chenopodium album L.	19	10.06	58.73
Erigeron canadensis L.	16	8.47	67.20
Digitaria sanguinalis L.	8	4.23	71.43
Geranium molle L.	5	2.65	74.07
Veronica persica Poir.	5	2.65	76.72
Lilium sp.	5	2.65	79.36
Vicia cracca L.	4	2.12	81.48
Bromus tectorum L.	4	2.12	83.60
Silene alba L.	4	2.12	85.71
Convolvulus arvensis L.	3	1.59	87.30
Sonchus oleraceus L.	3	1.59	88.89
Other species	21	11.11	100.00
Total	189	100.00	100.00

Table 5 - Composition of the herbaceous cover; Sassella 1998.

Species	n	%	% cumulative
Orlaya grandiflora Hoffm.	54	29.67	29.67
Silene armeria L.	47	25.82	55.49
Lactuca sp.	32	17.58	73.07
Setaria viridis L.	14	7.69	80.77
Chenopodium album L.	12	6.59	87.36
Amaranthus retroflexus L.	10	5.49	92.85
Erigeron canadensis L.	4	2.20	95.05
Sonchus oleraceus L.	4	2.20	97.25
Digitaria sanguinalis L.	4	2.20	99.45
Convolvulus arvensis L.	1	0.55	100.00
Total	182	100	100.00

Weaver varies from 0.58 to 1.31 and the same situation is confirmed by other indices.

In the Sassella vineyard with weeds the values of the indices on the whole were very low in the first year of study. The index of Shannon-Weaver had a value of 0.58 and the index of J' of Pielou of 0.426, the lowest amongst those found in the three years. If we consider the constancy of the population of the Heteroptera fauna in 1997

Table 6 - List of the species of Heteroptera found in the three environments.

Species	S. I.	S. D.	P. I.	Species	S. I.	S. D.	P. I.
Miridae				**Pentatomidae**			
Adelphocoris lineolatus (Goeze, 1778)	X		X	*Dolycoris baccarum* (Linnaeus, 1758)	X	X	X
Dicyphus errans (Wolff, 1804)	X	X	X	*Nezara viridula* (Linnaeus, 1758)	X		X
Liocoris tripustulatus (Fabricius, 1781)	X	X	X	*Eysarcoris ventralis* (Westwood, 1837)	X	X	X
Stenodema calcaratum (Fallèn, 1807)	X		X	*Aelia acuminata* (Linnaeus, 1758)	X	X	X
Orthops kalmi (Linnaeus, 1758)	X			*Palomena prasina* (Linnaeus, 1761)		X	X
Deraeocoris serenus Douglas & Scott, 1868	X		X	*Carpocoris pudicus* (Poda, 1761)	X		X
Deraeocoris punctulatus (Fallèn, 1807)		X	X	*Carpocoris fuscispinus* (Boheman, 1851)	X	X	
Trigonotylus ruficornis (Geoffroy, 1785)	X		X	*Graphosoma lineatum* (Linnaeus, 1758)	X		
Charagochilus weberi Wagner, 1953		X		**Coreidae**			
Notostira erratica (Linnaeus, 1758)			X	*Coreus marginatus* (Linnaeus, 1758)		X	X
Lygus rugulipennis (Poppius, 1911)		X	X	*Syromastus rhombeus* (Linnaeus, 1767)	X		X
Halticus pusillus (Herrich-Schäffer, 1835)			X	*Coriomeris* sp.		X	
Lygeidae				*Bathysolen nubilus* (Fallèn, 1807)			X
Nysius senecionis (Schilling, 1829)	X	X	X	*Haploprocta sulcicornis* (Fabricius, 1794)	X		X
Lygaeus equestris (Linnaeus, 1758)	X	X		*Ceraleptus gracilicornis* (Herrich-Schäffer, 1835)	X		
Aphanus rolandri (Linnaeus, 1758)	X	X	X	**Pyrrhocoridae**			
Emblethis verbasci (Fabricius, 1803)	X	X	X	*Pyrrhocoris apterus* (Linnaeus, 1758)	X	X	X
Megalonotus sabulicola (Thomson, 1870)	X	X	X	**Reduviidae**			
Megalonotus chiragra (Fabricius, 1794)			X	*Rhynocoris iracundus* (Poda, 1761)	X	X	X
Acompus pallipes (Herrich-Schäffer, 1834)	X			*Rhynocoris rubricus* (Germar, 1814)	X		X
Geocoris megacephalus (Rossi, 1790)	X		X	*Coranus griseus* (Rossi, 1790)	X		X
Scolopostethus sp.		X		*Peirates hybridus* (Scopoli, 1763)		X	
Peritrechus gracilicornis (Puton, 1877)			X	**Nabidae**			
Rhyparochromus alboacuminatus (Goeze, 1778)			X	*Aptus mirmicoides* (O.G.Costa, 1834)	X		X
Stygnocoris fuligineus (Geoffroy in Fourcroy, 1785)			X	*Prostemma guttula* (Fabricius, 1787)	X	X	
Platyplax salviae (Schilling, 1829)			X	*Nabis* sp.	X		X
Rhopalidae				*Alloeorhynchus flavipes* (Fieber, 1836)		X	
Rhopalus subrufus (Gmelin, 1790)	X		X	**Pyrrhocoridae**			
Corizus hyoscyami (Linnaeus, 1758)	X	X	X	*Sehirus morio* (Linnaeus, 1761)		X	
Stictopleurus punctatonervosus (Goeze, 1778)	X		X	*Macroscytus brunneus* (Fabricius, 1803)		X	
Stictopleurus crassicornis (Linnaeus, 1758)	X			*Legnotus limbosus* (Geoffroy, 1785)			X
Stictopleurus abutilon (Rossi, 1790)	X			**Thyreocoridae**			
Alydidae				*Thyreocoris scarabaeoides* (Linnaeus, 1758)	X		X
Alydus calcaratus (Linnaeus, 1758)			X	**Tingidae**			
				Kalama tricornis (Schrank, 1801)	X		X

S.I. = Sassella with weeds; S.D. = Sassella without weeds; P.I. = Postalesio with weeds

Table 7 - Biodiversity indices in the different lots.

Vineyard	H'	N_o	N_1	N_2	N_{inf}	D	J'
Sassella with weeds 1997	0.58	23	2.524	1.795	1.35	0.557	0.387
Sassella with weeds 1998	1.043	17	5.284	7.52	3.57	0.133	0.847
Sassella with weeds 1999	1.187	21	6.652	12.08	5.88	0.0828	0.898
Sassella without weeds 1997	0.838	18	3.809	3.389	1.923	0.295	0.67
Sassella without weeds 1998	0.886	10	4.113	5.88	3.03	0.17	0.886
Sassella without weeds 1999	0.6778	5	2.95	4.48	2.994	0.223	0.969
Postalesio with weeds 1997	1.316	33	8.169	14.28	6.33	0.07	0.867
Postalesio with weeds 1998	0.96	20	4.965	5.56	2.78	0.179	0.74
Postalesio with weeds 1999	1.004	14	4.977	7.628	4.273	0.1311	0.876

Table 8 - Values of the index of similarity of Sörensen.

Comparison between vineyards	QS
Sassella with weeds - Sassella without weeds 1997	43.90
Sassella with weeds - Sassella without weeds 1998	44.40
Sassella with weeds - Sassella without weeds 1999	23.08
Sassella with weeds - Postalesio with weeds 1997	50.00
Sassella with weeds - Postalesio with weeds 1998	54.00
Sassella with weeds - Postalesio with weeds 1999	45.70

for this vineyard through the study of the cumulative curve (Fig. 1) it is evident that out of 23 species, only one constituted 74.09% of the total Heteroptera found (183 individuals out of 247). The index of N_{inf} also has the lowest value amongst those studied, being 1.35. This indicates a high abundance of the species quoted among all the ones present. Basically, the community appears therefore badly structured. Figure 2 shows that the second most frequent species only has a small percentage compared to the total specimens found. All the other species were present in very low numbers (15 species have been collected with only one specimen).

In 1998 the situation changed: the index of Shannon-Weaver had a value of 1.04 and the Pielou one of 0.85 denoting that the biodiversity of the community of Heteroptera in this vineyard, where 17 species were collected, was equal to 84.7% of the maximum possible. Therefore, even though there was a reduction in the number of species with respect to 1997 they were in any case better distributed in the whole community, as highlighted in figure 1. The community of this vineyard was dominated by *Megalonotus sabulicola* (Thomson) but which only constituted 28.57% of the total; so it had a lower weight in the structure of the community. This can be concluded also from the index N_{inf} which goes from 1.35 in 1997 to 3.57, indicating

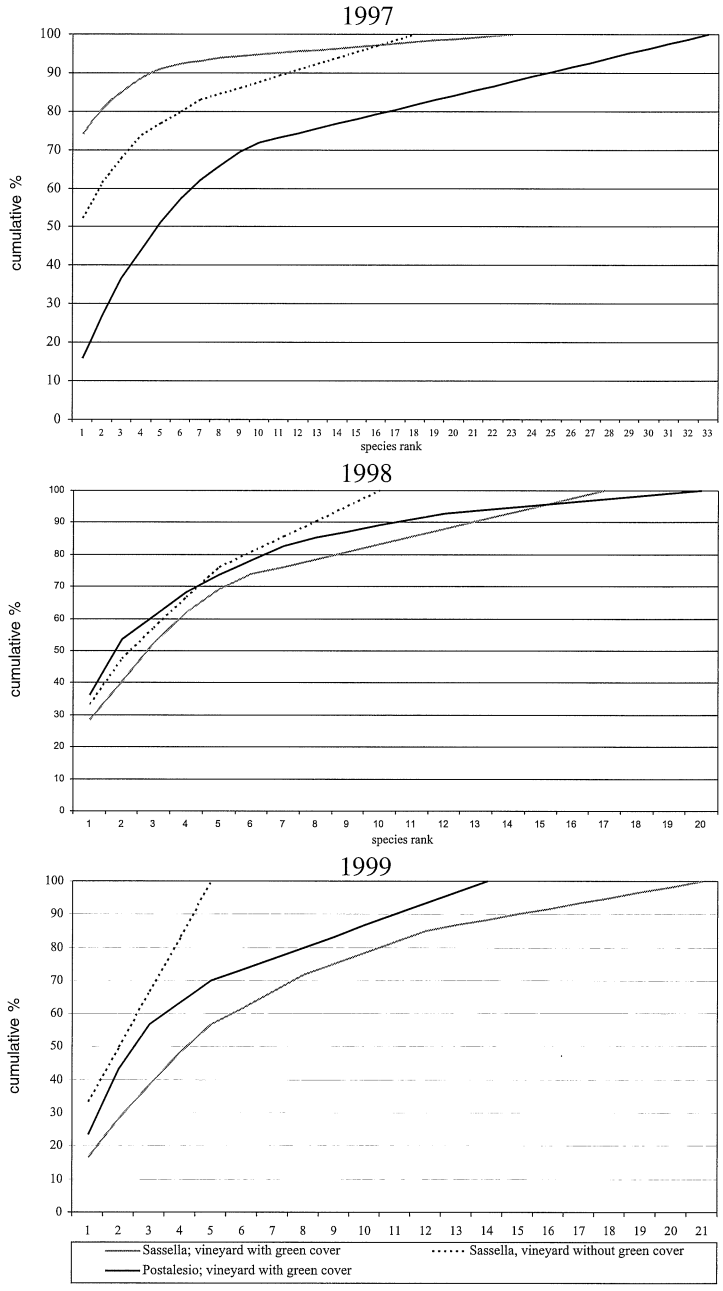

Fig. 1 - Cumulative curves of Heteroptera in the three vineyards.

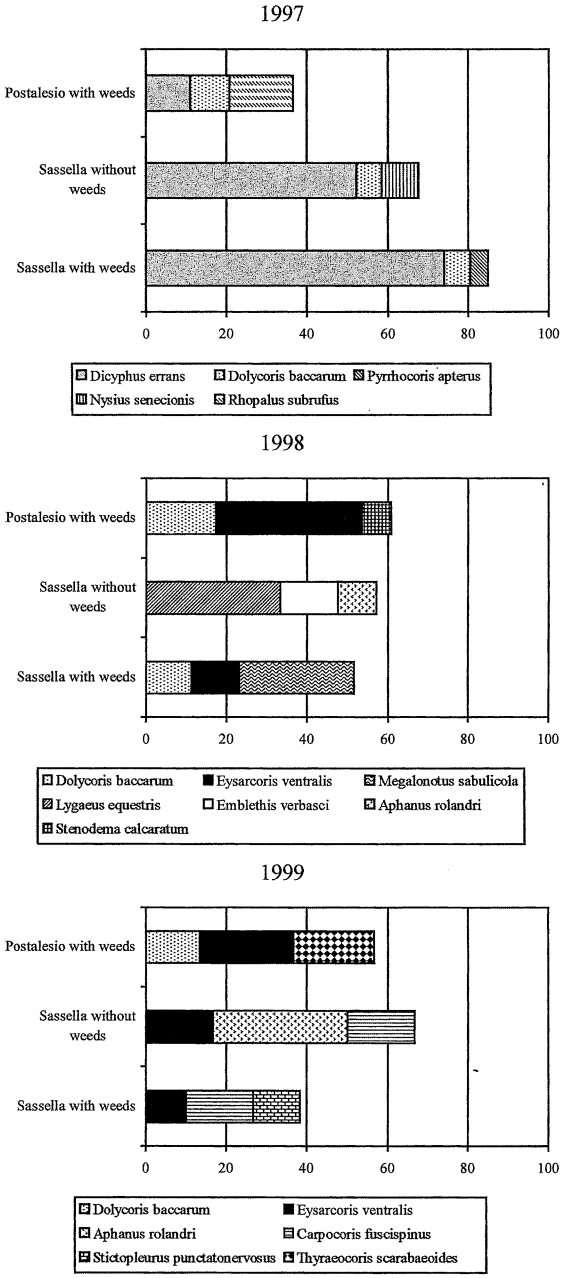

Fig. 2 - Contribution of the three dominating species in each vineyard to the composition of the Heteroptera communities.

that the most abundant species (different from the one of the year before) was no so far from the others.

In 1999 there was a further increase of the values in all the indices calculated. Even N_{inf} had a higher value than the first two years, and this shows a better distribution of the species in the community. On the whole in 1999 the Sassella vineyard with weeds was the one that had the highest biodiversity indices.

As far as the weed-free vineyard in Sassella is concerned, one can see from table 7 that in 1997 and in 1998 the indices of biodiversity of the Heteroptera were very similar. In 1997 in the face of a higher number of species captured with respect to the following year, the indices were slightly lower. In particular in 1997 the biodiversity was 67% of the maximum possible and in 1998 was 88,6%. Figure 1 shows that in 1997 the dominant species in the weed-free Sassella vineyard represented just over 50% of the captures and in 1998 just over 30%. Even the different percentage between the dominant species and the second most represented in 1997 was greater than in 1998. This indicates a slightly better situation in 1998. In 1999 only 5 species were collected and as a result one cannot really speak about biodiversity.

In the Postalesio vineyard with weeds quite high values were found of the indices in all three years. The index of Shannon-Weaver shows a high biodiversity and those of Pielou and N_2 also show that the community of Heteroptera is well structured. In particular the values of J' in 1997 and in 1999 tell us that in this vineyard the biodiversity found was 86.7% and 87.6% respectively of the maximum possible for that number of species. The histograms, too, of the dominant species (Fig. 2) and the cumulative curves (Fig. 1) indicate that there is a diversification of the species present without there being a real dominant one.

The Sörensen's index (Table 7) shows that there is a higher similarity of species between the two vineyards with weeds than between the vineyard with weeds and the weed-free one in the same locality. This, together with the observation on the cumulative curves, suggests that in the Sassella vineyard with weeds there has been, even considering the short time of the study, an improvement of the structure of the community, nearing the one of the Postalesio vineyard with weeds.

Considerations on the relationships between flora, entomological fauna and indices

The Postalesio vineyard with weeds presented a homogenous growth of weeds as far as ground coverage is concerned, and varied in terms of botanical composition (Tables 2 and 3). In this vineyard many Mirid species were found (Table 5), which normally are rather frequent on gramineae and on other herbaceous plants. *Adelphocoris lineolatus* (Goeze) for example, is typically feeding on herbaceous species as *Exolygus rugulipennis* Poppius. There are many species of Lygeidae that feed on various types of plants and are particularly favoured by the low herbaceous layers where they hibernate in mass, for example *Megalonotus sabulicola* (Thomson). There were also many Pentatomidae, Coreidae and Rhopalidae that mainly exhibit a phytophagous diet. Together with species typically associated to environments modi-

fied by man such as *Trigonotylus ruficornis* (Geoffroy), *A. lineolatus, Coreus marginatus* L., *Syromastus rhombeus* L., *Aelia acuminata* L., *Dolycoris baccarum* L. others are more specific to the marsh land and habitats without human impact. This data would confirm therefore the importance of the forest and of the hedges in determining the presence of some species without economic importance. In the Sassella vineyard the botanical composition has enhanced a better distribution of species inside of Heteroptera communities.

A high number of specimens of *D. errans* has been found especially in the vineyards of Sassella in 1997 (183 specimens in the one with weeds and 34 in the weed-free one), and in particular on *A. retroflexus*. This plant was abundant both in the vineyard with weeds and in the weed-free one. In 1997 it represented 35.5% of the vegetation, while the following year the number was greatly lower in the vineyard with weeds. This evolution has had a heavy consequence on the presence of the *D. errans*: in 1997 it constituted 74.09% of the community of Heteroptera in the vineyard with weeds and 52.31% in the weed-free vineyard, while in 1998 in the vineyard with weeds not even one specimen was found, and in the weed-free vineyard it represented only 4% of the total. Moreover, with the disappearance of *D. errans* in the vineyard with weeds was followed by a noteworthy improvement of the situation in terms of biodiversity. The study of the cumulative curves allows us to observe that in the second year of investigation there was a more homogenous presence of the species. This situation could be due to the decrease in abundance of *A. retroflexus* substituted by other species, with an overall increase in diversity of the vegetation and as a consequence of the entomological fauna. Two hypotheses can be made on the disappearance of this vegetation: first, the presence of *A. retroflexus* as well as *C. album* was due to the fact that these two plants are possibly resistant to the herbicides applied. In 1997 a parts of the vineyard was left with weeds and this has allowed other plants to become established. Passarelli & Pirola (1990) sustain instead, that this species is characterised by wide fluctuations and it determines noteworthy variations of the botanical composition of the weeds from one year to the next.

As far as the weed-free vineyard in Sassella is concerned, it has already been shown the type of weed-control done allows a coverage of the vegetation not having a strong impact on the biodiversity of Heteroptera, but determining a stagnation of the values of the indices in the three years examined. If we consider that in this weed-free vineyard only two species, *A. retroflexus* and *S. nigrum* constituted the greatest part of the vegetation present, one can observe that they have determined a lower number of Heteroptera with respect to that of the other vineyards but anyway they have allowed a certain biodiversity.

From the study of the community one can also see that the diversification of the growth of weeds favours especially phytophagous Heteroptera or on a phytophagous - detritivorous diet: 20 species were found in the weed-free Sassella vineyard, 33 in the one with weeds, 40 in the Postalesio vineyard with weeds. The zoophytophagous species more or less stayed at the same levels in the different kinds of soil management (*D. errans, Deraeocoris serenus, Deraeocoris punctulatus*). The zoophagous

species (*Rhynocoris iracundus, Rhynocoris rubricus, Prostemma guttula, Coranus griseus*, and *Peirates hybridus)* have been found almost exclusively in the vineyards with weeds except for *Alloeorhynchus flavipes* (Nabidae) collected in the weed-free Sassella vineyard as a single specimen.

CONCLUSIONS

The situation observed in the Postalesio vineyard with weeds, both in terms of the structure of the community and in terms of the indices of biodiversity, is the one that comes closest to a homogenous distribution, characterised by the absence of dominating species on the one hand and rare ones on the other. This aspect is typical for the most "stable" agroecosystems. In fact, one cannot really speak about stability in agroecosystems influenced by the action of man. Nonetheless the observations concerning this vineyard lead us to conclude that the presence of a homogenous growth of weeds, very similar to a movable meadow, and the forest, have apparently provided natural sources for Heteroptera. To be more precise, they have found places for refuge and hibernation, thanks to which, in three years of work, it has been possible to see a higher level of biodiversity with respect to other vineyards. A very interesting piece of information is the improvement of the biodiversity, found during the research period in the Sassella vineyard with weeds. Here, in the first year, the situation appeared almost comparable to the weed-free vineyard, together with the fact that the vegetation coverage of the two were almost identical. Starting from the second year when the herbicide was not longer used there was a remarkable diversification of the flora present and a constant increase of the indices of biodiversity. The data collected leads us to conclude that in terms of evolution of the biocenosis this vineyard is still in the growing stage, but only further research can eventually lead to data that might support this hypothesis. It also has to be considered that Sassella in itself is very interesting for studies of the Heteroptera fauna, as the high exposure to the sun together with the presence of low dry walls reflecting the sunrays and constituting probable areas of refuge, are favourable elements to the ecology of Heteroptera, that include numerous thermophilous species, often exclusively found in very dry areas. If we add to these elements the positive effect of weeds observed during the three years of our study, one can summarise that enhancement of the weeds in this particular viticultural situation can easily lead to encouraging results in terms of increased biodiversity. It would be interesting, for example, to carry out aspirations and sampling on specific plant species, since, as it has already been observed, there are tall flowers that can be picked individually. This type of research could give indications on the types of flowers that are more attractive for Heteroptera. Furthermore, the captures on flowers could be compared to those on dry walls, to verify if, as recorded in works by other authors, these areas constitute effectively refuge areas for Heteroptera and other orders of insects.

ACKNOWLEDGEMENTS

The Authors thank Dr. Ernest Boller (Swiss Federal Research Station Wädenswill) for critically reviewing the manuscript.

REFERENCES

BOLLER E.F., 1995 - IOBC/WPRS and the development of Integrated Production in Europe. - 3° Encontro Nacional de Proteccao Integrada, 18-19 december 1995, Lisbon/Portugal.

BOLLER E.F., GUT D., REMUND U., 1997 - Biodiversity in Three Trophic Levels of the Vineyard Agro-Ecosystem in Northern Switzerland. *Ecological Studies* 130, 299-318.

DAGET P., POISSONET J., 1969 - Analyse phytologique des praires. Application agronomiques - Centre national Recherche Scientifique, Montpellier, France: 1-14.

DIOLI P., 1980 - Eterotteri della brughiera di Rovasenda (Piemonte) - Quaderni sulla "Struttura delle zoocenosi terrestri" 1: 35-56.

DIOLI P., 1990 - *Rhynocoris iracundus* e *Rhynocoris rubricus* in Valtellina. - Il naturalista valtellinese, Atti Mus. Civ. Stor. Nat. Morbegno 1: 55-60.

FAVRETTO M.R., PAOLETTI M.G., LORENZONI G.C., DIOLI P., 1988 - Lo scambio di invertebrati tra un relitto di bosco planiziale ed agroecosistemi contigui. L'artropodofauna del bosco di Lison. - Nova Thalassia 18: 329-358.

HILL M., 1979 - Ecology and Systematics - Cornell University, Ithaca, New York: 1-95.

LAGERLOF J., STARK J., SVESSON B., 1992 - Margins of agricultural fields as habitats for pollinating insects - Agric. Ecosystem Environ. 40: 117-124.

LOZZIA G.C., RIGAMONTI I.E., 1994 - Modello di gestione integrata dell'agroecosistema vigneto - Atti convegno "La difesa integrata dell'uva da tavola e da vino per gli aiuti comunitari del regolamento CEE 2078/92", Latina: 75-98.

LOZZIA G.C., RIGAMONTI I.E., MARIANI L., 1996 - Ruolo della vegetazione spontanea nel mantenimento di alcuni Artropodi predatori nel vigneto - Vignevini, 23 (7-8): 9-13.

MAUDSLEY M.J., WEST T., ROWCLIFFE H., MARSCHALL E.J.P., 1997 - Spatial variability in plant and insects (Heteroptera) communities in hedgerows in Great Britain. - Species Dispersal and Use Processes - Cooper and J. Power, Yale, (UK): 229-236.

PASSARELLI D., PIROLA A., 1990 - La flora spontanea dell'area della vite in Valtellina. - Il Naturalista Valtellinese, Atti Mus. Civ. Stor. Nat. Morbegno, 1: 79-114.

PIELOU E.C., 1996 - The measurement of diversity in different type of biological collections - J. Theor. Biol. 13: 131-144.

REMUND U., GUT D., BOLLER E.F., 1992 - Beziehungen zwischen Begleitflora und Arthropodenfauna in Ostschweizer Rebbergen. - Schweiz. Z. Obst - Weinbau 128 (20): 528-540.

TAVELLA L., ARZONE A., ALMA A., GALLIANO A., 1996 - IPM application in peach orchards against *Lygus rugulipennis* Poppius. - Bulletin OILB/SROP, 19 (4): 160-164.

PROF. GIUSEPPE C. LOZZIA, DR. BARBARA MANACHINI, DR. IVO E. RIGAMONTI, DR. MARTINO SALVETTI. Istituto di Entomologia agraria, Università degli Studi di Milano, Via Celoria 2, I - 20133 Milano. E-mail: Giuseppe.Lozzia@unimi.it

DR. PARIDE DIOLI, Via Valeriana 19 - 23100 Sondrio.

Accepted 20 June 2000