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Effects of variety and management practices on mite species diversity in Italian vineyards

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Abstract

The influence of grape variety (Fiano, Nero d'Avola, Refosco, Verdicchio) and vineyard management (conventional, organic and untreated) on mite diversity was investigated in important Italian vine growing areas over three years. The analysis focused on Phytoseiidae and Tydeidae, which were the most diverse and numerous mites observed. Eleven phytoseiid species were collected. *Kampimodromus aberrans* (Oudemans), *Typhlodromus exhilaratus* Ragusa, *Typhlodromus pyri* Scheuten, *Amblyseius andersoni* (Chant) and *Phytoseius finitimus* Ribaga were detected on all four vine varieties. The highest densities of the first two species were observed on Verdicchio, while *T. pyri* and *A. andersoni* were mainly found on Nero d'Avola. Only *A. andersoni*, *T. exhilaratus* and *P. finitimus* were recorded in all types of vineyard management. *K. aberrans* and *T. exhilaratus* were most abundant in untreated vineyards while *T. pyri* populations were much higher in the organic ones. Among tydeid species, *Tydeus caudatus* (Dugès), *Tydeus californicus* (Banks) and *Pronematus ubiquitus* (McGregor) were the most frequent. No differences were detected between the biodiversity indexes of the four vine varieties, while these indexes were different in the management experiment: biodiversity was higher in organic and untreated vineyards than in conventional ones. The correlation between mite group densities was evaluated.

Key words: vine cultivar, organic/conventional vineyard, species distribution, Phytoseiidae, Tydeidae.

Introduction

In the Mediterranean area, mite communities on vines are characterized by a low number of herbivorous species (mainly tetranychids and eriophyoids), a pool of predators (mainly generalist phytoseiids) and a number of unspecialized feeders (predominantly tydeids, which may be fungivores, predators, scavengers or feeders on different plant exudates and pollens) (Castagnoli, 1989; Castagnoli *et al.*, 1997; Kreiter *et al.*, 2000; Papaioannou-Souliotis, 2006).

Studies on the relationships among these species have clarified that the main cause of tetranychid outbreaks in vineyards is the reduced presence of phytoseiids, their natural enemies (Castagnoli *et al.*, 2001; Duso, 1997; Kreiter *et al.*, 2002). Much of the available data concerns the influence of chemicals, vine varieties, agronomic practices, soil characteristics and surrounding vegetation on phytoseiid and other vine mite populations (Castagnoli *et al.*, 1997, 1999; Duso and Vettorazzo, 1999; Duso *et al.*, 2004; Pozzebon *et al.*, 2002; Tixier *et al.*, 2000). Despite the difficulty in inferring general rules from studies conducted in a wide range of situations, the evidence is that each change in vineyard management, including the choice of variety, affects the mite composition and relationship among species.

The relationship between plant varieties and herbivorous arthropods is well documented and depends on both the biochemical contents of the plant and its physical and morphological features. In non-herbivores (especially phytoseiid mites), the physical and morphological leaf traits likely play the most important roles in variety preferences (Kreiter *et al.*, 2002, Beard and Walter, 2001; Romero and Benson, 2005). In contrast to the ample literature on the effects of different chemicals on vine mite communities (see Duso *et al.*, 2007), little is known about organic vs. conventional systems in Italian vineyards and the available data are limited to a single geographical area (Bigot and Zandigiacomo, 2000).

The framework of the present study is the development of a viticulture aimed at improving the quality and typicality of the final product. The study was part of a national multidisciplinary project (PROVIT) involving all the most important Italian regions devoted to high quality wine. The main objectives of the project were to evaluate the qualitative and productive potential of some fine Italian vine varieties now in demand and to investigate the effects of these varieties and some vineyard management practices on the wine quality, with the aim of eventually shifting from conventional to organic production. In this context, we focused on mites as an important component of the arthropod fauna; mites are especially sensitive to biotic and abiotic changes and an undesired influence of variety or crop management could have serious effects on the wine quality and production. A multiyear study was carried out to evaluate the effects of three management practices and four autochthonous vine varieties (not previously considered in this regard) on the density of mites. In a previous paper (Simoni and Castagnoli, 2007), the observations were limited to mite families, which were significantly affected by the varieties and management practices. In the present paper, we focus on the distribution of single species and their main relationships.

Materials and methods

Two separate studies on the effects of variety (VAREX) and management practices (MANEX) on mite composition in Italian vineyards were carried out over three years (2004-2006). As the different geographical areas, the samplings were synchronized on the basis of the same phenological phases of the plant. All mites found were counted and most of them were identified at the species level. In the examined vineyards, if not otherwise indicated, the farmers selected the chemicals, adopting an integrated pest management control strategy (named conventional hereafter).

VAREX, variety experiment

The vine leaf samples were collected in 15-year-old experimental vineyards in 13 localities of different geographical areas (figure 1A). In each locality, four vineyards were considered. In each vineyard only one of the following four varieties was grown: Fiano, Nero d'Avola, Refosco and Verdicchio. Yearly, in each vineyard, at the first grape growing and at ripening, phases usually corresponding to high mite densities, 16 leaves in each of three sampling plots were randomly collected in the middle of the canopy. In each locality, vineyards were subjected to the same cultural management.

The difference in undersurface leaf pubescence of Fiano, Verdicchio and Nero d'Avola vine varieties sampled were consistent with the description of Violante and Ciarimboli (1960), Bruni (1962), Mazzei and Zappalà (1964). For Refosco which is a complex of different sub-varieties of different origins (Marzotto, 1923; Cosmo *et al.*, 1960), we sampled sub-varieties with rather smooth leaves.

MANEX, management practice experiment

In four different geographical locations (figure 1B), three management systems were compared: conventional, organic and untreated. Pesticides used in conventional and organic vineyards are reported in table 1. Untreated study sites were plots of conventional vineyards where no chemical treatments were conducted during

Table 1. Pesticides used in conventional and organic vineyards against different pests and diseases in the management experiment (D = downy mildew; P = powdery mildew; B = gray mold; I = insects) in the different areas (N = northern Italy, C = central Italy, S = southern Italy).

Conventional					
Pesticides	Year	Pest	Location		
Copper compounds	all	D	N	C	S
Cymoxanil	all	D	N	C	S
Tiram	all	D		C	
Famoxadone	all	D		C	
Fosetyl-Al	all	D	N	C	
Mancozeb	all	D	N		S
Metalaxil	all	D			S
Dimethomorph	all	D	N		S
Folpet	3rd	D			S
Sulphur	all	P	N	C	S
Myclobutanil	all	P		C	
Quinoxifen	all	P		C	
Meptyldinocap	2nd	P			S
Triadimenol	3rd	P			S
Cyprodinil	All	B		C	
Fludioxonil	All	B		C	
Indoxacarb	All	I		C	
Azinphos-methyl	2nd	I			S
Chlorpyrifos	2nd	I			S
Deltamethrin	2nd	I			S
Fenitrothion	3rd	I			S
Cypermethrin	3rd	I			S
Organic					
Pesticides	Year	Pest	Location		
Copper compounds	All	D	N	C	S
Sulphur	All	P	N	C	S
Bacillus thuringiensis	All	I			S

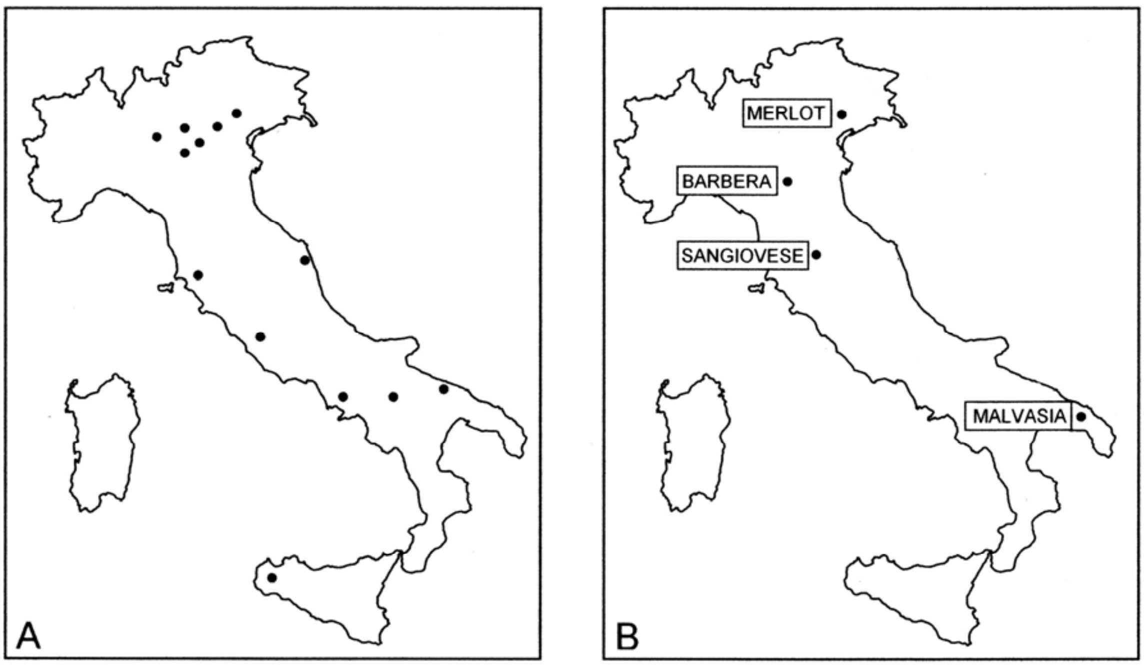

Figure 1. Geographical location of the study sites in the variety experiment (A) and in the management experiment (B).

the study period. The very common varieties in Italy - Merlot, Sangiovese, Barbera and Malvasia - were selected to this study and only one variety was examined in each locality. Sampling procedures similar to those of the previous experiment, VAREX, were carried out. Samplings were performed at the first grape growing, at the beginning of ripening and, again, at the end of ripening when all chemical treatments ceased.

Data analysis

For the variety and management practice experiments, the Shannon index (H') was calculated to estimate the biodiversity level on vine leaves. The diversity level was also evaluated by the Evenness index (J') derived from the Shannon function (see Krebs, 1989). Both the indexes, H' and J', were calculated for each sample (VAREX, n=608; MANEX, n=224). The results of the diversity indexes were analysed with one-way ANOVA and Tukey test (Burgio, 1999; SPSS, 1999). The coefficient of Sorensen was calculated in VAREX and MANEX, over all the experimental period, to define the similarity of mite diversity.

The effects of the different independent variables were evaluated on mite species densities by General Linear Model Analyses (Multivariate approach, SPSS, 1999). First, this analysis was applied to determine how the experimental factors (leaf, location, sampling time, in both experiments; vine variety only in VAREX, agronomic management only in MANEX) affected the density of the most representative and numerous species of mites; subsequently, the same analysis was adopted to evaluate if the presence of these species was affected by and/or related to the presence of other mite groups. If statistical analysis did not reveal any significant effect of single

Table 2. Species and total number of mites sampled in the variety experiment (VAREX). Location: N = northern Italy; C = central Italy; S = southern Italy. Vine variety: Fi = Fiano; Na = Nero d'Avola; Re = Refosco; Ve = Verdicchio.

Family/species	Location			Vine variety				n. of mites
Phytoseiidae								
Amblyseius andersoni (Chant)	N		S		Na	Re	Ve	219
Euseius finlandicus (Oudemans)	N	C			Na			2
Euseius stipulatus (Athias-Henriot)			S	Fi	Na			5
Kampimodromus aberrans (Oudemans)	N	C	S	Fi	Na	Re	Ve	13050
Phytoseius finitimus Ribaga		C	S	Fi	Na	Re	Ve	10541
Paraseiulus talbii Athias-Henriot	N			Fi		Re	Ve	14
Paraseiulus triporus (Chant et Yoshida Shaul)		C	S	Fi	Na	Re	Ve	117
Typhlodromus exhilaratus Ragusa		C	S	Fi	Na	Re	Ve	805
Typhlodromus pyri Scheuten	N			Fi	Na	Re	Ve	1492
Tydeidae								
Homeopronematus anconai (Baker)			S	Fi	Na	Re		23
Lorria sp.		C	S	Fi			Ve	11
Pronematus ubiquitus (McGregor)		C	S	Fi	Na	Re	Ve	473
Triophtydeus triophthalmus (Oudemans)	N		S		Na	Re		19
Tydeus calabrus (Castagnoli)		C	S		Na	Re		2
Tydeus californicus (Banks)	N	C	S	Fi	Na	Re	Ve	1237
Tydeus caudatus (Dugès)	N	C	S	Fi	Na	Re	Ve	1840
Tydeus kochi Oudemans			S	Fi	Na	Re	Ve	114
Tetranychidae								
Eotetranychus carpini (Oudemans)		C	S			Re		102
Panonychus ulmi (Koch)	N	C	S	Fi	Na	Re	Ve	1190
Tetranychus urticae Koch	N	C	S	Fi	Na	Re	Ve	163
Eriophyidae								
Calepitrimerus vitis (Nalepa)	N	C	S	Fi	Na	Re	Ve	54628
Colomerus vitis (Pagenstecher)	N	C	S	Fi	Na	Re	Ve	720*
Tarsonemidae								
Tarsonemidae sp.	N	C	S				Ve	3
Tenuipalpidae								
Tenuipalpus granati (Sayed)			S	Fi	Na	Re	Ve	16
Brevipalpus lewisi McGregor			S		Na			1
Stigmaeidae								
Agistemus collyerae Gonzales			S		Na			23
Eryngiopus sp.			S	Fi	Na	Re	Ve	152
Anystidae								
Anystis sp.			S			Re		1
Ascidae								
Blattisocius sp.	N						Ve	6

*only galls were counted.

Table 3. Species and total number of mites sampled in the management experiment (MANEX). Location: N = northern Italy; C = central Italy; S = southern Italy. Management practice: or = organic; co = conventional; un = untreated.

Family/species	Location			Management practice			n. of mites
Phytoseiidae							
Amblyseius andersoni (Chant)	N	C		or	co	un	947
Anthoseius rhenanus (Oudemans)	N	C		or		un	10
Euseius finlandicus (Oudemans)	N	C	S	or	co		7
Euseius stipulatus (Athias-Henriot)			S	or		un	13
Kampimodromus aberrans (Oudemans)	N	C		or		un	63
Phytoseius finitimus Ribaga		C	S	or	co	un	3857
Paraseiulus talbii Athias-Henriot	N	C		or	co		3
Typhlodromus exhilaratus Ragusa		C	S	or	co	un	823
Typhlodromus kerkirae Swirski et Ragusa		C				un	2
Typhlodromus pyri Scheuten	N			or		un	1141
Tydeidae							
Homeopronematus anconai (Baker)		C		or		un	11
Pronematus ubiquitus (McGregor)	N	C		or		un	745
Triophtydeus triophthalmus (Oudemans)		C		or		un	46
Tydeus californicus (Banks)	N	C		or	co	un	1727
Tydeus caudatus (Dugès)	N	C		or	co	un	1976
Tydeus kochi Oudemans	N	C	S	or	co	un	43
Tetranychidae							
Panonychus ulmi (Koch)	N	C		or	co	un	2142
Tetranychus urticae Koch	N	C	S	or	co	un	238
Eriophyidae							
Calepitrimerus vitis (Nalepa)	N		S	or	co	un	22
Colomerus vitis (Pagenstecher)	N	C		or	co	un	83*
Tarsonemidae							
Tarsonemidae sp.	N	C	S	or		un	14
Tenuipalpidae							
Brevipalpus lewisi McGregor	N	C		or			4
Winterschmidtiidae							
Calvolia transversostriata (Oudemans)	N			or		un	12

*only galls were counted.

independent factors, the data were pooled over the non-significant factor. When significance of a factor was determined, Analysis of Variance and post hoc Tukey test comparisons were calculated. Pearson correlation analyses were performed for both experiments (n = 728 in VAREX and n = 304 in MANEX) to evaluate the closeness of relationship between the mite groups and between these and the most representative species found. All the statistics were calculated and analysed by the statistical program SPSS (1999).

Results

General aspects

The tables 2 and 3 report the abundance and distribution of the mite species found in this study. About 87,000 mites were collected in the variety experiment and about 14,000 in the management experiment. Collected mites belonged to Phytoseiidae (13 species), Tydeidae (8 species), Tetranychidae (3 species), Eriophyidae (2 species) and other 5 families (7 species).

Phytoseius finitimus Ribaga was an abundant phytoseiid species in both experiments, frequently observed with more than 2 specimens/leaf; *Kampimodromus aberrans* (Oudemans) was mainly found in VAREX experiment, *Typhlodromus pyri* Scheuten, *Amblyseius andersoni* (Chant) and *Typhlodromus exhilaratus* Ragusa in MANEX experiment. The most abundant tydeid species were *Tydeus caudatus* (Dugès) and *Tydeus californicus* (Banks) in both experiments; *Panonychus ulmi* (Koch) and *Calepitrimerus vitis* (Nalepa) were the most abundant phytophagous species, although the eriophyoid mite was strongly concentrated in only one sampling location. Other phytophagous mites were always recorded at very low density. The locality had a strong effect on the presence of some phytoseiids species: *T. pyri* was sampled only in northern Italian vineyards; *P. finitimus* and *T. exhilaratus* only in central and southern Italy. The tydeid *Pronematus ubiquitus* (McGregor) was also only found in central and southern Italy.

The total number of mites was not affected by either the variety or the management practice (see figures 2 and 3). All the most abundant phytoseiids and tydeids were generally collected on all four vine cultivars and frequently in all three types of vineyards. Uncommon species, i.e. *Typhlodromus kerkirae* Swirski et Ragusa, *Anthoseius rhenanus* (Oudemans) and *Euseius stipula-*

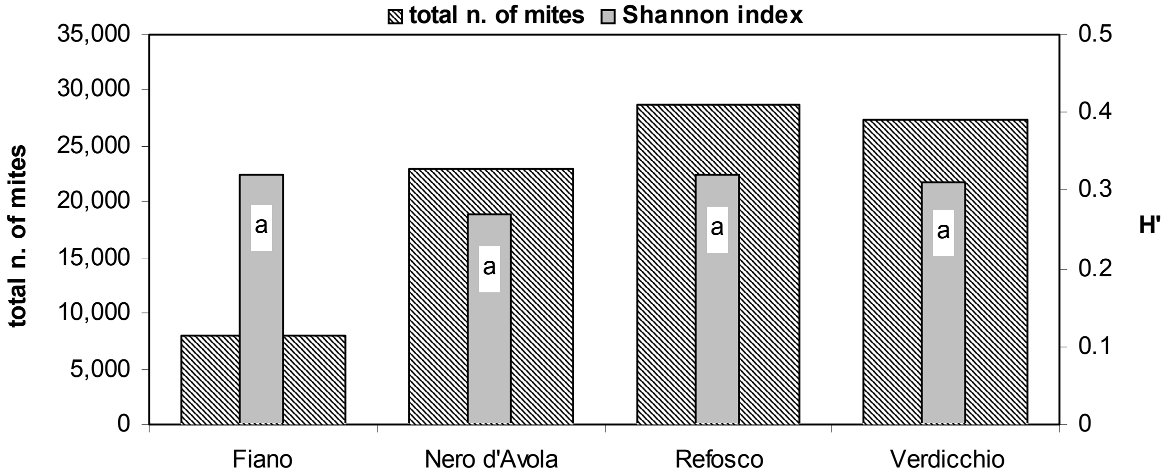

Figure 2. Number of mites and biodiversity in the variety experiment (VAREX); different letters indicate significant differences in Shannon index values (H').

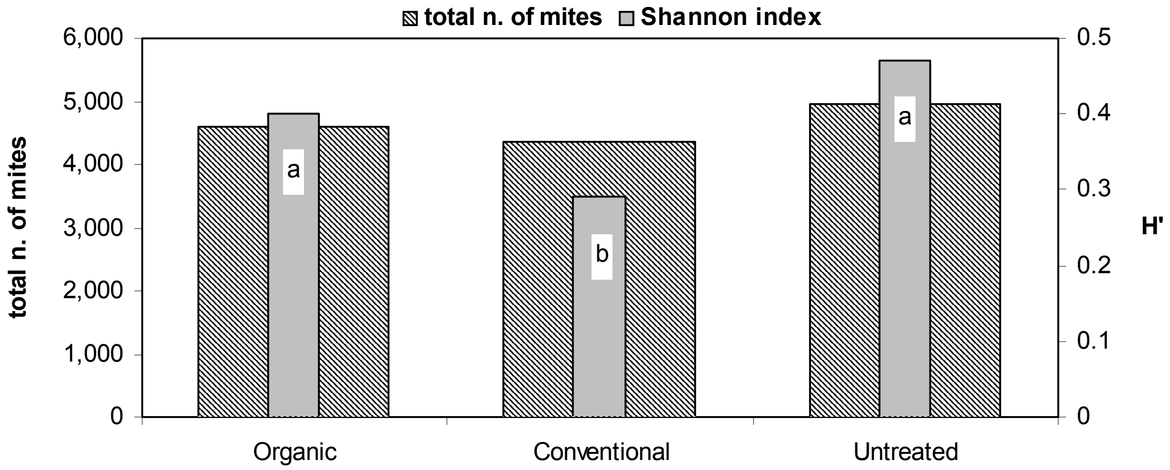

Figure 3. Number of mites and biodiversity in the management practice experiment (MANEX); different letters indicate significant differences in Shannon index values (H').

tus (Athias-Henriot) were mainly recorded in organic or untreated vineyards. Generally in most samples, only one phytoseiid species was predominant. Considering both experiments, the species more frequently found together were *T. exhilaratus* with *P. finitimus*; furthermore in MANEX, *K. aberrans* was associated with *A. andersoni*, *T. pyri* with *A. andersoni*.

Following the general analysis considering all mite species, the subsequent steps of the evaluation procedures concerned the phytoseiids *K. aberrans*, *A. andersoni*, *T. exhilaratus*, *P. finitimus*, *T. pyri* and the tydeids *T. californicus*, *T. caudatus*, *T. kochi*, *P. ubiquitus*. On the whole, these mite species represented more than 1% of the total number of mites collected in both studies.

Effects of vine variety, VAREX

Concerning the effect of vine variety on biodiversity, there were no significant differences among Shannon index values (figure 2) between the four varieties considered. The coefficient of Sorensen showed high similarity values between the four vine varieties (range 0.74-0.87). Moreover, the distribution of individuals among varieties was low: Evenness index ranged between 0.08 and 0.10.

Among phytoseiids, the vine variety affected the presence of *K. aberrans* ($P = 0.026$), *A. andersoni* ($P = 0.022$), *T. exhilaratus* ($P = 0.016$) and *T. pyri* ($P < 0.001$). *K. aberrans* and *T. exhilaratus* were more common on Verdicchio, and *A. andersoni* and *T. pyri* on Nero d'Avola (table 4). Only *K. aberrans* was significantly affected by the sampling period ($P < 0.001$), and its largest population occurred at the first grape growing. The presence of the most common tydeids was not affected by vine variety.

The presence of *K. aberrans* ($P < 0.001$) and *T. exhilaratus* ($P = 0.016$) was positively correlated with the presence of tydeids. In the case of *K. aberrans* tydeids were represented for the 62% by *T. caudatus* and 34% by *T. californicus*; in the case of *T. exhilaratus* for the 67% by *P. ubiquitus* and 14% by *T. caudatus.* The two phytoseiids were also highly correlated ($P < 0.001$) with the presence of phytophagous mites. The presence of the tydeid *T. caudatus* was positively correlated with the presence of phytoseiids ($P = 0.008$) and phytophagous mite species ($P = 0.009$).

Table 4. Mean number (± standard error) of phytoseiids/replicate in the variety experiment (VAREX). In columns, means followed by different letters are significantly different. Multiple comparisons were performed by ANOVA (Tukey test, P = 0.05).

Vine cultivar	*K. aberrans*	*A. andersoni*	*T. exhilaratus*	*P. finitimus*	*T. pyri*
Fiano (n = 176)	16.26 ± 3.05ab	----	0.49 ± 0.19b	16.98 ± 2.98a	1.04 ± 0.32b
Nero d'Avola (n = 180)	13.13 ± 3.82b	1.17 ± 0.68a	0.83 ± 0.26b	12.57 ± 2.17a	5.87 ± 1.94a
Refosco (n = 176)	14.25 ± 3.19b	0.02 ± 0.01b	0.56 ± 0.21b	15.39 ± 2.38a	1.27 ± 0.32b
Verdicchio (n = 196)	27.13 ± 4.24a	0.03 ± 0.03b	2.40 ± 0.81a	13.17 ± 2.17a	0.15 ± 0.13b

Table 5. Mean number (± standard error) of phytoseiids/replicate in the management practice experiment (MANEX). In columns, means followed by different letters are significantly different. Multiple comparisons were performed by ANOVA (Tukey test, P = 0.05); the t-test was adopted when the phytoseiid was only found in 2 samplings.

Vineyard management	*K. aberrans*	*A. andersoni*	*T. exhilaratus*	*P. finitimus*	*T. pyri*
organic (n = 103)	0.06 ± 0.06b	2.16 ± 0.75a	0.10 ± 0.07b	7.60 ± 2.62a	7.62 ± 2.31a
conventional (n = 97)	----	3.70 ± 1.36a	1.18 ± 0.52b	13.76 ± 3.68a	----
untreated (n = 104)	0.55 ± 0.20a	3.52 ± 1.20a	6.72 ± 2.11a	16.73 ± 4.68a	3.42 ± 1.57b

Effect of management practices, MANEX

In the management practice experiment, Evenness ranged from 0.08 to 0.15 and the Shannon index values of the organic and untreated vineyards were significantly different from that of the conventional ones ($F_{2,221}$ = 6.69, P < 0.001) (figure 3). Sorensen's coefficient showed that the organic and untreated vineyards were more similar to each other (0.90) than the organic and conventional (0.67) and than untreated and conventional ones (0.65).

Vineyard management affected the presence of *K. aberrans* (P = 0.009), *T. exhilaratus* (P = 0.001) and *T. pyri* (P = 0.024). *K. aberrans* and *T. exhilaratus* were most abundant in untreated vineyards, and *T. pyri* in organic vineyards. *K. aberrans* and *T. pyri* were not recorded in conventional vineyards (table 5). The sampling period affected the densities of *K. aberrans* (P = 0.040) and *T. exhilaratus* (P = 0.015), which were highest at the first sampling, and *P. finitimus* (P < 0.001) and *A. andersoni* (P = 0.019), highest at the third sampling.

Among phytoseiids, only the occurrence of *A. andersoni* was highly correlated with the presence of phytophagous mites (P < 0.001). The presence of *K. aberrans*, *A. andersoni*, *T. exhilaratus* and *T. pyri* was positively correlated with the presence of tydeids (P = 0.009). However, the tydeid species found correlated with each phytoseiid species were different: *K. aberrans* was mainly found with *T. californicus* (62%) and *T. caudatus* (10%); *A. andersoni* was frequently found with *T. caudatus* (80%); *T. pyri* was found with *T. caudatus* and *T. californicus* with the same frequencies (49%); *T. exhilaratus* was found in the 67% of records with *P. ubiquitus* and in 14% with *T. caudatus*.

Among tydeids, only *T. californicus* was affected by the management practice, being more abundant in untreated vineyards (P < 0.001). *T. californicus* (P < 0.001) and *T. kochi* (P < 0.05) were positively correlated with the presence of phytoseiids, while *P. ubiquitus* was negatively influenced by the presence of these predators (P = 0.037). Furthermore, *T. californicus* (P < 0.001) and *P. ubiquitus* (P = 0.049) were often collected on leaves with phytophagous mites.

Discussion

The number and composition of the mite species found on vineyard leaves were similar to what was reported in previous papers on the Sangiovese and Canaiolo varieties in a Tuscan vineyard (Castagnoli *et al.*, 1997; 1999). Furthermore, the recorded phytoseiid species are widespread on vines in the Mediterranean area (Castagnoli, 1989; Castagnoli *et al.*, 1997; Kreiter *et al.*, 2000; Papaioannou-Souliotis, 2006; Duso, 2006).

The management practices and vine varieties examined in this study have been reported to affect the density of the main groups of mites found in Italian vineyards: the phytoseiid population was highest in untreated vineyards, tetranychids and tydeids in conventional vineyards; Verdicchio was the variety most inhabited by phytoseiids, Refosco by tetranychids and tydeids (Simoni and Castagnoli 2007).

As regards the relationship between mites and plant variety, leaves with some hair vesture and domatia are generally preferred because they provide places to shelter and oviposit and assure suitable microclimatic conditions (Norton *et al.*, 2001; English-Loeb *et al.*, 2002; Roda *et al.*, 2003). However, this general preference varies according to the mite species considered. The varieties investigated in our study differed substantially in hairiness. The undersurface of the Fiano leaf is classified as "cottony", i.e. with very dense hair vesture. This structure did not seem to be as suitable for the recorded phytoseiid species as the rather smooth leaves of Refosco variety tested. Verdicchio leaves are characterized by a "downy" undersurface, i.e. with medium-high hair vesture, and were mainly colonized by *K. aberrans* and *T. exhilaratus*. Nero d'Avola, with its "arachnoid" leaves covered with loose hairs, was instead colonized mainly by *A. andersoni* and *T. pyri*. "Cottony" leaves could hamper the movement of the phytoseiid species, while medium vesture may be preferred by species with a relatively small body and short-medium dorsal setae (such as *K. aberrans* and *T. exhilaratus*); species with a larger body and longer setae (such as *A. andersoni*) may prefer poorly pubescent varieties. All four varieties hosted high populations of *P. finitimus*.

Similar preferences determined by leaf pubescence have been observed for other vine varieties for *A. andersoni*, *K. aberrans* and *T. exhilaratus* (Castagnoli and Liguori, 1985; Camporese and Duso, 1996; Duso and Vettorazzo, 1999; Kreiter *et al*., 2002). Our results are in contrast with reports that *P. finitimus* and *T. pyri* mainly colonize pubescent varieties (Duso and Vettorazzo, 1999; Castagnoli and Liguori, 1985; Duso, 2006). Hence, extrinsic factors, such as prey occurrence and interspecific competition, probably have an effect in addition to leaf morphology (Camporese and Duso, 1996).

The low abundance of *K. aberrans* in MANEX further confirms the dependence of species on medium leaf pubescence since the varieties considered for this experiment were quite glabrous (Merlot, Sangiovese, Malvasia) or very highly pubescent (Barbera). The lower abundance of *A. andersoni* in VAREX than in MANEX, where the quite glabrous varieties were predominant, confirms its preference for less pubescent leaves already observed in the VAREX experiment. Unlike the phytoseiids, no tydeid species was affected by the four varieties tested. On the whole, the biodiversity index (H') did not differ among the four vine varieties, ranging between 0.27 and 0.32, while in Sangiovese, a completely glabrous undersurface variety, it was 1.65 (Castagnoli *et al*., 1997).

As regards the management practices (MANEX), problems with injurious mites did not increase in organic vineyards; in addition, the biodiversity on vine leaves was quite similar to that recorded in untreated vineyards. These findings agree with the general opinion that arthropod biodiversity increases in organic systems (Altieri *et al*., 2003). For example, more phytoseiid species were found in organic vineyards than in conventional ones in north-eastern Italy (Bigot and Zandigiacomo, 2000). Since the only difference between the MANEX conventional and untreated vineyards was the pesticide use, it is evident that chemicals were the most important factors affecting mite biodiversity in the test conditions. Unusually, *T. pyri* never colonized the MANEX conventional vineyards, even though it was numerous in untreated and organic ones of the same locality. In view of the well-known ability to develop resistant strains, this finding suggests that more complex factors affect the presence of *T. pyri* on vines (Pozzebon and Duso, 2008). In contrast, *P. finitimus* was equally present in vineyards with diverse management practices. As this species was also equally abundant on all tested varieties, it seems to have been the phytoseiid species least affected by the considered variables.

The correlation between phytoseiids and herbivores, which usually occurred at low levels in this study, was not always found: for example, correlations were not detected for *T. pyri* and *P. finitimus.* Although all phytoseiids recorded on vine can be considered generalist predators according to the McMurtry and Croft (1997) definition, these two species, more than the others, behaved independently of herbivores. In addition to the beneficial effect of the availability of pollen for all the phytoseiids considered, the positive influence of downy mildew on *T. pyri* (but also on *A. andersoni)* has also been reported in the literature (Duso *et al*., 2003).

The positive correlation between *K. aberrans* and tydeids, dependent mainly on *T. caudatus* in VAREX and on *T. californicus* in MANEX, is difficult to explain. The two tydeid species, never found together, are very similar taxonomically and behaviourally. Both occasionally prey on vine eriophyoid mites (Camporese and Duso, 1995, personal observation) and *T. caudatus* feeds on downy mildew (Duso *et al*., 2005). However, only *T. pyri* (and not *A. andersoni*) develops and reproduces on *T. caudatus* as prey in laboratory experiments (Calis *et al*., 1988), whereas *T. pyri*, *A. andersoni* and *K. aberrans* have sometimes been observed preying upon *T. caudatus* in the field (Duso *et al*., 2005). In contrast, *T. exhilaratus* was mainly associated with *P. ubiquitus.* This was the only tydeid species negatively correlated with the phytoseiids as a group, probably on account of its more marked predatory behaviour in comparison to the other representative tydeid species sampled (Knop and Hoy, 1983).

In view of the wide range of viticulture situations taken into account, this study could be considered an attempt to evaluate by means of a holistic approach the factors affecting the diversity and density of vine mites, with particular attention to the two most representative families (Phytoseiidae and Tydeidae), the overall aim being to develop sustainable viticulture. Our results help to give a more detailed picture of the mite community of Italian vineyards and to increase the knowledge of mite fauna relationships.

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