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Effects of vineyard management on biodiversity at three trophic levels

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In annual crops, where disturbance intensities are generally high, numerous investigations demonstrated beneficial effects of organic and other extensive farming practices on biodiversity. It is however unclear if organic farming has the same beneficial effect in perennial crops (e.g. vineyards) because of a generally reduced background disturbance level. Moreover, the impact of farming practices on biodiversity may differ between trophic levels. We tested the effect of farming practices differing in disturbance intensity on the abundance, species richness and community composition of three trophic levels (plants, grasshoppers and spiders) in Swiss vineyards. Organic and conventional vineyards were compared, and within the latter different options of weed control (mowing vs. mulching) and pest management (hand spraying vs. helicopter spraying) were investigated. In contrast to findings in annual crops, organic farming promoted neither diversity nor abundance at any trophic level. Grasshopper diversity was even significantly lower in organic compared to conventional vineyards. Weed control as well as pest management differed in their effects, depending on the trophic level. Within conventionally managed vineyards, spider and grasshopper diversity were enhanced by mulching, while plants benefited from the lower disturbance of mowing. The greater disturbance of fungicide spraying by hand than by helicopter was disadvantageous for grasshoppers, but did not affect spiders and plants. Thus, different taxa respond differently not only to an increase in disturbance but also to different types of disturbance and local site conditions. We conclude that disturbance in organically farmed vineyards appears to be too low to be beneficial for biodiversity.

1. Introduction

High levels of disturbance by agricultural management are usually negative for biodiversity (Donald et al., 2000; Tilman et al., 2001; Benton et al., 2002; Robinson and Sutherland, 2002; Millennium Ecosystem Assessment, 2005). Many ecosystem services of particular importance for agriculture such as pollination and natural pest control often depend on the number of species in an ecosystem (Tilman et al., 2002). Thus, the impoverishment of natural communities by agriculture should be minimized to avoid negative feedbacks on production.

Organic farming is usually associated with reduced disturbance intensity (Reganold et al., 1987). Therefore it is a potential solution to counteract species loss, because it favours higher biodiversity compared to the more intensive conventional farming practices (Bengtsson et al., 2005; Fuller et al., 2005; Hole et al., 2005; Schmidt et al., 2005). Beneficial effects of organic farming on species richness have mostly been observed in annual crops or grasslands (reviewed in Bengtsson et al. (2005) and Hole et al. (2005)), where disturbance intensities by management practices are particularly high. For example, plant diversity in annual crops has been shown to be consistently higher in organic compared to conventional agriculture (Bengtsson et al., 2005; Hole et al., 2005).

However, reduced levels of disturbance do not always lead to an increase in species richness. Theoretical and empirical work has shown that diversity is related to disturbance in a non-linear way (the intermediate disturbance hypothesis; Grime, 1973; Horn, 1975; Connell, 1978; Wootton, 1998; Molino and Sabatier, 2001; Svensson et al., 2007). Highest levels of diversity are often found at intermediate levels of disturbance. With low disturbance, competitive exclusion by the dominant species arises, while high disturbance selects for the few stress-tolerant species (Huston, 1979; Townsend and Scarsbrook, 1997). At intermediate intensities or frequencies of disturbance, there is a balance between competitive exclusion and loss of competitive dominants by disturbance; thus, intermediate disturbance conditions favour the coexistence of competitive species and stress-tolerant species (Mackey and Currie, 2001). Thus, a peak in diversity should occur at intermediate intensities and frequencies of disturbance.

Increasing the disturbance intensity may either promote or reduce biodiversity, depending on the general intensity of disturbance in the observed system (Fig. 1). For example, in nutrient-rich environments, where spontaneous vegetation remains undisturbed, a

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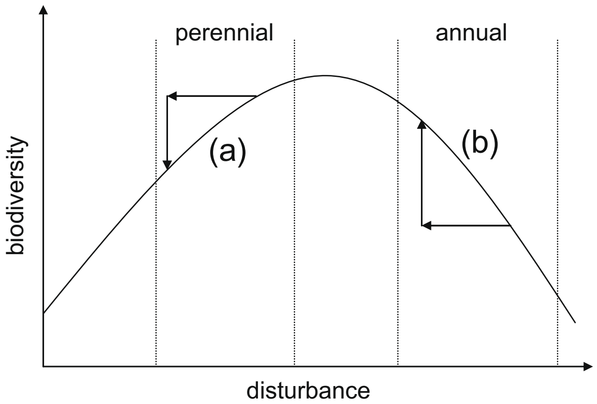

Fig. 1. Hypothetical relationship between biodiversity and disturbance according to the intermediate disturbance hypothesis (Grime 1973; Horn 1975; Connell 1978). Decreases in disturbance (horizontal short arrows) lead to either increases or decreases in biodiversity (vertical short arrows), depending on the level of background disturbance. For example, in annual (arable) systems (b), with a generally higher background disturbance level, a decrease in disturbance (e.g. due to organic farming) often is beneficial for biodiversity, while in perennial cropping systems (a), with a lower background disturbance level, decreasing disturbance may even lead to a loss of biodiversity.

few competitively superior taxa dominate, leading to an impoverishment of biodiversity (Huston, 1994; Proulx and Mazumder, 1998). Perennial crops, such as fruit orchards or vineyards, are generally less disturbed in comparison to annual crops. Thus, the response of plant diversity to organic farming may not be the same in perennial compared to annual systems because disturbance intensity differs in these two systems.

Moreover, the intensity of disturbance needed for the maintenance of high diversity may vary between different organism groups and trophic levels (Wootton, 1998; Duffy, 2003). In general, higher trophic levels are expected to be more vulnerable to disturbance than lower trophic levels (Kruess and Tscharntke, 1994; Menge and Sutherland, 1976; Connell, 1975), because they are affected by disturbance both directly and indirectly through reduced densities of their hosts or prey. In annual systems, where the intensity of soil disturbance is reduced in organic compared to conventional farming, predatory arthropods generally benefit from organic farming, while non-predatory arthropods often show no difference in diversity (Bengtsson et al., 2005).

To date, few studies in perennial crops have compared the response of communities to different management regimes (but see Hadjicharalampous et al., 2002; Steffan-Dewenter and Leschke, 2003; Cárdenas et al., 2006; Isaia et al., 2006; Peverieri et al., 2009). Such studies would be of particular interest with regard to vineyards, because vineyards are not only important for agriculture but often also for conservation. In temperate Europe, vineyards typically occupy sites with particularly warm and dry climates. They host many rare and endangered species and biodiversity in general can be very high (Costello and Daane, 1998; Gliessman, 2001; Isaia et al., 2006). For example, the Grape hyacinth (*Muscari racemosum*), which is included in the red list for plants of Switzerland, and the spider species *Erigonoplus globipes*, which is generally rare in Central Europe (Hänggi et al., 1995), can both be very common in Swiss vineyards. Therefore vineyards have a special conservation value and an expanded knowledge on the effect of different farming practices and the protection of such habitats is of paramount importance. Whether organic farming in vineyards is beneficial for biodiversity at any trophic level is still poorly known.

In this study we investigated the effect of different management regimes on biodiversity in vineyards in northern Switzerland. We studied the diversity of plants (angiosperms), grasshoppers (Saltatoria) and spiders (Arachnida: Araneae), which belong mostly to the producer, herbivore, and predator trophic level, respectively. We compared species diversity in organic and conventional vineyards, and, within the latter group, four varieties of conventional management that differ in their disturbance intensity. Conventional farming included different possibilities of weed control and pest management. Weed control was either by mowing or mulching, while fungicides were sprayed either by hand or by helicopter. The effect of these differences in disturbance intensities on biodiversity might be of particular interest for management policy to guide conservation actions in vineyards.

We investigated the following questions:

1. Does organic farming have a positive effect on species richness compared to conventional farming in Swiss vineyards?
2. Are higher trophic levels more affected, in terms of species numbers, by different management practices (i.e. disturbance intensities) than lower trophic levels within conventionally farmed vineyards?

2. Material and methods

2.1. Study sites

The study took place in 2005 near Ligerz (N47°5′, E7°8′) in northern Switzerland. This vine region covers 179 ha on a south-east facing slope on limestone and has a mild, sub-Mediterranean climate. It is subdivided into vineyards of different management types. Twenty-five of these vineyards, distributed over the entire vine-growing region, were selected as study sites (Fig. 2). We only selected vineyards surrounded by other vineyards in order to minimize the effect of landscape factors on local species composition and abundance. Study sites had an average size of 771 m^2 (200–2100 m^2) and were at least 10 years old. Vines were spaced 1.35 m between rows and 0.8–1 m within rows. In contrast to annual crops, vineyards in the region of this study incorporate permanent cover crops, defined as planted or resident vegetation in vineyard row middles (Tourte et al., 2008), which allow breaking the monoculture structure and thereby enhancing habitat availability (Altieri, 1999). Cover cropping is a common farming practice in vineyards all over the world, to reduce soil erosion, nutrient loss and for pest management (Ingels et al., 1998). Vineyards like the ones investigated in this study are typical, concerning size and management, for vine regions north of the European Alps (e.g. Switzerland, southern Germany). Organic vineyards in Switzerland cover an area of about 2% of the total vine-growing area (Linder et al., 2006).

The different management types investigated in our study were spatially interspersed and evenly distributed over the study area. In the five vineyards with organic farming practices, cover crop was mowed and fungicides were applied by hand (only agents accredited for organic farming). The 20 conventionally managed sites were chosen forming a balanced, 2 × 2 design with respect to weed control (mowing vs. mulching) and pest management (manual vs. helicopter spraying). The treatments mowing and mulching manipulated cover crop between vine rows. They were both performed 2 to 3 times per year, only in every second row at a time to conserve arthropod populations (natural enemies of pests, in particular). In the mowed sites, cover crop was cut and left on site. Mulching additionally shredded the plant material. In contrast to mowing where plants are cut once at a certain height by blades, plants are shredded by the mulching machine by a rotation axis equipped with drumstick-like protrusions. During mulching, the rotating axis often touches the ground thereby destroying parts of the top soil and thus creating a greater disturbance than mowing. Fungicides were sprayed either by hand or by helicopter, following the guidelines

Fig. 2. Location of the 25 experimental vineyards in the vine region Ligerz, in northern Switzerland. Different patterns indicate the five different treatment combinations: small dots = mowed, manually sprayed; bold dots = mowed, helicopter-sprayed; dashed = mulched, manually sprayed; black = mulched, helicopter-sprayed; white = organic. The area denoted by the bold outline is the zone of helicopter spraying (however not all vineyards within that zone are sprayed).

of integrated production (IP: www.ipsuisse.ch). Fungicides were applied up to 10 times per growing season, and thereof 5 times by helicopter in the "helicopter" treatment. Thus in the manual spraying treatment, fungicides were sprayed purely by hand, while the helicopter spraying treatment represented a mixture of mostly helicopter plus a few hand applications. We expected hand spraying to create a greater disturbance effect for plant and arthropod communities than helicopter spraying, because it involves trampling and soil compression. Insecticides were not used during the study because insect pest infestations were low in this area during the past 20 years. Study sites were not fertilized.

In addition to management, the studied vineyards varied in local site conditions, which also may affect species abundance and composition. In each vineyard, we recorded the local slope (a proxy for soil moisture), which was directly measured with the help of a water level at five points at each site (accuracy of measurements ±5°, the site average was used in the analyses), and local altitude (a proxy for the temperature regime), which was estimated from a topographical map (1:25,000, www.swisstopo.ch, Wabern, Switzerland).

2.2. Sampling of flora and fauna

Spiders were sampled with pitfall traps, which were opened 4 times for two weeks, between April and August 2005 (21.4–4.5, 25.5–7.6, 23.6–5.7, and 28.7–10.8). They consisted of plastic cups 65 mm in diameter and 80 mm deep filled to one third with a propandiol–water solution (1:2) and a scentless detergent. Plastic roofs of 15 $\times$ 15 cm protected the traps from rain water. To standardize sampling in fields of different size and shape, in every vineyard three pitfall traps were placed between the second and the fourth vine row counting from the south-eastern corner into the direction of the north-western part of the field. The distance between traps was at least 5 m. One trap each was placed under a vine row and to its left and right side, respectively. Captured spiders and grasshoppers were transferred to 80% ethanol for preservation. The abundance of all adult spider species, pooled over all four trapping periods were considered for the analyses.

Grasshoppers were sampled with a combination of standardized methods to include a wide spectrum of species. Gryllidae and Tetrigidae were taken from the pitfall traps that were used also for spiders. Individuals from the 2nd and 3rd trapping period were determined and counted, because activity of adults was highest during these trapping periods. The remaining grasshopper families were sampled acoustically on August 9 and 10 from 10 am until 4 pm during sunny weather, and by sweep netting and direct observations in the same area where the pitfall traps were placed. Acoustic observations were made by recording all audible grasshoppers twice for 5 min from two different points in each field. Afterwards, a sweep-net (38 cm diameter) was swung 20 times along one vine row, moving one step forward after each swing. Grasshoppers were determined in the field. Finally, all individuals of visible species were recorded while walking once through each field. A combination of sampling methods was used because the efficiency of different sampling methods varied between grasshopper species. We used cumulative counts of all methods as measures of species abundances.

Vascular plants were recorded in May, before weed control (mowing or mulching) took place, along 15 m to the left and to the right of the third vine row in the south-eastern corner of each field where also grasshoppers and spiders were sampled. The percent cover of each plant species was estimated (Perner et al., 2005; Woodcock et al., 2007).

2.3. Data analysis

The percent cover of plant species, and the number of individuals captured per animal species were used as measures of relative density for comparisons between study sites. Species richness was compared between organic and conventional sites by t-tests (assuming unequal variances). However, since sample sizes differed considerably for organic ($N = 5$) and conventional ($N = 20$) treatments we also calculated exact error probabilities by comparing the t statistics (assuming unequal variances) obtained from the observed data to the distribution of the t statistics obtained from 10,000 permutations of our data while randomly assigning treatments (organic, conventional) to samples. Differences among treatments within conventional sites were balanced and analyzed with two-factorial analysis of variance (ANOVA). The response of the communities to management and site conditions was analyzed by ordination. Because Detrended Correspondence Analysis (DCA) yielded gradient lengths smaller than two, species data were analyzed by Redundancy Analysis (RDA) (Jongman et al., 1995). Species data were square-root transformed prior to analysis to reduce skewness. First, partial ordinations were carried out to test for the effects of management and site conditions on plant, grasshopper and spider communities. The significance of environmental variables (organic/conventional management, weed control and pesticide management, site conditions: slope, altitude) was tested using Monte Carlo permutation (MCP) with 9999 randomizations. Relations of species richness to management and site conditions were tested with general linear models in each trophic level. Ordinations were carried out in Canoco (version 4.5; ter Braak and Smilauer, 2002), *t* statistics permutations in Excel, and all other analyses in R (version 2.7.1; R Development Core Team, 2008). Means ± standard errors are given in text and figures.

3. Results

3.1. Species richness and abundance

Neither plant cover nor grasshopper abundance or spider activity density differed significantly between organic and conventional vineyards (*t*-tests and permutation tests: all *p*-values >0.3). Between treatments of conventional sites only the interaction of weed control and pest management had a significant positive effect on plant cover (plants: $F_{1,\,16} = 6.5$, $P = 0.022$): plant cover was higher in low disturbance treatments (mowed/helicopter-sprayed) than in all the other treatments. Grasshopper abundance and spider activity density was not influenced by the different treatments of conventional vineyards (all *p*-values >0.05).

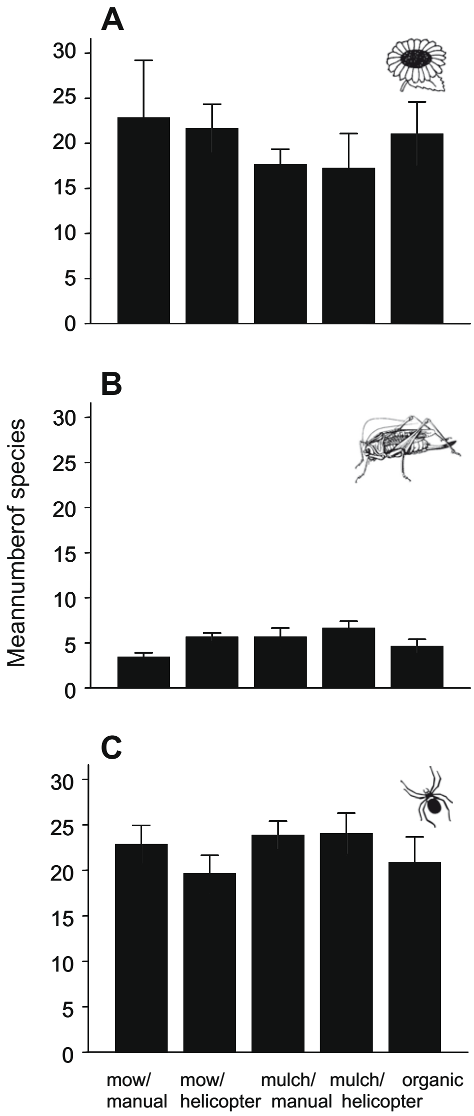

Fig. 3. Mean plant (A), grasshopper (B) and spider (C) species number sampled in vineyards of five different management types.

On average, 22.2 ± 2.9 plant species were found per site, making up a total of 86 species (Appendix S1). Plant species richness was not significantly different between organic and all conventional vineyards (*t*-test: $t = -0.57$, $P = 0.58$; permutation test $P = 0.55$; Fig. 3A). Within the conventional vineyards, on average 5.0 more plant species occurred in mowed compared to mulched vineyards ($F_{1,\,16} = 5.55$, $P = 0.032$). The different methods of pest management had no significant influence on species richness, neither alone nor in interaction with the methods of weed control (both $P > 0.5$).

Overall, 748 grasshopper individuals of 10 species were found with the different sampling methods (Appendix S2). Conventional vineyards ($N = 20$) had on average 0.7 more grasshopper species than organic vineyards (*t-test:* $t = 2.8$, $P = 0.026$; permutation test $P = 0.016$; Fig. 3B). Among the conventionally managed sites, significantly higher numbers of grasshopper species in mulched ($F_{1,\,16} = 4.74$, $P = 0.045$) and helicopter-sprayed ($F_{1,\,16} = 7.41$, $P = 0.015$) vineyards were found. There was no significant interaction between the method of weed control and pest management ($F_{1,\,16} = 1.18$, $P = 0.29$).

The 4807 adult spider individuals caught belonged to 67 different species from 15 families (Appendix S3). Organic compared to all conventional vineyards showed no difference in spider species richness (*t*-test: $t = 1.1$, $P = 0.31$; permutation test $P = 0.30$; Fig. 3C). Among the conventional vineyards, more species were captured in mulched than in mowed vineyards ($F_{1,\,16} = 8.08$, $P = 0.012$). Pest management alone and in combination with the method of weed control had no significant influence on species richness (both $P > 0.5$).

3.2. Communities

Partial ordination revealed that site conditions alone explained 13.9% of plant community composition ($F = 1.79$; $P = 0.0014$). Management explained a lower, non-significant fraction of the overall variation (12.0%; $F = 1.03$; $P = 0.42$), and the overlap was 0.4% (Fig. 4). Of the environmental variables, slope explained most of

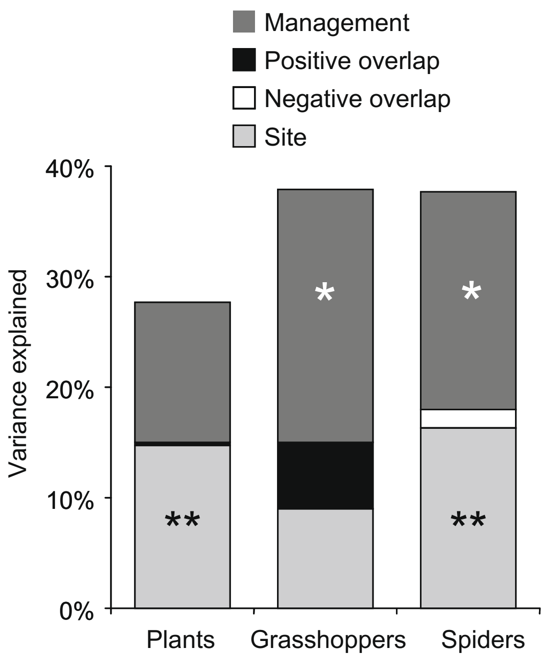

Fig. 4. Amount of variation in plant, grasshopper and spider communities explained by site conditions and management practices, and the amount of overlap between both groups of explanatory variables (partial Redundancy Analysis RDA).

the variation, followed by altitude (Table 1). In accordance with the greater importance of site conditions, the plant communities did not show a clear pattern with respect to management in the ordination plots (Fig. 5A). Among the most commonly found plant species (average cover over all vineyards more than 10%) in all vineyards *Valerianella locusta* (Fam. Valerianaceae) was positively and *Bromus erectus* (Fam. Poaceae) negatively associated with altitude, while *Daucus carota* (Fam. Apiaceae) and *Vicia sepium* (Fam. Fabaceae) were positively and *Veronica persica* (Fam. Plantaginaceae) negatively related with slope (Fig. 5A).

Table 1
Environmental variables influencing community composition of the three study organisms, tested by MCP. λ represents the amount of variance explained. Significant parameters are bold typed.

Environmental variables		Plants		Grasshoppers		Spiders	
		λ	p	λ	p	λ	p
Site condition	Slope	0.084	0.001	0.087	0.081	0.053	0.226
	Altitude	0.076	0.003	0.102	0.050	0.102	0.030
Management	Helicopter/ manual	0.037	0.629	0.084	0.097	0.026	0.770
	Mulch/ mow	0.034	0.772	0.119	0.030	0.120	0.012
	Organic	0.005	0.124	0.170	0.006	0.025	0.802

Grasshopper community composition responded significantly only to management (22.9% variance explained; $F = 2.34$; $P = 0.026$). Site conditions explained 9.0% of the variation ($F = 1.37$; $P = 0.21$), and there was a 6.0% overlap between management and site conditions (Fig. 4). The greatest amount of variance was explained by conventional vs. organic management, followed by the method of weed control. Among site conditions, only altitude explained a significant amount of variation in grasshopper communities (Table 1). Ordination plots clearly separated grasshopper communities in organic vineyards from those in conventional vineyards, and communities from mulched vineyards showed only a small overlap with communities from mowed vineyards (Fig. 5B). The most common grasshopper species (more than 100 individuals) at the study site, *Chorthippus biguttulus* (Fam. Acrididae), was positively associated with altitude and mulching, in contrast to the closely related *Chorthippus brunneus* (Fam. Acrididae). The field cricket *Gryllus campestris* (Fam. Gryllidae) responded positively to organic farming (Fig. 5B).

Spider community composition responded significantly to both site conditions (16.3% variance explained; $F = 2.36$; $P = 0.0069$) and management (19.7% variance explained; $F = 1.90$; $P = 0.035$). Here, the overlap between both sets of explanatory variables was negative (−1.7%), meaning that accounting for management or site conditions enhanced the amount of variation explained by the other group of explanatory variables, respectively (see Whittaker, 1984) (Fig. 4). Weed control (mowing/mulching) was the best single explanatory variable, followed by altitude (Table 1). Ordination

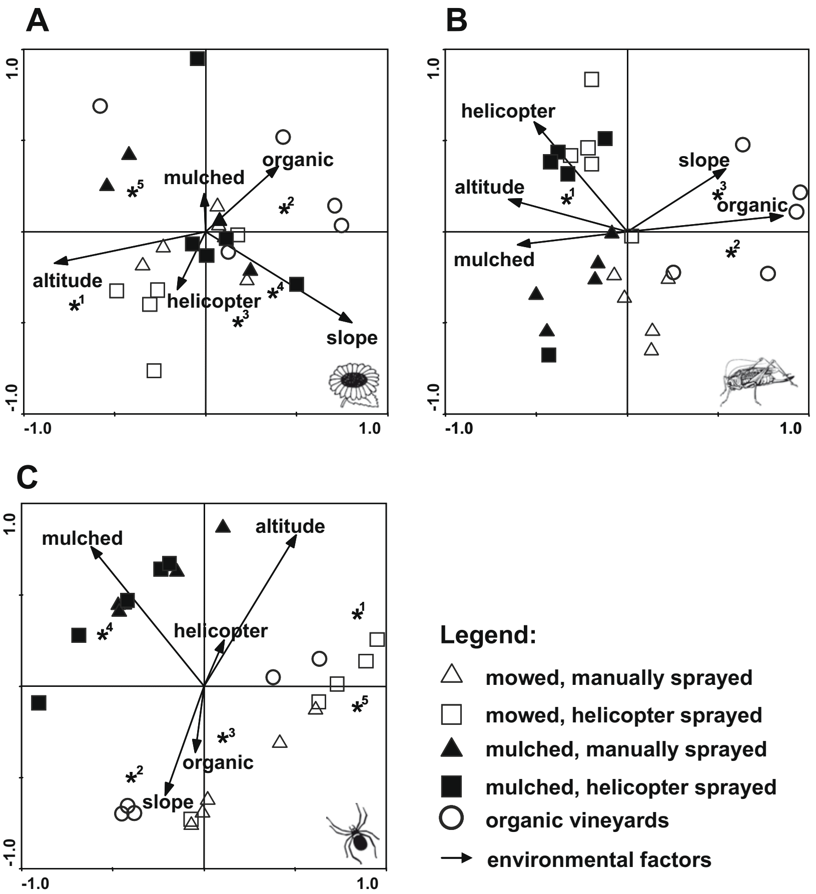

Fig. 5. Ordination biplots of plant (A), grasshopper (B) and spider (C) assemblages in all five treatments in relation to environmental factors (RDA). Each treatment is depicted by another symbol. Arrows indicate the environmental factors: organic farming, helicopter spraying, mulching, the slope and altitude of the site. The position of common species in the ordination are indicated by asterisks. Plant species: [1]*Valerianella locusta*, [2]*Bromus erectus*, [3]*Daucus carota*, [4]*Vicia sepium*, [5]*Veronica persica*. Grasshopper species: [1]*Chorthippus biguttulus*, [2]*Chorthippus brunneus*, [3]*Gryllus campestris*. Spider species: [1]*Alopecosa cuneata*, [2]*Zodarion italicum*, [3]*Tenuiphante tenuis*, [4]*Erigonoplus globipes*, [5]*Aulonia albimana*.

plots produced three clearly separated groups of spider communities (Fig. 5C). All mulched vineyards formed a group at the upper left of the diagram, while all mowed vineyards grouped at the lower right. The organic vineyards grouped in-between but closer to the mowed than to the mulched sites. Only little overlap existed between communities from mowed, manually sprayed vineyards and from mowed, helicopter-sprayed vineyards. Among the abundant species (200 individuals or more), *Alopecosa cuneata* (Fam. Lycosidae) was positively associated with altitude while *Zodarion italicum* (Fam. Zodariidae) and *Tenuiphantes tenuis* (Fam. Linyphiidae) preferred lower elevations. *E. globipes* (Fam. Linyphiidae), a very common species in the vineyards studied but rare in other habitats of Switzerland, was positively influenced by mulching while *Aulonia albimana* (Fam. Lycosidae) preferred vineyards with mowed cover crop (Fig. 5C).

Communities of plants, grasshoppers and spiders in organic vineyards were sub-sets of communities in conventional sites. Apart from a few singletons (i.e. species that were represented by one individual only in the entire study), we did not find species that occurred exclusively in organically farmed sites at any trophic level. There were however more abundant species that could only be found in conventional fields. Restricted to conventionally managed sites were, for example, the plant species *Capsella bursa pastoris* and *Euphorbia helioscopia*, both generally common in arable land with disturbed ground, the grasshopper species *Parapleurus alliaceus*, generally found in dry meadows, and the spiders *Phrurolithus minimus*, a species of calcareous grasslands, and *Xerolycosa miniata*, typically found in dry habitats.

In all investigated vineyards, 9% of the plant species and 30% of the grasshopper species found were categorized as near threatened or vulnerable according to the red list of threatened species of Switzerland (Monnerat et al. 2007; Moser et al. 2002). Among the observed spider species 22% could be considered as rare for Central Europe (Hänggi et al., 1995; see Appendices S1–S3).

4. Discussion

Organic farming did not promote diversity or abundance at any trophic level in the studied vineyards. Spider and plant species richness was not higher in organic compared to conventional farming and grasshopper species richness was even significantly lower in the organically treated vineyards. We also found no species that was typical for organic sites. Instead, species found in organic fields were sub-sets of the species present in conventional sites. Thus, our results indicate that biodiversity in vineyards may not benefit to the same degree from organic farming as in annual systems.

The absence of beneficial effects of organic farming in vineyards can be explained by different levels of disturbance in annual vs. perennial cropping systems, following the argumentation of the intermediate disturbance hypothesis (Grime, 1973; Horn, 1975; Connell, 1978; Fig. 1). In annual systems with a high disturbance background, a decrease in disturbance (e.g. reduced pesticide applications in organic farming) will favour diversity, because unfavourable environmental conditions are ameliorated (Bengtsson et al., 2005; Hole et al., 2005; Fig. 1b). In contrast, in generally less disturbed perennial systems a decrease in disturbance reduces environmental heterogeneity and allows superior competitors to exclude the more stress-tolerant species (Hobbs and Huenneke, 1992; Fig. 1a). In contrast to our results, Peverieri et al. (2009) found a positive effect of organic farming on biodiversity of mites living on vine leaves. However, organism groups directly associated with crops are presumably exposed to a generally higher disturbance level than the ones we studied.

Our study not only investigated differences between different management systems (organic vs. conventional) but also revealed effects of single management treatments on biodiversity. With respect to weed control, mulching of the cover crop, which constitutes a higher disturbance level, was more beneficial for grasshopper and spider communities than mowing. In contrast, plants were negatively affected by higher levels of ground disturbance due to mulching. Similarly, soil disturbance has been found to reduce diversity of dicotyledonous plants in grasslands (Fuller, 1987). Also the pest management treatment had different effects on the taxa of the different trophic levels observed. The higher disturbance of applying fungicides by hand and the associated soil trampling decreased grasshopper diversity while the other taxa were unaffected. Kruess and Tscharntke (2002) made similar observations in a study system of different grazing intensities. While grasshopper diversity was negatively affected by increased grazing (trampling), plant diversity was not different between intensively and extensively grazed pastures or ungrazed grasslands. In an independent experiment of salt meadows in Austria, vegetation composition and spider diversity was not different between grazed and ungrazed meadows (Zulka et al., 1997).

These taxon-specific reactions show that different taxa react differently not only to an increase in disturbance but also to different types of disturbance (Abensperg-Traun et al., 1996). Whether an increase in disturbance leads to an increase or decrease in biodiversity not only depends on the general level of disturbance (intermediate disturbance hypothesis), but also on the taxon investigated and the type of disturbance measured (Mackey and Currie, 2001). In a more formal way, considering the relationships between disturbance and diversity, the location of the diversity maxima in different taxa may not be at the same position along the disturbance gradient. Thus, the effects of changes of the disturbance level on one taxon cannot necessarily be used to predict effects on other taxa, if for example taxa differ in their sensitivity to different types of disturbance. This may explain why grasshoppers showed reduced diversity in hand-sprayed vineyards while plants and spiders were not affected. Increased soil compaction through trampling in hand-sprayed vineyards may render them unsuitable for oviposition by grasshoppers, while plants may still be able to tolerate this. Moreover, even the common expectation that higher trophic levels are more affected by disturbance than lower trophic levels (e.g. Kruess and Tscharntke, 1994) was not generally supported in our study. Our results on the weed control treatment could be explained if, for example, mulching increases habitat heterogeneity and grasshoppers and spiders would benefit more from this increased heterogeneity than plants. The intermediate disturbance hypothesis is therefore only applicable for one single taxon, but not for a whole community of different interacting taxa (Abensperg-Traun et al., 1996).

Investigations of farming practices in arable land led to the development of site-, crop- and organism-specific management strategies to enhance species richness and abundance (Perrings et al., 2006). This is especially important, because anthropogenic disturbance causes not only a general decline in biodiversity, but also predictable functional shifts as sets of species with particular traits are replaced by other sets with different traits (Grime et al., 2000; McCollin et al., 2000). Changes of ecosystem functioning may have severe consequences in the agricultural landscape, because they can lead to pest outbreaks or to a decline of pollination of cultivated plants. According to Loreau et al. (2001) at least a minimum number of species is essential for ecosystem functioning under constant conditions. For ecosystems in landscapes subject to increasingly intensive land use, even a larger pool of species is required to sustain the assembly and functioning of ecosystems. To improve ecosystem functioning it is however of particular importance to increase the knowledge of different trophic levels and how they interact. In our investigation we have seen that plant communities are not influenced in the same way by site conditions and management as grasshopper and spider communities. This indicates that taxon-specific or trophic-level-specific responses to farming practices may translate into shifts in ecosystem functioning. Vineyards are in this perspective of special interest because they generally harbour more species, whereof several which are generally rare for Switzerland (see also Isaia et al. 2006).

5. Conclusions

Organic farming is often considered a low impact farming method supporting high biodiversity. Our results suggest that the biodiversity benefits of organic farming in annual cropping systems may not hold for perennial crops, particularly if the use of pesticides is minimal. Extensive farming methods apparently do not promote biodiversity in all types of farming systems and at all taxonomic levels. Thus, under certain circumstances more intensive conventional management systems with higher disturbance levels better promote biodiversity in agricultural landscapes.

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