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Potential of Cover Crops to Control Arthropod Pests in Organic Viticulture

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RESEARCH ARTICLE

Abstract
Plant diversity has the potential to conserve beneficials and thereby naturally controlling arthropod pests. Beneficials' activity can be increased by pollen-rich plant species. Here we aimed to develop innovative viticultural systems that naturally control arthropod pests, by increasing plant diversity within vineyards planting of selected cover crops. The experimental vineyards were set-up in Chablis (France), Piacenza (Italy), Murfatlar (Romania), Manče (Slovenia), Valencia (Spain) and Nyon (Switzerland). Each vineyard was divided in a traditional and innovative subplot and monitored in 2019 and 2020. The effect of cover crops on arthropods was assessed according to a common protocol using visual samplings and specific traps. Analysing the obtained data, there were no statistically significant differences in the abundance of sampled arthropod pests in the innovative and the traditional systems. Yet, two of five studied pest species tended to be less abundant in the innovative systems. Regarding arthropod beneficials, flying parasitoids and bees tended to benefit from the planting of cover crops in the innovative compared to the traditional systems. Alike, predators such as spiders and carabids were more abundant in vineyards with understorey vegetation. Overall, the arthropod biodiversity seems to benefit from the planting of cover crops but without necessarily favouring pest suppression.

Keywords: conservation biological control; pest control; functional diversity

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INTRODUCTION

Functional diversity is a component of biodiversity that specifies the roles that organisms play in communities and ecosystems (Petchey et Gaston, 2006). Studies on functional diversity have mainly focused on how species influence ecosystem functioning and respond to environmental changes (Hooper et al., 2005). Overall, functional diversity is important in maintaining or increasing ecosystems services (Winter et al., 2018), defined as the benefits that the ecosystems provide to humans (Reid et al., 2005). Data stress that biodiversity has positive effects on most ecosystem services, including ecosystem resistance to pests (greater plant diversity results in lower plant damage) and invasive species (plant biodiversity reduces the success of invaders). Plant diversity has therefore the potential to naturally control arthropod pests and pathogens (Fiera et al., 2020). Grapevines and grapes are attacked by a large range of arthropods and in particular insect and mite species. They are causing damage to different parts of the plants at different periods of the year. The most important European pests are the grape moth (*Lobesia botrana* Den &Schiff.),

the fruit tree red spider mite (*Panonychus ulmi* Koch), the two-spotted spider mite (*Tetranychus urticae* Koch) as well as the two vine leafhoppers *Empoasca vitis* Gothe and *Scaphoideus titanus* Ball. While the nearctic *Scaphoideus titanus* is still expanding its distribution over Europe, the other viticultural pests are common and can be found in most vineyards of Europe (Linder et al., 2016). However, vineyards also host beneficials such as predatory mites, soil predators (e.g. carabids and spiders), parasitoids, lacewings, hoverflies and pollinators (e.g. bees and bumblebees).

This research aimed at developing innovative viticultural systems with increased plant diversity in order to control arthropod pests (Chiasson et al., 2001, Wanzala et al., 2016). We therefore planted selected cover crop species within vineyards. Candidate plant species were identified by an extensive literature review. Cover crops were planted at large scale in innovative systems within organic vineyards and compared to current vineyard management practices. Over two grape growing seasons, we evaluated the effect of the two systems on the density of arthropod pests and beneficials.

MATERIALS AND METHODS

Six small organic vineyards (around 0,5 ha) situated in the Chablis – France (on Pinot Noir), Piacenza –Italy (on Croatina), Murfatlar – Romania (on Feteasca neagra), Manče – Slovenia (on Zelen), Valencia – Spain (on Cabernet Sauvignon) and Nyon – Switzerland (on Chasselas) were divided in two. In one half, cover crops were planted in autumn or spring as an innovative system (in France and Switzerland – special mixture MCS4b (*Bromus tectorum* L 50%, *Lotus corniculatus* L. 5%, *Medicago lupulina* L. 5%, *Poa compressa* L. 30%, *Prunella vulgaris* L, 5%, *Sanguisorba minor* Scop. 5%, in Italy and Romania – mixture of *Lolium perenne* L. 50%, *Onobrychis viciifolia* Scop. 25% and *Trifolium repens* L. 25%, in Slovenia and Spain - spontaneus flora) and the other half was managed according to the current practices (=traditional systems). The effectiveness of the innovative systems in pest control and the promotion of beneficials was thereafter evaluated by their comparison to the traditional systems. The presence and abundance of arthropod pests and beneficials was monitored according to a common protocol over two seasons post-sowing (2019 and 2020).

In order to measure damages by the grapevine moth *Lobesia botrana*, at least 100 inflorescences or grape clusters per system were visually inspected once a week from early spring to late summer. To assess the community of spider mites (e.g. *Panonychus ulmi* and *Tetranychus urticae*) and predatory mites, 50 leaves per treatment were collected at the 3 to 4 leaf stage of grapevines (BBCH 13-14). The leaves were thereafter examined under the binocular for the presence of mites. The abundance of the two vine leafhoppers *Empoasca vitis* and *Scaphoideus titanus* was monitored by the installation of yellow sticky traps horizontally within the grapevine canopy at BBCH 83-85 for two weeks (Figure 1 a). Before the flowering of grapevines (BBCH 53-57), pitfall traps were placed for 14 days in the middle of inter-row space to estimate the activity of ground dwelling predators such as carabids and spiders (Figure 1b). Finally, yellow water traps were also set-up in the middle of inter-rows before flowering (BBCH 53-57) for a period of two weeks to examine the community of flying beneficials. Yellow sticky traps as well as the catches from pitfall traps and yellow water traps were sent to Agroscope, where the arthropods were identified, counted and attributed to a functional group.

The observational data of the two years were pooled and eventual statistical differences between the innovative and traditional systems were explored using non-parametric paired-sample sign tests (Zar, 2010) that is characterised by the calculation of the according Z-value who thereafter provides the corresponding P-value.

(a) **(b)**

Figure 1. Field experiment in Romania (a) yellow sticky traps in the canopy (b) pit fall traps in cover crops

RESULTS AND DISCUSSION

Analysing the data collected in 2019 and 2020 together, there were no statistically significant differences in the abundance of arthropod pests such as the red spider mites *Panonychus ulmi* (Z = 1.41, P = 0.16), the two-spotted spider mites *Tetranychus urticae* (Z = 0.38, P = 0.71) and the leafhopper *Scaphoideus titanus* (Z = 0.38, P = 0.71) between the innovative and the traditional system (Table 1). However, damages by the grapevine moth *Lobesia botrana* (Z = 1.73, P = 0.08) and the abundance of the leafhopper *Empoasca vitis* (Z = 1.90, P = 0.06) tended to be lower in the innovative compared to the traditional systems.

Table 1. Abundance of pests monitored in the experimental vineyards sown with cover crops for the innovative systems in 2019 and 2020

Type of system	% bunches with grapevine moths		% leaves with red spider mites		% leaves with two-spotted spider mites		N green leafhopper		N American grapevine leafhoppe	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Innovative systems (mean)	**0.6**	**1.9**	**2.3**	**4.4**	**4.3**	**15.5**	**31.8**	**105.7**	**3.6**	**5.4**
Italy	0	0	0	0	0	0	133.8	210.2	0	2.2
Romania	1.7	3.9	14.0	22.0	1.3	34.3	11.8	1.4	4.2	0.3
Slovenia	1.0	5.5	0	0	0.7	1.3	5.1	269.3	0.3	0.2
Spain	0	0	0	0	23.0	40.0	24.7	40.0	0	0
Switzerland	0	0	0	0	0	2.1	10.3	7.5	17.0	24.3
Traditional systems (mean)	**0.7**	**2.3**	**4.0**	**6.4**	**7.9**	**15.9**	**39.5**	**121.2**	**2.3**	**7.4**
Italy	0	0	0	0	0	0	178.0	294.4	0	2.7
Romania	2.3	4.8	24.0	32.0	0	33.0	8.3	2.2	1.3	0.5
Slovenia	1.0	6.5	0	0	0.3	1.7	5.2	255.5	0	1.2
Spain	0	0	0	0	47.0	45.0	29.0	45.3	0	0
Switzerland	0	0	0	0	0	0	11.3	8.5	12.7	32.5

No *Lobesia botrana* damage was observed in the experimental vineyards of Italy, Switzerland and Spain (Table 1), where the first two were protected by mating disruption. Although widely present in Spain, *Lobesia botrana* was not observed at the study site in Valencia. Although grape clusters were only sporadically attacked by *Lobesia botrana* larvae in Romania and Slovenia, infestation rates were always higher in the traditional compared to the innovative systems. Thus, damage tended to be overall slightly lower where cover crops were planted.

With the exception of the experimental vineyard in Italy, spider mites were present in all countries (Table 1). Whereas the European red spider mite (*Panonychus ulmi*) was only present at the study site in Romania, two-spotted spider mites (*Tetranychus urticae*) could be found in the experimental vineyards of Romania, Slovenia, Spain and Switzerland. However, the planting of cover crops did not affect the presence of the two mite species in the grapevine canopy.

While the leafhopper *Empoasca vitis* was present in all five countries, the vector of Flavescence dorée *Scaphoideus titanus* was not observed in the Spanish vineyard close to Valencia (Table 1). Only few *Empoasca vitis* were captured in Romania, Spain and Switzerland, while several hundred individuals could be counted per yellow sticky trap in Italy and Slovenia. However, the reasons for the massive increase of *Empoasca vitis* over the two years is unclear. Overall, the presence of cover crops tended to lower the presence *Empoasca vitis* over the two study years. Conversely, no such difference between the two systems was observed for *Scaphoideus titanus*.

Regarding the abundance of beneficials in 2019 and 2020, there were no significant differences in the presence of predatory mites (Z = 1.67, P = 0.10), spiders (Z = 1.51, P = 0.13) and carabids (Z = 1.26, P = 0.21) between the innovative and traditional systems (Table 2). However, from the complex of flying insects, parasitoids (Z = 1.90, P = 0.06) and bees (Z = 1.9, P = 0.06) tended to be more abundant in the innovative compared to the traditional system, while the number of hoverflies captured (Z = 1.41, P = 0.16) was not directly affected by the planting of cover crops.

Table 2. Abundance of beneficials in the experimental vineyards sown with cover crops for the innovative systems in 2019 and 2020

Type of system	% leaves with predatory mites		N spiders		N carabids		N parasitoids		N hoverflies		N bees	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Innovative systems (mean)	**38.9**	**27.9**	**20.4**	**12.4**	**5.3**	**3.7**	**9.3**	**11.2**	**1.7**	**0.8**	**13.0**	**24.6**
France	-	-	7.4	-	1.4	-	6.6	-	0.2	-	8.0	-
Italy	14.0	12.0	25.5	10.0	1.0	0.2	4.4	5.8	2.3	3.0	7.8	23.2
Romania	19.3	27.0	22.3	1.3	3.2	1.9	4.0	29.0	3.8	0.2	25.7	24.1
Slovenia	63.7	3.7	38.5	17.5	12.5	6.5	23.0	4.4	1.8	1.0	4.8	1.2
Spain	19.0	22.0	3.3	0.5	3.7	0	-	0.5	-	0	-	0
Switzerland	54.0	75.0	7.5	32.7	3.0	9.7	8.25	16.3	0.5	0	27.0	37.3
Traditional systems (mean)	**40.8**	**29.7**	**12.4**	**8.3**	**7.6**	**2.8**	**3.7**	**10.9**	**0.6**	**1.1**	**6.8**	**11.5**
France[1]	-	-	8.0	-	1.0	-	0.0	-	0.0	-	4.0	-
Italy	28.0	16.0	10.0	1.3	0.5	0	0.0	2.5	3.0	0.5	8.0	4.5
Romania	26.0	36.0	12.0	1	1.0	1.0	5.0	24.3	0.0	0.0	12.0	21.8
Slovenia	69.3	3.7	21.0	7.8	20.0	7.3	10.7	14.8	0.0	0.6	1.5	0
Spain	22.0	24.0	2.0	3.0	2.5	0	-	0	-	0	-	0.5
Switzerland	30.0	68.8	12.5	28.3	8.0	5.7	2.75	13.0	0.5	4.3	20.5	30.7

[1]No data for 2020 since cover crops failed to establish in the innovative system

Predatory mites were found in vineyards of every country and the percentage of occupied leaves was very similar between the two systems (Table 2). The planting of cover crops did therefore not directly affect their presence.

Likewise, ground dwelling predators such as spiders and carabids were found in all countries and their activity was not directly influenced by the presence of cover crops (Table 2). Yet, additional analyses with generalised linear models revealed, that spiders and carabids benefited from understorey vegetation in the inter-rows (innovative system in all countries and traditional system in Italy, Switzerland and Slovenia) compared to bare soil (traditional system in France, Romania and Spain).

Parasitoids and bees were observed in the vineyards of all six countries, while no hoverfly was captured in Spain (Table 2). Moreover, parasitoids (Figure 2) and bees (Figure 3) tended to be more abundant in the innovative than the traditional systems. As they both rely on nectar and pollen for feeding, they probably directly benefited from the planting of nectar- and pollen-rich cover crop species.

Overall, the determined arthropod community tended to be more abundant in the innovative systems than the traditional ones. This is in line with recent studies from Eckert et al. (2020) and Peris-Felipo et al. (2021) who both could show that arthropod communities increased by the planting of cover crops within vineyards. Arthropod biodiversity therefore seems to benefit from the planting of cover crops but without necessarily directly favouring pest suppression.

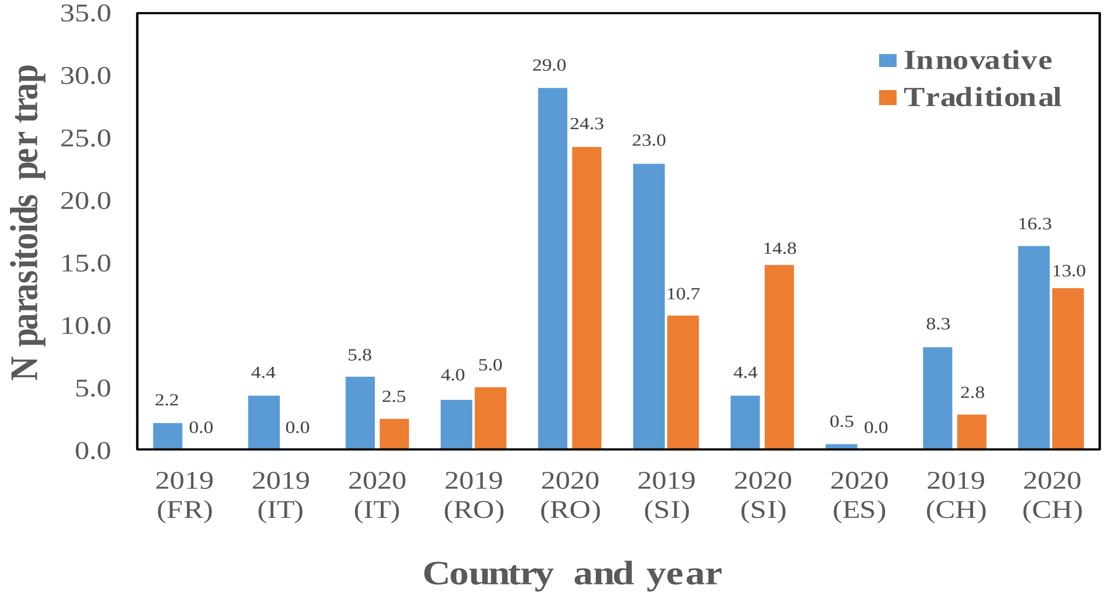

Figure 2. Number of parasitoids captured per water trap comparing the traditional with the innovative system planted with cover crop in 2019 and 2020

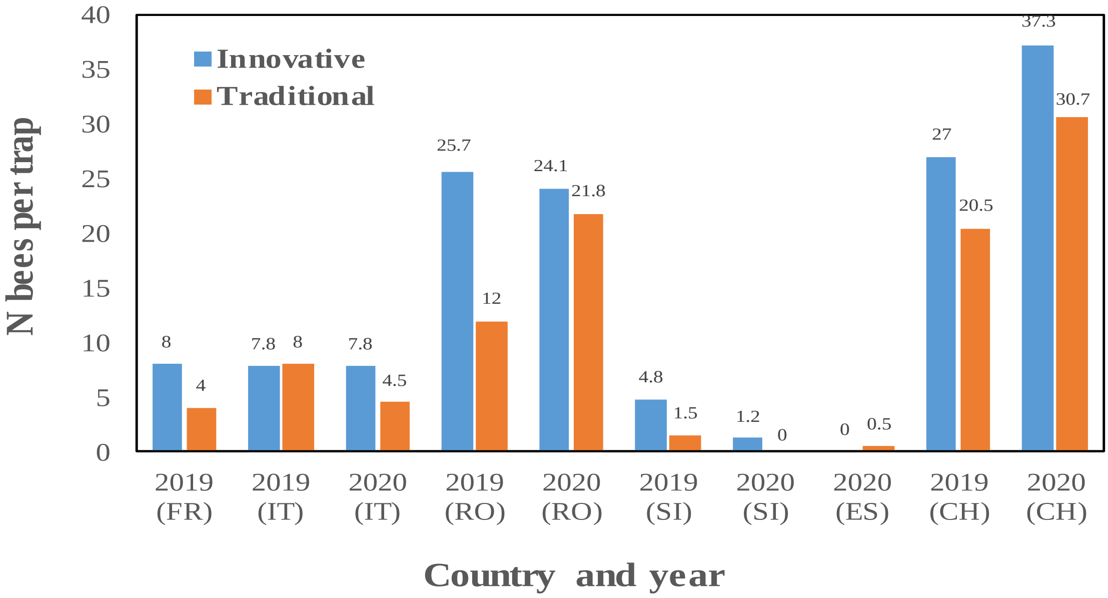

Figure 3. Number of bees captured per water trap comparing the traditional with the innovative system planted with cover crop in 2019 and 2020

CONCLUSIONS

After only the two years of study, we have weak statistical evidences that the planting of cover crop mixtures in the innovative systems affects the presence of pest species. Whereas pest populations of the two spider mites *Panonychus ulmi* and *Tetranychus urticae*, as well as the abundance of the vine leafhoppers *Scaphoideus titanus* remained unaffected, damages by the grapevine moth *Lobesia botrana* and the number of captured leafhoppers of *Empoasca vitis* tended to slightly decrease in the innovative systems. Moreover, the abundance of flying beneficials (e.g. parasitoids and bees) that feed on pollen and nectar seemed to profit from the planting of cover crops in the innovative systems. Overall, arthropod biodiversity seems to benefit from cover crops but without necessarily favouring pest suppression.

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Conflicts of Interest

The authors declare that they do not have any conflict of interest.

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