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Short communication

Effect of management strategies on arthropod communities in the colonies of rosy apple aphid, *Dysaphis plantaginea* Passerini (Hemiptera: Aphididae) in south-eastern France

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ABSTRACT

Apple orchardists are encouraged to adopt pest control strategies with less pesticide use and thus less harmful environmental impacts. In this study, we compared the possible effects of organic, integrated pest management (IPM), and conventional protection strategies on the rosy apple aphid-ant-natural enemy communities in 12 apple orchards in south-eastern France in 2008 and 2009. The organic orchards had the smallest aphid populations and the most diverse and abundant natural enemy populations compared with the other orchards. More diverse and abundant natural enemy populations were observed in IPM compared with conventional orchards. In 2009, the aphid abundance in IPM orchards was, however, significantly higher than in conventional orchards. No significant differences in ant densities were observed among protection strategies in 2008, but in 2009, these densities were significantly higher in conventional compared with organic orchards. Three predator groups were the most common: Coccinellidae, Forficulidae, and Syrphidae. These were significantly more abundant in organic orchards than in the other orchards, except in 2008 when there was no significant difference in syrphid and earwig abundance between organic and IPM orchards. Parasitoids were significantly more abundant in organic orchards in 2009 but not in 2008. The smaller number of aphids in organic orchards appears to results from the absence of toxic insecticides and thus to increased natural enemies compared with other orchards. Our findings emphasize the importance of no or less intensive synthetic pesticide usage for the conservation of natural enemies biodiversity and biological control of rosy apple aphid in apple orchards.

1. Introduction

Commercial apple orchards are highly manipulated agro-ecosystems, in which a conventional protection strategy inputs a large quantity of pesticides to increase productivity (Bouvier et al., 2005). In apple orchards in Southern France, over 35 pesticide treatments are applied each year to control pests (Sauphanor et al., 2009). The intensive use of broad-spectrum pesticides has long been recognized as undesirable due to a number of side effects, including the negative effect on beneficials, decrease in biodiversity, and impact on human health (Simon et al., 2007). Thus there is a need to adopt pest control strategies with less harmful environmental impacts. Organic and Integrated Pest Management (IPM) strategies are the most frequently adopted strategies to date. Organic strategies exclude all usage of both synthetic fertilizers and pesticides. In contrast, IPM strategies involve a restricted use of chemical compounds (Bouvier et al., 2011), but even if fewer insecticides are involved, the harmful impact on the environment appears similar to that of conventional systems (Bouvier et al., 2005). Measures of the ecological impact of management practices on pests and non-target organisms are likely to be important components of any definition of sustainability (Wearing, 1997). Species abundance and richness are biodiversity indicators that can be used in such assessments (Vindimian, 2001).

Approximately 60 phytophagous arthropod species are known to be pests of apples (Jenser et al., 1999). Among these, the rosy apple aphid, *Dysaphis plantaginea* Passerini (Hemiptera: Aphididae) has stimulated special interest, due to the significant economic losses in yield it causes (Blommers et al., 2004). *D. plantaginea* has been problematic not only in organic, but also in conventional orchards due to a very low treatment threshold (i.e., as soon as the pest is detected (Cross et al., 2007)) and

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increasing insecticide resistance (Delorme et al., 1997). Among the alternatives to chemicals, some studies agree on the positive effects of biological and mineral substitutes and repellent agents (Cross et al., 2007). The risks of resistance and adverse effects on non-target organisms still, however, exist (Boisclair and Estevez, 2006). For this reason, the use of natural enemies is another promising avenue in the quest for better control of *D. plantaginea*. Natural enemies influence the growth of *D. plantaginea* populations, but natural enemies population survival requires favorable habitats and living conditions (particularly without pesticides) (Dib et al., 2010a,b). Studies on the effects of apple orchard management strategies on natural enemies are thus required. Very little information is available regarding the relative importance of these effects on the local entomofauna in *D. plantaginea* colonies. The main objective of this study was therefore to compare the possible effects of organic, IPM, and conventional protection strategies on rosy apple aphid-ant-natural enemy communities in 12 apple orchards in south-eastern France.

2. Materials and methods

2.1. Study area and protection strategies in apple orchards

The study area, about 20 km in diameter, was located in south-eastern France (coordinates in the WGS84 system from 43°46′27″N to 43°51′23″N and from 4°51′12″E to 4°57′34″E). It is characterized by a dense network of ditches and windbreak hedgerows. These hedgerows were generally monospecific and composed of cypresses, poplars or plane trees. Fruit orchards dominate the agricultural landscape, but vineyard, vegetable, and cereal crops are also present. Apples and pears are the most common fruits under harvest, and together represent 87% of all fruit production areas.

Fieldwork was carried out in 12 commercial apple orchards that had an average size of one hectare and were planted with one or more of four cultivars (Granny Smith, Royal Gala, Golden Delicious, Akane), which were previously found to be susceptible to *D. plantaginea* (Miñarro and Dapena, 2007; Romet, 2004). The four cultivars were always present in each of the three studied protection management strategies. The impact of cultivar factor can be thus considered low or negligible in this study. Among the orchards under investigation, four were managed under European guidelines for organic farming, five under conventional strategies, and three under IPM guidelines. In organic apple orchards, the use of synthetic chemicals (both fertilizers and pesticides) is excluded. A fungicide program using copper and sulfur preparations was used to control apple scab and/or powdery mildew diseases. The control of codling moth, *Cydia pomonella* L. (Lepidoptera: Tortricidae) relied on granulosis virus treatments and mating disruption techniques. Kaolin and mineral oils were applied to control aphids. Conventional orchards are managed using synthetic chemical pesticides according to the 1997 French national charter of apple production. The IPM orchards are conventional orchards where a synthetic female pheromone is diffused to disrupt codling moth mating. IPM orchards are sprayed with a reduced number of chemical insecticide applications used to prevent this pest.

2.2. Assessment of arthropod populations in D. plantaginea *colonies*

The composition of the arthropod community found in the *D. plantaginea* colonies was assessed by visual inspection at only one date (coinciding with the last third of the *D. plantaginea* season) on 25 terminal one-year old shoots (infested with *D. plantaginea*) per orchard. At this date, all groups of the natural enemies of *D. plantaginea* (precocious and late) are present (Dib et al., 2010a,b). On 13 June 2008 and on 28 May 2009, three and four, three and three, and four and five orchards under organic, IPM, and conventional protection strategies, respectively, were studied. The ten apical leaves of each shoot were examined to

Table 1
Comparison of the abundances and population parameters of rosy apple aphid (RAA), natural enemies (NE), active natural enemies (ANE), ant, three major predators (Coccinellidae, Forficulidae, and Syrphidae) and parasitoids (mummies) in 2008 and 2009 in the three protection strategies (organic (O), IPM, and conventional (C)).

Population parameter	2008					2009				
	O	IPM	C	$F_{(2)}$	P	O	IPM	C	$F_{(2)}$	P
No. RAA(1)	32.11 c (6.64)	70.44 b (9.91)	86.23 a (8.58)	16.900	<0.0001	52.69 c (6.33)	142.48 a (9.28)	77.90 b (7.69)	30.642	<0.0001
No. NE(1)	3.75 a (0.63)	3.03 a (0.57)	1.93 b (0.48)	8.245	0.0003	7.48 a (0.86)	3.11 b (0.76)	0.93 c (0.35)	60.830	<0.0001
No. NE groups(2)	6.0	4.0	2.5			5.6	2.7	1.8		
No. ANE(1)	1.35 a (0.16)	0.85 b (0.19)	0.29 c (0.08)	24.326	<0.0001	1.33 a (0.14)	0.20 b (0.10)	0.06 b (0.02)	72.010	<0.0001
No. ANE groups(2)	4.7	3.0	2.0			4	1.3	0.6		
Ratio (ANE/RAA)(3)	0.0419	0.0121	0.0034			0.0252	0.0014	0.0007		
% Shoots with ANE(3)	65.3	41.3	16.0			57.6	8.0	4.8		
Shannon index (H')(3)	1.99	1.02	0.89			1.42	0.82	0.99		
Equitability index (E)(3)	0.63	0.32	0.38			0.51	0.35	0.42		
No. ants(1)	2.11 a (0.91)	0.37 a (0.23)	0.64 a (0.19)	1.654	0.193	0.19 b (0.07)	0.29 ab (0.22)	0.98 a (0.31)	3.888	0.021
% Shoots with ants(3)	12.0	6.7	17.0			6.4	4.0	12.0		
No. coccinellids(1)	0.99 a (0.33)	0.03 b (0.02)	0.06 b (0.02)	9.171	0.0001	0.69 a (0.10)	0.29 b (0.27)	0.04 b (0.02)	25.747	<0.0001
No. forficulids(1)	0.37 a (0.08)	0.31 a (0.11)	0.07 b (0.04)	6.499	0.002	0.46 a (0.08)	0.00 b (0.00)	0.00 b (0.00)	30.516	<0.0001
No. syrphids(1)	0.21 a (0.06)	0.32 a (0.13)	0.08 b (0.05)	3.321	0.038	0.11 a (0.03)	0.03 b (0.02)	0.00 b (0.00)	7.571	0.001
No. cecidomyiids(4)	0.16	0.13	0.08			0.05	0.12	0.00		
No. chrysopids(4)	0.04	0.05	0.00			0.02	0.00	0.14		
No. cantharids(4)	0.04	0.00	0.07			0.01	0.00	0.01		
No. mirids(4)	0.01	0.00	0.00			0.03	0.03	0.00		
No. anthocorids(4)	0.00	0.01	0.00			0.00	0.00	0.00		
No. spiders(4)	0.03	0.00	0.00			0.03	0.00	0.01		
No. parasitoids(1)	1.89 a (0.57)	2.17 a (0.47)	1.65 a (0.47)	1.734	0.179	6.11 a (0.84)	2.64 b (0.69)	0.74 c (0.34)	33.327	<0.0001
% Shoots with mummies(3)	16.0	38.7	26.0			52.0	33.3	10.4		
% General parasitism rate(5)	5.0	7.8	1.7			12.4	1.8	1.8		
% Local parasitism rate(6)	44.2	14.4	6.9			17.7	6.2	5.5		
No. studied orchards	3	3	4			4	3	5		

Values followed by different letters within the same row and same year represent the significant differences based on ANOVA and Kruskal–Wallis tests with a 5% significance level. (1) Mean (standard error) per shoot. (2) Mean per orchard. (3) Value per orchard. (4) Mean per shoot. (5) Parasitism rate in all shoots. (6) Parasitism rate in parasitized shoots only.