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Albert et al.: Agroecological management
in cider apple orchards

Environmental Entomology
Biological control – parasitoids and predators

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Impact of Agroecological Infrastructures on the Dynamics of *Dysaphis plantaginea* Passerini (Hemiptera: Aphididae) and its Natural Enemies in Apple Orchards in Northwestern France

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1 **ABSTRACT**

2

3 Apple orchard production is facing new environmental and societal challenges, resulting, in particular,
4 in strong pressure to reduce pesticide use. Cider-apple production, for which the perfect visual aspect
5 of fruits is not a marketability imperative, offers good opportunities to study production systems that are
6 developing new agronomic strategies, which could be subsequently extended to all apple-production
7 types. Agroecological infrastructures play an important role in providing shelter, food resources or
8 reproduction habitats to many arthropods. Consequently, setting-up agroecological infrastructures in the
9 vicinity of or within orchards could increase natural enemy presence and thus improve the biological
10 control of pests. In this study, we focused on *Dysaphis plantaginea* (Passerini), one of the major pests
11 in apple orchards in Europe, which causes important economic production losses. During two years
12 (2014 and 2015), we monitored the population dynamics of *Dysaphis plantaginea*, its natural enemies
13 and mutualistic ants in commercial production cider-apple orchards. The influences of the cider-apple
14 cultivar, insecticide use and distance to agroecological infrastructures (hedgerows and flower strips)
15 were assessed. Our results suggest that flower strips favour an increase in natural enemy abundance
16 in the vicinity of the orchards and could thus play an important role in the production system by improving
17 the biological control of *Dysaphis plantaginea*.

18

19 **Keywords**

20 Biological control, cider-apple orchard, *Dysaphis plantaginea*, flower strip, hedgerow

21

22 In the second half of the 20th century, the green revolution allowed an unprecedented increase in
23 agricultural yields in developed countries. This yield increase was achieved by the generalization of
24 agricultural mechanization and the use of synthetic pesticides and fertilizers. The green revolution
25 resulted in agricultural landscape simplification (Robinson and Sutherland 2002, Benton et al. 2003) and
26 produced numerous negative side effects on biodiversity (Krebs et al. 1999), human health (Lee et al.
27 2004, Simon et al. 2007) and the quality of soil and water (Moss 2008). Consequently, a change in the
28 current agricultural paradigm and the development of more environmentally friendly agricultural
29 practices are strongly required.

30 Agroecology proposes to primarily base agricultural production on the mobilization of natural processes
31 and the improvement of ecosystem services (e.g. pollination, nutrient cycling, biological control of pests)
32 rather than on chemical inputs. In particular, promoting the natural control of pests would lead to
33 insecticide use reduction. The resulting reduction of economic and environmental costs would contribute
34 to increase farmer benefits and the environmental sustainability of agriculture (Tschumi et al. 2015).

35 Various approaches have been proposed to improve pest biological control, including changes in
36 practices (e.g. pesticide use reduction, accurate choice of cultivars) and establishing agroecological
37 infrastructures within or in the vicinity of the crop (Haenke et al. 2009, Miñarro and Prida 2013).

38 Agroecological infrastructures include hedgerows, flower strips, permanent grasslands and woodlands.
39 They may provide pests and natural enemies with various beneficial functions, including suitable
40 microclimatic conditions and refuge during adverse seasons (Landis et al. 2000). Thus, spiders, beetles
41 and syrphids use them as overwintering areas (Collins et al. 2003, Sarthou et al. 2005, Pfiffner et al.
42 2013). Agroecological infrastructures also provide pollen and nectar resources that increase the
43 longevity of parasitoids (Wäckers 2001, Berndt and Wratten 2005) and improve the fecundity of other
44 insects (Schmale et al. 2001, Wäckers 2001, Winkler et al. 2006, Hogg et al. 2011, Laubertie et al. 2012,
45 Rijn et al. 2013). Agroecological infrastructures also provide alternative prey for generalist predators
46 when these resources are not available in the crop (Wyss 1996, Denys and Tscharntke 2002, Lavandero
47 et al. 2005).

48 Northwestern France (i.e. Bretagne, Normandie and Pays de la Loire regions) is the number one cider-
49 apple producing area in Europe. Cider-apple orchard cultivation is thus important in the local economy.
50 The management of apple orchards is based on the intensive use of pesticides to control pests and
51 pathogens (Sauphanor et al. 2009). Currently, farmers are under strong pressure to develop
52 environmentally friendly protection strategies to address the new challenges imposed by society, and
53 environmental laws. Because cider-apples are transformed, their perfect visual aspect is not a
54 prerequisite of their marketability and fewer pesticide treatments are applied in cider-apple orchards
55 than in orchards for fresh fruit production (approximately 15 vs 35 treatments per year). Consequently,
56 cider-apple orchards offer an opportunity to develop and test protection strategies using less pesticide,
57 which could subsequently be generalized.

58 Approximately 60 phytophagous arthropod species are considered to be apple pests (Jenser et al.
59 1999). The rosy apple aphid (RAA) *Dysaphis plantaginea* Passerini (Hemiptera: Aphididae), is among

60 the most detrimental pests, causing significant economic losses by reducing yield (Blommers et al.
61 2004). The RAA is problematic not only in organic but also in conventional orchards due to its very low
62 abundance threshold for economic damage, resulting in a low treatment threshold (i.e., as soon as the
63 pest is detected) (Cross et al. 2007). As a consequence, an increase in insecticide resistance has been
64 recorded (Delorme et al. 1998). Many recent studies have suggested that improving biological control
65 efficiency could be an alternative to insecticides use to limit RAA populations (Hemptinne et al. 2003,
66 Dib et al. 2010, Miñarro and Prida 2013). RAA is a host-alternating aphid species. Its primary host is the
67 apple tree *Malus domestica* Borkh. (Rosales: Rosaceae), and its secondary hosts are plantain herbs
68 *Plantago spp*, mainly *P. lanceolata* L. (Lamiales: Plantaginaceae) (Blommers, 1999). At the beginning
69 of spring, eggs laid in autumn hatch on apple trees producing parthenogenically reproducing females
70 (Lathrop 1928, Bonnemaïson 1959, Blommers et al. 2004). Migration to a secondary host occurs from
71 mid-June to July in the North of France. The aphids return to apple trees in autumn, where a sexual
72 generation of oviparous females lays fertilized overwintering eggs on the apple trees. The economic
73 losses caused by this leaf-roller aphid, which develops on the lower side of the leaves, are mainly due
74 to the deformations caused to the fruits and growing shoots, decreasing the yield in the year of
75 infestation, as well as in following years (Bonnemaïson 1959, De Berardinis et al. 1994, Wilkaniec and
76 Trzcinski, 1997, Blommers et al. 2004).

77 Several recent studies have focused on the community of natural enemies, which could play a role in
78 the biological control of *D. plantaginea* during spring. In Europe, this community is mostly composed of
79 syrphids, coccinellids, parasitoids (mainly *Ephedrus* sp – Hymenoptera: Braconidae), earwigs, spiders
80 and *Aphidoletes* sp (Diptera: Cecidomyiidae) (Wyss et al. 1999, Miñarro et al. 2005, Dib et al. 2010,
81 Arnaudov et al. 2013). The abundance of these natural enemies in orchards depends on the abundance
82 of RAA prey (Dib et al. 2016) and on the intra-guild predation pressure (Rosenheim et al. 1993,
83 Rosenheim et al. 1995, Korenko and Pekár 2010). Thus, while an increase in natural enemy abundance
84 is expected to result in a decrease in RAA abundance, this trend may reverse when intra-guild predation
85 is important (Snyder and Ives 2001). RAA population dynamics also depend on the presence of ants in
86 the colony, as *D. plantaginea* is commonly attended by ants (Bonnemaïson 1959, Starý 1970).
87 Interactions between the ants and myrmecophilous aphids are beneficial for both arthropods: ants are
88 supplied with sugar through aphids' honeydew whereas aphids improve their reproductive rate (El-Ziady
89 and Kennedy 1956, Banks and Nixon 1958, Flatt and Weisser 2000) and are protected against natural

90 enemies (Stadler and Dixon 1999, Yao et al. 2000, Kaneko 2003). Thus, the relationship between ants
91 and *D. plantaginea* enhances the growth of aphid colonies by reducing aphid predation by their natural
92 enemies (Stewart-Jones et al. 2008, Miñarro et al. 2010).

93 Several recent studies noted the potential of agroecological infrastructures to improve the biological
94 control of *D. plantaginea* by favouring the natural enemy community (Dib et al. 2012, Miñarro and Prida
95 2013, Pfiffner et al. 2013). Knowledge about the distance at which agroecological infrastructures are
96 operating would help to determine the required density needed to provide an efficient biological control.

97 Indeed, several studies noted that the distance to agroecological infrastructures influenced parasitoids
98 (Corbett and Rosenheim 1996, Lavandero et al. 2005), spiders (Miliczky and Horton 2005) and syrphids
99 (Bowie 1999) abundances. Moreover, the link between the distance to agroecological infrastructures
100 and natural enemy abundance is not systematically linear. For instance, Tylianakis et al. (2004) have
101 shown that the proportion of the aphid *Metopolophium dirhodum* parasitised by *Aphidius rhopalosiphii*
102 decreased exponentially with the distance to flower resources.

103 The present project aimed to determine the impact of two types of agroecological infrastructures - flower
104 strips and hedgerows - on the abundance of arthropods interacting with *D. plantaginea* (natural enemies
105 and ants) and its consequences on RAA population dynamics. The influence of the distance to these
106 two types of agroecological infrastructures on arthropod dynamics was assessed in 14 cider-apple
107 orchards in northwestern France, which exhibit a range of farming practices (cultivars, insecticide use).
108 For this purpose, the arthropod populations (aphids, their main natural enemies and their mutualistic
109 ants) were monitored in spring during two successive years.

110

111

Materials and Methods

112

Monitored Cider-Apple Orchards

113 Experiments were carried out in the spring and early summer in 2014 and 2015 in cider-apple orchards
114 in seven locations in northwestern France (Fig. 1). The orchards were planted between 2010 and 2012
115 with three different cider-apple cultivars (three consecutive rows of each cultivar: Douce de l'Avent_{cov},
116 Dabinett and Judor) grafted onto MM106 rootstock. The three cultivars differed in their vigour and
117 precocity: Douce de l'Avent_{cov} (DDA) was the most vigorous and precocious cultivar, Dabinett (DAB)
118 was the less precocious cultivar and Judor (JUD) was intermediate.

119 In each location, two contiguous orchards were studied that differed in regard to insecticide application
 120 and in the agroecological infrastructures established (Table 1). Only five out of the seven locations were
 121 monitored in 2014 (Fig. 1).

122

123 **Monitored Trees**

124 Approximately one-third of the trees were systematically monitored in each orchard (63 to 423
 125 contiguous trees, depending on the considered orchard - Table 1). For each apple tree, the distance to
 126 the closest hedgerow (ranging from 5 m to 57 m), the distance to the closest flower strip (ranging from
 127 0 m to 63 m) and the insecticide use were recorded, and the arthropod population dynamics were
 128 monitored.

129 The hedgerows were mainly composed of *Carpinus betulus*, *Cornus* sp, *Corylus avellana*, *Viburnum* sp,
 130 *Sambucus nigra* and *Quercus pedunculata*. All flower strips, established specifically for the study,
 131 included *Centaurea cyanus*, *Silene vulgaris*, *Silene latifolia alba* and *Achillea millefolium*.

132

133 **Assessment of Insecticide Toxicity to Beneficial Arthropods**

134 Calendars of the insecticide treatments in 2014 and 2015 were collected. The Environmental Impact
 135 Quotient (EIQ) was used to estimate the toxicity of each insecticide (<https://nysipm.cornell.edu/eiq>) to
 136 beneficial arthropods. EIQ assigns to each insecticide ingredient a score ranging from 5 to 125 according
 137 to its toxicity to beneficial arthropods (Kovach et al. 1992). We calculated the cumulative impact of the
 138 insecticides applied during the period of RAA presence in the apple trees (from March to July) in each
 139 orchard using the following formula:

$$140 \quad EIQ_{field\ use\ rating} = \sum(EIQ_i * RT_i * \%active\ ingredient_i),$$

141 where EIQ_i is the EIQ value assigned to the active ingredient contained in the insecticide i relative to
 142 beneficial arthropods, RT_i , the rate of insecticide i use and $\%active\ ingredient_i$ the percentage of active
 143 ingredient in the insecticide i . The $EIQ_{field\ use\ rating}$ ranged from 0 to 6.61, depending on the year, the
 144 orchard and the cultivar (Table 1). The main active ingredients used against RAA in the cider orchard
 145 were flonicamid, acetamiprid and lambda cyhalothrin.

146

147 **Monitoring of Arthropod Population Dynamics**

148 The monitored trees were visually inspected to record the RAA abundance and the abundance of natural
 149 enemies and ants within the RAA colonies. The mean height of the monitored trees was 3.4 m (SD 0.49
 150 m). All terminal shoots of each monitored tree were inspected from the lowest branch up to a height of
 151 1.7 m for practical reasons. In 2014 and 2015, the trees were monitored every week from mid-April to
 152 the end of June and every two weeks from mid-March to mid-April and during July (except in the two
 153 orchards (4a and 4b) located at location 4, where the RAA populations were recorded every two weeks
 154 from April to July).

155

156 *Dysaphis plantaginea*

157 At each observation date, the total number of RAA individuals was counted on each monitored tree.

158

159 *Natural Enemies and Ants Observed in RAA Colonies*

160 At each observation date, the number and identity of each natural enemy type and the number of ants
 161 found within the RAA colonies were recorded and summed for each monitored tree. We also recorded
 162 the developmental stage of all of the observed natural enemies, as not all stages are involved in aphid
 163 control. In most cases, natural enemy identification was at the family level. Ants were not identified to
 164 the species level. However, we observed only *Lasius niger* and *Formica* sp.

165

166 **Data Analysis**

167 *Dysaphis plantaginea*

168 Three variables were considered to characterize the RAA population dynamics on each monitored tree
 169 and for each studied year to assess the different ecological processes:

- 170 (i) The presence/absence variable (*PA*), indicating the RAA colonization process, was set to 0 when no
- 171 RAA was observed at any date or to 1 when at least one RAA was observed on the monitored tree
- 172 (ii) The logarithm of the area under the curve (*logAUC*) of the tree population abundance, indicating *in*
- 173 *situ* RAA population dynamics (survival and reproduction)
- 174 (iii) The presence duration (*PD*), in days (last date at which at least 1 aphid was observed minus the
- 175 first date at which at least 1 aphid was observed), indicating the RAA emigration process

176

177 *Natural Enemies and Ants*

178 Natural enemy dynamics and ants were only assessed on the monitored trees in which at least one RAA
179 was observed (i.e., a monitored tree where the RAA presence/absence was set to 1). The natural enemy
180 dynamics were characterized using the same variables as for RAA (*PA*, *logAUC* and *PD*) for each
181 considered developmental stage (egg, larva, adult) of each taxon. A global variable (*allNE*) was also
182 created by summing the counts of all observed natural enemies for any stage and taxon. The three
183 dynamics variables were also calculated for *allNE*. The ant dynamics were characterized in the same
184 way as those of RAA and their natural enemies (*PA*, *logAUC* and *PD*).

185

186 *Statistical Analyses*

187 The main purpose of our study was to assess the influence of agroecological infrastructures on the three
188 above variables characterizing RAA population dynamics. First, Generalized Linear Mixed Models
189 (GLMM) were used to assess the influence of each considered factor (distance to the closest hedgerow,
190 distance to the closest flower strip, *EIQ_{field rating use}* and cultivar) on each RAA population dynamics
191 variable (*PA*, *logAUC* and *PD*) as well as its significance. Second, to assess in what extent factor effects
192 could result from variations in natural enemy and ant population dynamics, the same GLMMs were fitted
193 to the population dynamics variables associated to each natural enemy taxon and to ants but including
194 as well the rosy apple aphid abundance (*logAUC*) as a supplementary explanatory variable. This allowed
195 assessing how the dynamics of natural enemies and ants are impacted by agroecological infrastructures
196 and other agricultural variables for a given level of rosy apple aphid abundance. Introducing the *logAUC*
197 of RAA as a fixed factor was equivalent to analysing the influence of the factors under study on the
198 abundance ratio between the natural enemies and aphids or between the ants and aphids. In all models
199 two random factors were added, the orchard location and the studied year. All statistical analyses were
200 carried out with the R 3.1.3 software (R core Team 2015) using the tree as the observation unit.

201 *PA* were fitted assuming a binomial distribution, *logAUC* were fitted assuming a normal distribution and
202 *PD* were fitted using a Gamma distribution, regardless of the arthropod taxon. The mixed linear models
203 were fitted using the lme4 package, version 1.1-7 (Bates et al. 2015). A significance threshold of $p=0.05$
204 was considered.

205

206

206 **Results**

207

208 **Aphid Abundance and its Variation in Space and Time**

209 The mean abundance of RAA observed per tree and per sampling date varied widely, depending on the
 210 studied year and studied orchard. For instance, in 2014, the mean number of RAA per tree and per
 211 sampling date ranged from 0.8 in orchard *3b* to 95.5 in orchard *7a* (Table 2 and Appendix B). Globally,
 212 the pest abundance was higher in 2015 than in 2014 in all orchards, except in orchards *4a* and *4b*
 213 (Appendix B).

214

215 **Community of Natural Enemies and its Variation in Space and Time**

216 The composition of the natural enemy community remained fairly stable from one year to the next (Table
 217 2). The natural enemy community was dominated by Syrphidae (45% and 32% of the natural enemies
 218 observed in 2014 and 2015, respectively) and Coccinellidae (22% and 36% of the natural enemies
 219 observed in 2014 and 2015, respectively), followed by Forficulidae (18% and 15% of the natural enemies
 220 observed in 2014 and 2015, respectively) and Araneae (9% of the natural enemies observed in both
 221 years). Few Chrysopidae, Hemiptera and Cantharidae were observed in both years and were not
 222 retained for the subsequent detailed statistical analyses (Table 2). Similarly few mummies were
 223 observed and the ratio of the mummy number to the RAA number never exceeded 0.2% whatever the
 224 considered year and orchard.

225 A large variation in the abundance of RAA, natural enemies and ants was observed among the orchards
 226 (Appendix B).

227 The natural enemy community composition varied strongly during the season. The community was
 228 dominated by Syrphidae early in the season and then by Coccinellidae and other natural enemies (Fig.
 229 2). In both years, the RAA populations peaked between mid-May and the end of May.

230

231 **Influence of Agricultural Practices and Agroecological Infrastructures on the Main** 232 **Observed Arthropod Taxa**

233

234 Table 3 provides a synthetic overview of the results of the GLMMs. Aphids and ants appeared to be
 235 more abundant in the vicinity of the hedgerows. On the contrary, hedgerows had in most cases no effect
 236 on the natural enemies. They only have a positive effect on the presence duration of Syrphidae larvae
 237 and of Syrphidae eggs and a negative effect on the presence duration of Coccinellidae larvae. On the
 238 contrary, aphids and ants were less abundant in the vicinity of the flower strips, while all of the natural

239 enemies except the Araneae were positively impacted. All arthropods were generally more abundant on
 240 the Douce de l'Avent_{cov} cultivar, followed by Judor, and were generally negatively impacted by the
 241 insecticide use ($EIQ_{field\ use\ rating}$). However, the insecticide effect on the Syrphidae and Coccinellidae was
 242 ambiguous. Indeed, the Syrphidae eggs ($logAUC$ and PD) and Coccinellidae larvae (PD) were positively
 243 impacted by the $EIQ_{field\ use\ rating}$ but the Syrphidae larvae (PA) and the Coccinellidae eggs were negatively
 244 impacted by the $EIQ_{field\ use\ rating}$ (PA) (Appendix A). Finally, all natural enemy and ant abundances were
 245 positively impacted by aphid abundance. The results were generally consistent regardless of the
 246 variables used to describe the arthropod dynamics (PA , $logAUC$ and PD) or the considered natural
 247 enemy stage (egg, larva, adult). Detailed results by stage and variables are provided in Appendix A.

248
 249

Discussion

250

Main Findings

251 This study was carried out under field and farming production conditions. Spatio-temporal variations
 252 regarding the abundance of aphids and of their natural enemies have long been reported to depend on
 253 farming practices (Marliac et al. 2015) and on climatic conditions (Hemptinne et al. 1994, Roy et al.
 254 2002). Variations among locations and between years in population dynamics of RAA and their natural
 255 enemies are not surprising and were modelled as random factors to focus on the effects of farmer
 256 practices (insecticide treatment and cultivar choice) and of agroecological infrastructures (distances to
 257 the closest hedgerow and to the closest flower strip). All of these factors had an impact on population
 258 dynamics of aphids, of natural enemies and of ants. The tested factors appeared to be widely consistent
 259 among all natural enemy groups, suggesting that agricultural practices and agroecological
 260 infrastructures either favoured or disfavoured the entire community of natural enemies. While the cultivar
 261 and insecticide use intensity had a mostly similar influence on all arthropod abundances, the
 262 agroecological infrastructures had opposite effects on aphids and ants on the one hand and on natural
 263 enemies on the other hand. This result suggests that agroecological infrastructures actually impacted
 264 the level of RAA biological control by its natural enemies.

265 Analyses were carried out using three response variables characterizing arthropod population
 266 dynamics: presence probability, logarithm of the area under the curve and presence duration. Our
 267 hypothesis was that each variable was related to different ecological processes that could have been
 268 differentially influenced by the agricultural practices and agroecological infrastructures. However, in
 269 most cases in this study, the three variables were influenced in the same way by the agricultural

270 practices and agroecological infrastructures, suggesting that environmental and agronomical practices
271 had a similar influence on all of the population dynamics components.

272

273 **Structuration of the Arthropod Community**

274 Regardless of the year and orchard, Syrphidae and Coccinellidae were consistently the two most
275 abundant groups of natural enemies, with Syrphidae being generally present earlier than Coccinellidae.

276 These results are consistent with those of previous studies (Miñarro et al. 2005, Dib et al. 2010).

277 However, the synchronization between the RAA and natural enemy dynamics varied between the
278 studied years. The lowest RAA infestation level was observed in 2014, when RAA and natural enemy
279 dynamics appeared to be the most synchronized. Indeed, in 2014, the increase of natural enemy
280 abundance was concomitant to the increase of RAA population whereas in 2015, the natural enemy
281 abundance was at its lowest level when the RAA infestation was highest (Fig. 2).

282 Hymenoptera parasitoids were very rare in both year and in all orchards. The ratio of the number of
283 mummies to the aphid number was much lower (always less than 0.2% in all years and orchards) than
284 in previous surveys conducted in organic apple orchards (*Dib et al. 2010*: up to 6.9%; *Cruz de Boelpaep*
285 *et al. 1987*: 3.3%). However, other studies similarly reported the absence or a very low abundance of
286 parasitism in RAA colonies (*Miñarro et al. 2005*, *Brown and Mathews 2007*). The low level of parasitism
287 observed in our study could result from the high sensitivity of the hymenoptera parasitoid to insecticides
288 (*Theiling and Croft 1988*). Another explanation could be an antagonist effect between ants and
289 parasitoids as evidenced in previous studies (*Völkl 1992*, *Stewart-Jones et al. 2008*).

290 As expected, all natural enemies exhibited a positive response to RAA abundance either in their
291 probability of presence (Coccinellidae, Araneae) or in both their probability of presence and abundance
292 (Syrphidae, Forficulidae). This is not surprising, as natural enemies frequently aggregate in places
293 where preys are abundant. In fact, previous studies showed that it is the case for Carabidae and
294 Staphylinidae, (*Bryan and Wratten 1984*) or for Syrphidae (*Tenhumberg and Poehling 1995*, *Miñarro et*
295 *al. 2005*).

296 Similarly, the presence probability, logarithm of the area under the curve and presence duration of ants
297 responded positively to RAA abundance, which was expected considering the mutualistic relation
298 between *D. plantaginea* and the two species of ants observed (*Lasius niger* L., *Formica* sp.) (*Flatt and*
299 *Weisser 2000*, *Stewart-Jones et al. 2008*).

300 This dependence of ant and natural enemy abundances on RAA abundance supported our choice to
 301 include RAA abundance as a factor in the models (through the *logAUC* of RAA). In this way, we were
 302 able to analyse the direct effects of farmer practices and agroecological infrastructures on natural
 303 enemies and ants.

304

305 **Practices and Cultivar Influence**

306 *Impact of Insecticides on RAA and Natural Enemy Population Dynamics*

307 As expected, we observed a decrease in the probability and duration of RAA presence with an increase
 308 of the *EIQ_{field use rating}*, but the *EIQ_{field use rating}* effect on RAA abundance (*logAUC*) was not significant (Table
 309 3 and Appendix A). Such an effect is especially expected in leaf-curling aphids, such as *D. plantaginea*.
 310 Indeed, aphids are more vulnerable to insecticides in the first phase of colonization, resulting in a
 311 reduction of the colonization success and hence on the presence probability. The aphid vulnerability
 312 further decreases while the colony size increases because the rolling-up of leaves provides them with
 313 protection against insecticides (Cross et al. 2007). Moreover, the negative effect of insecticides on
 314 natural enemies might further reduce aphid biological control. A negative effect of insecticide treatments
 315 was observed on the presence probability of *allNE* and on their abundance (*logAUC*). This negative
 316 effect was significant on the presence probability of Syrphidae larvae, of Syrphidae eggs and of
 317 Coccinellidae eggs, as well as on the Forficulidae abundance and on Araneae presence duration.
 318 Insecticide treatments applied early in the season seem to be the most efficient to control the
 319 development of *D. plantaginea* colonies. Insecticide applications after the leaf curling, would impact
 320 more strongly the natural enemies than aphids. High *EIQ_{field use rating}* also reduced ant abundance in RAA-
 321 infested trees, suggesting that insecticide treatments also negatively impact the ant population.

322

323 *Effect of Cultivar on RAA and Natural Enemy Population Dynamics*

324 A strong impact of the cultivar was observed in our study and its effect varied whether we considered
 325 the presence probability and the presence duration of RAA and natural enemies or the abundance of
 326 RAA and natural enemies (except for the Dabinett cultivar, which always exhibited the lowest presence
 327 probability, abundance and presence duration of RAA and natural enemies). Douce de l'Avent_{cov} had
 328 the highest presence probability and presence duration of RAA and natural enemies (*allNE*), followed
 329 by Judor. For the RAA, this ranking matches cultivars ranked according to precocity. Douce de l'Avent_{cov}

330 was the most precocious cultivar, followed by Judor, with Dabinett being the latest cultivar. Miñarro and
331 Dapena, (2007) still showed that early-leaving apple cultivars were more infested and damaged by RAA
332 than late-leaving ones. We can suppose that the same process operates for natural enemies. However,
333 a different cultivar ranking was obtained when the abundance of RAA and natural enemies was
334 considered, switching between cultivars: Judor had the higher abundance of RAA and of natural
335 enemies (*A/INE*), followed by Douce de l'Avent_{cov}. This apparent inconsistency could result from an
336 interaction between the colonization rate and treatment frequency. In fact, the most heavily colonized
337 cultivar (Douce de l'Avent_{cov}) was also the earliest one treated with insecticides, resulting in low
338 abundances of both aphids and natural enemies throughout the season.

339

340 **Hedgerows Favour RAA Populations**

341 Unexpectedly, hedgerows appeared to be consistently beneficial to RAA populations. Indeed, hedgerow
342 proximity had a positive impact on all of the RAA population dynamics parameters. This hedgerow effect
343 may result from either direct effects on the RAA population dynamics, from indirect effects through its
344 influence on mutualistic or antagonist arthropods, or both. The vicinity of the hedgerow may influence
345 the flight behaviour of arthropods by modifying the wind speed and turbulences (Pasek 1988), which
346 could result in the accumulation of insects on the leeward side of the hedgerow (Lewis 1965, Grüebler
347 et al. 2008). Such an effect could result in a higher colonization rate by RAA of apple trees situated in
348 the vicinity of hedgerows.

349 Hedgerows may also indirectly favour aphids by favouring mutualistic ants possibly by providing a
350 suitable nesting habitat. Indeed, the ant presence probability increased with the proximity to the
351 hedgerow in our study. To our knowledge, very few studies have assessed hedgerow influence on ants.
352 Stutz and Entling (2011) found no effect of a woody habitat in the surrounding landscape on ant
353 presence on cherry trees, but Armbrrecht and Perfecto (2003) reported a dramatic decrease of twig-
354 nesting ants with an increase in the distance to forest fragments in coffee plantations in Mexico.

355 Finally, the proximity of hedgerows may modify the arthropods interaction network. For instance, the
356 presence of a hedgerow could reduce RAA biocontrol by increasing the intra-guild predation between
357 natural enemies (Straub et al. 2008) or by diverting natural enemies from pests by offering them
358 alternative prey (Kozar et al. 1994, Koss and Snyder 2005, Symondson et al. 2006). Moreover, as the
359 presence of ants is higher in the hedgerow vicinity, the protection they provide to RAA against their

360 natural enemies could be enhanced. Contrary to previous studies (Altieri and Schmidt 1986, Miñarro
361 and Prida 2013), few hedgerow-distance effects on natural enemy occurrence or abundance in aphid
362 colonies were found in our study. The only significant effects were the decrease of the presence
363 probability and of the presence duration of Coccinellidae larvae and the increase of the presence
364 duration of Syrphidae larvae and Syrphidae eggs in the vicinity of the hedgerow.

365

366 **Flower Strips Reduce RAA Populations and Increase Natural Enemy Abundance**

367 Contrary to hedgerows, flower strips had a negative impact on the RAA populations in our study. Indeed,
368 the presence probability, the abundance and the presence duration of RAA all decreased with flower
369 strips proximity. A direct effect of flower strips on aphids was very unlikely. We then assumed that flower
370 strips exerted an indirect effect through their influence on the natural enemies and/or on ants. Indeed,
371 Wyss, (1995) and Wyss et al. (1995) showed that introducing flower strips in apple orchards resulted in
372 an increase in natural enemy abundance (Chrysopidae, Coccinellidae, Araneae). Similarly, in our study,
373 the abundance (*logAUC*) and presence duration of natural enemies (*allNE*) increased in proximity to
374 flower strips. More specifically, the presence probability and abundance of Syrphidae (eggs and larvae),
375 presence probability of Coccinellidae (eggs and larvae) and abundance of Forficulidae decreased
376 significantly with the distance to flower strips. This increase of presence and/or of abundance of natural
377 enemies could enhance aphid biological control in the vicinity of flower strips. Hogg et al. (2011) showed
378 that floral resources enhanced aphid suppression by the hoverfly *Eupeodes fumipennis* in a California
379 lettuce field. In addition, the negative influence of flower strips on aphid populations could also be
380 amplified by their negative effect on the ant presence probability. Nagy et al. (2013) showed that
381 applying artificial sugar sources in apple orchards resulted in a reduction of the number of ant-attended
382 *D. plantaginea* colonies and in an increase in natural enemy pressure. Similarly, by providing alternative
383 sugar resources, flower strips could distract ants from aphid attendance. Katayama et al. (2013) showed
384 that extrafloral nectar was more attractive to ants than aphid honeydew. In total, our results suggest that
385 flower strips are beneficial to natural enemies and reduce ant attendance that could account for the
386 observed reduction of *D. plantaginea* infestation in cider-apple trees located in the vicinity of flower
387 strips.

388

389

389 **Conclusion**

Comment citer ce document :

Albert, L., Franck, P., Gilles, Plantegenest, M. (2017). Impact of Agroecological Infrastructures on the Dynamics of *Dysaphis plantaginea* (Hemiptera: Aphididae) and Its Natural Enemies in Apple Orchards in Northwestern France. *Environmental Entomology*, 46 (3), 528-537 . DOI : 10.1093/ee/nvx054

390 This study showed an impact of the distance to agroecological infrastructures on *D. plantaginea*
 391 dynamics in cider-apple orchards. Hedgerows increased the RAA infestation level. This could result
 392 from an indirect effect due to modifications in the RAA interactions network with other arthropods.
 393 Indeed, our results showed an increase in the presence of mutualistic ants and a decrease in RAA
 394 natural enemy abundance in the vicinity of hedgerow. On the contrary, flower strips appeared
 395 unfavourable to *D. plantaginea*. Again it could result from indirect effect due to an increase in natural
 396 enemy abundance and a decrease of ant presence in the RAA colony. Additionally, we confirmed a
 397 strong influence of cultivars and of insecticide use intensity on *D. plantaginea* dynamics.

398

399

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TABLE

Table 1: Main characteristics of the 14 studied cider-apple orchards. Two contiguous orchards (referred by *a* or *b*) have been monitored in each location (referred by number). In each orchard, 3 cider-apple cultivars were planted (DDA = Douce de l'Avent_{cov} cultivar, DAB = Dabinett cultivar and JUD= Judor cultivar). The Environmental Impact Quotient (EIQ) of each insecticide applied during the RAA presence on the apple trees was used to assess the cumulative toxicity of insecticides used in each orchard each year ($EIQ_{field\ use\ rating}$). *: only 63 trees monitored in 2014; **:only 425 trees monitored in 2014. NA means Not Applicable.

Location	1		2		3		4		5		6		7	
Orchard	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b
Year of planting	2010	2010	2012	2012	2011	2011	2012	2012	2011	2011	2011	2011	2010	2010
Density of planting														
by number of trees/ha														
	774	774	495	774	774	774	495	774	1000	1000	774	774	774	774
(planting distance between														
rows*planting distance														
within rows)														
Number of monitored trees	198	198	153	153	162	162	117*	117*	234	234	279	279	270**	270**
$EIQ_{field\ use\ rating}$ 2014														
DDA	0.61	5.58	0	1.20	0.35	0.35	0	0	NA	NA	NA	NA	0	0.29
in (for each apple														
cultivar)														
DAB	0.61	5.58	0	1.20	0.35	0.35	0	0	NA	NA	NA	NA	0	2.09
JUD	0.61	5.58	0	1.20	0.35	0.35	0	0	NA	NA	NA	NA	0	0
$EIQ_{field\ use\ rating}$ 2015														
DDA	0.67	6.61	0	0	0	2.80	0	1.16	0.087	0.33	0	6.81	0	0.24
in (for each apple														
cultivar)														
DAB	0.67	6.61	0	0	0	1.60	0	1.16	0.087	0.33	0	4.67	0	0.35
JUD	0.67	6.61	0	0	0	2.80	0	1.16	0.087	0.33	0	6.61	0	0.35

Mean distance			34.5	0	38.9	1	43.6	2	24.9					1.5	39.8
(+SD) of orchard	2014	0 (0)	(14.2)	(0)	(11.3)	(0)	(12.0)	(0)	(4.6)	NA	NA	NA	NA	(0)	(13.2)
trees to the closest															
flower strip (in m)			34.5	0	38.9	1	43.6	2	31.8	10.8	27.0	11.9	36.9	1.5	33.4
(according to the	2015	0 (0)	(14.2)	(0)	(11.3)	(0)	(12.0)	(0)	(8.6)	(6.2)	(12.9)	(6.9)	(14.8)	(0)	(11.9)
year)															
Mean distance		16.0	21.3	23.9	20.7	21.3	21.3	15.5	13.8					21.5	28.1
(+SD) of orchard	2014	(7.2)	(11.8)	(12.9)	(10.4)	(11.0)	(11.0)	(6.0)	(4.64)	NA	NA	NA	NA	(11.3)	(12.9)
trees to the closest															
hedgerow (in m)		16.9	21.3	23.9	20.7	21.3	21.3	20.8	18.3	14.3	15.2	27.6	27.6	23.7	23.7
(according to the	2015	(7.2)	(11.8)	(12.9)	(10.4)	(11.0)	(11.0)	(10.4)	(8.2)	(6.6)	(6.5)	(14.1)	(14.1)	(12.7)	(12.7)
year)															

Table 2: Total number of observed arthropods (and range of the mean number for one monitored tree per observation in one studied orchard) by taxonomic group, life stage and year.

			Year		Total
			2014	2015	
Number of studied orchards			10	14	
Total number of observations (date*orchard)			35 (from 5 to 10)	57 (from 5 to 11)	103
Order	Family	Life stage			
Diptera	Syrphidae	Eggs	1083 (from 5.6 ⁻² to 0.50)	1122 (from 2.9 ⁻² to 1.7)	2205
		Larvae	408 (from 1.0 ⁻² to 0.47)	429 (from 3.0 ⁻² to 0.51)	838
		Adults	9 (from 0 to 1.0 ⁻²)	51 (from 0 to 5.3 ⁻²)	60
		All	1500 (from 6.6 ⁻² to 0.71)	1602 (from 6.0 ⁻² to 2.3)	3103
Coleoptera	Coccinellidae	Eggs	533 (from 0 to 4.7 ⁻¹)	1325 (from 0 to 5.2)	1858
		Larvae	141 (from 0 to 2.7 ⁻¹)	343 (from 0 to 3.8 ⁻¹)	484
		Adults	65 (from 6.3 ⁻³ to 8.8 ⁻²)	161 (from 0 to 3.8 ⁻¹)	226
		All	739 (6.3 ⁻³ to 0.79)	1829 (from 0 to 6.4)	2568
	Cantharidae	Adults	17 (from 0 to 1.2 ⁻²)	68 (from 0 to 4.1 ⁻²)	85
Hemiptera	Anthocoridae	-	34 (from 0 to 4.5 ⁻²)	92 (from 0 to 5.0 ⁻²)	126
	Miridae	-	37 (from 0 to 1.2 ⁻²)	114 (from 0 to 1.7 ⁻¹)	153
	Nabidae	-	67 (from 0 to 2.4 ⁻¹)	0 (from 0 to 0)	67

			Year		Total
			2014	2015	
Number of studied orchards			10	14	
Total number of observations (date*orchard)			35 (from 5 to 10)	57 (from 5 to 11)	103
Neuroptera	Chrysopidae	Eggs	9 (from 0 to 1.2 ⁻²)	0 (from 0 to 0)	9
		Larvae	0 (from 0 to 0)	2 (from 0 to 6.0 ⁻³)	2
		Adults	0 (from 0 to 0)	3 (from 0 to 2.3 ⁻³)	3
		All	9 (from 0 to 1.2 ⁻²)	5 (from 0 to 6.0 ⁻³)	14
Dermoptera	Forficulidae	Juveniles+adults	582 (from 0 to 0.36)	742 (from 2.9 ⁻³ to 0.60)	1324
Hymenoptera		Mummies	33 (from 0 to 3.2 ⁻²)	108 (from 0 5.4 ⁻²)	141
		Adults	12 (from 0 to 3.2 ⁻²)	25 (from 0 to 1.9 ⁻²)	37
		All	45 (from 0 to 6.5 ⁻²)	133 (from 0 to 5.7 ⁻²)	178
Araneae		Juveniles+Adults	296 (from 0 to 0.16)	440 (from 0 to 0.16)	737
AIINE			3326 (from 0.10 to 1.45)	5025 (from 0.30 to 7.4)	8355
Number of RAA			206195 (from 0.77 to 95.5)	554230 (from 21.0 to 182.4)	760425
Ratio (natural enemies per RAA)			0.016 (from 5.0 ⁻⁴ to 0.18)	0.009 (from 2.4 ⁻³ to 0.21)	0.0109
Ants			9279 (from 2.4 ⁻² to 3.8)	15578 (from 4.7 ⁻² to 7.1)	24857

Table 3: Synthetic overview of the Generalized Linear Mixed models results: “+” (resp. “-”) indicates that the factor is favourable (resp. unfavourable) to the considered arthropods. For the distance, a “+” (resp. “-”) indicates that the arthropods are more (resp. less) present in the vicinity of the agroecological infrastructure. For the cultivar factor “*” means that cultivar has a significant effect on the response variable (*PA*, *logAUC* or *PD*) for at least one arthropod stage. 0 indicates that the factor did not significantly influence the variable. NA: not applicable. See Appendix A for detail.

	RAA	AIINE	Syrphidae	Coccinellidae	Forficulidae	Araneae	Ants
Distance to the							
closest	+	0	+	-	0	0	+
hedgerow							
Distance to the							
closest flower	-	+	+	+	+	0	-
strip							
Cultivar							
(<i>PA</i> / <i>logAUC</i> / <i>PD</i>)	*/*/*	*/*/*	*/0/*	*/*/*	*/0/0	*/0/0	*/0/0
<i>EIQ</i> _{field use rating}	-	-	-	-	-	-	-
RAA	NA	+	+	+	+	+	+

FIGURE LEGENDS

Fig. 1. Map of the seven studied locations (two orchards per location). Black dots are the locations studied both in 2014 and 2015. Grey dots are the locations studied in 2015.

Fig. 2. Mean number (+ SE) of RAA (black dot), of all natural enemies (grey dotted line with circle mark), of Syrphidae (all stages) (grey dotted line with triangle mark) and of Coccinellidae (all stages) (grey dotted line with square mark) per monitored apple tree in aphid colonies in 2014 (A) and 2015 (B).

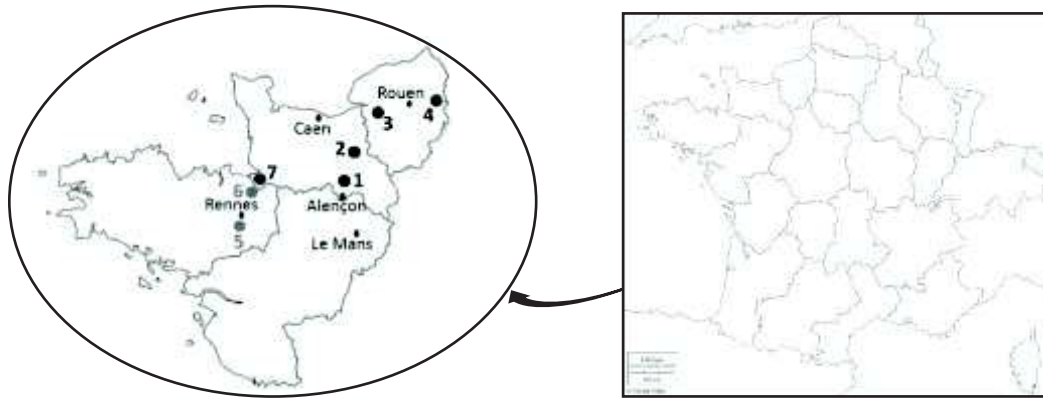


Fig. 1

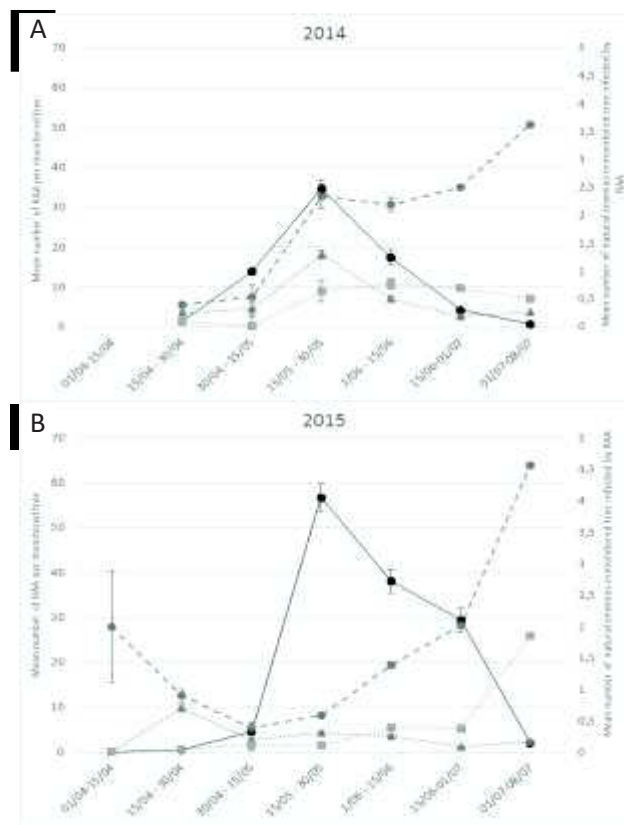


Fig. 2

Supplementary Material

Impact of Agroecological Infrastructures on the Dynamics of *Dysaphis plantaginea* Passerini (Hemiptera: Aphididae) and its Natural Enemies in Apple Orchards in Northwestern France

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Appendix B: Sum of arthropods observed per orchard each studied year (2014 and 2015) and mean number of arthropods per sampling date per tree infected with rosy apple aphid

Appendix A: Results of Generalized Linear Models obtained for each arthropod (by taxon and stage) and each variable. The first line is the pvalue of the variable, when inferior to 0.05, the second line is the coefficient. NS means no-significant. EIQ means Environmental Impact Quotient. AUC mean Area Under the Curve. DAB means cultivar of Dabinett, DDA means cultivar of Douce de l'Avent_{COV} and JUD means cultivar of Judor.

		Variables studied				EIQ _{field use rating}
		Log AUC of <i>D. plantaginea</i>	Distance to the hedgerow	Distance to the flower strips	Cultivar	
<i>Dysaphis plantaginea</i>	Probability of presence (binomial distribution)		**0.002537 -0.0058	*** < 2.2e-16 0.0111	5.348e-12 DAB<JUD<DDA	*** 7.166e-05 -0.057
	Log(Area Under the Curve) (normal distribution)		*** 0.0001546 -0.0171	*0.03814 0.0063	** 0.003741 DAB<DDA<JUD	NS 0.7999
	Presence duration (Gamma distribution)		*** <2.2^-16 -0.0057	*** 7.867e-16 0.0022	*** < 2.2e-16 DAB<JUD<DDA	*** 8.676e-13 -0.019
Global natural enemies	Probability of presence (binomial distribution)	***< 2.2e-16 0.277	NS 0.3227	NS 0.1266	***1.279e-10 DAB<JUD<DDA	*** 4.617e-05 -0.091
	Log(Area Under the Curve) (normal distribution)	***< 2.2e-16 0.194	NS 0.4274	***3.266e-06 -0.0082	***0.0004949 DAB<DDA<JUD	0.005526 -0.051
	Presence duration (Gamma distribution)	*** 2.894e-11 0.0535	NS 0.1892	**0.001459 -0.0029	** 0.003236 DAB<JUD<DDA	NS 0.2187
Eggs of Syrphidae	Probability of presence (binomial distribution)	*** < 2.2e-16 0.185	NS 0.7486	* 0.0366 -0.0048	*** 2.754e-05 DAB<JUD<DDA	0.01154 -0.0586
	Log(Area Under the Curve) (normal distribution)	*** 7.458e-08 0.122	NS 0.8587	** 0.001588 -0.00787	NS 0.1269	NS 0.1041
	Presence duration (Gamma distribution)	*** 4.961e-06 0.0422	*0.04781 -0.0034	*** 6.688e-05 -0.0044	NS 0.6885	*0.03559 0.0225
Larvae of Syrphidae	Probability of presence (binomial distribution)	***< 2.2e-16 0.286	NS 0.8352	** 0.002112 -0.0078	*** 9.99e-06 DAB<JUD<DDA	*** 0.0008589 -0.090
	Log(Area Under the Curve) (normal distribution)	*** 1.125e-07 0.117	NS 0.8032	* 0.03901 -0.00452	NS 0.08464	NS 0.4199
	Presence duration (Gamma distribution)	*** 0.0009433 0.0376	** 0.00516 -0.00536	NS 0.4155 -0.00091	* 0.02581 DAB<DDA<JUD	NS 0.6054
Eggs of Coccinellidae	Probability of presence (binomial distribution)	*** 8.057e-07 0.219	NS 0.1241	0.02953 -0.010	NS 0.2564	** 0.006066 -0.364
	Log(Area Under the Curve) (normal distribution)	NS 0.6864	NS 0.3697	NS 0.1016	** 0.002943 JUD<DAB<DDA	NS 0.8945
	Presence duration (Gamma distribution)	NS 0.06483	NS 0.4644	NS 0.3969	*0.04445 JUD<DAB<DDA	NS 0.3095
Larvae of Coccinellidae	Probability of presence (binomial distribution)	*** < 2.2e-16 0.285	** 0.005793 0.0162	*** 0.000528 -0.011	**0.00986 DAB<DDA<JUD	NS 0.4914
	Log(Area Under the Curve)	* 0.02581 0.122	NS 0.75	NS 0.4144	NS 0.728	NS 0.294

	(normal distribution)					
	Presence duration (Gamma distribution)	NS 0.1201	* 0.03643 0.0057	NS 0.7773	* 0.01121 JUD<DAB<DDA	NS 0.07431
Adults of Coccinellidae	Probability of presence (binomial distribution)	*** 7.437e-15 0.246	NS 0.6654	NS 0.4651	* 0.01922 JUD<DAB<DDA	NS 0.09964
	Log(Area Under the Curve) (normal distribution)	NS 0.491	NS 0.1347	NS 0.895	NS 0.1843	NS 0.5245
	Presence duration (Gamma distribution)	NS 0.8494	NS 0.5724	NS 0.6548	*0.01378 JUD<DAB<DDA	NS 0.4131
Forficulidae (Juveniles and adults)	Probability of presence (binomial distribution)	*** < 2.2e-16 0.223	NS 0.9295	NS 0.8388	*0.01662 DAB<DDA<JUD	NS 0.2327
	Log(Area Under the Curve) (normal distribution)	** 0.001888 0.0892	NS 0.1346	0.04627 -0.005	NS 0.05784	* **0.0006422 -0.097
	Presence duration (Gamma distribution)	*0.03107 0.0304	NS 0.2126	** 0.005847 -0.00534	NS 0.5498	NS 0.9349
Araneae (Juveniles and adults)	Probability of presence (binomial distribution)	*** 4.533e-12 0.146	NS 0.9254	NS 0.1275	*** 1.155e-10 DAB<JUD<DDA	NS 0.08618
	Log(Area Under the Curve) (normal distribution)	NS 0.3479	NS 0.9367	NS 0.3193	NS 0.74	NS 0.1281
	Presence duration (Gamma distribution)	NS 0.1252	NS 0.5216	NS 0.4528	NS 0.1029	** 0.001295 -0.059
Ants	Probability of presence (binomial distribution)	*** < 2.2e-16 0.405	*** 0.000344 -0.0146	0.008168 0.0068	* 0.01761 JUD<DAB<DDA	NS 0.8418
	Log(Area Under the Curve) (normal distribution)	*** < 2.2e-16 0.509	NS 0.5379	NS 0.8873	NS 0.4117	* * 0.006257 -0.049
	Presence duration (Gamma distribution)	*** < 2.2e-16 0.152	NS 0.1676	NS 0.8688	NS 0.6604	NS 0.2145

Appendix B: Sum of arthropods observed per orchard each studied year (2014 and 2015) and mean number of arthropods per sampling date per tree infected with rosy apple aphid

Orchard	Sampling year	Sum of monitored tree per year	Diptera				Coleoptera				Dermaptera	Hymenoptera		Araneae	All NE	Ants	Number of tree with RAA	Number of RAA per tree infected by RAA	Ratio NE/RAA
			Syrphidae				Coccinellidae				Forficulidae	-	-	-	-				
			Eggs	Larvae	Adults	Total	Eggs	Larvae	Adults	Total	Nymph +adults	Mummies	adults	Juvenile +Adults	-	-			
1a	2014	1980	246 0.26	102 0.10	0 0	348 0.37	41 0.04	5 5.3 ⁻³	7 7.5 ⁻³	53 0.05	337 0.36	3 3.2 ⁻³	0 0	105 0.11	850 0.91	3580 3.85	929 46,91%	62291 67.05	0.01
	2015	2574	294 0.43	63 0.09	3 4.4 ⁻³	360 0.53	13 0.01	1 1.4 ⁻³	4 5.8 ⁻³	18 0.02	411 0.60	0 0	0 0	29 0.04	836 1.23	3915 5.77	678 26,34%	123724 182.48	6.7 ⁻³
1b	2014	1980	234 0.29	11 0.01	0 0	245 0.31	0 0	0 0	5 6.3 ⁻³	5 6.3 ⁻³	156 0.19	0 0	0 0	19 0.02	425 0.54	2461 3.14	783 39,54%	29953 38.25	0.01
	2015	2574	43 0.04	21 0.03	1 1.4 ⁻³	65 0.09	0 0	2 2.1 ⁻³	8 8.4 ⁻³	10 0.01	211 0.22	0 0	2 2.1 ⁻³	39 0.04	382 0.40	6712 7.11	943 36,63%	158824 168.4	2.4 ⁻³
2a	2014	1377	282 0.50	119 0.21	0 0	401 0.71	260 0.46	43 0.07	9 0.01	312 0.55	18 0.03	1 1.7 ⁻³	0 0	46 0.08	821 1.45	342 0.60	564 40,95%	16194 28.71	0.05
	2015	1683	23 0.09	36 0.14	0 0	59 0.23	53 0.21	35 0.13	5 0.01	93 0.37	4 0.01	9 0.03	0 0	12 0.04	212 0.84	12 0.04	251 14,91%	20977 83.5	0.01
2b	2014	1377	148 0.19	84 0.11	0 0	232 0.31	32 0.04	15 0.02	5 6.7 ⁻³	52 0.06	8 0.01	2 2.6 ⁻³	0 0	81 0.10	403 0.54	245 0.32	743 53,95%	32682 43.98	0.01
	2015	1683	13 0.02	39 0.15	1 3.9 ⁻³	53 0.21	126 0.28	125 0.28	7 0.01	258 0.59	4 9.1 ⁻³	5 0.01	3 6.8 ⁻³	14 0.03	382 0.87	528 1.21	436 25,90%	57232 131.2	6.6 ⁻³
3a	2014	810	19 0.06	3 0.01	0 0	22 0.08	15 0.05	1 3.6 ⁻³	6 0.02	22 0.08	3 0.10	0 0	0 0	0 0	48 0.17	20 0.07	274 33,82%	263 0.95	0.18
	2015	972	235 1.79	67 0.51	7 0.05	309 2.35	221 1.68	51 0.38	37 0.28	309 2.35	24 0.18	0 0	2 0.01	0 0	691 5.27	239 1.82	131 13,47%	22047 168.2	0.03
3b	2014	810	16 0.05	3 0.01	0 0	19 0.06	0 0	0 0	5 0.01	5 0.01	5 0.01	0 0	0 0	2 7.0 ⁻³	31 0.10	7 0.02	285 35,18%	222 0.77	0.13
	2015	972	21 0.13	23 0.17	0 0	44 0.33	0 0	0 0	4 0.02	4 0.02	31 0.19	0 0	0 0	3 0.01	89 0.55	57 0.35	161 16,56%	8388 52.0	0.01

4a	2014	378	6 0.07	9 0.11	0 0	15 0.18	19 0.24	21 0.26	4 0.05	44 0.55	0 0	1 0.01	0 0	13 0.16	92 1.16	80 1.01	79 20,89%	2411 30.51	0.03
	2015	819	34 0.65	2 0.03	1 0.01	37 0.71	247 4.75	15 0.28	20 0.38	282 5.43	1 0.01	0 0	1 0.01	1 0.01	354 6.80	0 0	52 6.34%	1629 31.3	0.21
4b	2014	378	11 0.16	2 0.02	0 0	13 0.19	32 0.47	16 0.23	6 0.088	54 0.79	7 0.10	0 0	0 0	6 0.08	92 1.35	3 0.04	68 17,98%	1309 19.25	0.07
	2015	819	28 0.35	5 0.09	1 0.019	34 0.65	441 5.58	35 0.44	31 0.39	507 6.41	0 0	1 0.01	0 0	1 0.01	587 7.43	2 0.02	79 9.64%	1661 21.02	0.35
5a	2015	2574	109 0.10	52 0.04	4 3.8 ⁻³	165 0.15	27 0.025	2 1.9 ⁻³	6 5.7 ⁻³	33 0.03	13 0.01	57 0.05	3 2.8 ⁻³	117 0.11	368 0.35	570 0.54	1044 40,55%	23252 22.27	0.01
5b	2015	2574	206 0.19	66 0.06	7 6.7 ⁻³	279 0.26	108 0.10	72 0.06	27 0.024	136 0.12	9 8.5 ⁻³	24 0.02	5 4.7 ⁻³	99 0.09	651 0.62	1251 1.19	1048 40,71%	61721 58.89	0.01
6a	2015	2790	24 0.05	13 0.03	3 6.9 ⁻³	40 0.09	89 0.20	4 9.3 ⁻³	11 0.025	104 0.24	1 2.3 ⁻³	1 2.3 ⁻³	0 0	70 0.16	245 0.57	641 1.49	429 15,37%	20844 48.58	0.01
6b	2015	2790	8 0.03	0 0	6 0.01	14 0.03	0 0	1 3.9 ⁻³	1 3.9 ⁻³	2 7.8 ⁻³	1 3.9 ⁻³	0 0	3 0.01	41 0.16	79 0.30	845 3.13	255 9.13%	16913 66.32	4.6 ⁻³
7a	2014	1875	8 0.12	42 0.45	1 0.10	51 0.54	24 0.25	26 0.27	4 0.04	54 0.58	1 0.10	3 0.03	3 0.03	3 0.03	115 1.23	262 2.81	93 4,96%	8889 95.5	0.01
	2015	2700	26 0.12	18 0.08	6 0.02	50 0.24	0 0	0 0	0 0	0 0	15 0.07	0 0	3 0.01	7 0.03	76 0.36	187 0.90	207 7.66%	10105 48.81	7.5 ⁻³
7b	2014	1875	47 0.17	33 0.09	1 2.8 ⁻³	81 0.22	85 0.24	12 0.03	8 0.02	105 0.29	43 0.12	20 0.05	3 8.4 ⁻³	5 0.01	267 0.75	733 2.07	353 18,82%	17173 48.64	0.01
	2015	2700	58 0.17	24 0.11	11 0.05	93 0.44	0 0	0 0	0 0	0 0	17 0.05	11 0.03	3 9.1 ⁻³	7 0.02	122 0.37	619 1.88	329 12,18%	26913 81.80	4.5 ⁻³