

AperTO - Archivio Istituzionale Open Access dell'Università di Torino

Glue barriers reduce earwig damage on apricots in north-western Italy

This is the author's manuscript

Original Citation:

Availability:

This version is available <http://hdl.handle.net/2318/1642812> since 2020-04-06T19:59:26Z

Published version:

DOI:10.1080/09670874.2016.1178823

Terms of use:

Open Access

Anyone can freely access the full text of works made available as "Open Access". Works made available under a Creative Commons license can be used according to the terms and conditions of said license. Use of all other works requires consent of the right holder (author or publisher) if not exempted from copyright protection by the applicable law.

(Article begins on next page)

This is the author's final version of the contribution published as:

Saladini, Matteo Alessandro; Asteggiano, Laura; Pansa, Marco Giuseppe; Giordani, Luca; Serre, Luca; Vittone, Graziano; Tavella, Luciana; Tedeschi, Rosemarie. Glue barriers reduce earwig damage on apricots in north-western Italy. *INTERNATIONAL JOURNAL OF PEST MANAGEMENT*. 62 (3) pp: 214-221.

DOI: 10.1080/09670874.2016.1178823

The publisher's version is available at:

<http://www.tandfonline.com/doi/pdf/10.1080/09670874.2016.1178823>

When citing, please refer to the published version.

Link to this full text:

<http://hdl.handle.net/2318/1642812>

1 **Title: Glue barriers reduce earwig damage on apricots in northwestern Italy**

2

3 Matteo Alessandro Saladini^a, Laura Asteggiano^{b c}, Marco Giuseppe Pansa^a, Luca Giordani^b, Luca
4 Serre^b, Graziano Vittone^b, Luciana Tavella^a, Rosemarie Tedeschi^{a*}

5

6 ^aDipartimento di Scienze Agrarie, Forestali e Alimentari (DISAFA), ULF Entomologia Generale e
7 Applicata, University of Torino, largo Paolo Braccini 2, I-10095 Grugliasco (TO), Italy

8 ^bConsorzio di Ricerca Sperimentazione e Divulgazione per l'Ortofrutticoltura piemontese (CReSO),
9 via Falicetto 24, I-12030 Manta (CN), Italy

10 ^cCurrent address: Tree Fruit Research and Extension Centre (TFREC), Washington State
11 University, 1100 N Western Ave, Wenatchee WA 98801

12

13 *Corresponding author, e-mail rosemarie.tedeschi@unito.it, phone number +39 011 6708675.

14

15 **Abstract**

16 The European earwig, *Forficula auricularia* L. (Dermaptera: Forficulidae), is a well-known species
17 that is cosmopolitan and present throughout Europe. Due to its omnivorous feeding behaviour, this
18 species can act as a generalist predator, preying on several top fruit pests, but also as a pest causing
19 shallow gouges or holes in soft fruits such as apricots, strawberries, raspberries or blackberries. In
20 Piedmont (NW Italy), significant fruit damage has been observed lately in apricot orchards where
21 earwigs fed on ripening fruits and made a considerable part of the produce unmarketable. In this
22 study, we sampled earwig populations in three apricot orchards in Piedmont and tested the
23 effectiveness of glue barriers applied to the tree trunks in reducing both earwig density in the
24 canopy and fruit damage. The arboreal glues Rampastop[®] and Vebicolla[®] were tested both in the
25 field and laboratory trials. Glue barriers demonstrated to be effective control measures, significantly
26 reducing earwig abundance in the canopy and fruit damage. Rampastop[®] gave better results on old

27 trees with a very rough and cracked bark, since in that case Vebicolla® could not perfectly bond
28 with the trunk.

29

30 **Keywords**

31 *Forficula auricularia*, *Prunus armeniaca*, arboreal glue, corrugated cardboard, orchards

32

33 **1 Introduction**

34 The European earwig, *Forficula auricularia* L. (Dermaptera: Forficulidae), is a well-known
35 cosmopolitan species. Native to Europe, it has spread all over the world since the beginning of the
36 20th century (Moerkens et al. 2011). *Forficula auricularia* is omnivore and feeds on a variety of
37 plant materials, mosses, fungi, and small arthropods. In tree fruit crops, it is often considered as a
38 potential biological control agent (Logan et al. 2007, Maher & Logan 2007, Peusens & Gobin 2008,
39 Romeu-Dalmau et al. 2012) because it is an important predator of several fruit pests such as aphids,
40 psyllids, scale insects, lepidopteran eggs and larvae and spider mites (Gobin et al. 2008). It was
41 reported to prey on apple aphid *Aphis pomi* DeGeer, woolly apple aphid *Eriosoma lanigerum*
42 (Hausmann) (Mueller et al. 1988, Nicholas et al. 2005), rosy apple aphid *Dysaphis plantaginea*
43 (Passerini) (Dib et al. 2010, 2011), codling moth *Cydia pomonella* (L.) (Glenn 1977), pear psyllid
44 *Cacopsylla pyri* (L.) (Sauphanor et al. 1994), leafroller *Epiphyas postvittana* (Walker) (Moerkens et
45 al. 2009, Suckling et al. 2006), and different citrus aphids (Romeu-Dalmau et al. 2012).

46 However, feeding on buds, flowers, fruits and leaves, the European earwig can also cause direct
47 plant damage, reduced crop yields and aesthetic injuries (Alston & Tebeau 2011). In citrus groves,
48 it is a foe for flowers and developing fruits (Kallsen 2006, Romeu-Dalmau et al. 2012). In grapes,
49 berry contamination with earwig faeces, berry erosion and transfer of pathogens, with a subsequent
50 deterioration of grape quality, were observed in several viticultural areas in Germany (Huth et al.
51 2011). Fruit damage is particularly relevant on soft fruits such as peaches, nectarines, apricots,
52 cherries, strawberries, raspberries and blackberries, where the European earwig feeds on ripening

53 fruits and may cause shallow gouges or holes that extend deeply into the fruit (Asteggiano &
54 Vittone 2013, Caroli et al. 1993, Flint 2012, Lordan et al. 2014, Pollini 2010, Santini & Caroli
55 1992). The incidence and severity of earwig outbreaks in soft fruit orchards have recently increased
56 (Asteggiano & Vittone 2013, Lordan et al. 2014, Pollini 2010), probably due to advances in
57 integrated pest management (IPM) techniques and consequent reduction in use of broad-spectrum
58 insecticides for control of common agricultural pests (Kallsen 2006, Logan et al. 2011).
59 In Piedmont (NW Italy), fruit growers have recently reported an increased fruit damage in apricot
60 orchards, where earwigs feed on ripening fruits and make unmarketable a high percentage of the
61 production (Vittone G., personal communication). To confirm earwigs as responsible for the
62 damage, apricot branches bearing healthy fruits were isolated in white polythene net cages, and in
63 half of the cages 10 earwigs per cage were introduced and kept for a week. After insect removal,
64 fruit damage was observed only in the cages where earwigs were inserted, while no damage was
65 observed in the controls (unpublished data).
66 Earwig control by means of insecticides is extremely hard to achieve and presents important
67 challenges. Spraying as soon as earwigs migrate to the trees has little effectiveness because,
68 although they are univoltine, their migration to the trees is not simultaneous. Insecticides with a
69 long-lasting persistence would be required, but they are not consistent with IPM principles. On the
70 other hand, spraying close to harvest time would make the product unsuitable for the market due to
71 possible presence of agrochemical residues. It is therefore crucial increasing the knowledge on
72 earwig presence and abundance in apricot orchards, and testing control strategies with low
73 environmental impact that might be adopted also in organic fruit production. To this end, we
74 sampled earwig populations in apricot orchards in Piedmont and compared two arboreal glues
75 applied on the trunk as a mean to prevent earwigs from reaching and damaging fruits.

76

77 **2 Material and methods**

78 ***2.1 Field trials***

79 Earwig populations were sampled in three commercial apricot orchards located in Costigliole
80 Saluzzo, Piedmont, NW Italy in 2010 and 2011. In orchard 1 [UTM WGS84 4934460N 379094E;
81 545 m above sea level (a.s.l.), 0.163 ha], ‘Pinckot’ apricot trees were planted in 2006 with spacing
82 of 4.0×3.6 m. In orchard 2 (UTM WGS84 4934461N 379703E; 528 m a.s.l., 0.158 ha), ‘Tonda di
83 Costigliole’ apricot trees were planted in 1999 with spacing of 4.5×3.5 m. Orchard 2 was uprooted
84 by the grower in the fall of 2010, and in 2011 it was replaced with orchard 3 (UTM WGS84
85 4935557N 380196E; 456 m a.s.l., 0.346 ha), an apricot orchard with trees of cv Pinckot planted
86 with spacing of 4.3×3.5 m in 2005. In all orchards, weeds were chemically controlled only under
87 the trees, making soil tillage unnecessary. Pest control consisted of one etofenprox treatment and
88 one imidacloprid or acetamiprid treatment at the petal fall/fruit set stage, in the first half of April.
89 Since earwigs are nocturnal and readily hide in shelters during daytime, population density was
90 monitored in each orchard by means of corrugated cardboard strips (20×50 cm) as used by Helsen
91 et al. (1998), Burnip et al. (2002), and Nicholas et al. (2005). Cardboard strips were placed on the
92 lower part of the trunk (approximately 30 cm above the ground) of five randomly selected trees, one
93 strip per tree, on March 30 in 2010 and on April 4 in 2011, and checked weekly for presence of
94 earwigs until the end of harvesting (July 8 in 2010 and June 20 in 2011). During field surveys,
95 cardboard strips were replaced, and hidden individuals were collected with the help of a portable
96 vacuum cleaner. All collected individuals were preserved in 70% ethanol and transferred to the
97 laboratory for subsequent identification following description by Fontana et al. (2002).
98 In surveyed apricot orchards, we assessed the effectiveness of two arboreal glues in preventing
99 earwigs from climbing up toward tree canopy. In each orchard, three plots were marked out to
100 compare paste glue Rampastop[®] (Protecta s.a.s., Le Thor, France; treatment 1), liquid glue
101 Vebicolla[®] [Vebi Istituto Biochimico s.r.l., S. Eufemia di Borgoricco (PD), Italy; treatment 2], and
102 control (treatment 3). In the plots, treatments were randomly assigned and five trees per treatment
103 were randomly chosen within each plot for observation. Glues were applied at the end of April,
104 when the first earwigs were observed in the cardboard traps on control trees. No further glue

105 application was made. Glues were applied on the lower part of the trunk (approximately 30 cm
106 above the ground) of all trees in each plot: Vebicolla[®] was applied on plastic tape previously
107 wrapped around the tree trunk, while Rampastop[®] was spread directly on the trunk. Rampastop[®]
108 was applied also on neighbouring plants and on orchard stakes in all plots to prevent earwigs from
109 reaching the plants by climbing up on the stakes. Earwigs trapped in the glues were counted weekly
110 and removed with a small spatula, preserved in 70% ethanol, and subsequently identified to species
111 level in the laboratory. In addition, in 2011 a corrugated cardboard strip (20 × 50 cm) was placed
112 above the glue on the trunk of all treated trees in order to assess earwigs' capability to bypass the
113 glues. These strips were placed on May 24, and checked weekly for the presence of earwigs as
114 described above. At harvest, all fruits of sampled trees were checked for damage by earwigs, and
115 the number of damaged fruits was recorded. In 2010, harvest started on June 29 and July 16, and
116 finished on July 7 and July 26 (four picks) in orchard 1 and orchard 2, respectively. In 2011, harvest
117 started on June 4 and finished on June 20 (six picks) in both orchards 1 and 3. Data on local weather
118 conditions during field experiments were provided by Rete Agrometeorologica, Regione Piemonte,
119 Settore Fitosanitario (Torino, Italy).

120 **2.2 Laboratory trials**

121 In September, male and female earwigs were collected in IPM apricot orchards, and transferred to
122 the laboratory in a large container before they were used in the experiments. Cardboard boxes
123 (50 × 40 × 25 cm) were prepared as test units by standing a piece of apricot tree trunk
124 (approximately diameter 10 cm, length 30 cm) in the box, on top of which a ripe apricot was laid.
125 Three treatments were included: paste glue Rampastop[®], liquid glue Vebicolla[®], and control, with
126 four replicates per treatment. Rampastop[®] and Vebicolla[®] glues were applied on the trunks
127 following the same methodology used in field trials. Five randomly chosen earwigs were introduced
128 per test unit, and cardboard boxes were subsequently sealed with masking tape in order to avoid
129 insect escape. The use of sealed cardboard boxes allowed darkness conditions to encourage earwig

130 activity. Percentage of damaged fruits, and for treated units number of insects trapped in the glue
131 were recorded 24 and 48 hours after earwig introduction.

132 **2.3 Statistical analysis**

133 Numbers of earwigs captured in cardboard strips placed above the glues and on control trees were
134 compared using the non-parametric analysis of Kruskal-Wallis as the assumption of normality and
135 homogeneity were not met (Shapiro-Wilk test and Levene test); the means were then separated
136 using Mann-Whitney *U*-test ($P < 0.05$). Data on fruit damage were analysed by a generalized linear
137 model with a binary distribution and logit link, considering a randomised block design where each
138 fruit was a statistical unit; the blocks were represented by the two orchards. In the model the fixed
139 effects were glue (treatment), year and block, and the interaction glue * year. In case of significant
140 differences, means were separated through Bonferroni test ($P < 0.05$).

141 In the laboratory trials, after checking normality and homogeneity (Shapiro-Wilk test and Levene
142 test), numbers of insects stuck in the glue were compared using one-way ANOVA ($P < 0.05$), and in
143 case of significance means were separated using Tukey test ($P < 0.05$). The percentages of damaged
144 fruits were compared using the non-parametric analysis of Kruskal-Wallis, as the assumption of
145 homogeneity was not met (Levene test); the means were then separated using Mann-Whitney *U*-test
146 ($P < 0.05$).

147 The SPSS[®] statistical package for Windows (version 17.0; SPSS[®] Inc., Chicago, IL, USA) was used
148 for the statistical analyses.

149

150 **3 Results**

151 **3.1 Field trials**

152 In the orchards under investigation, the European earwig *F. auricularia* was the predominant
153 species, while just a few specimens of maritime earwig *Anisolabis maritima* (Bonelli)
154 (*Anisolabidae*) and of short-winged earwig *Apterygida media* (Hagenbach) were recorded. Earwig
155 populations were mainly composed of nymphs until mid-June, and then adults increased. Seasonal

156 abundance of earwigs was variable in the three orchards. In orchard 1, in both years earwig nymphs
157 were first observed at the end of April and nymph abundance peaked in mid-June. Adults appeared
158 in mid-June in 2010 and at the end of May in 2011, and their abundance reached 83.7 adults trap⁻¹
159 on July 8 in 2010, and 60.6 adults trap⁻¹ on June 20 in 2011 (Figs. 1, 2). In orchard 2 in 2010,
160 earwigs were first observed at the end of April. Nymph abundance peaked on June 3 with 266.3
161 nymphs trap⁻¹, and adult abundance peaked on June 24 with 201.5 adults trap⁻¹ (Fig. 1). In orchard 3
162 in 2011, earwigs were found starting from early May. Nymph abundance peaked on May 16 with
163 17.8 nymphs trap⁻¹, and adult abundance peaked on June 20 with 13.8 adults trap⁻¹ (Fig. 2). [Figures
164 1 and 2 near here]

165 Earwig captures on Vebicolla[®] and Rampastop[®] glues were very low. Mean number of earwigs
166 stuck in the glue was higher than 2 only on Rampastop[®] on June 18 and on Vebicolla[®] on July 1 in
167 orchard 2 in 2010, and on Rampastop[®] on June 6 in orchard 3 in 2011. The number of earwigs
168 captured in the cardboard traps placed above the glues in 2011 was also very low. Maximum
169 densities of earwigs trap⁻¹ were 2.8 for Rampastop[®] and 13.6 for Vebicolla[®] in orchard 1, and 0.2
170 for Rampastop[®] and 4.6 for Vebicolla[®] in orchard 3 (Table 1). The number of earwigs captured in
171 the cardboard traps was significantly higher in control trees than in treated trees on May 31
172 (Kruskal-Wallis analysis: df = 2, chi-square = 10.789, P = 0.005), on June 6 (Kruskal-Wallis
173 analysis: df = 2, chi-square = 12.133, P = 0.002), and on June 13 (Kruskal-Wallis analysis: df = 2,
174 chi-square = 10.556, P = 0.005) in orchard 1. In orchard 3, the number of specimens captured on
175 control trees was significantly greater than that recorded on trees with glues on May 31 (Kruskal-
176 Wallis analysis: df = 2, chi-square = 11.0765, P = 0.004), and on June 6 (Kruskal-Wallis analysis:
177 df = 2, chi-square = 11.024, P = 0.004). [Table 1 near here]

178 In order to assess fruit damage, in 2010 8,419 and 16,951 fruits were checked in orchard 1 and
179 orchard 2, respectively, while in 2011 2,039 and 2,981 fruits were checked in orchard 1 and orchard
180 3, respectively. Significant differences were found between treatments, years and blocks (glue:
181 Wald $\chi^2 = 360.755$, P < 0.01; year: Wald $\chi^2 = 4.195$, P = 0.041; block: Wald $\chi^2 = 485.845$, P < 0.01;

182 glue*year: Wald $\chi^2 = 63.658$, $P < 0.01$) (Fig. 3). Percentage of fruit damage was significantly higher
183 in the control than in treatments in both years. Moreover, both glues were significantly more
184 effective in damage reduction in 2011 than in 2010, and overall Rampastop® proved to be the most
185 efficient control method. [Figure 3 near here]

186 **3.2 Laboratory trials**

187 At the first inspection 24 hours after earwig introduction, percentages of individuals trapped on the
188 glue were 15% on Rampastop® and 5% on Vebicolla®, with no significant differences between
189 treatments (ANOVA: $df = 1, 6$, $F = 0.857$, $P = 0.390$). At the second inspection 48 hours after insect
190 introduction, the rate of individuals glued on Rampastop® increased to 50%, whereas the percentage
191 of individuals glued on Vebicolla® did not change (ANOVA: $df = 1, 6$, $F = 13.714$, $P = 0.010$).
192 Percentage of damaged fruits was null for Rampastop® and Vebicolla®, while it reached 75% in the
193 control (Kruskal-Wallis analysis: $df = 2$, $\text{chi-square} = 7.333$, $P = 0.026$) (Table 2). In the control all
194 individuals were alive at both inspections. [Table 2 near here]

195

196 **4 Discussion**

197 Surveys by means of cardboard traps demonstrated that *F. auricularia* is the predominant earwig
198 species in apricot orchards in Piedmont and represents a serious treat for fruit farming. *Forficula*
199 *auricularia* is a univoltine species even though some females can produce two broods, as was
200 observed in southern France and Belgium (Guillet et al. 2000, Moerkens et al. 2009). In this case, a
201 small number of females produce a second clutch in early summer of the same year, and during
202 summer adults of the first brood coexist with nymphs of the second brood. Our sampling data lead
203 us to suppose that the population living in the study area exhibits only one brood, since the
204 appearance of adults corresponded with a progressive decrease of juvenile stages at the end of
205 spring. Nonetheless, further sampling throughout the whole season is required to confirm this
206 hypothesis.

207 In the present study, earwig density was highly variable throughout years and orchards. In 2010, the
208 great difference in population levels in orchards 1 and 2 could be explained by the presence of two
209 different cultivars in these orchards. ‘Tonda di Costigliole’ in orchard 2 is an old, local variety
210 characterised by late yield and by fruits with a very intense aroma and a juicy pulp (Valentini et al.
211 2004). As reported by local growers, these qualities could make it more luring for *F. auricularia*,
212 justifying the high number of insects collected on the cardboard traps placed on the trunks of these
213 plants. On the other hand, different earwig abundance recorded in 2011 could be due to the different
214 altitudinal location of the two orchards, with orchard 1 characterised by a lower temperature range
215 (data not shown) and thus probably more favourable to earwig population. The relationship between
216 *F. auricularia* biological cycle and temperature has already been highlighted, and allowed the
217 development of day degree models to predict the phenology of earwig populations (Helsen et al.
218 1998, Moerkens et al. 2011).

219 The application of arboreal glues on tree trunk proved to be effective for earwig control and
220 determined a significant reduction in fruit damage. The very low number of *F. auricularia* captured
221 in the cardboard traps placed above the glues compared with captures obtained on control trees
222 proved the effectiveness of glues as physical barriers to prevent earwigs from climbing up the
223 trunks and reaching ripening fruits. In particular, Rampastop[®] was the most successful one on trees
224 with a very rough and cracked bark (orchard 3), since in this case the plastic tape spread with
225 Vebicolla[®] could not completely adhere to the trunk. These positive results were also confirmed by
226 laboratory trials.

227 The positive effect of the glues in reducing fruit damage was notably evident in 2011, but less in
228 2010. In 2010, ‘Tonda di Costigliole’ apricot trees (orchard 2) showed a very low percentage of
229 damaged fruits also on untreated plants, despite a very high earwig population density. It is
230 probable that the fruits are very luring for *F. auricularia*, attracting a huge number of insects on the
231 trunks, but maybe the texture is not appreciated. These results demonstrate also that a high earwig

232 population density in the orchard does not always correspond to a high rate of fruit damage, and that
233 different cultivars can show different suitability for *F. auricularia*.

234 Despite the high number of earwigs captured in the cardboard traps on control trees, the number of
235 earwigs trapped on the glues was always very low regardless of apricot cultivar. Moreover, no other
236 insects were observed trapped on the glues, except for some flies. This suggests that glues could
237 have a repellent action against insects, even if this was only partially confirmed by results obtained
238 in laboratory trials, where more than 40% of the individuals were stuck on Rampastop[®]. However,
239 laboratory trials imply artificial conditions and little space for earwigs to move in, factors that might
240 have partially affected the insects' behaviour.

241 The use of glues should be harmless to the agro-ecosystem and safe for beneficial insects. However,
242 further research is needed to ascertain the impact of glues on beneficial arthropods. Previous studies
243 demonstrated that glue rings could also exclude ants from the trees, in particular aphid-tending ants.
244 As a consequence, higher predator densities and lower aphid densities can be observed (Miñarro et
245 al. 2010, Stutz & Entling 2011), while in other cases aphid abundance increases due to the
246 concurrent exclusion of earwigs (Piñol et al. 2009). The present study was not aimed at assessing
247 the effect of glues on ant populations, and ant abundance in sampled orchards was unremarkable.
248 Nonetheless, during field surveys no ants were recorded on the glues. The possible increase of
249 aphid populations due to earwig exclusion, as observed in citrus and apple orchards (Mueller et al.
250 1988, Nicholas et al. 2005, Romeu-Dalmau et al. 2012), is worthy of further investigations.

251 Anyway, in all the cases in which earwig populations are so high to cause significant damage to the
252 fruits, and other control strategies are not advisable (e.g., chemical treatments close to harvest time),
253 the use of arboreal glues offers more pros than cons.

254 The presence, even if small, of earwigs in cardboard traps above the glues suggests that the
255 European earwig adults can somehow bypass the glue. According to the literature, *F. auricularia*
256 rarely flies even though it has completely developed wings (Fontana et al. 2002). Empirical remarks
257 indicated that a small number of individuals was able to reach the canopy of isolated apricot trees

258 with a very large band of Rampastop[®] glue on the trunk (authors' unpublished data), suggesting that
259 earwigs might eventually move by flying, when no other possibility is available. In the presence of
260 large earwig populations, the application of glue on the trunk might therefore not be sufficient to
261 completely prevent fruit damage and should be complemented with other techniques. According to
262 some studies, earwig population density can be reduced with proper orchard management practices
263 such as soil tillage, which negatively affects earwigs during their nesting phase (Moerkens et al.
264 2011, 2012, Sharley et al. 2008). Combining soil tillage at earwig nesting phase and application of
265 glue barriers on tree trunk at time of earwig migration to the tree could help in reducing fruit
266 damage by earwigs without the use of insecticides, thus avoiding the negative side-effects spray
267 applications might have on beneficial insects present in the orchard, such as bees and hoverflies.

268

269 **Acknowledgments**

270 The authors would like to thank the fruit growers Cristian Occelli, Felice Gozzarino, and Giovanni
271 Bonetto for permission to conduct field research in their orchards. We thank Prof. Dario Sacco
272 (DISAFA, University of Torino) for his support in statistical analyses. This research was supported
273 by grants from Regione Piemonte – Assessorato Agricoltura.

274

275 **References**

276 Alston DG, Tebeau A. 2011. European Earwig (*Forficula auricularia*). UTAH Pests Fact Sheets
277 ENT-145-1. (<http://extension.usu.edu/files/publications/factsheet/earwig-tf.pdf>) (Accessed May 18,
278 2015).

279

280 Asteggiano L, Vittone G. 2013. Albicocche e nettarine, come contenere i danni delle forficule.
281 Frutticoltura 6:60-61.

282

283 Burnip GM, Daly JM, Hackett JK, Suckling DM. 2002. European earwig phenology and effect of
284 understorey management on population estimation. *N. Z. Plant Protect.* 55:390-395.
285

286 Caroli L, Perri F, Santini L. 1993. Defoliazioni da *Forficula auricularia* L. su agrumi e drupacee.
287 *Inftore Fitopatol.* 43:19-23.
288

289 Dib H, Simon S, Sauphanor B, Capowiez Y. 2010. The role of natural enemies on the population
290 dynamics of the rosy apple aphid, *Dysaphis plantaginea* Passerini (Hemiptera: Aphididae) in
291 organic apple orchards in south-eastern France. *Biological Control* 55:97-109.
292

293 Dib H, Jamont M, Sauphanor B, Capowiez Y. 2011. Predation potency and intraguild interactions
294 between generalist (*Forficula auricularia*) and specialist (*Episyrphus balteatus*) predators of the
295 rosy apple aphid (*Dysaphis plantaginea*). *Biological Control* 59:90-97.
296

297 Flint ML. 2012. Earwigs. University of California Statewide, Integrated Pest Management Program,
298 Agriculture and Natural Resources. Pest Notes, Publication 74102
299 (<http://www.ipm.ucdavis.edu/PDF/PESTNOTES/pnearwigs.pdf>) (Accessed May 13, 2015).
300

301 Fontana P, Buzzetti FM, Cogo A, Odé B. 2002. Guida al riconoscimento e allo studio di cavallette,
302 grilli, mantidi e insetti affini del Veneto: Blattaria, Mantodea, Isoptera, Orthoptera, Phasmatodea,
303 Dermaptera, Embiidina. Vicenza (Italy): Museo Naturalistico Archeologico di Vicenza.
304

305 Glenn DM. 1977. Predation of codling moth eggs, *Cydia pomonella*, the predators responsible and
306 their alternative prey. *J. Appl. Ecology* 14:445-456.
307

308 Gobin B, Moerkens R, Leirs H, Peusens G. 2008. Earwigs in fruit orchards: phenology predicts
309 predation effect and vulnerability to side-effects of orchard management. IOBC/WPRS Bull. 35:35-
310 39.

311

312 Guillet S, Guiller A, Deunff J, Vancassel M. 2000. Analysis of a contact zone in the *Forficula*
313 *auricularia* L. (Dermaptera: Forficulidae) species complex in the Pyrenean Mountains. Heredity
314 85:444-449.

315

316 Helsen H, Vaal F, Blommers L. 1998. Phenology of the common earwig *Forficula auricularia* L.
317 (Dermapetra: Foficulidae) in an apple orchard. Int. J. Pest Manag. 44:75-79.

318

319 Huth C, Schirra KJ, Seitz A, Louis F. 2011. A beneficial species becomes a pest-the common
320 earwig *Forficula auricularia* (Linnaeus 1758). IOBC/WPRS Bull. 67:249-256.

321

322 Kallsen C. 2006. Earwigs Flying Under the Radar of Many Citrus Pest Control Advisors. Topics in
323 Subtropics Newsletter 4:3-4.

324

325 Logan DP, Maher BJ, Connolly P. 2011. Increased numbers of earwigs (*Forficula auricularia*) in
326 kiwifruit orchards are associated with fewer broad-spectrum sprays. N Z Plant Prot 64:49-54.

327

328 Logan DP, Maher BJ, Connolly PG, Pettigrew MJ. 2007. Effect of cardboard shelter traps on
329 predation of diaspidid scale insects by European earwigs, *Forficula auricularia*, in kiwifruit. N. Z.
330 Plant Protect. 60:241-248.

331

332 Lordan J, Alegre S, Blanco R, Sarasúa MJ, Alins G. 2014. Aggregation behavior in the European
333 earwig: Response to impregnated shelters. Crop Prot. 65:71-76.

334

335 Maher BJ, Logan DP. 2007. European earwigs, *Forficula auricularia*, and predation of scale insects
336 in organic and conventionally managed kiwifruit. N. Z. Plant Protect. 60:249-253.

337

338 Miñarro M, Fernández-Mata G, Medina P. 2010. Role of ants in structuring the aphid community
339 on apple. Ecological Entomology 35:206-215.

340

341 Moerkens R, Leirs H, Peusens G, Gobin B. 2009. Are populations of European earwig, *Forficula*
342 *auricularia*, density dependent? Entomol. Exp. Appl. 130:198-206.

343

344 Moerkens R, Gobin B, Peusens G, Helsent H, Hilton R, Dib H, Suckling DM, Leirs H. 2011.
345 Optimizing biocontrol using phenological day degree models: the European earwig in pipfruit
346 orchards. Agric. Forest. Entomol. 13:301-312.

347

348 Moerkens R, Leirs H, Peusens G, Belien T, Gobin B. 2012. Natural and human causes of earwig
349 mortality during winter: temperature, parasitoids and soil tillage. J. Appl. Entomol. 136:490-500.

350

351 Mueller TF, Blommers LHM, Mols PJM. 1988. Earwig (*Forficula auricularia*) predation on the
352 woolly apple aphid, *Eriosoma lanigerum*. Entomol. Exp. Appl. 47:145-152.

353

354 Nicholas AH, Spooner-Hart RN, Vickers RA. 2005. Abundance and natural control of the woolly
355 aphid *Eriosoma lanigerum* in an Australian apple orchard IPM program. BioControl 50:271-291.

356

357 Peusens G, Gobin B. 2008. Side effects of pesticides on the European earwig *Forficula auricularia*
358 L. (Dermaptera: Forficulidae). IOBC/WPRS Bull. 35:40-43.

359

360 Piñol J, Espadaler X, Cañellas N, Pérez N. 2009. Effects of the concurrent exclusion of ants and
361 earwigs on aphid abundance in an organic citrus grove. *BioControl* 54:515-527.
362

363 Pollini A. 2010. La forbicetta è comunissima e danneggia talvolta i frutti prossimi alla raccolta. *Inf.*
364 *Agrar.* 10:31.
365

366 Romeu-Dalmau C, Piñol J, Espadaler X. 2012. Friend or foe? The role of earwigs in a
367 Mediterranean organic citrus orchard. *Biological Control* 63:143-149.
368

369 Santini L, Caroli L. 1992. Danni ai fruttiferi da forficola comune (*Forficula auricularia* L.). *Inftore*
370 *Fitopatol.* 42:35-38.
371

372 Sauphanor B, Lenfant C, Brunet E, Faivre D'Arcier F, Lyoussoufi A, Rieux R. 1994. Regulation
373 des population de psylle de poirier, *Cacopsylla pyri* (L.) par un predateur generaliste, *Forficula*
374 *auricularia* L. *IOBC/WPRS Bull.* 17 (2):125-131.
375

376 Sharley DJ, Hoffmann AA, Thomson LJ. 2008. The effects of soil tillage on beneficial invertebrates
377 within the vineyard. *Agric. Forest Entomol.* 10:233-243.
378

379 Stutz S, Entling MH. 2011. Effects of the landscape context on aphid-ant-predator interactions on
380 cherry trees. *Biological Control* 57:37-43.
381

382 Suckling DM, Burnip GM, Hackett J, Daly JC. 2006. Frass sampling and baiting indicate European
383 earwig (*Forficula auricularia*) foraging in orchards. *J. Appl. Entomol.* 130:263-267.
384

- 385 Valentini N, Aigotti R, Botta R, Zeppa G, Mellano MG. 2004. Tonda di Costigliole: dal Piemonte
386 l'albicocca più tardiva. Rivista di frutticoltura e di ortofloricoltura 66 (9):60-63.
387

388 **Table captions**

389

390 Table 1 – Total number and percentage of adults of European earwigs collected in corrugated
391 cardboard traps placed on the trunks above Rampastop® and Vebicolla® glues and on control trees
392 in two apricot orchards in 2011. In the rows, means per cardboard trap followed by different letters
393 are significantly different (Mann-Whitney *U*-test, $P < 0.05$).

394

395 Table 2 – Percentage of damaged fruits and insects stuck on Rampastop® and Vebicolla® glues in
396 laboratory trials. In the columns, means followed by different letters are significantly different
397 (damaged fruit, Mann-Whitney *U*-test, $P < 0.05$; insects on glue, Tukey test, $P < 0.05$).

398

399 **Figure captions**

400

401 Fig. 1 – Nymphs and adults *Forficula auricularia* (mean number \pm SE) collected in corrugated
402 cardboard traps (control trees) in apricot orchards 1 (a) and 2 (b) in 2010.

403

404 Fig. 2 – Nymphs and adults *Forficula auricularia* (mean number \pm SE) collected in corrugated
405 cardboard traps (control trees) in apricot orchards 1(a) and 3 (b) in 2011.

406

407 Fig. 3 – Logit of apricots damaged by European earwig at harvest in the orchards surveyed in 2010
408 and 2011, predicted by Generalized Linear Model (glue: Wald $\chi^2 = 360.755$, $P < 0.01$; year: Wald χ^2
409 = 4.195, $P = 0.041$; glue*year: Wald $\chi^2 = 63.658$, $P < 0.01$). Data marked by different letters are
410 significantly different (Bonferroni test, $P < 0.05$).

411

Date	Corrugated cardboard on untreated plants		Corrugated cardboard placed above			
			Rampastop [®]		Vebicolla [®]	
	Total±SE	% adults	Total±SE	% adults	Total±SE	% adults
Orchard 1						
31May	13.4±3.4 a	1.5	0.2±0.2 b	100.0	1.2±0.6 b	16.7
06June	44.0±1.7 a	1.8	0.0±0.0 b	0.0	3.8±1.9 c	42.1
13June	70.8±1.9 a	6.5	0.4±0.4 b	100.0	4.0±3.8 b	85.0
20June	68.8±11.6 a	88.1	2.8±1.4 a	100.0	13.6±8.4 a	100.0
Orchard 3						
31May	6.8±1.9 a	41.2	0.2±0.2 b	100.0	0.2±0.2 b	100.0
06June	8.8±1.7 a	95.4	0.0±0.0 b	0.0	0.7±0.3 b	97.8
13June	2.0±1.9 a	100.0	0.0±0.0 a	0.0	0.6±0.4 a	100.0
20June	13.8±11.6 a	100.0	0.2±0.2 a	100.0	4.6±2.5 a	100.0

412

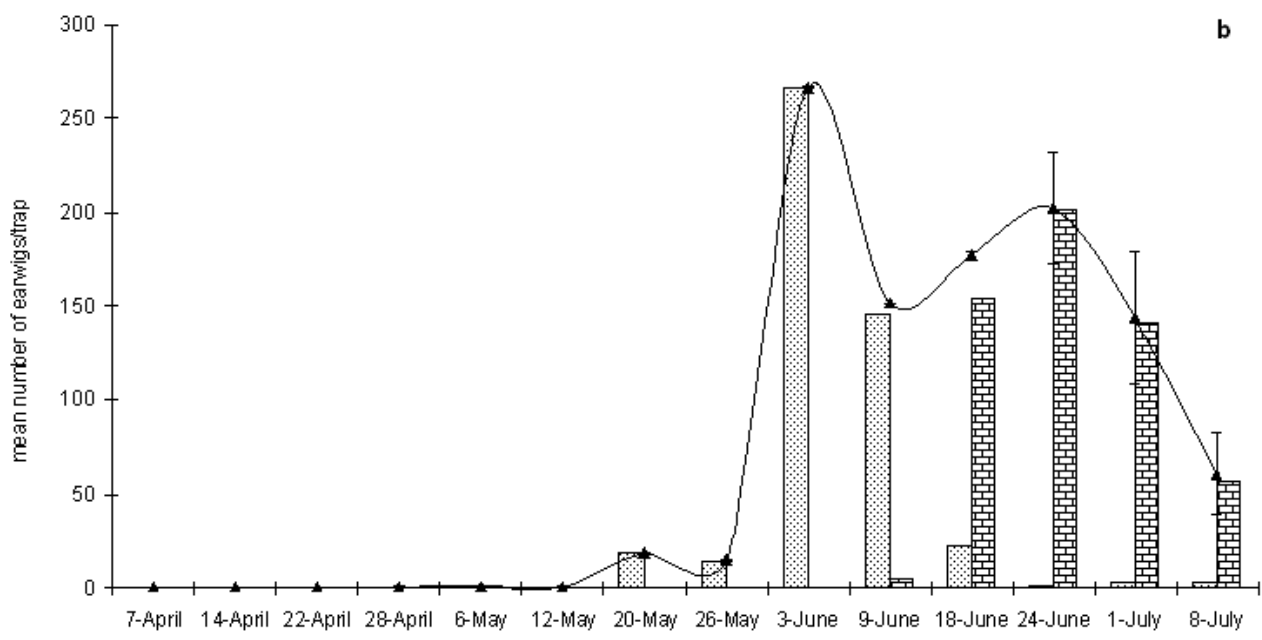
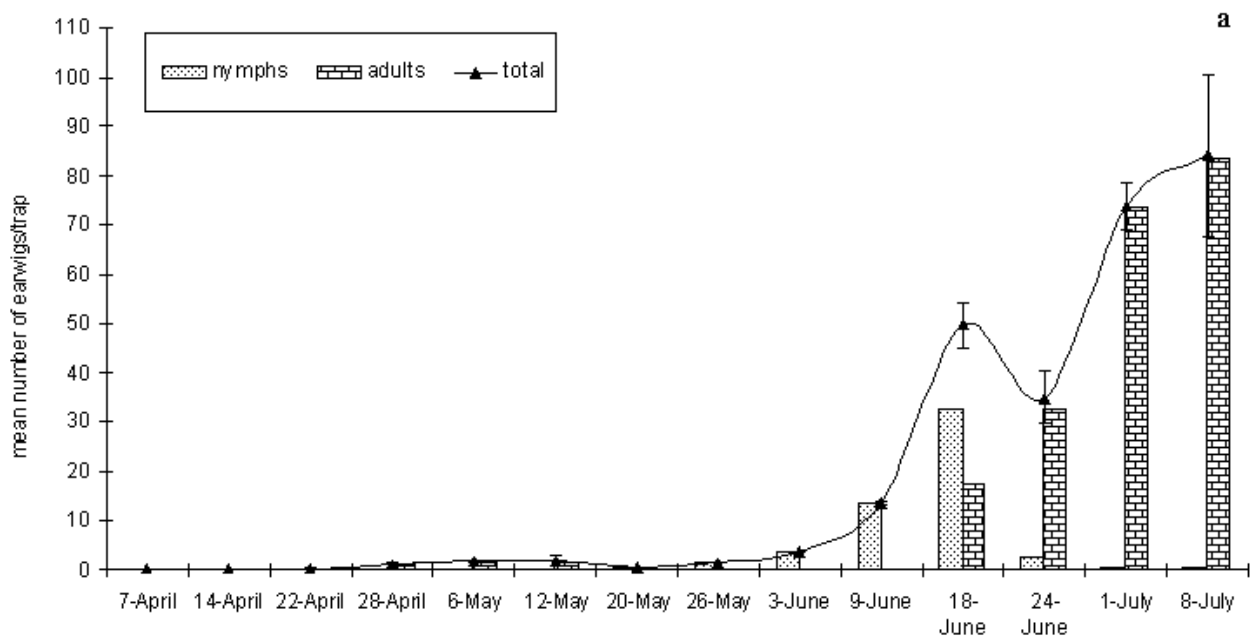
413 Saladini *et al.*, Table 1.

414

Treatments	Insects on glue (%)±SE		Damaged fruits (%)±SE	
	After 24 h	After 48 h	After 24 h	After 48 h
Rampastop [®]	15±0.5 a	50±0.5 a	0 a	0 b
Vebicolla [®]	5±0.2 a	5±0.2 b	0 a	0 b
Control	-	-	0 a	75±0.2 a

415

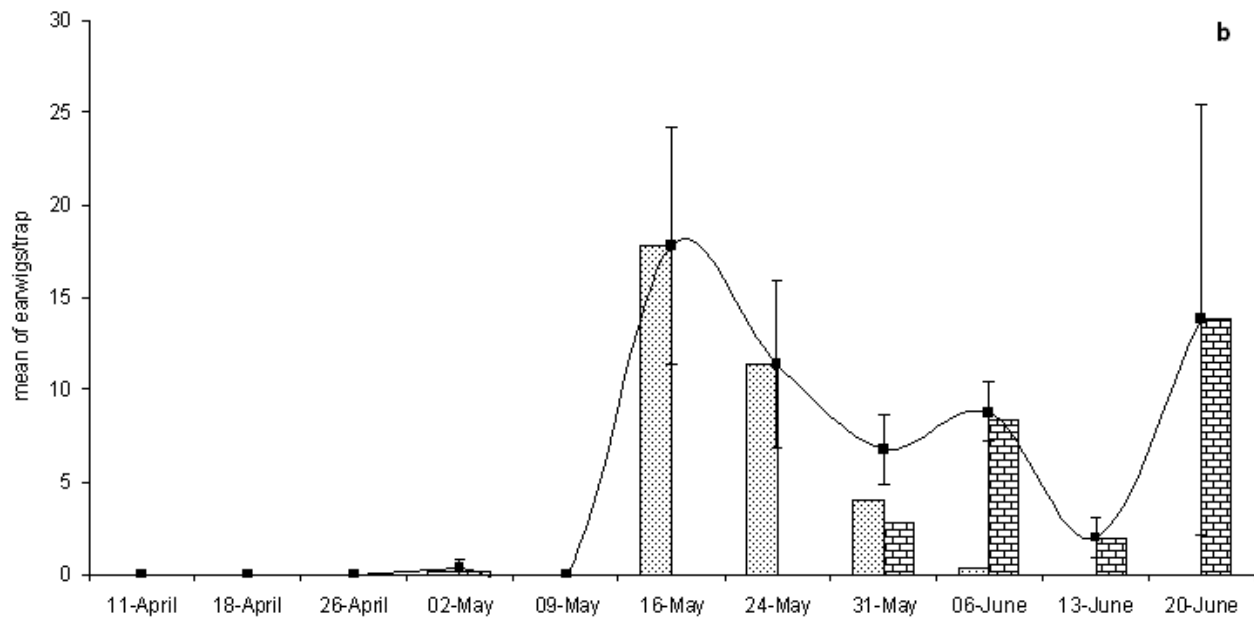
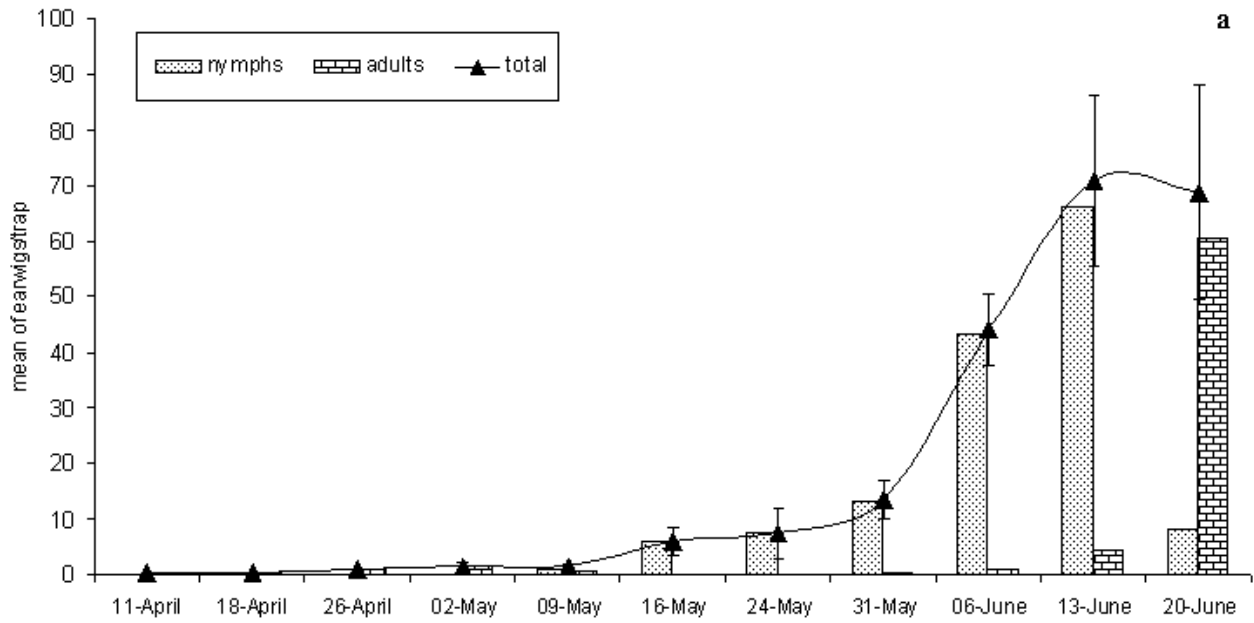
416 Saladini *et al.*, Table 2.



417

418 Saladini *et al.*, Figure 1.

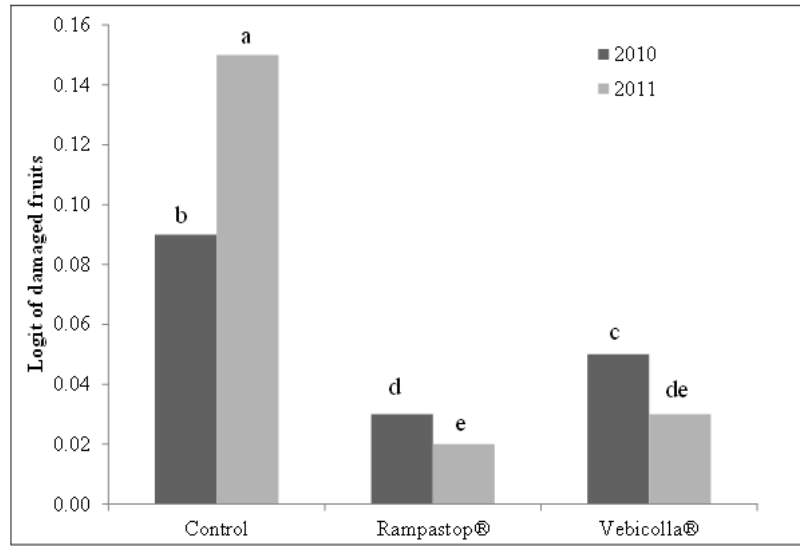
419



420

421 Saladini *et al.*, Figure 2.

422



423

424 Saladini *et al.*, Figure 3.

425