Control of the woolly apple aphid (*Erisoma lanigerum* Hausm.) by releasing earwigs (*Forficula auricularia L.*) and support oil applications

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Abstract

In order to develop an on-farm strategy to control the woolly apple aphid (Eriosoma lanigerum Hausm.) in organic orchards a research project funded by the German Federal Agency for Agriculture and Food was conducted from 2007 to 2009 in cooperation with different research facilities in Germany. The focus was directed at the release and encouragement of the common earwig (Forficula auricularia L.) and support oil applications to control the woolly apple aphid. Additional trials were conducted to determine the pollution of apples by earwigs´ faeces and the influence of mechanical soil management to the wintering earwigs. The release of earwigs alone proved to be insufficient to control a high infestation of woolly apple aphid in case of emergency. A combination of long term encouragement of earwigs and an oil application (brushing or spraying) in early spring in infested orchards looks like a promising strategy to keep the woolly apple aphid infestation at reasonable levels where the biological regulation by all natural predators including Aphelinus mali and earwigs can work.

Key words: woolly apple aphid *(Erisoma lanigerum* Hausm.) – earwig (*Forficula auricularia L.)* – oil application

Introduction

The woolly apple aphid *(Eriosoma lanigerum* Hausm.) is still an unsolved problem in organic fruit growing. Several experiments trying to regulate the woolly apple aphid with the parasite *Aphelinus mali* Hald. were performed in recent years but supplied no satisfying results for a practical fruit growing strategy (Hetebrügge et al. 2006). Kelderer et al. (2008) described effective applications with lime sulphur and mineral oil but used application rates which have no registration in Germany.

The common earwig (*Forficula auricularia*) is a nocturnal omnivore feeding on animals and plant materials and is an important natural antagonist of the woolly apple aphid. Gobin et al. (2008) describe a negative correlation between degree of aphid infestation and the number of earwigs present in the trees in Belgian orchards. Helsen et al. (2007) describe the same for Dutch orchards. Earwigs climb the trees from the third nymph stage onwards at the end of May/beginning of June. By then the population of woolly apple aphid may have reached high infestation levels.

Earwigs hide in artificial refuges during daytime. In autumn lots of earwigs can be found in the clusters between the ripening apples, where they may contaminate the fruit with

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faeces. Earwigs are known to feed on fruit too, but the mandibles of earwigs are not strong enough to break through the intact apple skin, so they cause only secondary feed damage on spots where the skin has already been damaged (LOHRER 2008, LAHUSEN ET AL. 2006).

Earwigs winter in underground nests where the females lay their eggs in late winter or early spring and raise the brood until second nymph stage. A mechanical soil management is common in organic orchards and earwigs may be disrupted by the soil treatment while hiding underground.

The project was funded for three years (2007-2009) by the Federal Agency for Agriculture and Food (Bundesanstalt für Landwirtschaft und Ernährung, BLE) within the "Bundesprogramm ökologischer Landbau" (Project Number: 06OE325).

The trials have been established in cooperation with several partners: At the "DLR Rheinpfalz, Kompetenzzentrum für Gartenbau" in Ahrweiler, at the "Kompetenzzentrum Ökoobstbau Niedersachsen" (KÖN) in cooperation with the "Ökoobstbau Norddeutschland Versuchs-und Beratungsring e.V."(ÖON) in Jork, and at the "Kompetenzzentrum Obstbau Bodensee" (KOB). Additionally round-robin tests in practical growing situations were run under coordination of the "Beratungsdienst Ökologischer Obstbau". The health states of the earwigs from all sites were examined in the laboratory of the "Julius-Kühn-Institut" (JKI) in Darmstadt.

We want to show selected field trial results.

Material and Methods

Different field trials have been made during the last three years in different orchard in three apple growing regions of Germany (Lake Constance region, 'Altes Land', West Germany). On focus were oil applications by brush and by spraying in combination with a releasing of earwigs, respectively, to control the woolly apple aphid.

The oil applications serve to keep infestations at moderate levels until the earwigs appear in the trees. In 2009 within an on-farm field trial the oil application by brush has been tested with different application rates in an orchard with 'Jonagold' (for details see Tab. 1). The treatments were repeated four times in plots with six trees each plot (assessment on four trees per repeating; 16 trees per treatment). A brush whose bristles were cut in half to exploit also the mechanical effect was used to apply the oils. We used the mineral oil product 'Promanal Neu'. To offer attractive hideouts for the earwigs to outlast the day bamboo tubes were left in the trees throughout the summer and were used to estimate the population monthly by counting the individuals in the hideouts. The hideouts consist of three about 20-30cm long bamboo tubes which where bound together and placed vertically (opening down) near to the trunk. These hideouts proved to be very attractive for the earwigs in vineyards where they showed the highest catching rate in a comparison between different trap types (Huth et al. 2009). The infestation with woolly apple aphid colonies has also been determined monthly by investigating the infestation in area [cm²] per tree.

Table 1: Treatment details, field trial, Ahrweiler, 2010

treatment	application rate	application date
untreated control		
brushing 2%	Promanal 2%	21st April
brushing 20%	Promanal 20%	21st April
brushing undiluted	Promanal undiluted	21st April
brushing + earwigs	Promanal undiluted + 50 earwigs per tree	21st April

To examine possible damage to the trees, two oil products were tested for their phytotoxicity potential by undiluted brushing. 'Para Sommer' and 'Promanal Neu' were applied by brush in comparison to a brushing only with water on trunk spots, on pruning cuts and on compound spurs. The phytotoxicity was rated on a scale from zero (no damage) to three (intense damage).

Shortly before harvest the apples from the different testing plots were tested for pollution by earwig's faeces to detect possible economic damage caused by the released earwigs in the orchards. Therefore the apples from selected trees in the testing plot were counted and the amount of polluted apples was documented.

To determine a possible influence of the mechanical soil management to the wintering earwigs a field trial was set up in an organic orchard in Western Germany. Therefore one row of apples was covered with 'Maypex'-foil whereas the neighbouring row was left uncovered and treated with standard soil management. In each tree a roll of corrugated board was placed to observe the earwig population density during the season. The trial was started in 2008 and repeated in 2009.

Results and Discussion

Results show that the efficacy of released earwigs was hardly determinable and depended on the prior infestation intensities. We observe a migration of the earwigs to high infested trees and therefore spread out into untreated plots so that the influence is dispersed. The migration by earwigs was also described by Bloksma and Wijnen (1991). When the earwigs appear in the trees lots of other beneficial organisms can be found like ladybeetles (Coccinellidae) and their larvae as well as larvae of hover flies (Syrphidae) and green lacewings (Chrysopidae) which all feed on woolly apple aphid and seem to obscure the earwigs` feed influence.

The trials included comparisons between oil application by brush and by spraying in combination with earwig release, respectively. The brushing was made in April when the first woolly colonies can be found in the orchards. For better efficacies the spraying must be accomplished before the aphids start to produce their woolly cover. At high infestation levels the oil application by brush proved to be much more effective but is time consuming. The efficacies for 2 per-cent spraying were highly variable (data not shown). At low infestation levels an oil application in April before the aphid starts to produce their woolly covers seems to limit the development of the aphids. However at higher infestation levels a spraying seems to have no influence on the populations´ development.

The undiluted brushing has no registration in Germany, even though the application rate per ha for the brushing does not exceed the application rate which is aloud for spraying. Therefore in 2009 we ran a trial comparing different application rates for the brushing with 'Promanal Neu' including a two per-cent test variant which is the registered application rate for spraying. The brushing with a two per-cent and 20 per-cent emulsion showed efficacies around 50% (Henderson & Tilton). The brushing with undiluted oil showed efficacies around 80% (Henderson & Tilton) and therefore proved to be much better (Fig. 1,

efficacies computed for the 15th of July, where infestation reached maximum levels considering the infestation on the 21st of April before treatment). In this case an additional release of earwigs does not improve the efficacy of undiluted oil brushing significantly.

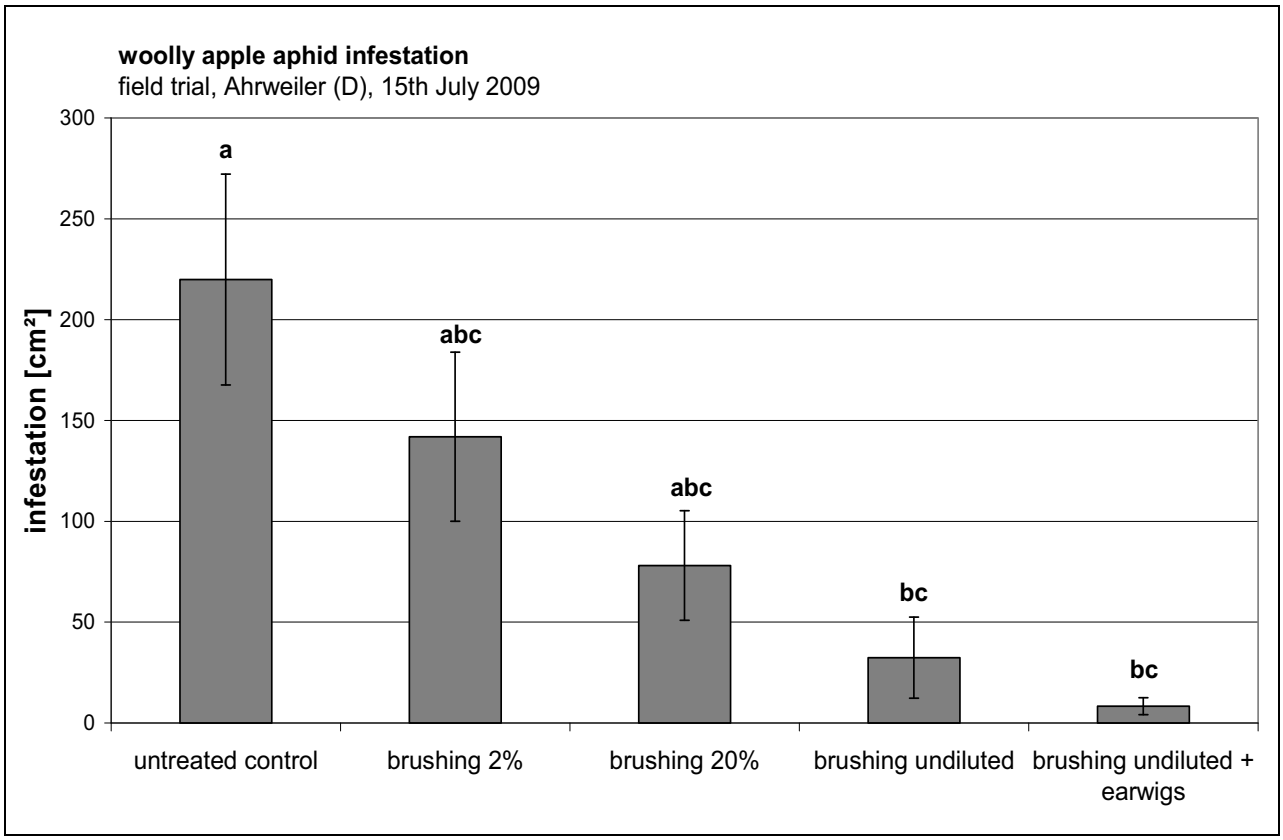

Fig. 1: field trial results 2009, comparison between different application rates for the brushing of 'Promanal Neu', infestation at 15th July (maximum infestation level), (Statistik: Welch-test, Tamhane post hoc, p=0,05, pillars with standard error)

An oil application by brush directly onto aphid colonies sitting on the trunk and on pruning cuts caused only low levelled damage which was mostly due to oil which drops onto shoots. An oil application onto compound spurs caused intense damage to shoots (Fig. 2). We found only slight differences between the four varieties we have tested ('Jonagold', 'Golden Delicious', 'Elstar', 'Cox Orange'). 'Jonagold' seems to be a little bit less sensitive then the other varieties. Comparing the two oil products 'Promanal Neu' proved to be a little bit more aggressive than 'Para Sommer'. Spots on the trunk and pruning cuts are usually the first spots where the woolly apple aphid can be found in spring. Applying oil by brush on these spots causes only damage if too much oil drops onto shoots. Therefore a careful oil application is effective and causes hardly any shooting damage.

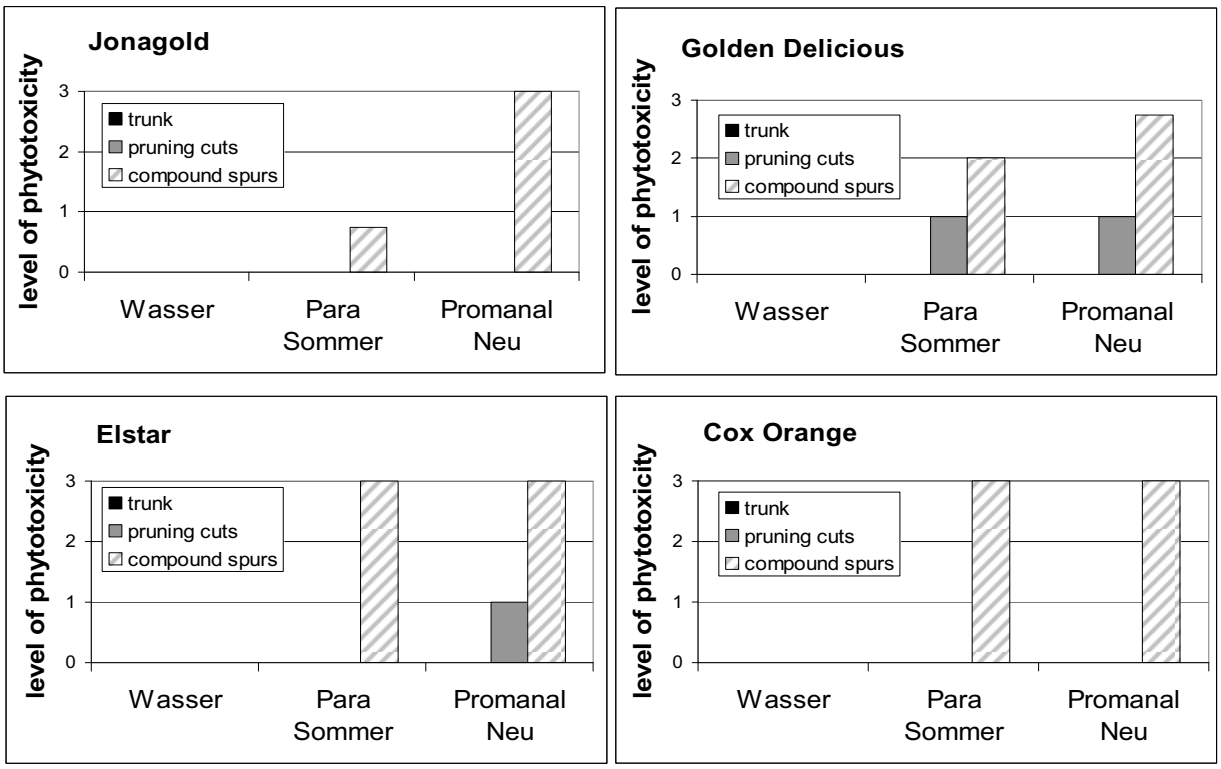

Fig. 2: phytotoxicity of two oil products applicated by brush on different spots of the tree, field test 2007, Lake Constance region (D) (0 = no damage, 3 = intense damage)

Pollution with faeces depends on variety (short or long stemmed), thinning and earwig population density. If apples build tight clusters, because of no thinning and short stems, always more earwigs can be found between the apples and therefore pollution is higher. In our field trials the pollution was slightly higher in testing plots where we released earwigs. But we also observe a migration of earwigs between testing plots especially into trees with high woolly apple aphid infestation density. The average pollution rate remained in most cases below 10% (Table 2) and caused no commercial damage due to contamination. The faeces were in most cases dry and fall of while picking. Even the high pollution rate of 24% in the testing plot with 'Holsteiner Cox' ('Altes Land') caused no commercial damage.

Table 2: averaged apples polluted by earwig faeces in different testing plots

variety/testing site/year of trial	polluted apples [%] (earwig released in testing plots)	polluted apples [%] (no earwigs released in testing plots)
Jonagold/Ahrweiler/2007-09	7,5	5,6
Holsteiner Cox/'Altes Land'/2007	24,2	7,9
Elstar/'Altes Land'/2009	9,3	7,3
Braeburn/Lake Constance region/2007	1,25	1,1

The trial to determine possible influence of the mechanical soil management showed no significant differences between the population density of the mechanical treated plot and the foil covered plot (Fig. 3). There was no high population density in the testing plots of the orchard and it even decreased in the second year of the trial which we are not yet able to explain. Huth et al. (2009) found in their monitoring a significant difference between the individual amount of earwigs in grassed alleyways and alleyways without vegetation (regularly soil management) in vineyards. Furthermore 78% of the earwig's nests were found at the base of plant roots mainly of dandelion (*Taraxacum officinale*), grass varieties

etc. Because of these results we figure that earwigs in organic orchards build their nests and winter in the vegetation covered alleyways or build them below soil treatment depth to avoid the mechanical soil management.

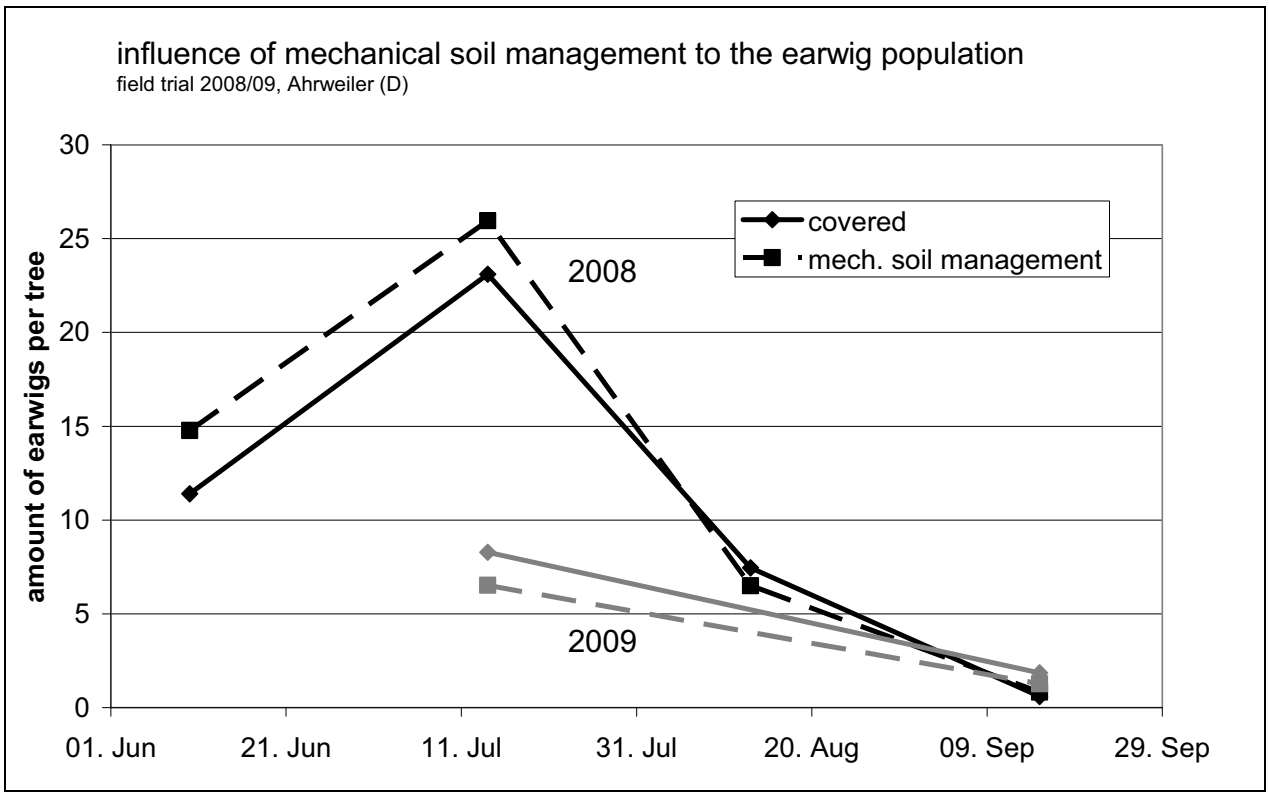

Fig. 3: influence of the mechanical soil management to earwig population, field trial 2008/09 in two rows of 'Jonagold', one covered with 'Maypex'-foil, the other treated with conventional soil management

Conclusion

The release of earwigs alone proved to be insufficient to control a high infestation of woolly apple aphid in emergency. A combination of long term encouragement of earwigs and oil application (brushing or spraying) in early spring in infested orchards looks like a promising strategy to keep the infestation of woolly apple aphid at reasonable levels where the biological regulation by all natural predators including *Aphelinus mali* and earwigs still works. The oil brushing proved to be much more efficient than the spraying but is time consuming and has no registration in Germany so far. For the spraying more research needs to be done to figure out a more effective strategy. The pollution of apples with faeces always remains at reasonable levels. The mechanical soil management in organic orchards seems not to harm earwigs as they seem to avoid the treatment by building their nests deeper and place them in the grassed alleyways.

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