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East Malling Research is an officially recognised efficacy testing station and this work is registered as study number ORETO 2010/007

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CONTENTS

GROWER SUMMARY

Headline

Selection of plant protection products on tree fruits should consider effects on earwigs.

Background and expected deliverables

Earwigs are very important generalist predators in both apple and pear orchards. They play a key part in regulating populations of several highly damaging pests including woolly aphid and other aphid pests, mussel scale, codling moth and pear sucker. Recent laboratory tests and field experiments in other European countries indicate that several very commonly used insecticides including Calypso (thiacloprid), Steward (indoxacarb) and Tracer (spinosad) have harmful effects on earwigs and could be responsible for the low populations of these important predators in some orchards. This project is further investigating the lethal and sub-lethal effects of these and other commonly used insecticides on different earwig life stages in laboratory and field studies.

Summary of the project and main conclusions

In laboratory tests in year 1, chlorpyrifos was the most toxic insecticide to earwigs with most dying within a couple of days of exposure in Petri dishes. In order of decreasing toxicity Tracer (spinosad)> Runner (methoxyfenozide)> Calypso (thiacloprid)> Steward (indoxacarb)/Envidor (spirodoclofen)/Gazelle (acetamaprid) were also harmful. Agrimec (abamectin), Coragen (chlorantraniliprole), Mainman (flonicamid), Calypso (thiacloprid) and a coded product showed very few signs of toxicity. Runner was toxic to nymphs, but less so to adult earwigs.

In field studies by other workers (Vogt *et al*. 2009), Tepekki (flonicamid) resulted in fewer earwigs in the canopy of trees. A recent review of the literature by Logan *et al*. (2011) rated residues of chlorpyrifos, spinosad, bifenthrin, diazinon and thiacloprid as highly toxic (>50% mortality) to earwigs and abamectiin, methoxyfenozide, spirotetramat, tebufenozide and thiamethoxam of low toxicity to earwigs. An older field study by Sauphanor *et al*. (1993) demonstrated that Dimilin Flo (diflubenzuron) was highly toxic to earwigs in pear orchards causing a subsequent rise in pear sucker numbers.

Based on the findings from the laboratory experiment and other researchers, we tested the most toxic products in the field in 2012, plus two coded products, to assess a more realistic field exposure and the resultant effects. The products tested in field conditions included Pyrinex (chlorpyrifos), Mainman (flonicamid), Runner (methoxyfenozide), Envidor (spirodiclofen), Calypso (thiacloprid) and two novel plant protection products. Six cv. Discovery trees per plot were sprayed at the recommended rates for apple. There were 4 plots of each treatment. Trees were assessed between 22:00 and 24:00 h for numbers of earwigs foraging on trees with a 30 s observation per tree. Numbers of earwigs in refuge bottles and numbers of aphids in the tree canopy were also estimated.

Earwigs exposed to chlorpyrifos on trees were less affected by the pesticide product than in laboratory studies in Petri dishes. However, numbers of adults decreased over time in trees treated with the insecticide in the spring compared to the untreated control. This may have been caused by mortality, a lack of food or a combination of these. Hence, caution should be used when considering this product even in the spring when females are often foraging for food to feed to earwig nymphs.

Of the products tested, Calypso was by far the most detrimental to earwig adult and nymph numbers in the canopy of the trees. In addition, dead earwigs were found in the feeding bottles on trees treated with this product. Numbers of earwigs on the trees was correlated with the numbers of earwigs in the refuge bottles. There was no correlation between the numbers of earwigs in trees and the total numbers of aphids, suggesting that the effects were not due to a lack of food for the earwigs.

In laboratory experiments nymphs exposed to methoxyfenozide (Runner, moulting hormone agonist) had a significantly reduced body weight (40% reduction) by the end of the experiment, but in field tests the product had no effect on nymph numbers. Two new coded products did not affect the numbers of adults or nymph earwigs foraging in the apple trees after treatment.

Earwigs in this study were only exposed to one or two doses of a single insecticide product. This study did not take into consideration mixtures or repeated exposures to plant protection products. It did highlight that both earwig adults and nymphs are affected by some insecticides and that consideration of the time of year that some products are applied need to be given (see Figure 1 courtesy of Penny Greeves). However, combined with data from other researchers it acts as a baseline for field studies in the coming growing seasons.

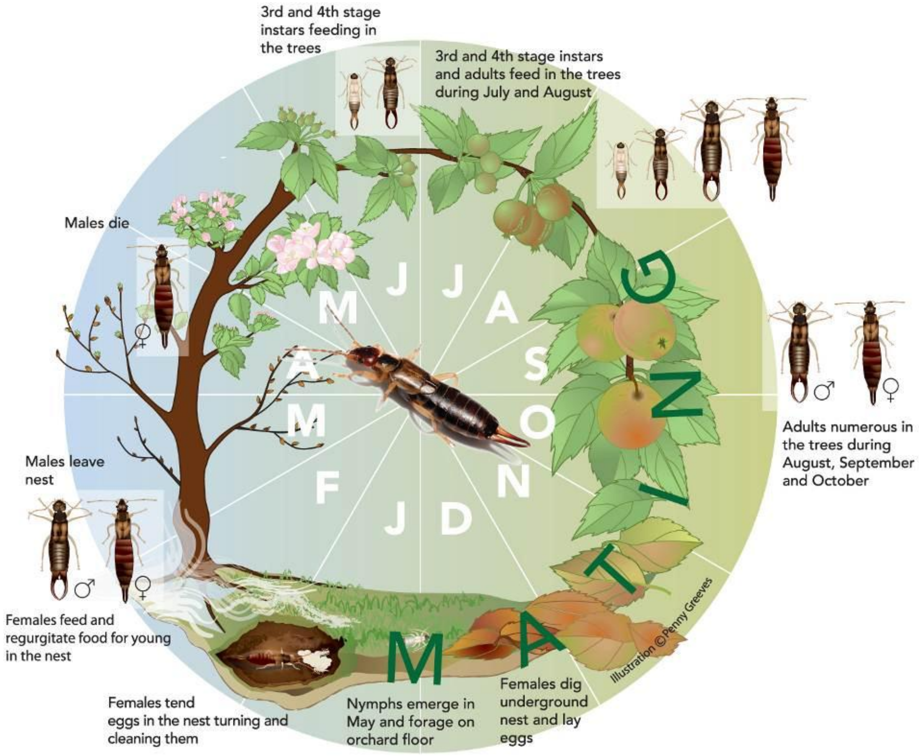


Figure 1. Earwig life-cycle

Financial benefits

- The industry will be provided with independently obtained information on the relative safety of the most commonly used insecticides in UK apple and pear production on earwigs, an important natural enemy of several damaging pests.

- Growers will be better able to judge which insecticides to use for vital pest control tasks such as control of codling moth, aphids, mussel scale and pear sucker (see table below).

Table 1. Summary table of data on safety of active ingredients to earwigs. Data is for adult earwigs unless stated otherwise

a.i.	Tests in this this project	Other researchers	Reference*
abamectin	Safe	Harmful	1
acetamiprid	Safe	-	
Bacillus thuringiensis	-	Safe	9
bifenthrin	-	Harmful	1,7
chlorantraniliprole	Safe	-	
chlorpyrifos	Harmful in lab	Harmful	1,2
cypermethrin	-	Harmful to nymphs and knockdown effect	1,8
deltamethrin	-	Harmful and knockdown effect	1,4,7,8
dimethoate	-	Harmful	1,8
fenitrothion	-	Harmful	8
flonicamid	Safe	Safe or harmful	1,3,5
indoxacarb	Harmful males and knockdown	Harmful and knockdown effects	1,3,4,5
methoxyfenozide	Harmful to nymphs in lab	Harmful	4
permethrin	-	Harmful	7
pirimicarb	-	Safe	1,8
spinosad	Harmful nymphs & adults, knockdown	Harmful to nymphs and adults	1,2,3,5,6
spirodiclofen	Harmful to nymphs in lab	-	
thiacloprid	Harmful to nymphs and adults	Harmful	1,3,5

*1 Peusens and Gobin 2008; 2 Cineros *et al*. 2002; 3 Vogt *et al*. 2010; 4 Peusens *et al*. 2010; 5 Vogt *et al*. 2009; 6 Peusens *et al* 2009; 7 Colvin and Cranshaw 2010; 8 Ffrench-Constant and Vickerman 1985; 9 Maher *et al*. 2006

Action points for growers

- Growers should make considered choices of pesticide products based on the knowledge of important predators in the orchard at the time of spraying.

- In particular, growers should use the precautionary principle in apple and pear orchards and only use products known to be harmless to important pear sucker predators, including anthocorids, earwigs, ladybirds and spiders.

SCIENCE SECTION

Introduction

Background

There are only seven species of earwig (Dermaptera) in Britain. The earwig most commonly encountered in UK orchards is the common European earwig, *Forficula auricularia* L. (Fitzgerald & Solomon 1996; Solomon *et al*. 1999).

Earwigs are omnivorous, feeding on other arthropods, plants, microscopic algae and fungi and are even cannibalistic. They are important predators of many pests of orchards including scale insects (Karsemeijer, 1973; McLeod & Chant 1952), psyllids (Solomon *et al*. 1999; Lenfant *et al*., 1994), woolly apple aphid (Phillips 1981; Ravensburg 1981; Noppert *et al*. 1987; Mueller *et al*. 1988; Nicholas *et al*. 2005; Dib *et al*. 2010) and codling moth (Glenn 1977). Excluding earwigs from woolly apple aphid or psyllid infested trees leads to a proliferation of the pests (Mueller *et al*. 1988; Sauphanor *et al*. 1993; Nicholas *et al*. 2005; Gobin *et al*. 2008). Also, in laboratory tests, He *et al*. (2008) found that earwigs were capable of eating up to 68 apple leaf curling midge larvae in a single evening and trees with earwig refuges were more actively foraged for the larvae than trees without refuges.

Reports that earwigs are declining in some orchards (Gobin *et al*. 2008) has raised concern for this effective natural predator. Moerkens *et al*. (2009) and Gobin *et al*. (2008) also recognised the inter-orchard and inter-annual variation in earwig populations, with a population crash at the time of moulting to adults. They concluded that contributing factors could include pesticides or orchard management, but that there was no conclusive evidence of this. Other influences could be migration, starvation, pathogens, parasitoids, parasites, predation and/or cannibalism (Moerkens *et al*. 2009).

In September male and female earwigs pair bond, begin to mate and can be found together in the autumn and winter. They live in a chamber, often in the soil, about 2.5-10 cm deep. After mating, the sperm may remain in the female for months before the eggs are fertilized. From mid-winter to early spring, the male will leave, or be driven out by the female. A female *F. auricularia* lays 50 to 90 eggs. She attends the first stage nymphs, which are particularly delicate, and regurgitates food to them (Staerkle & Kolliker 2008). Females die before midsummer but can be found foraging in trees in

May. Third instar nymphs move into the tree canopy (Phillips 1981) from June onwards and after the 4th instar emerge as adults (July-August) (Gobin *et al*. 2008).

Studies have revealed that the species is composed of a complex of two sibling species, one species being one-brooded and the other two (Wirth *et al*. 1998). In 2011 earwig females in at least two UK orchards had at least two broods (C. Nagy pers. comm.). This has consequences for earwig dispersal. Single brood earwigs disperse four times the distance of double brood earwig populations; up to 29 m compared to 8 m in a month, respectively (Moerkens *et al*. 2010). There does not appear to be a difference in dispersal between the sexes (Moerkens *et al.* 2010) and as earwigs rarely fly dispersal is almost always by walking. The number of broods earwigs have, and the stage of development, have consequences for spray application timings through the season. Harmful insecticides applied between June and October are likely to have effects on earwig populations. Even small effects on behaviour may have consequences on populations for the rest of the year. In reality it is not known whether orchards in the UK are dominated by one sibling species or whether they are a mixture of the two.

Because earwigs are nocturnal their numbers can also be underestimated in orchards and although they may not be directly exposed to pesticide applications applied in the daytime they may be exposed to chemical residues whilst moving around and feeding at night. The sensitivity of earwigs to many modern insecticides at recommended field doses remains unknown. In addition, the vulnerability of the different life stages to pesticides requires investigation (Ffrench-Constant & Vickerman 1985).

Earwigs can be exposed to pesticides in tests by direct exposure (topical or oral), indirect exposure (contact with residue on glass, soil or leaves) or field exposure (encapsulating on sprayed trees or field sprays).

In the second year of this project, reported here, whole trees were sprayed with plant protection products and numbers of earwig nymphs and adults (male and female) were feeding in the trees estimated at two timings by examining the trees at dusk.

Objectives

The objective of this study was to investigate the field effects of foliar sprays of chlorpyrifos (Pyrinex), flonicamid (Mainman), methoxyfenozide (Runner), spirodiclofen (Envidor), thiacloprid (Calypso) and two novel plant protection products on earwigs (*Forficula auricularia*) feeding in apple trees (year 2).

Materials and methods

Compliance

This study will be conducted according to the EMQA ORETO quality management system. It has been registered as study number ORETO 2012/005.

Treatments

Insecticides commonly used in top fruit orchards, and with different modes of action, (Table 2.1) were tested at the maximum recommended field concentrations. Two coded products and an untreated control were included.

Site

Wiseman Orchard blocks; 135 - 143 at East Malling Research were used (3.75 x 1.75 m row and tree spacing, Fig. 2.1) by kind permission of Graham Caspell (EMR). Only the rows of the variety Discovery were used.

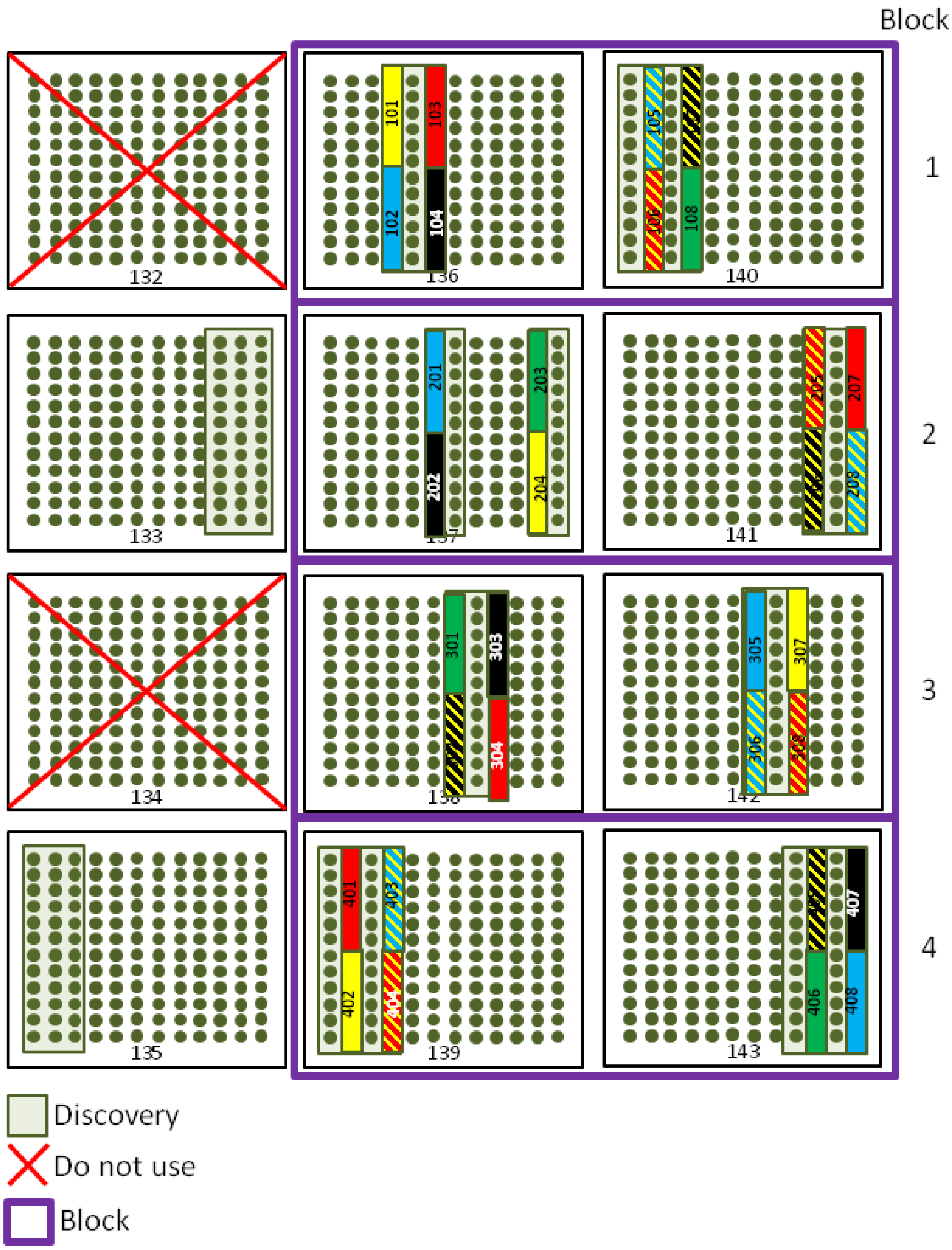


Figure 2.1 Plan of Wiseman orchard and plots used at EMR

Treatment application

Treatments (Table 2.1) were insecticides tested at the recommended field concentration. Sprays were applied according to the label recommendations (dose and max number, Table 2.2) and were applied post-flowering. There were two applications of one or two sprays (7 days apart) applied when the overwintering adults (26 April, 2 May) or nymphs (19, 26 June) were abundant in the trees.

Table 2.1 Treatments

Active ingredient Product	Mode of action	Chemical class
Chlorpyrifos	acetylcholinesterase inhibitor (irreversible)	Organophosphate
Coded HDCI 048	-	-
Coded HDCI 010	-	-
Flonicamid	feeding inhibitor	Pyridinecarboxamide
Methoxyfenozide	moulting hormone agonist	Diacylhydrazine
Spirodiclofen	lipid biosynthesis inhibition	Tetronic acid
Thiacloprid	binds to acetylcholine receptor	Neonicotinoid
Untreated control	-	-

Table 2.2 Products and their rates of application

Active ingredient	Product	Dose /ha	Concen-tration	No sprays Spring	Summer
Chlorpyrifos	Pyrinex	2.0 l	4.0 ml/l	26 Apr, 2 May	19 Jun, 26 Jun
Coded HDCI 048	-	3.0 kg	6.0 g/l	26 Apr, 2 May	19 Jun, 26 Jun
Coded HDCI 010	-	1.5 l	3.0 ml/l	26 Apr, 2 May	19 Jun, 26 Jun
Flonicamid	Mainman	0.14 kg	0.28 g/l	26 Apr, 2 May	19 Jun, 26 Jun
Methoxyfenozide	Runner	0.6 l	1.2 ml/l	26 Apr, 2 May	19 Jun, 26 Jun
Spirodiclofen	Envidor	0.6 l	1.2 ml/l	26 Apr	19 Jun
Thiacloprid	Calypso	0.375 l	0.75 ml/l	26 Apr, 2 May	19 Jun, 26 Jun
Untreated control	-	-	-	-	-

Experimental design and statistical analyses

A randomised complete block with four replicates of seven treatments was used (Fig. 2.1). Six trees in each plot were sprayed. In each plot there were three earwig refuges. Repeated measures ANOVA was done on Log_{10} (mean +1) transformed data.

Treatment application

Sprays were applied by EMR staff with a motorised air-assisted knapsack sprayer at 500 l/ha (a volume rate that is realistic for commercial application by growers), ensuring uniform coverage of foliage and fruit. The accuracy of application of each treatment was estimated by measurement of the amount of spray that had actually been applied (calculated from the final tank volume subtracted from the initial tank volume, then expressed as a percentage of the target volume). Applications were generally within 10% of required (Table 2.3). Applications were all within 13% of target volume.

Husbandry

Insecticide sprays that were likely to affect the trial were avoided. Otherwise a normal spray programme of fungicides, nutrients and herbicides was applied by the farm manager.

Meteorological records

Wet and dry bulb temperature, wind speed and direction were recorded before and after each spray application (Table 2.4). RH% was estimated from the dry and wet bulb temperature readings. In addition, EMR has a UK Met Office weather station giving full access to daily weather data (Appendix 1).

Table 2.3 Accuracy of spray application estimated from the amount of sprayate remaining in the spray tank after spray application

Treatment	26 April	02 May	19 June	26 June
Chlorpyrifos	89%	104%	103%	98%
Coded HDCI 048	97%	103%	98%	101%
Coded HDCI 010	92%	100%	100%	95%
Flonicamid	88%	104%	102%	100%
Methoxyfenozide	100%	104%	107%	100%
Spirodiclofen	102%	-	101%	-
Thiacloprid	104%	104%	98%	92%

Table 2.4 Weather conditions at each spray application

Date	Time	Air temperature			Wind	
		^{o}C dry	^{o}C wet	% rh	speed (Kmh)	direction
26 Apr	14:00	14	11	70	11	SW
02 May	09:45	10.5	9.5	90	2	NW
19 Jun	09:45	15	14	90	0	N/A
26 Jun	10:00	22	17.5	65	0	N/A

N/A = Not applicable

Growth stage development

The crop growth stage was recorded each time the crop was visited for treatment or assessment and at every assessment the crop was at full canopy density (crop adjustment factor= 1).

Artificial infestation

In each plot, on the 15 March, three earwig refuges were tied into trees 3, 4 and 5. Earwig refugees consisted of a 2 litre plastic bottle with the bottom cut off (Fig. 2.2). A roll of corrugated card was inserted and held in place with wire. Refuges were tied to the posts adjacent to the apple trees, but touching the tree trunks. Earwigs in the trees with the refugia were provided with supplementary food. An earwig feeder consisting of a 300 ml plastic drink bottle with four holes (3 mm diameter) melted into the side of the bottle at equal distances around the circumference (near the base). Each feeder contained 5 ml of crushed 'Iams' cat food and the bottle was taped above the refuge bottle on the tree or stake (Fig. 2.2). This was done to encourage earwigs into the trees and to remove any influence of a lack of available food source in the trees.

Figure 2.2 Earwig refuge (left) and feeder bottles (right)

Assessments

A pre-assessment of the numbers of earwigs present in each tree prior to spray applications was conducted. Then two subsequent assessments were conducted on all trees of each plot six days after each application. Due to the nocturnal nature of earwigs the assessments were conducted between 22:00 and 24:00. The number of earwigs on each tree in each plot was counted. A note was made of the sex, nymph stage and area of the tree found. To remove sampling bias a 30 second search of the trunk, branches, leaves and flowers was conducted. The numbers of earwigs in the feeders was also recorded.

An assessment was also made of the abundance of aphids on each tree. The entire tree was examined and the numbers of green apple aphid, rosy apple aphid, rosy leaf curling aphid and woolly apple aphid were recorded as a total number of each species of aphid on each tree.

Earwig refugia were also assessed for numbers of resident earwigs by unrolling the corrugated card over a bowl (10 May). After sampling, earwigs were released back onto the trees from which they were collected.

Sampling was done between 3-7 days after each spray application, depending on the weather. There was likely to be less earwig activity on cold rainy nights.

Experimental Approval and crop destruction

Two of the products used are not approved on apple in the UK. An Experimental Permit was obtained. The fruit from the experimental plot was not picked.

Results

Spring assessment

At the pre-assessment on 23 April (22:15-23:15 h) most of the earwigs (adults) were in the feed bottles. Very few were on the trees without feed bottles. The post spray application assessments were done on 01 May (22:10-22:50 h) and 08 May (22.10-22.50 h). Most of the earwigs on the first occasion were feeding on the anthers in the blossoms. At the second assessment the majority of earwigs were feeding on flowers or new aphid colonies. By the second assessment the majority of the earwigs were females.

Significantly fewer females were found in the thiacloprid treatment compared to the untreated control (Table 3.1). The numbers of females in the untreated trees increased over time, but in the trees treated with chlorpyrifos they dropped – although this was not significant (Fig. 3.1). There was no significant difference in the numbers of males found, most likely due to the initial low numbers, which had decreased further on the second assessment (Fig. 3.1).

There were also significantly fewer female earwigs in the refugia on the trees treated with thiacloprid (none) compared to the unsprayed trees (mean 5.5 per plot) on 10 May (Table 3.2).

The total numbers of earwigs observed in the trees at night was correlated to the numbers found in the refuge bottles during the day (Table 3.3). Numbers of females, but not males, in trees were significantly correlated to numbers of conspecifics in the refugia (Table 3.3).

Table 3.1 ANOVA table of the mean numbers of earwigs in the spring assessments

Treatment	Actual mean		Log$_{10}$ (n+1)	
	Female	Male	Female	Male
Chlorpyrifos	0.206	0.090	0.064	0.024
Coded HDCI 048	0.603	0.202	0.161	0.062
Coded HDCI 010	0.363	0.127	0.102	0.032
Flonicamid	0.236	0.147	0.069	0.044
Methoxyfenozide	0.748	0.157	0.190	0.048
Spirodiclofen	0.611	0.085	0.146	0.026
Thiacloprid	0.049	-0.018	0.015	-0.006
Untreated control	0.590	0.054	0.143	0.017
Tree				
1	0.385	0.047	0.108	0.014
2	0.376	0.094	0.093	0.028
3	0.461	0.063	0.123	0.019
4	0.482	0.219	0.121	0.062
Time				
01 May	0.32	0.172	0.089	0.050
08 May	0.531	0.039	0.134	0.012
Treat				
F prob.			0.093	0.269
s.e.d. (*df*=20)			0.0578	0.0244
l.s.d.			0.1207	0.0508
Tree				
F pr.			0.716	0.030
s.e.d. (*df*=71)			0.0293	0.0170
l.s.d.			0.0585	0.0339
Time				
F pr.			0.020	<.001
s.e.d. (*df*=96)			0.0189	0.0110
l.s.d.			0.0376	0.0219
			No time*treat interaction	

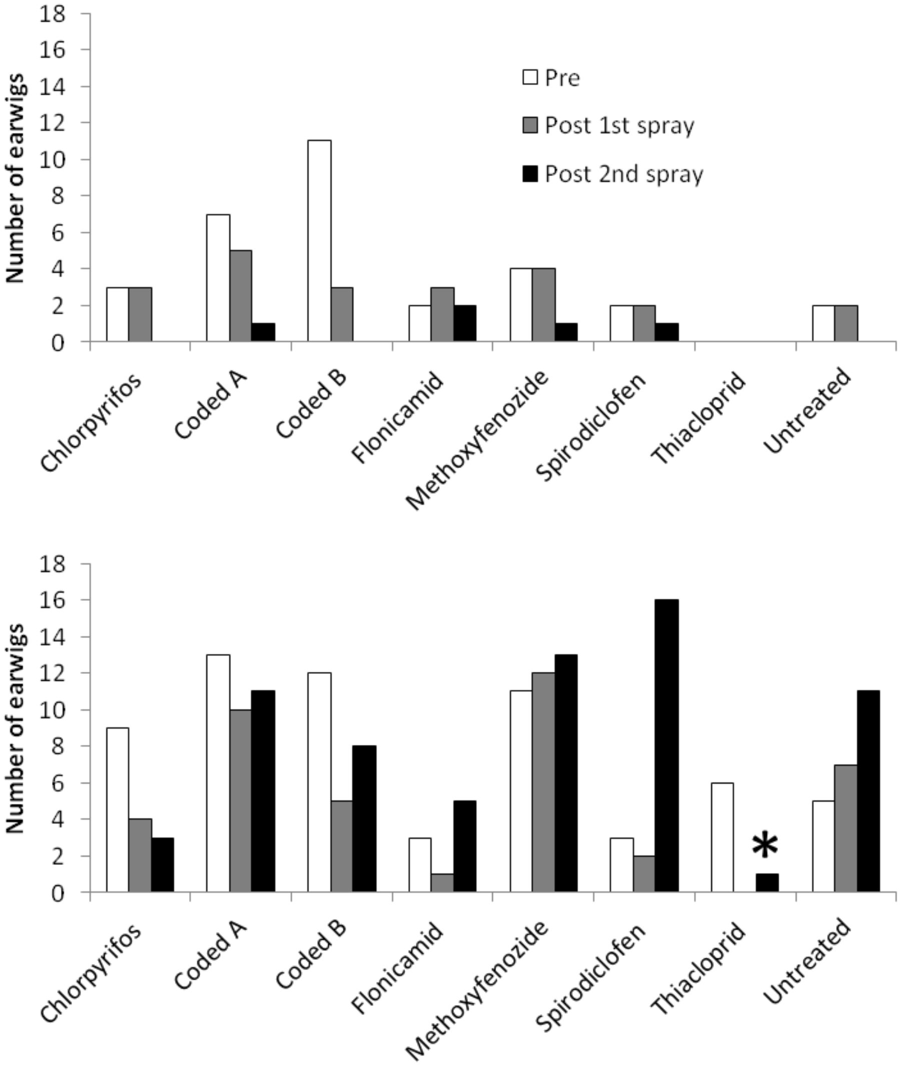


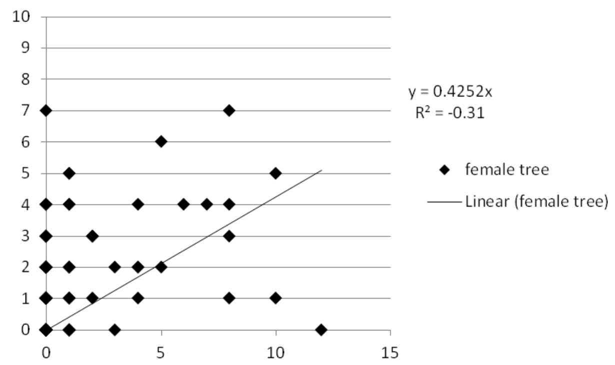
Figure 3.1 Numbers of male (top) and female earwigs on trees (30 sec assessment) at the pre assessment and then after the first and second spray applications. * = significantly lower numbers of earwigs compared to the untreated control

Table 3.2 ANOVA table of the numbers of earwigs in the refugia in the spring assessments (10 May)

Treat	**Actual mean**		**Log_{10} (n+1)**	
	Male	**Female**	**Male**	**Female**
Chlorpyrifos	0	1.5	0	0.140
Coded HDCI 048A	0.250	6.0	0.065	0.273
Coded HDCI 010	0.667	3.5	0.110	0.190
Flonicamid	0.167	3.5	0.050	0.145
Methoxyfenozide	0.333	8.5	0.058	0.478
Spirodiclofen	0	4.8	0	0.224
Thiacloprid	0	0	0	0
Untreated	0.333	5.5	0.090	0.304
F pr.			0.374	0.016
s.e.d. (*df*=85)			0.0581	0.1218
l.s.d.			0.1155	0.2423

Table 3.3 Relationship between the numbers of earwigs observed in trees at night and the numbers in refuge bottles in the trees

Source	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Females					
Regression	1	34	34.036	12.94	<.001
Residual	94	247.3	2.631		
Total	95	281.3	2.961		
Males					
Regression	1	0.43	0.433	0.64	0.426
Residual	94	63.56	0.676		
Total	95	63.99	0.673		
Total					
Regression	1	79.9	79.931	21.95	<.001
Residual	94	342.2	3.641		
Total	95	422.2	4.444		



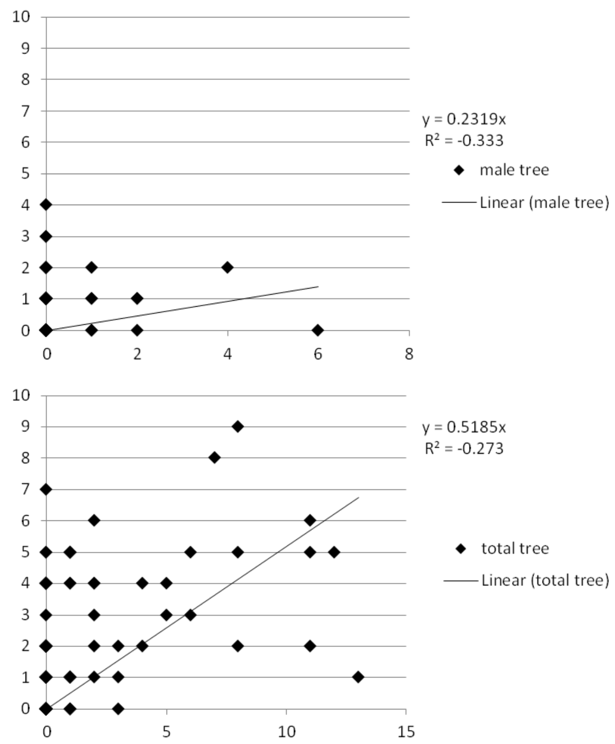


Figure 3.2 Relationship between numbers of female (top), males (middle) and total numbers (bottom) of earwigs in the trees at night and the refugia during the day

Summer assessments

At the pre-assessment on 18 June (23:00-24:00 h) most of the earwigs were in the feed bottles. Very few earwigs were on the trees without feed bottles. At the first assessment (25 June, 10:15-11:00 h) after the first spray application the majority of the earwigs were in feed bottles. Most of the earwigs were stage 3 and 4 nymphs. At the second assessment (02 July, 10:15-11:00 h) most earwigs were in the feed bottles or refuges. Nymphs were stage 2-5 with very few adults found foraging.

There were significantly fewer earwig nymphs on the trees treated with thiacloprid (Table 3.4, Fig. 3.3). Flonicamid plots narrowly missed having significantly fewer earwigs. Earwig nymphs overall, increased in number over the course of the experiment in most trees (Table 3.4). The decreased numbers of earwigs in the thiacloprid treatments was most likely due to an increase in mortality (Fig. 3.4).

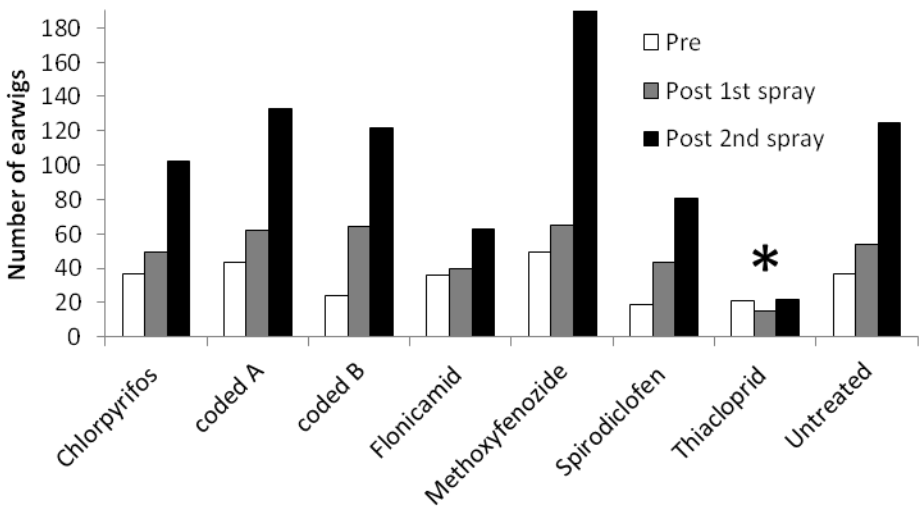


Figure 3.3 Numbers of live (top) earwig nymphs on trees (30 sec assessment) at the pre assessment and then after the first and second spray applications. * = significantly lower numbers of earwigs compared to the untreated control

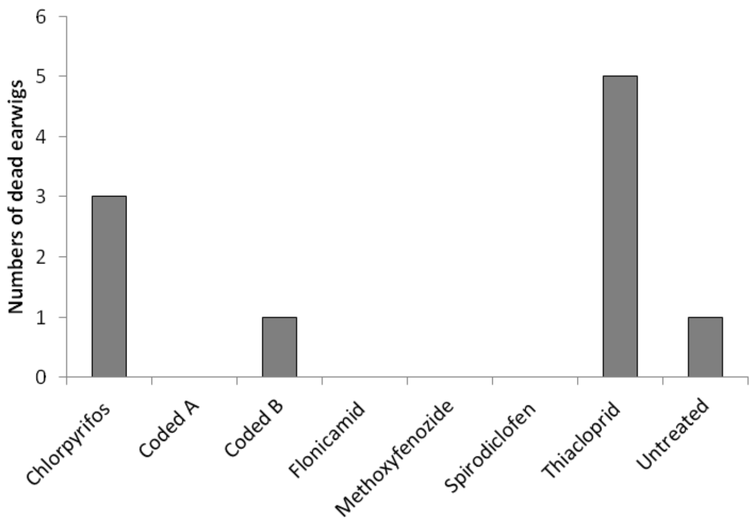


Figure 3.4 Numbers of dead (bottom) earwig nymphs on trees (30 sec assessment) at the pre assessment and then after the first and second spray applications

In addition, an aphid assessment was done to identify if the numbers of earwigs in the trees were correlated with the numbers of available prey (02 July, Fig. 3.5). There was no correlation between the numbers of aphids and the numbers of earwigs in the trees ($y = -0.0947x + 21.971$, $R^2 = 0.0001$) and no relationship between treatments with high or low numbers of earwigs. Hence, the availability of prey in the trees did not affect the numbers of earwigs in the trees.

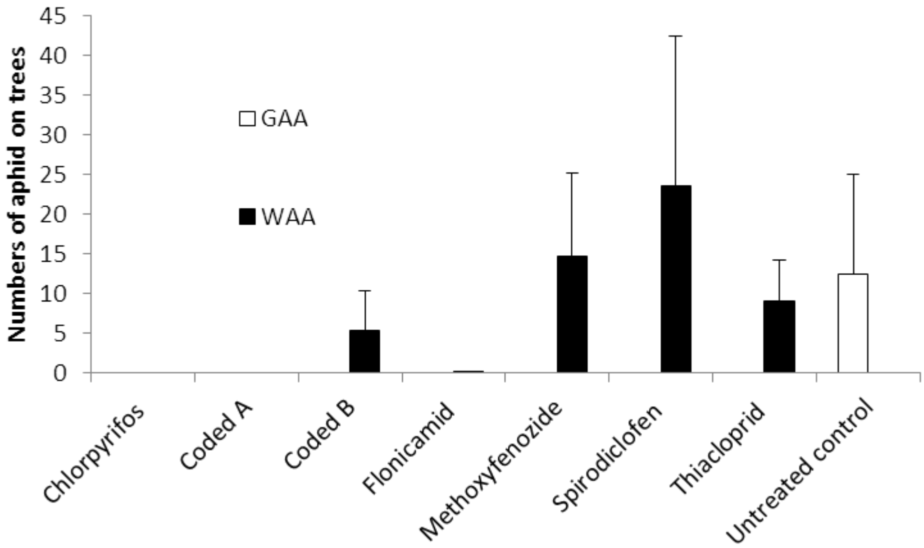


Figure 3.5 Numbers of aphids (GAA = green apple aphid, WAA = woolly apple aphid

Table 3.4 ANOVA table of the numbers of earwigs in the summer assessments

Treatment	Actual mean Nymphs	Log_{10} (n+1) Nymphs
Chlorpyrifos	4.52	0.621
Coded HDCI 048A	5.58	0.663
Coded HDCI 010	6.30	0.667
Flonicamid	3.07	0.468
Methoxyfenozide	7.14	0.706
Spirodiclofen	4.62	0.594
Thiacloprid	1.80	0.291
Untreated control	5.40	0.616
Tree		
1	2.15	0.290
2	7.36	0.774
3	5.17	0.666
4	4.54	0.583
Time		
25 Jun	3.06	0.472
02 Jul	6.55	0.684
Treat		
F pr.		<.001
s.e.d. (*df*=20)		0.0711
l.s.d.		0.1482
Tree		
F pr.		<.001
s.e.d. (*df*=71)		0.0507
l.s.d.		0.101
Time		
F pr.		<.001
s.e.d. (*df*=96)		0.028
l.s.d.		0.0556
	No treat time interaction	

Discussion

Earwigs exposed to chlorpyrifos in trees were less affected by chlorpyrifos than in laboratory studies in Petri dishes. However, numbers of adults decreased over time in trees treated with the insecticide in the spring (mortality or lack of food), so caution should be used when considering this product.

In the laboratory tests the most toxic products to the nymphs were spinosad (Tracer, 40% survival), thiacloprid (Calypso, 60% survival) and spirodiclofen (Envidor, 70% survival) (Table 4.1). In the field tests, in 2012, spinosad (Tracer) was not tested as it is also considered toxic to earwigs by other researchers (Peusens *et al*. 2009; Cineros *et al*. 2002). Spirodoclofen did not appear to have detrimental effects on survival in the field at the maximum application of one dose per year. Thiacloprid was by far the most detrimental to earwig adult and nymph numbers in the field. In addition, dead earwigs were found in the feeding bottles on trees treated with this product. In field studies by Vogt *et al* (2010) it was not clear whether lower numbers of earwigs in trees were due to mortality (direct exposure or starvation) or avoidance – i.e. earwigs repelled by the treatments.

In laboratory experiments nymphs exposed to methoxyfenozide (Runner, moulting hormone agonist) had a significantly reduced body weight (40% reduction) by the end of the experiment, but in field tests the product had no effect on nymph numbers. Two new coded products did not affect the numbers of adults or nymph earwigs foraging in apple trees after treatment with the products.

Conclusions

Earwigs in this study were only exposed to one or two doses of a single insecticide. This study does not take into consideration mixtures or repeated exposures to plant protection products.

In the laboratory test chlorpyrifos was by far the most toxic insecticide for earwigs (Table 5.1). In order of decreasing toxicity Tracer (spinosad)> Runner (methoxyfenozide, nymphs)> Calypso (thiacloprid)> Steward (indoxacarb)/Envidor (spirodoclofen)/Gazelle acetamaprid) (Table 5.1). In studies by other workers (Vogt *et al*. 2009) flonicamid (Tepekki) has resulted in fewer earwigs in trees. A recent review of the literature by Logan *et al*. (2011) rated residues of chlorpyrifos, spinosad, bifenthrin, diazinon and thiacloprid as highly toxic (>50% mortality) to earwigs and abamectiin, methoxyfenozide, spirotetramat, tebufenozide and thiamethoxam of low toxicity to earwigs. Their review did not include data on acetamaprid, chlorantraniliprole, flonicamid, indoxacarb or spiridoclofen. An older study by Sauphanor *et al*. (1993) demonstrated that diflubenzuron (Dimilin Flo) was highly toxic to earwigs in a pear orchards causing a subsequent rise in pear sucker numbers. In this study thiacloprid was the most detrimental of the actives tested.

Table 5.1. Pesticides ranked in order of most harmful. Up to 70% survival or lowest mean weight of nymphs at end of tests

Nymph survival	Female survival	Male survival	Nymph weight
Equity	Equity	Equity	Equity
Tracer	Tracer	Tracer	Runner
Calypso		Steward	Tracer
Envidor		Calypso	Gazelle

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Table 4.1. Summary table of data on safety of active ingredients tested in crop protection products on earwigs. Data is for adult earwigs unless stated otherwise

a.i.	Tests in this project	Other researchers	Reference*
abamectin	Safe	Harmful	1
acetamiprid	Safe	-	
Bacillus thuringiensis	-	Safe	9
bifenthrin	-	Harmful	1,7
chlorantraniliprole	Safe	-	
chlorpyrifos	Harmful	Harmful	1,2
cypermethrin	-	Harmful to nymphs and knockdown effect	1,8
deltamethrin	-	Harmful and knockdown effect	1,4,7,8
dimethoate	-	Harmful	1,8
fenitrothion	-	Harmful	8
flonicamid	Safe	Safe or harmful	1,3,5
indoxacarb	Harmful to adult males and knockdown effects	Harmful and knockdown effects	1,3,4,5
methoxyfenozide	Harmful to nymphs	Harmful	4
permethrin	-	Harmful	7
pirimicarb	-	Safe	1,8
spinosad	Harmful to nymphs and adults. Knockdown	Harmful to nymphs and adults	1,2,3,5,6
spirodiclofen	Harmful to nymphs	-	
thiacloprid	Harmful to nymphs and adults	Harmful	1,3,5

*1 Peusens and Gobin 2008; 2 Cineros *et al*. 2002; 3 Vogt *et al*. 2010; 4 Peusens *et al*. 2010; 5 Vogt *et al*. 2009; 6 Peusens *et al* 2009; 7 Colvin and Cranshaw 2010; 8 Ffrench-Constant and Vickerman 1985; 9 Maher *et al*. 2006

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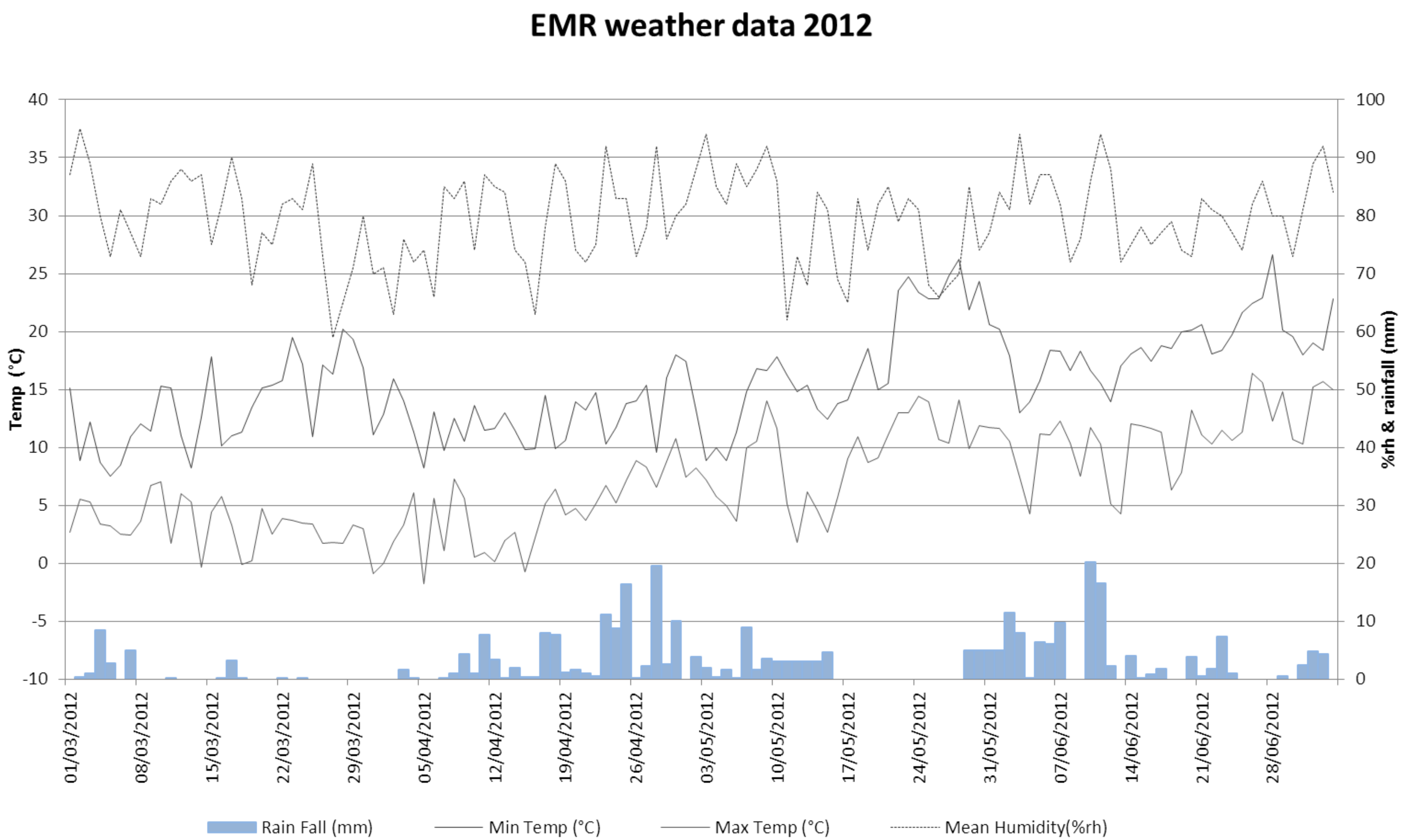

EMR weather data 2012
Temp (°C)
%rh & rainfall (mm)
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35
30
25
20
15
10
5
0
-5
-10
100
90
80
70
60
50
40
30
20
10
0
01/03/2012
08/03/2012
15/03/2012
22/03/2012
29/03/2012
05/04/2012
12/04/2012
19/04/2012
26/04/2012
03/05/2012
10/05/2012
17/05/2012
24/05/2012
31/05/2012
07/06/2012
14/06/2012
21/06/2012
28/06/2012
Rain Fall (mm)
Min Temp (°C)
Max Temp (°C)
Mean Humidity(%rh)

