Project Title:	Improving codling moth spray timing
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The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

CONTENTS

GROWER SUMMARY

Headline

- The 2013 results suggest that the interval between sprays for codling moth (expected cover period) should be reduced where significant crop damage occurred the previous year.

Background and expected deliverables

Codling moth is the most important pest of apples and also an important pest of pears in the UK. Most insecticide sprays approved on apple are used against it. Control is usually good, but populations are not being reduced to sufficiently low levels that spraying can be avoided or decreased in subsequent years: growers are on an insecticide treadmill. UK growers generally rely on pheromone traps to decide if and when to spray for codling moth but previous work in project TF189 suggested that they are of limited benefit and growers may not be making best use of their time and effort in using them.

Experience in the Netherlands indicates that as good or better control of codling moth can be obtained using development and population simulations given by the RIMpro-Cydia model, which uses data from local meteorological stations. The model, which is available to all growers, takes into account when conditions suitable for egg laying occur (dusk temperatures > 15 °C) as well as maturity and longevity of females rather than activity of males as indicated by sex pheromone trap catches. This work will determine which of the three alternative decision-making methods is best, leading to improvements in control and/or savings in monitoring costs and management time.

Summary of the project and main conclusions

In 2013, the trial comparing three methods of timing insecticide sprays for codling moth, was continued for a second year using the same plots in three commercial orchards in Kent. A significant modification was made to the codling moth sex pheromone trap threshold used. In 2012 the trap threshold was ≥5 moths/trap/week in two weeks (not necessarily successive weeks). In 2013 it was simplified (and lowered) to a single catch of ≥5 moths in June-July or ≥3 moths in August and September. Thus the new methods assessed were:

Method 1: Standard method of monitoring male moth flight using pheromone traps and spraying after a threshold of a single catch of ≥5 moths is exceeded in June-July or ≥3 moths is exceeded in August and September.

Method 2: Use of the RIMpro-Cydia forecasting model in conjunction with pheromone trap records. Sprays only applied if both model indicates egg laying risk and pheromone trap threshold exceeded.

Method 3: Use of the RIMpro-Cydia forecasting model in conjunction with an assessment of codling moth damage the previous year to indicate general codling moth risk in the particular orchard.

- The adjusted simpler sex pheromone trap thresholds (≥5 moths/trap/week in June-July, ≥3 moths/trap/week in August and September) performed satisfactorily in 2014.

- The 'Trap', 'RIMpro' and 'RIMpro+trap' treatments performed similarly in terms of control of codling moth and the resultant fruit damage. However, levels of damage (2.67-3.46 % fruits) were too high and considerably above an economically acceptable level at one site, and marginally too high (1.04-1.51%) at another. An economic damage threshold of >0.3% of fruits damage is appropriate.

The results suggest that the interval between sprays for codling moth (expected cover period) should be reduced where significant crop damage occurred the previous year. The RIMpro model resulted in one more insecticide spray being applied in early August at two sites but there was no obvious benefit from this extra spray in terms of improved control of codling moth.

As in 2012, the combo traps mainly caught males, generally in larger numbers than the sex pheromone traps. Catches of females were small and erratic. Whilst combo traps have a place for monitoring the success of sex pheromone mating disruption treatments, no real advantages over the sex pheromone traps were apparent for timing pesticide sprays. The trial is to be continued for one further season in 2014.

Financial benefits

Codling moth control programmes typically cost growers >£200/ha/season. Even a low level of fruit damage (< 0.3% fruits damaged) is likely to be economically unacceptable. Improving control and/or reducing insecticide use will be of financial benefit to growers.

Action points for growers

The findings from this project to date are preliminary and no grower action points are recommended at this stage.

SCIENCE SECTION

Summary

In 2013, the trial comparing three methods of timing insecticide sprays for codling moth was continued for a second year using the same plots in three commercial orchards in Kent, though a significant modification was made to the sex pheromone trap threshold used. In 2012 the trap threshold was ≥5 moths/trap/week in two weeks not necessarily successive. In 2013 it was simplified (and lowered) to a single catch of ≥5 moths in June-July or ≥3 moths in August and September. Thus the new methods were:

Method 1: Standard method of monitoring male moth flight using pheromone traps and spraying after a threshold of ≥5 moths is exceeded in June-July or ≥3 moths is exceeded in August and September;

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Method 3: Use of the RIMpro-Cydia forecasting model in conjunction with an assessment of codling moth damage the previous year to indicate general codling moth risk in the particular orchard.

The adjusted simpler sex pheromone trap thresholds (≥5 moths/trap/week in June-July, ≥3 moths/trap/week in August and September) performed satisfactorily in 2014. The 'Trap', 'RIMpro' and 'RIMpro+trap' treatments performed similarly in terms of control of codling moth and the resultant fruit damage. However, levels of damage (2.67-3.46 % fruits) were too high and considerably above an economically acceptable level at one site, and marginally too high (1.04-1.51%) at another. An economic damage threshold of >0.3% of fruits damage is appropriate. The interval between sprays for codling moth (expected cover period) should be reduced where significant crop damage occurred the previous year. The RIMpro model resulted in one more insecticide spray being applied in early August at two sites but there was no obvious benefit from this extra spray in terms of improved control of codling moth.

As in 2012, the combo traps mainly caught males, generally in larger numbers than the sex pheromone traps. Catches of females were small and erratic. Whilst combo traps have a place for monitoring the success of sex pheromone mating disruption treatments, no real

advantages over the sex pheromone traps were apparent for timing pesticide sprays. The trial is to be continued for one further season in 2014.

Introduction

Codling moth is the most important pest of apples and also an important pest of pears in the UK. Most insecticide sprays on apple are used against it. Codling moth control programmes typically cost growers >£200/ha/season. Control is usually good, but populations are not being reduced to such low levels that spraying is reduced in subsequent years: growers are on an insecticide treadmill. UK growers generally rely on pheromone traps to decide if and when to spray for codling moth but previous work in project TF 189 suggested that they are of limited benefit and growers may not be making best use of their time and effort in using them.

Experience in the Netherlands indicates that as good or better control of codling moth can be obtained using development and population simulations provided by the RIMpro-Cydia model using data from local met stations. The model, which is available to all growers, takes into account when conditions suitable for egg laying occur (dusk temperatures > 15 °C) as well as maturity and longevity of females rather than activity of males as indicated by sex pheromone trap catches.

This work aimed to determine which of the three alternative decision-making methods would best lead to improvements in control and/or savings in monitoring costs and management time.

Objectives

The general aim of this project is to determine better practical methods for timing sprays of insecticides for control of codling moth on apple and pear in the UK, so reducing overwintering populations and achieving better long term control. The specific objective is to determine which of the following methods is best for timing insecticide sprays to get the most cost effective control of codling moth, including in the long term:

> Method 1 ‘Trap’: Standard method of monitoring male moth flight using pheromone traps and spraying after a threshold of ≥5 moths is exceeded in June-July or ≥3 moths is exceeded in August and September;

Method 2 ‘RIMpro+trap’: Use of the RIMpro-Cydia forecasting model in conjunction with pheromone trap records. Sprays only applied if both model indicates egg laying risk and pheromone trap threshold exceeded;

Method 3 ‘RIMpro’: Use of the RIMpro-Cydia forecasting model in conjunction with an assessment of codling moth damage the previous year to indicate general codling moth risk in the particular orchard.

Outline of work

Three large dessert apple orchards on different farms in southern England were each divided into three plots, each plot receiving sprays for codling moth using one of the three different timing methods for three successive years (2012-2014).

The same insecticides were used (Coragen (chlorantraniliprole), Steward (indoxacarb) and chlorpyrifos) in 2013 but it was anticipated that the different methods of spray timing would result in different timings and numbers of sprays being applied. The orchards chosen had a history of significant codling moth pheromone catches and each had a local, high quality, calibrated weather station nearby. Adult codling moth populations in each plot were monitored with a sex pheromone and a pear ester kairomone + sex pheromone combi trap. Larval attack to fruits was assessed in July (first generation) and at harvest. Each year, the forecasts generated and the comparative success of the different methods were judged in terms of the standard of control achieved, the numbers of larvae overwintering and the numbers and costs of insecticides used.

Materials and methods

Sites

Site 1 (Advisor Paul Bennett, Agrovista): In ‘Mealy Meads’ Bramley orchard at Amsbury Farm, East Street, Hunton ME15 0Q by kind agreement of Clive Baxter (owner) and with help of farm manager Alan Burbridge and spray operator David Gosling (spraying) (Table 1, Figure 1).

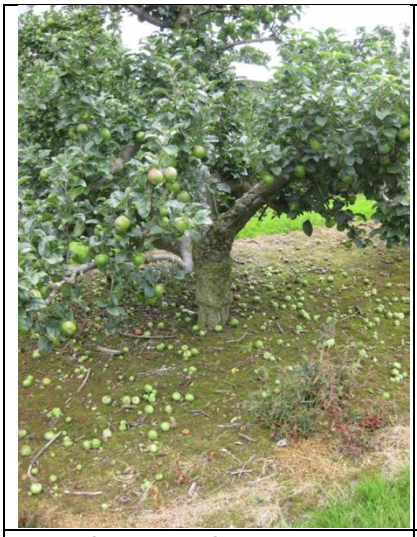
Site 2 (Advisor Paul Bennett, Agrovista)*:* In ‘Old Orchard’ Jonagold at West Pikefish Farm, Laddingford, Maidstone, Kent ME18 6BH by kind agreement of James Smith (owner) (Table 1, Figure 1).

Site 3 (Advisor Tim Biddlecombe, FAST): In ‘Deerson’ Kanzi orchard at Adrian Scripps Ltd, Wenderton Farm, Wenderton Lane, Wingham, Canterbury, Kent CT3 1EL by kind

agreement of general manager Mark Holden and local farm manager Russell Graydon (Table 1, Figure 1).

Table 1. Details of the orchards where the trials are located

Site 1. Amsbury Farm	
National grid reference	TQ 738 500
Orchard name	Mealy Meads
Variety	Bramley
Rootstock	MM106
Planting date	>25 years ago
Area	1.0 ha
System	Single row
Row spacing	18’ (= 5.5 m)
Tree spacing in row	9’ (= 2.75 m)
Tree density	661 trees/ha
Tree row height	4
CAF factor at full leaf	1
Site 2.West Pikefish Farm	
National grid reference	TQ 695 475
Orchard names	Old Orchard
Variety	Jonagold
Rootstock	M9
Planting date	Winter 2008/09
Area	2.65 ha
System	Single row
Row spacing	4 m
Tree spacing in row	1 m
Tree density	2500 trees/ha
Tree row height	
CAF factor at full leaf	
Site 3 Wenderton Farm	
National grid reference	TR 243 595
Orchard name	Deerson
Variety	Kanzi
Rootstock	M9
Planting date	Spring 2004
Area	13 ha
System	Single row
Row spacing	3.75 m
Tree spacing in row	1.25 m
Tree density	2133 trees/ha
Tree row height	2.5 m
CAF factor at full leaf	1.0



Site 1 Amsbury Farm
MM106 Bramley >25 yr old
1 ha; 666 trees/ha

Site 2. W. Pikefish Farm
M9 Jonagold 3 yr old
2.7 ha; 2500 trees/ha

Site 3. Wenderton Farm
M9 Kanzi 8 yr old
7 ha; 2500 trees/ha

Figure 1. Typical apple trees in the three orchards at the three sites

Treatments

In collaboration with the host grower, each plot received sprays for codling moth using one of three different scheduling/timing methods (Table 2). 2013 was the second year of the experiment, which will continue for one further year (2014 season). In 2013, based on the findings of the work in 2012, the threshold for spraying for codling moth was lowered from a catch of ≥5 moths in two weeks, not necessarily successive, to a single catch ≥5 moths in June-July or a single catch ≥3 moths per trap in August and September. Insecticides, their preferred order of use and recommended rates are given in Table 3.

Table 2. Treatments

Trt No.	Colour code and name	Method of timing sprays for codling moth
1	Green (G) Trap	Standard method of monitoring male moth flight using delta pheromone traps with sticky inserts and spraying after a threshold of ≥5 moths is exceeded in June-July or ≥3 moths is exceeded in August and September
2	Red (R) RIMpro+trap	Use of the RIMpro-Cydia forecasting model in conjunction with pheromone trap records. Sprays only applied if both model indicates egg laying risk and pheromone trap threshold exceeded
3	Blue (B) RIMpro	Use of the RIMpro-Cydia forecasting model in conjunction with an assessment of codling moth damage the previous year to indicate general codling moth risk in the particular orchard

Table 3. Insecticides to be used for codling moth

Product	Rate (/ha)	Max no. sprays/ season	Harvest interval (days)	Spray volume (l/ha)		
				Site 1	Site 2	Site 3
Coragen (chlorantraniliprole)	175 ml	2	14	500	200	250
Steward (indoxacarb)	250 g‡	3	7	500	200	250
Chlorpyrifos 480 g/l	2.0 l	3*	14	500	200	250
‡For 3.75 m tall trees. Reduce dose according to height, but not below 170 g/ha *Post blossom at this rate						

Experimental design and statistical analyses

Each orchard was divided into three large (approximately equal sized) plots. The allocation of plots to treatments is given in Table 4. Diagrams of the layouts of the trials are given in Figures 2-4 for the three sites, respectively.

Table 4. Allocation of treatments to plots

Site 1 (Amsbury) (Figure 2)			Site 2 (West Pikefish) (Figure 3)			Site 3 (Wenderton) (Figure 4)		
Plot no.	Treatment method		Plot no.	Treatment method		Plot no.	Treatment method	
	Col.	Method		Col.	Method		Col.	Method
101	G	Trap	201	B	RIMpro	301	R	RIMpro+trap
102	R	RIMpro+trap	202	G	Trap	302	B	RIMpro
103	B	RIMpro	203	R	RIMpro+trap	303	G	Trap

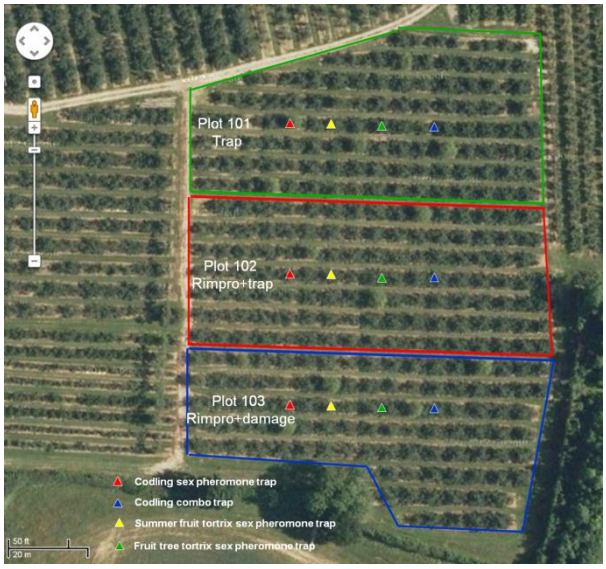


Figure 2. Plots and traps in Mealy Meads orchard at Amsbury Farm

Figure 3. Plots and traps in young Jonagold orchard at West Pikefish Farm

Figure 4. Plots and traps in Deerson orchard at Wenderton Farm

Treatment application

Sprays were applied by the host grower using the growers' normal spray application equipment and spray volume.

Meteorological records

The three farms each have a good quality, calibrated met station. Each year in late winter/early spring, the calibration of the local met station used for obtaining met data for the model are checked.

Assessments

A sex pheromone trap for codling moth, summer fruit tortrix moth and fruit tree tortrix moth and a codling moth combi trap was deployed in the centre of each plot and monitored weekly throughout the season with assistance from the host grower. For locations of the traps see Figures 2-4 for the three sites, respectively.

Larval attack to fruits was assessed in each plot in July (first generation) and at harvest on samples of at least 1,000 fruits per plot. A fixed number of trees were assessed at each farm, depending on fruit load and tree size. The assessments included fruit on the tree and dropped/fallen fruits.

Each year the forecasts generated and the comparative success of the different methods are being judged in terms of the standard of control achieved, the numbers of larvae overwintering and the numbers and costs of insecticides used.

Results

Trap treatment

Site 1, Amsbury Farm:

Codling moth sex pheromone trap catches (Figure 5) exceeded the threshold of 5 moths per trap per week every week between 20 June and 25 July with high catches of 36 and 35 moths per trap on 18 and 25 July, respectively. Trap catches were at or below the late season threshold of 3 per trap throughout August and September. Two sprays of Coragen were applied on 28 June and 23 July, respectively. A very low level of damage (0.2%) was present in late July/early August but 2.47% of fruit were found to be damaged by codling moth at harvest.

Site 2, West Pikefish Farm:

Codling moth sex pheromone trap catches (Figure 5) of 7 on 18 June and 5 on 24 June triggered sprays of Coragen and Steward on 19 June and 9 July respectively. Trap catches were at or below the late season threshold of 3 per trap throughout August and September. A low level of damage (0.87%) was present in late July/early August and only 0.17% of fruit were found to be damaged by codling moth at harvest.

Site 3, Wenderton Farm:

Codling moth sex pheromone trap catches (Figure 5) of 12 on 17 June, 14 on 1 July and 7 and 16 on 8 and 15 July triggered sprays of Chlorpyrifos, Coragen and Steward on 19 June, 3 July and 18 July, respectively. Trap catches were at or below the late season threshold of 3 per trap throughout August and September. No damage was present in late July/early August and only 0.07% of fruit were found to be damaged by codling moth at harvest.

RIMpro treatment

Site 1, Amsbury Farm:

RIMpro–cydia model predictions using data from the met station at Westerhill Farm, nearby, showed high levels of egg laying well above 100 on the risk scale on 19-21 June, 26 June, 29-30 June, 4-10 July and 13-27 July. Larval hatch was predicted to occur more or less continuously between 4 July and 11 August (Figure 7). Sprays of Coragen were applied on 28 June and 23 July (Table 5). A very low level of damage (0.15%) was present in late July/early August but 2.80% of fruit were found to be damaged by codling moth at harvest.

Site 2, West Pikefish Farm:

RIMpro–cydia model predictions using data from the farm met station showed high levels of egg laying well above 100 on the risk scale on 19-21, 27, 29 June and 4-10 and 13-24 July. Larval hatch was predicted to occur more or less continuously between 2 Jul and 10 Aug (Figure 7). Sprays of Coragen, Steward the Coragen were applied on 25 June, 16 July and 2 August, respectively (Table 5). A low level of damage (1.47%) was present in late July/early August and 0.44% of fruit were found to be damaged by codling moth at harvest.

Site 3, Wenderton Farm:

RIMpro–cydia model predictions using data from the farm met station at showed high levels of egg laying well above 100 on the risk scale on 20-21 June, 29 June – 9 July and 14 July –

3 August (Figure 7). Sprays of Chlorpyrifos, Coragen, Steward the Coragen were applied on 19 June, 3 July, 18 July and 2 August, respectively (Table 5). No damage was present in late July/early August and 0.26% of fruit were found to be damaged by codling moth at harvest.

RIMpro+trap treatment

Site 1, Amsbury Farm:

The risk of both trap and RIMpro predictions (Figure 6) led to sprays of Coragen being applied on 28 June and 23 July. A very low level of damage (0.13%) was present in late July/early August but 3.3% of fruit were found to be damaged by codling moth at harvest.

Site 2, West Pikefish Farm:

The risk of both trap and RIMpro predictions (Figure 6) led to sprays of Coragen, Steward and Coragen being applied on 25 June, 16 July and 2 August. A low level of damage (1.01%) was present in late July/early August and 0.50% of fruit were found to be damaged by codling moth at harvest.

Site 3, Wenderton Farm:

The risk of both trap and RIMPro predictions (Figure 6) led to sprays of Chlorpyrifos, Coragen and Steward and Coragen being applied on 19 June, 3 July and 18 July. No damage was present in late July/early August and only 0.22% of fruit were found to be damaged by codling moth at harvest.

Tortrix moths

Sex pheromone trap catches of fruit tree tortrix moth were greatest at Wenderton Farm, where they exceeded the threshold of 30 moths per trap in all plots in early July, reaching a peak on 22 July (Figure 8). Catches at Amsbury Farm were intermediate, only just exceeding the threshold. They were lowest at West Pikefish Farm, where the threshold was only exceeded in the RIMpro plot. Catches of summer fruit tortrix moth were very low in all plots at all sites (Figure 9). Damage to fruits due to tortrix moth larvae was negligible (Table 7).

Table 5. Dates of application of insecticide sprays according to treatment									
Site	**Trap**				**RIMpro**			**RIMpro+trap**	
	Product	Appl'n date	Trap thresholds trigger		Product	Appl'n date	RIMpro egg risk dates	Product	Appl'n date
Amsbury	Coragen Coragen	28 June 23 July	6 5,36	20 June 11,18 July	Coragen Coragen	28 June 23 July	18, 19 20, 21 June 13-23 July inclusive	Coragen Coragen	28 June 23 July
Pikefish	Coragen Steward	19 June 9 July	7 5	18 June 24 June	Coragen Steward Coragen	25 June 16 July 2 August	19-21, 27,29 June 4-10, 13-24 July	Coragen Steward	25 June 16 July
Wenderton	Chlorpyrifos Coragen Steward	19 June 3 July 18 July	12 14 7,16	17 June 1 July 8,15 July	Chlorpyrifos Coragen Steward Coragen	19 June 3 July 18 July 2 August	15 June 29,30 June, 1,2 July 5,7,8,9,14-18 July 22-31 July	Chlorpyrifos Coragen Steward	19 June 3 July 18 July

Table 6. Total number and percentage fruits damaged by codling moth in August plus at harvest in September/October.

	Trap		RIMpro		RIMpro + trap	
	no:/ha	**%**	**no:/ha**	**%**	**no:/ha**	**%**
Amsbury	6967	2.67	6097	2.95	5497	3.46
Pikefish	2833	1.04	1917	1.91	2583	1.51
Wenderton	213	0.07	853	0.26	853	0.22

Table 7. Number and percentage fruits damaged by tortrix moth at harvest in September-October. Note no damage was recoded at the August assessment

	Trap		RIMpro		RIMpro + trap	
	no:/ha	**%**	**no:/ha**	**%**	**no:/ha**	**%**
Amsbury	331	0.13	125	0.04	640	0.22
Pikefish	0	0.00	375	0.22	0	0.00
Wenderton	132	0.08	125	0.05	427	0.11

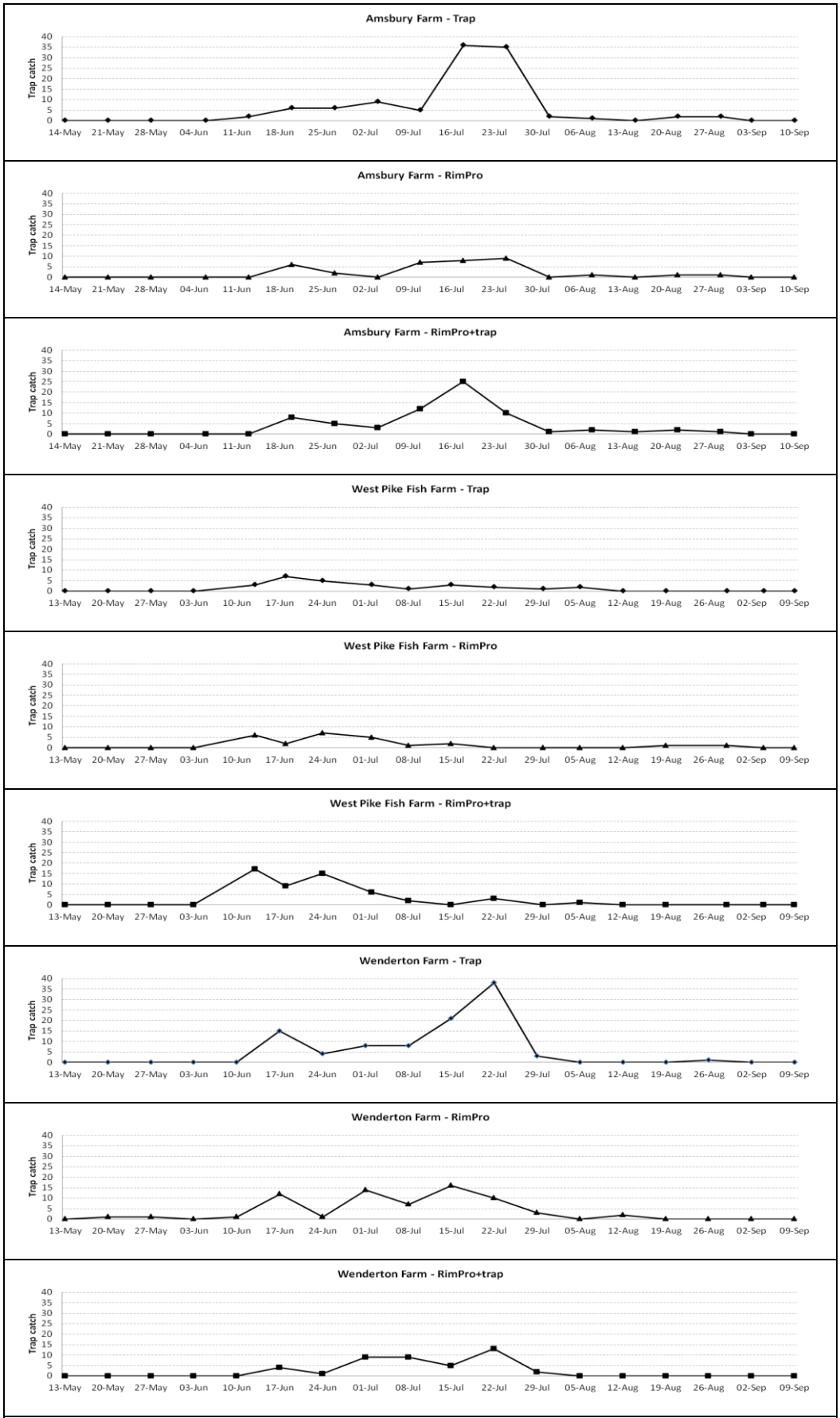


Figure 5. Codling moth sex pheromone trap catches

Figure 6. Codling moth RIMpro+trap combo catches

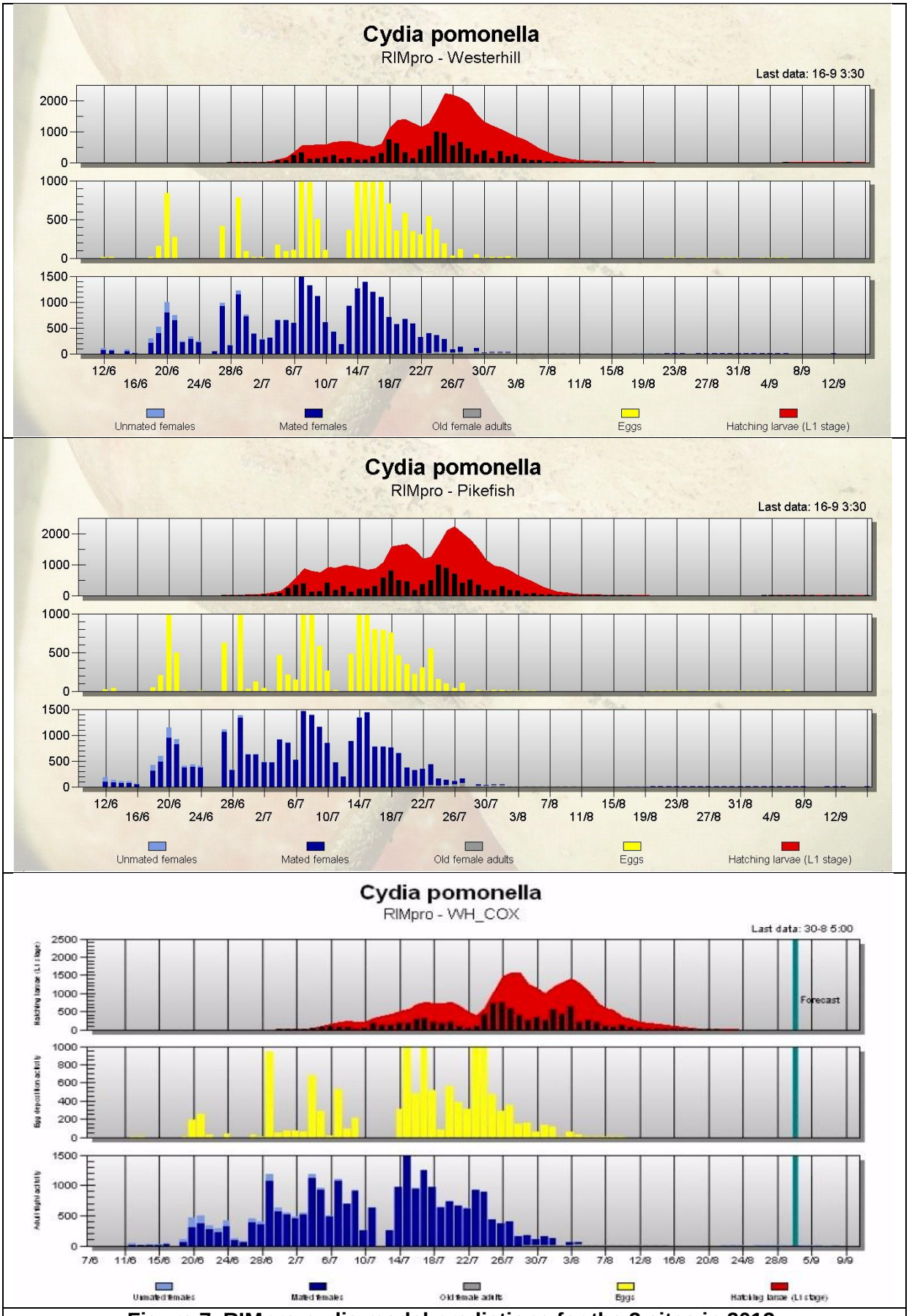


Figure 7. RIMpro-cydia model predictions for the 3 sites in 2013.

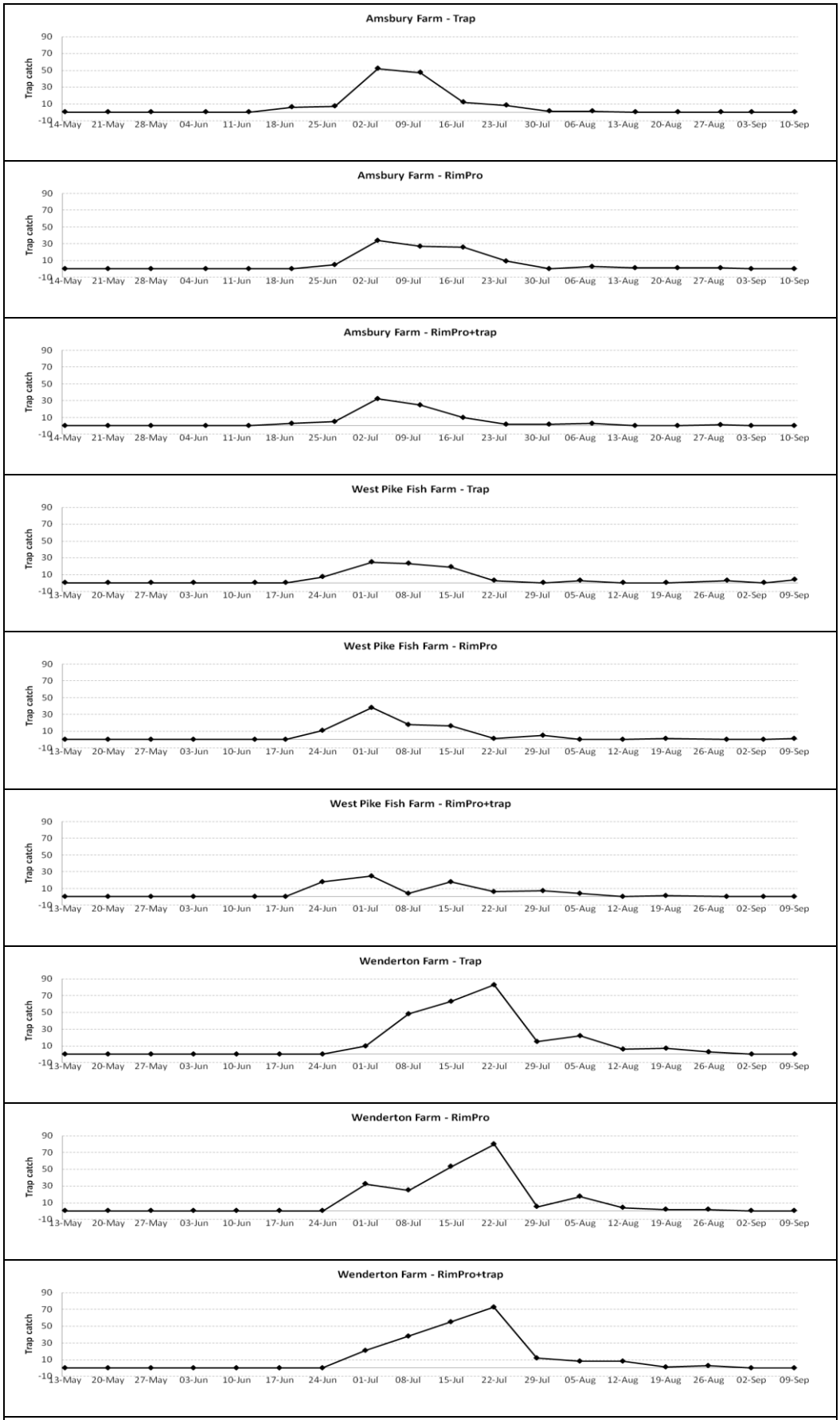


Figure 8. Fruit tree tortrix moth sex pheromone trap catches

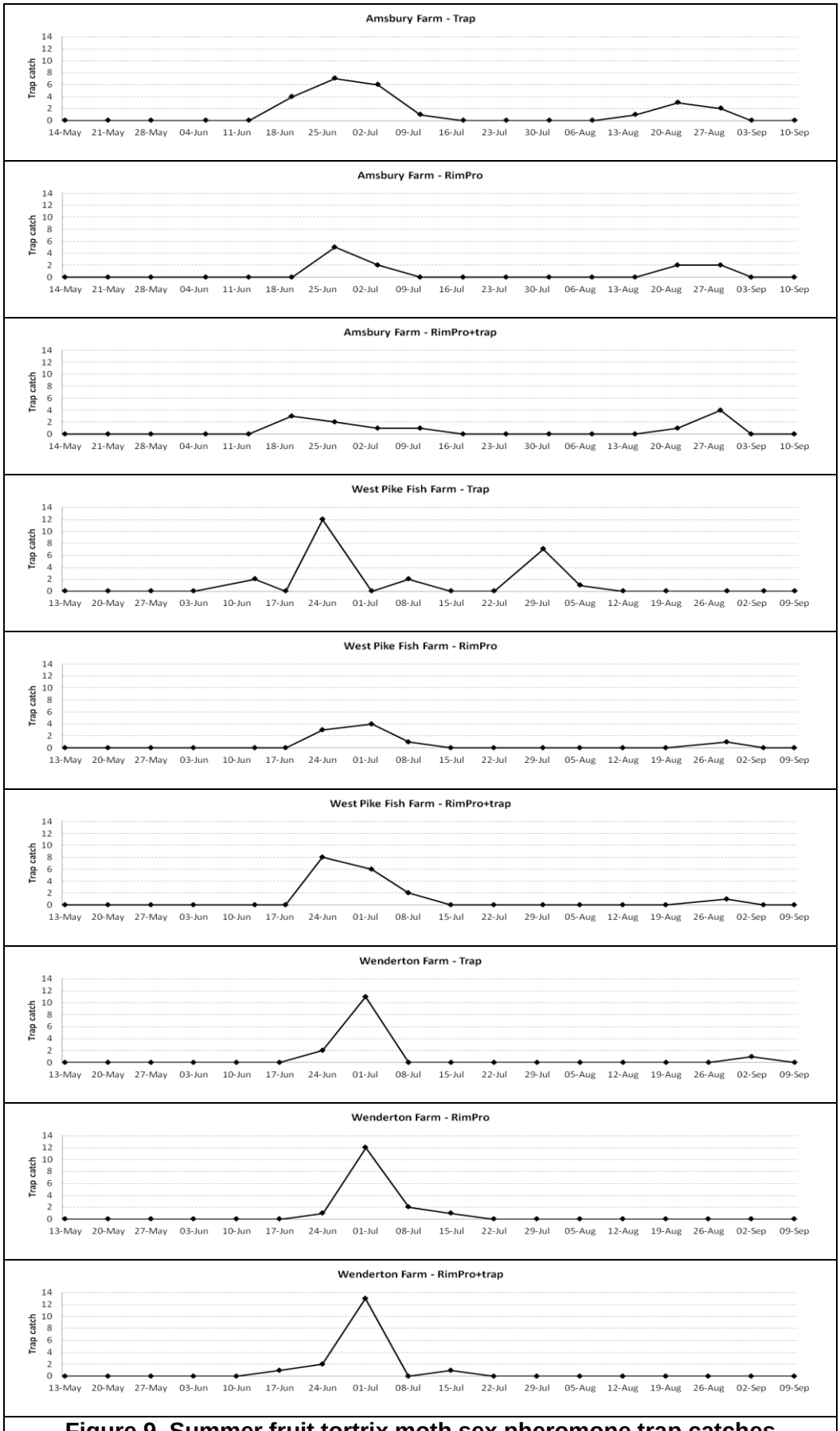


Figure 9. Summer fruit tortrix moth sex pheromone trap catches

Discussion

These adjusted trap thresholds implemented in the trial in 2013 were satisfactory and there were no serious anomalies where high levels of damage resulted as had occurred in 2012.

At any one site, the 'Trap', 'RIMpro' and 'RIMpro+trap' treatments performed similarly in terms of control of codling moth and the resultant fruit damage (Table 6). However, levels of damage (2.67-3.46 % fruits) were too high and considerably above an economically acceptable level at Amsbury Farm, and marginally too high (1.04-1.51%) at West Pikefish Farm. At Wenderton Farm damage levels (0.07-0.26%) were acceptably low. Note that a spray for codling moth costs circa £60/ha to protect fruit worth circa £20,000/ha, so an economic damage threshold of >0.5% of fruits damage is appropriate.

The higher levels of damage at Amsbury Farm are likely to have been due to the relatively high populations of codling moth at the site, coupled with the use of only two sprays for control. The previous year 16.55%, 3.62% and 10.72% fruits were damaged at harvest in the 'Trap', 'RIMpro' and 'RIMpro+trap' plots, respectively. Only two sprays (of Coragen) were applied for control on 28 June and 23 July. The codling moth catches reached a peak of 36 moths per trap in the 'Trap' plot on 18 July. Severe damage would have resulted had no sprays been applied. The sprays applied were thus highly efficacious but probably a higher degree of control would have resulted if the interval between sprays had been shortened to two weeks rather than over three weeks.

The RIMpro model resulted in one more spray of Coragen being applied in early August to the 'RIMPRO' plot than to the 'Trap' or 'RIMpro+trap' plots at West Pikefish and Wenderton Farm (Table 5). At West Pikefish Farm there was no obvious benefit from this extra spray in terms of improved control of codling moth. Levels of damage at Wenderton Farm were too low in any case, so the extra late spray was unnecessary.

As in 2012, the combo traps mainly caught males, generally in larger numbers than the sex pheromone traps. Catches of females were small and erratic. Whilst they have a place for monitoring the success of sex pheromone mating disruption treatments, no real other advantages over the sex pheromone traps were apparent for timing pesticide sprays. If they were to be used, treatment thresholds would need to be re-set for them.

The trial is to be continued for one further year in 2014.

Conclusions

- The adjusted simpler sex pheromone trap thresholds (≥5 moths/trap/week in June-July, ≥3 moths/trap/week in August and September) performed satisfactorily in 2014
- The 'Trap', 'RIMpro' and 'RIMpro+trap' treatments performed similarly in terms of control of codling moth and the resultant fruit damage
- The interval between sprays for codling moth (expected cover period) should be reduced where significant damage crop damage occurred the previous year.
- The RIMpro model resulted in one more insecticide spray being applied in early August at two sites but there was no obvious benefit from this extra spray in terms of improved control of codling moth
- As in 2012, the combo traps mainly caught males, generally in larger numbers than the sex pheromone traps. Catches of females were small and erratic. Whilst combo traps have a place for monitoring the success of sex pheromone mating disruption treatments, no real advantages over the sex pheromone traps were apparent for timing pesticide sprays

Acknowledgements

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