Alternative fruit fly treatment for interstate market access for strawberries

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Department of Employment, Economic Development & Innovation

Project Number: BS06002

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Final Report (February 2010)

Hainan Gu et al.
Market Access Team
Agri-science Queensland
Department of Employment, Economic Development and Innovation

Queensland Government

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PROJECT DETAILS

Horticulture Australia Ltd Project Number: BS06002

Project Title: Alternative fruit fly treatment for interstate market access for strawberries

Report Date: February 2010

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Project Objective:
To use a systems approach to developing an alternative to the dimethoate spray treatment for interstate market access

Funding: Queensland Primary Industries and Fisheries
Horticulture Australia Ltd.
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1 SUMMARY

Queensland is a major producer of strawberries in Australia, mainly providing a winter product for domestic markets, though the production season usually starts in May and finishes in October. Queensland fruit fly (*Bactrocera tryoni*) is a market access impediment for Queensland strawberries because this endemic quarantine pest can use strawberries as a host. The Market Access Team of Agri-science Queensland has recently completed a research project (BS06002) to assess the risk of fruit fly infestation in strawberries from south east Queensland and to test the efficacy of bait treatments with Naturalure® (Dow AgroSciences) as an alternative to dimethoate sprays for the preharvest control of fruit flies in strawberries. Field trials were conducted on multiple commercial farms in the production season of 2008 and 2009 respectively.

Cue-lure traps were used to monitor the activity of male fruit flies over the production season of 2008 and 2009. Trap catches of male fruit flies were very low between May and mid-September in 2008, though in 2009 significant increases occurred since mid-August. During the 2009 season, McPhail traps were also set up in the field to monitor female fruit fly activity. No female flies were trapped until mid-August and the majority of these early trapped female flies were reproductively immature. The seasonal pattern of activity and reproductive maturation in Queensland fruit fly was related with seasonal changes in environmental temperature. Likewise, assessments of strawberry samples have shown that the risk of fruit fly infestation in strawberries was very low in May, June, July and early August, probably due to low temperatures at this time of year being unfavourable for fruit fly activity and maturation. However, the reproductive maturation of female fruit flies as enhanced by warm temperatures in spring could increase the risk of infestation in strawberries, especially when the pest activity/abundance was high under favourable conditions.

The efficacy of current bait treatments to control fruit flies in strawberries was not adequate, probably due to low attraction of baits applied on plastic mulch. Queensland fruit fly originally inhabited rainforest, and the female flies prefer to shelter and forage food in trees and shrubs. Considering the biology and foraging behaviour of Queensland fruit fly, the method of bait application needs to be modified by applying bait to fruiting trees and other windbreak plants on a farm wide scale, as well as border trap crops wherever practically feasible. Furthermore, our experience with previous field trials suggests that hygiene practices such as removing abandoned fruiting blocks and residual host fruit on strawberry farms will benefit to bait treatment by reducing fruit fly pressure. Therefore, it is recommended that further trials be carried out to optimise the baiting system as a pre-harvest control measure against fruit flies in strawberries.

2 INTRODUCTION

Strawberry (*Fragaria* x *ananassa* Duch.) adapts to a wide range of climates and grows under various environmental conditions (Hancock, 1999). Strawberry crops are grown in all Australian states except the Northern Territory, but production is concentrated in Sunshine Coast in Queensland, the Yarra Valley in Victoria, Wannaroo and Albany in Western Australia, the Adelaide Hills in South Australia, and the Camden region of NSW. Queensland remains the largest producer of strawberries in Australia, with 32 million plants producing 26,000 tonnes of fruit in 2007-2008, which is estimated to be worth $122M per year to the Queensland economy according to the industry data presented in the Strawberry Industry Strategic Plan 2009-2013 (http://www.strawberriesaustralia.com.au). Usually, the production season of Queensland strawberries starts in May and finishes in October, mainly providing a winter product for Australian domestic markets.

Queensland fruit fly (*Bactrocera tryoni*) (Qfly) is one of the most important horticultural insect pests in Australia, necessitating both pre- and/or post-harvest control in a broad range of crops. It is a tropical to sub-tropical species, with a wide host range (Fletcher, 1987; Hancock et al., 2000). Because strawberries are recognised as a host for Qfly and it is endemic to all strawberry growing areas in Queensland, this quarantine pest has been a significant market access impediment for Queensland strawberries. Although previous research results from the Better Berries projects have shown that strawberries are rarely infested by Qfly when grown as a ground crop under commercial practices, Queensland strawberries are subject to the protocol ICA-11 for interstate market access. Under ICA-11, strawberries must be subject to pre-harvest dimethoate sprays plus in-field and pack-house culling and inspection, except for those harvested during a winter window period (e.g. between 1 June and 20 September for south east Queensland). It had been accepted that low fruit fly pressure reduced the risk of infestation in the winter strawberries, and interstate trade allowed without pre-harvest dimethoate treatment. However, the detection of Qfly larvae in two consignments of strawberries harvested in late August-early September, 2009 has led to withdrawal of the winter window option by both Victoria and South Australia. Now, the phytosanitary treatments specified in ICA-11 are required to apply to Queensland strawberries for interstate market access throughout the production season.

There are several issues with the application of pre-harvest dimethoate sprays in strawberries. Firstly, their application disrupts the integrated pest management (IPM) system established for mite control on strawberry plants (HAL Final Reports FR048 and FR115). Secondly, dimethoate is currently under review by the APVMA (Australian Pesticide and Veterinary Medicine Authority). It is uncertain whether the use of dimethoate on fruit commodities with edible peel, such as strawberries, will be allowed in the near future. Therefore, an alternative to dimethoate sprays for pre-harvest fruit fly control in strawberries has been identified as a priority for Queensland strawberry industry.

Spot or strip foliar sprays with protein baits have been the most widely used alternative to dimethoate cover sprays for fruit fly control in many tree crops. However, such treatments were considered to be unsuitable for the ground growing hosts of minimal foliage, such as strawberries. Research by the Market Access Team had demonstrated that fly response to ground application of protein baits was very poor, so that this treatment would not provide an effective alternative to dimethoate. On the other hand, preliminary research of the Better Berries project undertaken in 2002-2004 had shown the potential of applying protein baits to trap crops (e.g. lupins) as an alternative to dimethoate for fruit fly control in strawberries.

In two QPIF projects (HAL AH00012 and HAL HG02066) that were recently completed by the Market Access Team, the organically certified fruit fly bait Naturalure (Dow AgroSciences) was tested as a non-foliar application on trunks or plywood boards (Lloyd et al., 2003b, 2005). The results obtained from these projects suggested that off-crop application of Naturalure in or around strawberry blocks could provide effective fruit fly control.

This project was aimed at using a systems approach to develop an alternative to pre-harvest dimethoate sprays for Queensland strawberries to gain interstate market access, and providing quantitative, market access type data on the efficacy of bait application which is required by interstate quarantine authorities for modifying the existing protocol of pre-harvest treatment against fruit flies in strawberries. The original proposal was only focused on production seasons before and after the winter window period of south east Queensland. Therefore, the first year trials in 2008 were conducted to quantify the level of infestation in the untreated strawberries harvested prior to the winter window and to evaluate the efficacy of protein baiting for the pre-harvest control of fruit flies after the winter window. Additional studies were carried out to compare the level of fruit fly activity and infestation in ground grown strawberries and hydroponic ones raised above ground. In response to concerns with the winter window option raised by Victoria, the second year trials in 2009 were conducted throughout the production season of Queensland strawberries, including assessment of fruit fly infestation in strawberries harvested during the winter window period.

Trials were carried out in commercial strawberry farms located in the Caboolture-Nambour region, which is the major strawberry production area in south east Queensland. This report describes trial methods, presents trial data, and discusses implications for fruit fly control and market access for Queensland strawberries. Although the general term of fruit fly activity or infestation is mostly used in the following sections, the fruit fly trap catch data and infestation assessment presented in the report refer to Queensland fruit fly (*Bactrocera tryoni*), unless otherwise stated.

3 MATERIALS AND METHODS

3.1 Comparison of fruit fly activity and infestation in ground versus hydroponic strawberries

Trapping trials and limited fruit collection were undertaken in one untreated ground grown block and one hydroponic block, which were available over summer. These trials were attempted to obtain quantitative data to test whether the hydroponic strawberries raised above ground (Photo 1) were more susceptible to fruit fly attack than ground grown fruit (Photo 2).

Photo 1 Hydroponic strawberries above ground

Photo 2 Ground grown strawberries

The ground block was located near Wamuran, which was retained by the grower as an experimental block after commercial picking had finished. Three traps were installed in October 2006, one in the border vegetation next to a road and other two approx 20 m and 80 m into the crop block, respectively. These traps were cleared fortnightly until the crop was removed in March 2007. On October 11th 2006 fruit samples were taken from different areas of this block to determine whether there was a higher level of infestation in fruit closer to the bordering vegetation. In total, 342 fruit (7.4 kg) were collected near an adjacent dimethoate treated block, 312 fruit (7.8 kg) were collected from an area 80-100 m from border vegetation and 100 fruit (2.4kg) adjacent to border vegetation. The sample near the border was smaller due to a lack of fruit. A second sample of 51 fruit (0.8 kg) from near the border vegetation was collected on October 25th 2006. No fruit were available from the rest of the block.

The hydroponic block was located at Palmwoods. Traps were installed in October 2006 and cleared fortnightly. Four were installed in the bordering vegetation and two were installed within the block. Although the grower had been applying fruit fly treatments, there was concern that some fruit fly infestation was still occurring as indicated by the presence of damaged fruit. To check this possibility, 190 fruit (2.3 kg) rejected by the pickers on one day and 173 fruit (1.6 kg) rejected in the pack-house were taken for assessment of infestation.

Experimental tests were conducted in a field cage (80x25x5 m) at the Redlands Research Station of Queensland Primary Industries and Fisheries, in which nectarine trees were grown (Photo 3). All nectarine fruit was removed from the trial block prior to commencement of the trial.

Photo 3 Field cage at Redlands Research Station

Fruiting strawberry plants were sourced from ‘Nutrifruit’ hydroponic strawberry farm. The plants were grown in black plastic bags (approx 30x60 cm) each containing 6 plants. Several rows were set aside for this experiment and the fruit in these rows received no fruit fly treatments for a minimum of six weeks prior to commencement. When the rest of the block was sprayed the experimental plants were covered in plastic sheeting to prevent spray drift. To control fruit flies, the rest of the strawberry block and surrounding vegetation was treated with protein bait, plus supplementary applications of dimethoate as required.

Protein bait was only applied to the support posts of the trial plants to avoid contact with the plants or bags.

Two pairs of sites were chosen in a line approx 2.5 m from the edge of the first row of nectarine trees. Each pair was approximately 3 m apart both between and within sites. Within each pair, the placing of plants either on a wire bench 1.2 m above or on the ground was randomly allocated. After the first replicate, plants on the ground were covered by a wire cage (20 mm square aperture) to prevent ground animals from eating the fruit.

On the day prior to the test, four bags were selected, which had roughly equal numbers of fruit. These bags were then allocated to a position (i.e. 2 raised and 2 on ground). The next morning (approx 7 am) ~1000 sexually mature, laboratory reared *B. tryoni* (male: female = 50:50) were released in the centre of the nectarine block. After 24 hours, all mature strawberry fruit was harvested, counted, weighed and set up for assessment of infestation in an incubation room at 27 °C and 80% RH. After seven days, each fruit was dissected to determine infestation. This was repeated 5 times, giving a total of 10 replicates.

Two sample paired t-tests were performed to statistically compare the level of fruit fly infestation in the strawberries at 1.2 m above ground and on ground, using the software GenStat (Release 11.1, VSN International Ltd).

3.2 Trials in 2008

The first year field trials were carried out on different strawberry farms prior to and after the winter window, as the original project planned, though trapping to monitor fruit fly activity was continued over the winter window wherever possible.

3.2.1 Trials prior to winter window

Trials prior to winter window included monitoring fruit fly activity and assessing infestation in the strawberries of early season strawberry varieties. These trials were carried out on three farms at Chevallum, Palmview and Wamuran.

In early May, four Qfly traps were installed at each of the three farms to monitor fruit fly activity. Two traps were set up within a trial block (Photo 4) and others in the surrounding vegetation (Photo 5). Following a standard procedure for trap clearance, each grower checked the traps on their property and recorded the presence or absence of fruit flies on a weekly basis. The trapped fruit flies were sent to the Indooroopilly laboratory for species identification and recording.

Fruit samples were taken from the strawberries harvested from each of the three farms. The samples consisted of packed fruit and discards. All samples were assessed by the research team at the Indooroopilly laboratory. Before assessment, individual fruit were held in egg trays and then enclosed in plastic boxes with a fine mesh cover (Photo 6).

After seven days kept under standard conditions at 27 °C and 80% RH, fruit were individually checked for the presence of fruit fly larvae and pupae (Photo 7). The larvae and pupae were cultured for adult emergence. The species and sex of emerged adults were recorded.

Photo 4 Qfly trap set up in a strawberry block

Photo 5 Qfly traps set up in surrounding vegetation

Photo 6 Set-up of strawberry samples for incubation

Photo 7 Examination of fruit fly infestation in strawberry samples

3.2.2 Trials after winter window

The late season field trials with Naturalure Fruit Fly Bait Concentrate® from Dow AgroSciences were carried out on three strawberry farms, which are located at Bellmere, Wamuran and Chevallum. The trial blocks at Bellmere and Chevallum were 1.8 and 0.16 hectares respectively, with the strawberry variety of Festival, whereas the trial block at Wamuran was 0.5 hectares, with the variety of Ruby Gem. The research team provided the bait and a hand-operated sprayer to each participating grower and installed four Qfly traps in and around each trial block, as in trials prior to winter window. The growers conducted bait application and trap servicing on their property, following standard instructions written by the research team.

The Naturalure concentrate was used at the rate of 1L per hectare, as specified on the product label. After mixing 1 part of Naturalure concentrate with 3.5 parts of water, 5 ml bait spots were distributed with a hand held pump nozzle to every third or fifth row, 2-3 m apart on the plastic mulch between the two plant rows on the bed. Bait spots were also applied onto other host fruit trees and windbreak plants adjacent to trial blocks. Weekly bait application started on August 21st (re-applying sooner if rain washed off the bait) and continued until the end of fruit harvest.

The original experimental design included a sample of 3000 packed fruit from both early and late picks in each trial block and a sample of discarded fruit from the same trial block on the same harvest day. The sample size of the discarded fruit varied, depending on the level of fruit rejection in the field and packing shed. Thus, a total of 9000 packed fruit plus some discarded fruit samples would be assessed for each of the two picks. Unfortunately, excessive rainfall in the areas where the field trials were undertaken and low market price for strawberries during the season caused the pull-out of the trial block at Chevallum prior to the early pick. Unfavourable weather conditions had also reduced the fruit productivity and quality in the other trial blocks. Therefore, assessment was done with the fruit samples from each of the two remaining trial blocks at Bellmere and Wamuran.

3.3 Trials in 2009

The second year trials were conducted throughout the strawberry production season, including the winter window period. Trials were carried out on four strawberry farms located at Bellmere, Wamuran, Elimbah and Chevallum. The trial activities consisted of (1) monitoring fruit fly activities from May to October, (2) assessing strawberries harvested before June 1st, between June 1st and September 20th, and (3) weekly application of Naturalure bait from August 20th. Fruit from the baiting trial blocks were assessed after September 20th.

3.3.1 Monitoring of fruit fly activity

To gain insights into spatial as well as temporal variation in fruit fly activity, 18 to 21 Qfly traps were installed on each farm and serviced fortnightly from May 1st to October 7th, 2009. These traps were distributed within strawberry blocks and in the surrounding vegetation, according to the property habitat features. All traps were serviced by the research team. The collected fruit flies were taken to the Indooroopilly laboratory for counting, species identification and recording.

In addition, female fruit flies were collected from the three strawberry farms located in Bellmere, Wamuran and Chevallum. Four McPhail traps baited with orange-ammonia solution were positioned around in vegetation bordering strawberry blocks on each farm. The traps were initially installed on May 13th 2009. Orange-ammonia lure was prepared in accordance with Section 3.2.3 of the Fruit Fly Trapping & Monitoring Manual (Anonymous, 1996). Approx 100 ml of diluted solution was used in each trap. The traps were cleared and lure was replaced weekly. Trap contents were sieved to collect fruit flies. Fruit flies from each trap were separately placed in glass tubes containing 70% ethanol and clearly labelled for transport/storage pending dissection and examination.

Female flies were dissected in de-ionized water to determine their maturity according to the stage of ovaries. Four stages of ovarian development described by Pritchard (1970) were used to determine female maturation. Pritchard (1970) observed that the most evident external changes in the ovary were a decrease in the compactness of ovarioles and an increase in size of egg chambers associated with egg yolk deposition. Generally, both ovaries of a female fly were not at the same stage of development, and only the stage of the more advanced ovary was recorded. Flies were classified as mature when ovaries contained fully developed primary egg cells.

3.3.2 Assessment for fruit fly infestation in strawberries

Fruit fly infestation in the strawberries of early season varieties were assessed in May. These strawberries were taken from three farms at Wamuran, Elimbah and Chevallum (note: the farm at Bellmere did not have early season varieties). For each of the three farms where trials were conducted, a sample of at least 3000 packed fruit plus a sample of discards were sourced from blocks with no fruit fly treatments.

Strawberries from untreated blocks in each of the four farms were also taken in June, July, August and September, respectively, to assess the level of fruit fly infestation during the winter window period.

In the trials with late season varieties, off-plant protein baits with Naturalure were applied weekly to the plastic mulch from August 20th and strawberry samples were taken after September 20th for evaluation of the baiting efficacy. Two samplings were planned for each trial block in late September/early October and in late October, respectively. However, unfavourable weather conditions due to abnormal warm temperatures in late winter/early spring led to the foreshortening of the harvest season, and hence only one sample was obtained from each of the three farms at Bellmere, Wamuran and Elimbah (note: the farm at Chevallum did not harvest strawberries after the winter window).

The same method of baiting application and procedure of strawberry assessment as used for field trials in 2008 were followed.

3.4 Calculation of the upper confidence limit for percent infestation

The upper limit of infestation percent at the 95% confidence level was calculated for the assessed strawberry samples, using the program CQT_STATS (Couey and Chew, 1986).

4 RESULTS

4.1 Fruit fly behaviour and infestation in ground and hydroponic strawberries

Preliminary assessment of trapping data from ground grown strawberries showed a strong tendency of fruit flies occurring in the bordering vegetation. The mean trap catches per fortnight for the border, 20 m and 80 m into the block from the border were 35.3, 19.5 and 12.3, respectively. This trend was supported by the fruit infestation data. Fruit from the first sample near the border produced the equivalent of 10.1 flies/kg, compared to 2.2 flies/kg in the fruit picked at 80-100 m from the border. In the second border sample, the infestation increased to 51.1 flies/ kg.

On the other hand, in the hydroponic strawberries raised above ground, there were no differences in the numbers of fruit flies trapped within the block (mean 18.1/fortnight), compared to the bordering vegetation (mean 20.0/fortnight), over the period from October 2006 to April 2007. This relatively even distribution of the trap catches may be due to the trellis arrangement providing a sheltered environment allowing the fruit flies to move freely within the block. No fruit flies were reared from either the pick or pack reject fruit, indicating either that the observed damage was not caused by fruit flies or that the applied dimethoate treatments were effective in killing the immature stage of fruit flies.

In the experimental tests, 187 and 107 fruits were checked from strawberry plants positioned 1.2 m above ground and on ground, respectively. Out of these samples, 31 and 13 strawberries were infested by fruit flies (Table 1). The experimental data showed that the level of fruit fly infestation was slightly higher in the strawberry plants raised at 1.2m above (16.58%) than in those on the ground (12.15%), but the statistical differences were not significant (two-sample paired t-test: t =1.46, d.f. =8, P =0.182). It was also true for the number of flies found per fruit from the plants placed 1.2 m above ground (0.98) and those on ground (0.24) (t = 1.87, d.f. =8, P =0.099).

Table 1 Comparison of fruit fly infestation in strawberries 1.2 m above and on ground

Position	No. fruit	No. infested fı	No. immature	% fruit infested	Immature/fruit
1.2 m	187	31	166	16.58	0.89
Ground	107	13	26	12.15	0.24

4.2 Trials in 2008

4.2.1 Monitoring of fruit fly activity

Male trap catches over the strawberry production season of 2008 is presented in Figure 1, though trapping activity was not continued on each of the participant farms.

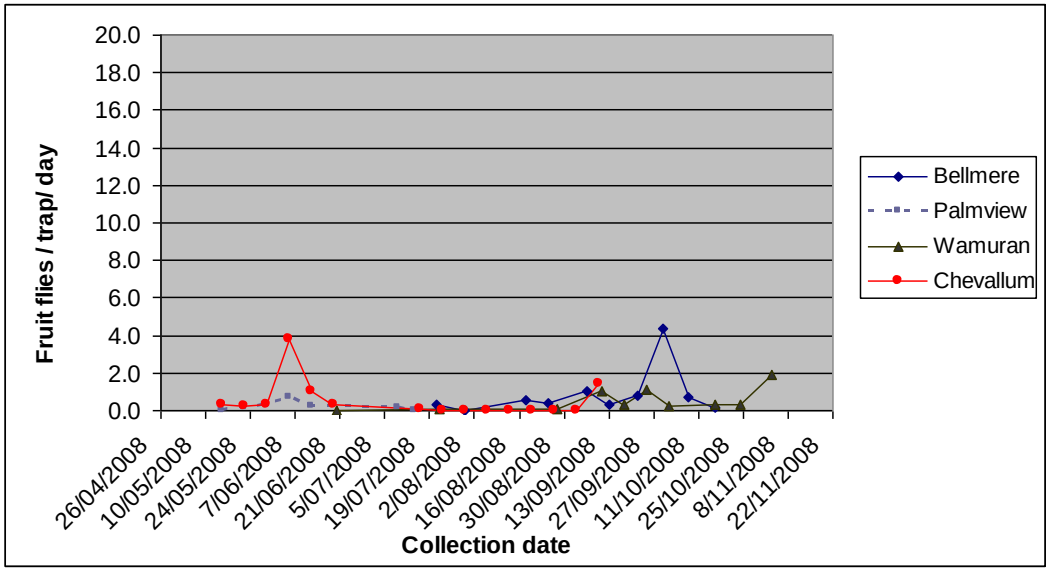

Figure 1 Male fruit flies trapped over the strawberry season of 2008

Prior to 1 June, the average male catches ranged from 0 to 0.32 fruit flies per trap per day, though an increase up to 3.78 occurred at Chevallum during the first week of the winter window. The result indicated that fruit fly activity in the early season of this year was low.

Although assessment for fruit fly infestation was not conducted for the strawberries during the winter window of 2008, fruit fly trapping was continued wherever possible. The trapping data showed that fruit fly activity during the winter window period was very low on all four farms, with almost no flies caught in most traps between late June and mid August.

The trap catches started to increase by early September and peaked in early October. Trapping data from Wamuran indicated a decline in fruit fly activity before it rapidly increased again around the end of October.

3.2.2 Assessment of fruit fly infestation in strawberries

Samples of 3163 packed fruit and 257 discards were collected from Chevallum on May 20th, 2469 packed fruit and 343 discards from Wamuran on May 26th, and 2794 packed fruit and 115 discards from Palmview on May 26th. No fruit fly infestation was found from the total of 9141 strawberries (equivalent to 141.6 kg) assessed in the laboratory. Based on this trial data, the upper infestation level of strawberries prior to the winter window of 2008 is estimated as 0.0328% at a 95% confidence (Table 2).

Data for fruit fly infestation in the strawberry samples harvested after the winter window are presented in Table 3. Assessments were made on 4887 and 3855 strawberries from the early and late picks from Bellmere, which took place on October 6th and 20th, respectively, and 3855 and 3542 strawberries from the two picks at Wamuran, which occurred on October 7th and 21st, respectively. The samples from Wamuran included all field-collected fruit because not enough fruit of pack quality was available for assessment. Seven of the 8742 fruit (132.6 kg) from Bellmere were found being infested with 13 immature

Queensland fruit fly detected, while only one of the 8021 fruit (72.9 kg) from Wamuran was infested with 2 fruit fly larvae. Accordingly, the upper level of infestation percent at a 95% confidence is estimated as 0.1504% for the samples from Bellmere and 0.0591% for those from Wamuran, respectively.

Table 2 Assessment of strawberries harvested prior to the winter window of 2008

Property	Variety	Sample	Date picked	No. fruit	Weight of fruit (kg)	No. fruit infested	No. larvae / pupae	Upper infestation level % (95% confidence)
Palmview	Mixed	Pack house	26 May	2794	37.1	0	0	0.1072
		Discards	26 May	115	1.0	0	0	
		Sub-Total		2909		0	0	0.1030
Wamuran	Ruby Gem	Pack house	26 May	2469	55.5	0	0	0.1213
		Discards	26 May	343	5.7	0	0	
		Sub-Total		2812		0	0	0.1065
Chevallum	Early Blush	Pack house	20 May	3163	40.2	0	0	0.0947
		Discards	20 May	257	2.1	0	0	
		Sub-Total		3420		0	0	0.0876
Total				**9141**	**141.6**	**0**	**0**	**0.0328**

Table 3 Assessment of strawberries harvested from the bait-treated blocks after the winter window of 2008

Property	Variety	Sample	Date picked	No. Fruit	Weight of fruit (kg)	No. fruit infested	No. larvae / pupae*	Upper infestation level % (95% confidence)
Wamuran†	Ruby Gem	Field	7 Oct	4479	47.3	1	2L	
		Field	21 Oct	3542	25.6	0	0	
		Sub-Total		8021	72.9	1	2L	0.0591
Bellmere	Festival	Pack house	6 Oct	4887	79.8	4	7L 2P	
		Pack house	20 Oct	3855	52.8	3	4P	
		Sub-Total		8742	132.6	7	7L 6P	0.1504
Across properties	Mixed		Early	9366		5	9L 2P	0.1123
			Late	7397		3	4P	0.1048
Total				**16763**	**205.5**	**8**	**9L 6P**	

† The strawberries for both dates from Wamuran were of very poor quality. An in-house sort of the first batch was conducted to remove the worst berries though none of the berries for either date were of saleable quality.
* All adults emerged from these larvae/pupae were identified as Queensland fruit fly (*B. tryoni*).

4.3 Trials in 2009

4.3.1 Monitoring of fruit fly activity

Trapping data of male fruit flies over the strawberry production season indicated that fruit fly activity differed between farms, with daily trap average ranging from 0.2 to 3.4 male flies, though there was variation in the number of fruit flies caught in different traps within a farm (Figures 2-5). In general, traps that were set up close to fruiting or other ornamental trees or in the vicinity of natural vegetation caught more fruit flies than did those placed inside strawberry blocks. The daily catch numbers from the former traps tended to be greater than the average on the farm, which is indentified with the mean daily catch of male flies for the trap concerned in these figures. It was noted that during the early season of strawberry production, i.e. in May, June and July, most male fruit flies were caught in traps located close to fruit trees or natural vegetation, though the fruit fly catch in the others traps gradually increased as the season progressed into August when the fruit fly populations increased significantly.

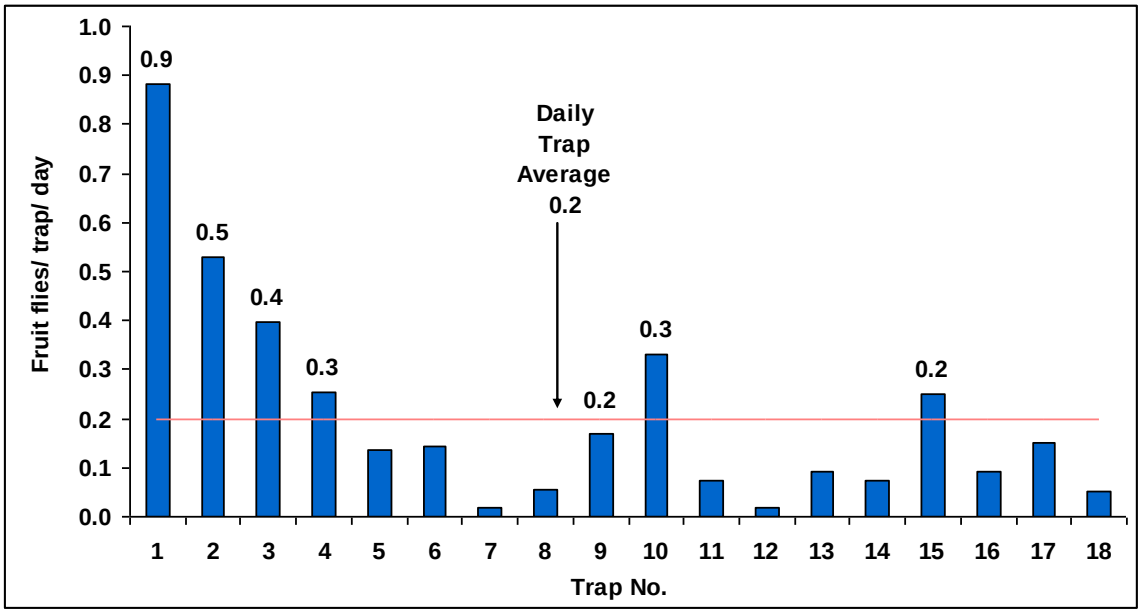

Figure 2 Daily male fruit fly catches from different traps set up at Bellmere, averaged over the strawberry production season of 2009

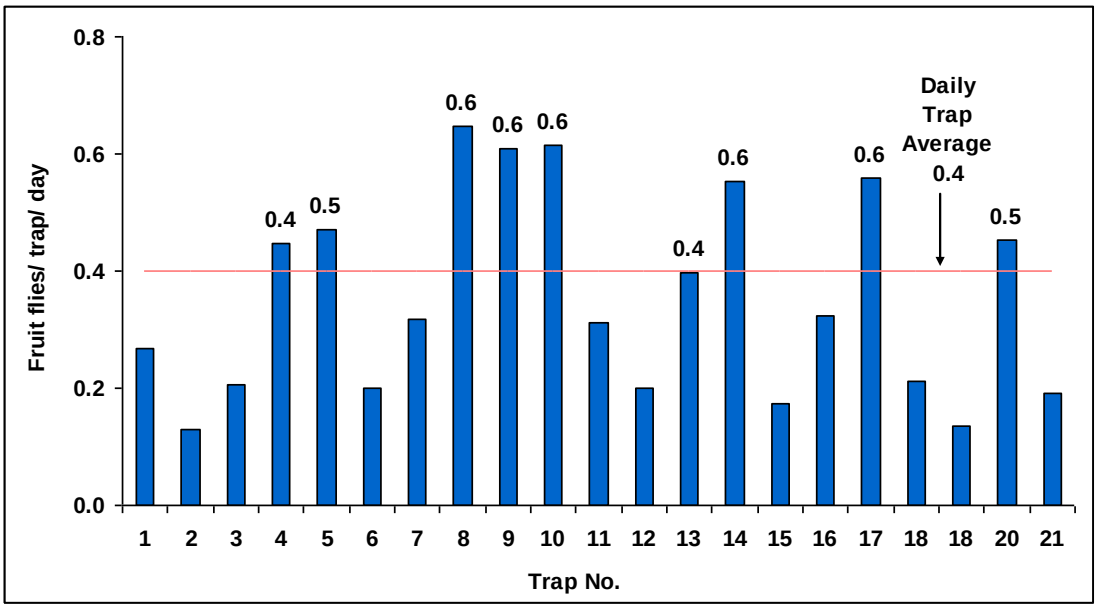

Figure 3 Daily male fruit fly catches from different traps set up at Wamuran, averaged over the strawberry production season of 2009

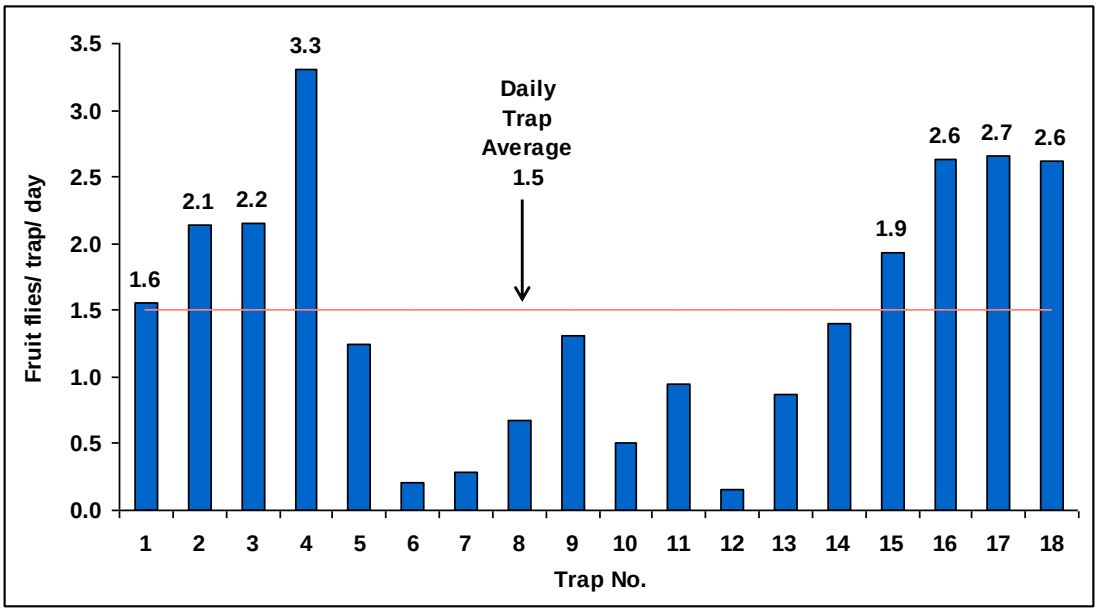

Figure 4 Daily male fruit fly catches from different traps set up at Elimbah, averaged over the strawberry production season of 2009

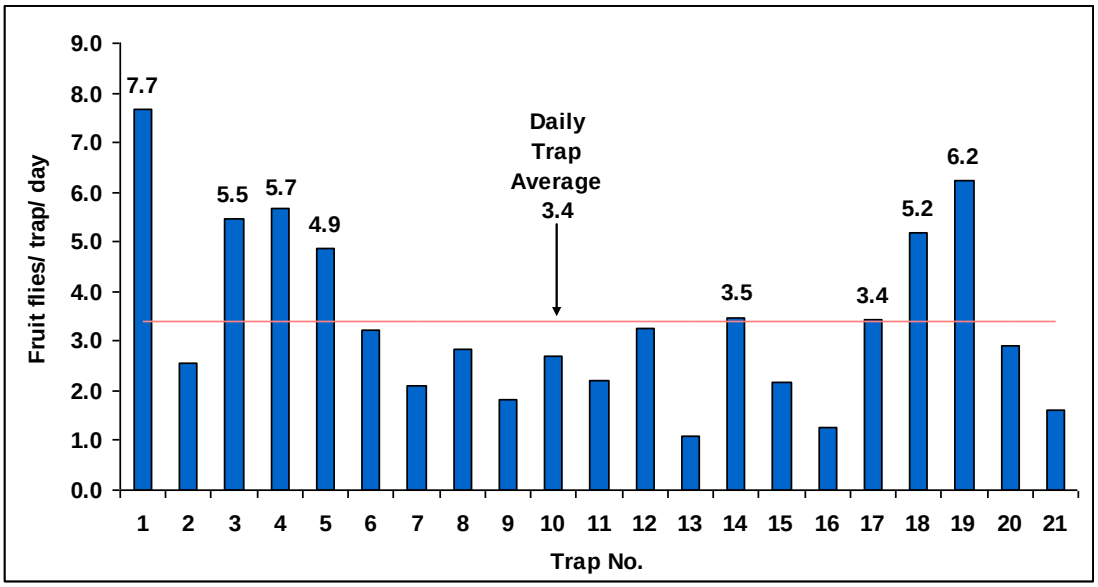

Figure 5 Daily male fruit fly catches from different traps set up at Chevallum, averaged over the strawberry production season of 2009

Although the average number of male fruit flies trapped differed between farms, the pattern of seasonal changes in the daily catches on the four farms was similar (Figure 6). Fruit fly activity was very low between 1 May and 19 August, with no flies caught in most traps between late June and mid August. It increased in late August and reached the first peak in early September; then it decreased to some extent in mid to late September before it rapidly increased again in early October.

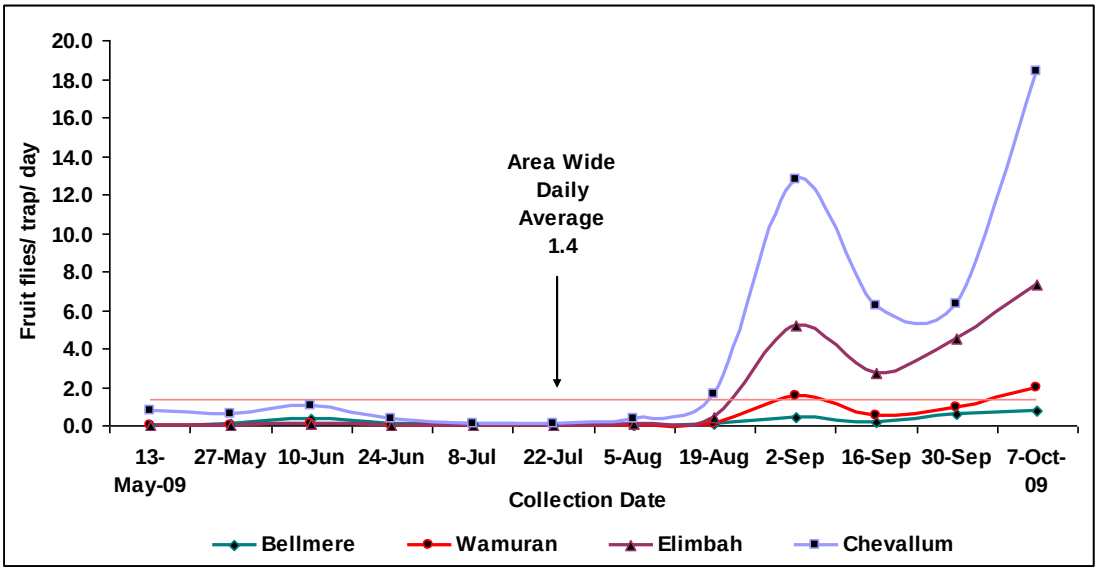

Figure 6 Seasonal changes in trap catches of male fruit flies at four different strawberry farms

Female trap catches showed a similar temporal pattern of activity during the strawberry season, though no female fruit flies were caught before August 19th (Figure 7). The number of trapped female flies rapidly increased from a daily average of 0.2 to a peak of 2.5-3.7 between early and mid September. Although the number decreased after September 16th some female fruit flies were always trapped in the late strawberry season.

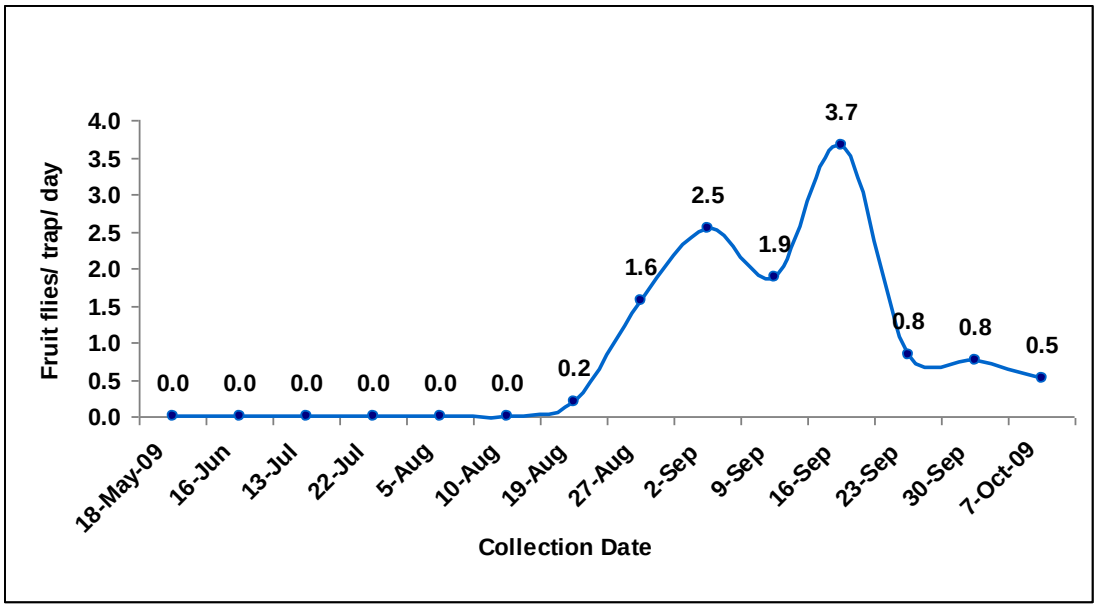

Figure 7 Seasonal changes in trap catches of female fruit flies, averaged from three different strawberry farms

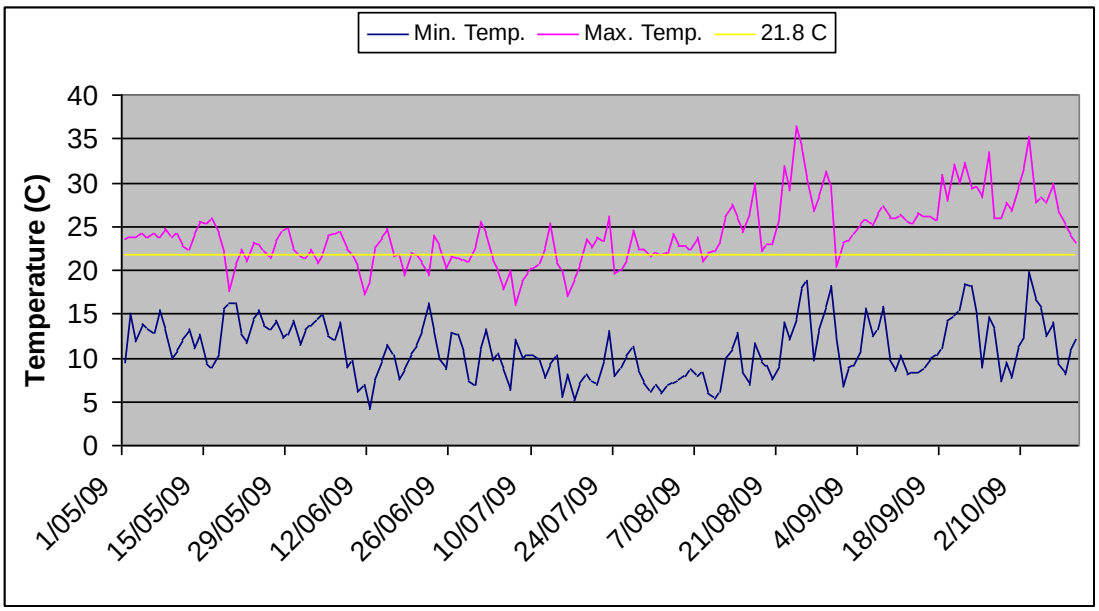

Figure 8 Daily temperature measurements at Beerburrum from May 1 to October 11, 2009, with a calculated threshold maximum temperature of 21.8 °C marked (see text)

Seasonal changes in fruit fly activity were apparently related to seasonal fluctuations in environmental temperature. Rapid increases in male and female trap catches happened when a noticeable increase in temperature occurred between late August and early September, as shown in meteorological records at Beerburrum (Figures 8).

Male fruit fly catches at all the four strawberry farms where Qfly traps were set up were significantly correlated with daily maximum temperature in the area, but the correlation with daily minimum temperature or rainfall was not significant, with an exception at Bellmere (Table 4).

Table 4 Correlations between trap catches of Qfly and climatic variables

	Maximum temperature		Minimum temperature		Rainfall (mm)	
Property	r	p	r	p	r	p
Bellmere	0.8483	0.001	0.6403	0.0338	-0.1177	0.7303
Chevallum	0.8631	<0.001	0.4330	0.1834	-0.2556	0.4474
Elimbah	0.9289	<0.001	0.4445	0.1708	-0.2776	0.4086
Wamuran	0.8687	<0.001	0.4569	0.1578	-0.2536	0.4518
Across property	**0.8957**	**<0.001**	**0.4501**	**0.1648**	**-0.2625**	**0.4356**

The correlation of the overall mean of fruit fly catches across the four farms with daily maximum temperature was highly significant (Table 4). The relationship between these two variables (Figure 9) fits to a linear regression model (Daily trap catch of male fruit flies = 0.5434 Maximum temperature – 11.85, F =36.53, P <0.001). According to this model, no fruit flies would be trapped on the days when daily maximum temperature was below 21.8°C. The daily maximum temperature of 21.8°C may be tentatively regarded as a threshold temperature for trapping male fruit flies in the Caboolture-Nambour region of Queensland, though it needs to be attested in further studies.

The ovarian maturation of female Queensland fruit flies is known to occur only when temperature remains at least 1.6 day-degrees above a development threshold of 13.5°C (Pritchard, 1970; Fletcher, 1975). The day-degree model based on the Beerburrum temperature data shows that warm conditions after late August favoured ovarian maturation and subsequent oviposition by female fruit flies because from this time on the day-degrees remained well above the threshold of 1.6 day-degrees (Figure 10). This influence of temperature is well reflected by changes in the rate of mature female fruit flies trapped over the strawberry season (Table 5).

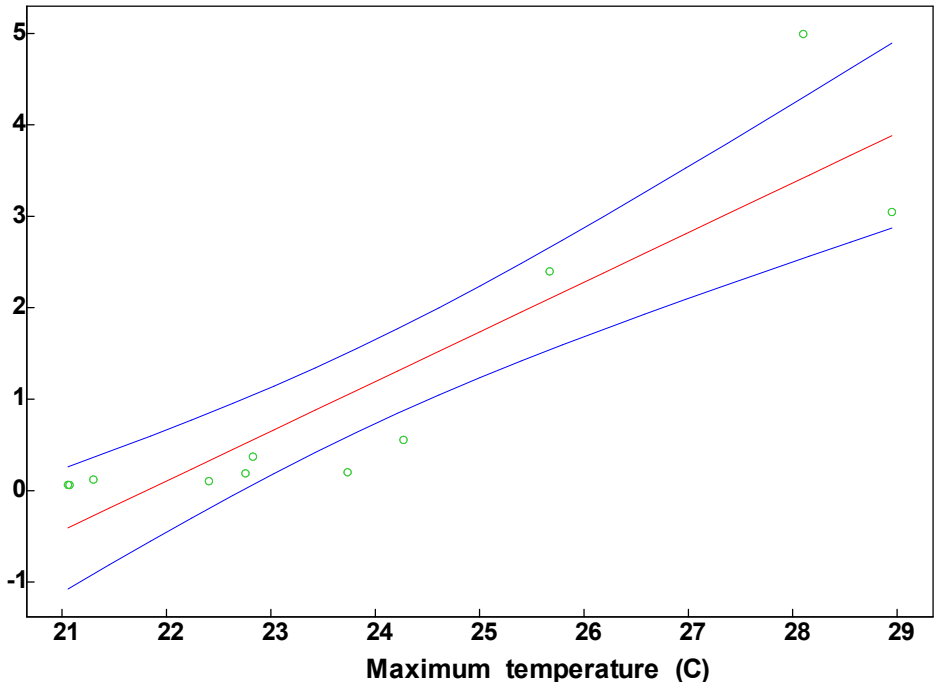

Figure 9 Fitted and observed relationship between daily male fruit fly catch and maximum temperature in south east Queensland over the strawberry production season of 2009 at a 95% confidence

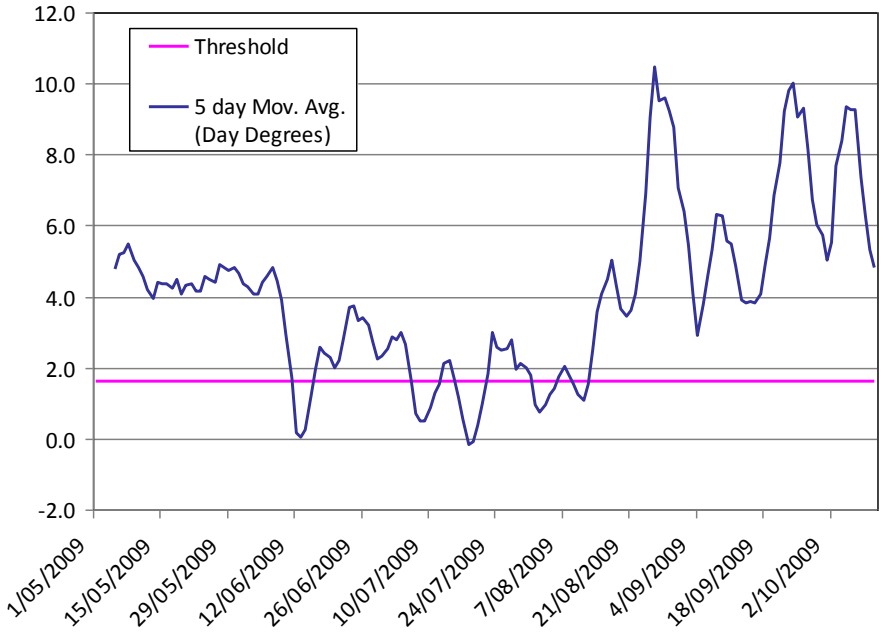

Figure 10 Day-degree model based on temperature records at Beerburrum from May 1 to October 11, 2009

Table 5 Examination of reproductive maturation in female fruit flies trapped from strawberry cropping farms in 2009

Trapping period	No. trapped	No. immature	No. mature	No. indeterminate	% mature
13-18 May	0	0	0	0	-
10-16 June	0	0	0	0	-
8-13 July	0	0	0	0	-
13-22 July	0	0	0	0	-
22 July -5 Aug	0	0	0	0	-
5-10 Aug	0	0	0	0	-
10-19 Aug	20	17	3	0	15.0
19-27 Aug	151	91	53	7	35.1
27 Aug-2 Sept	182	129	47	6	25.8
2-9 Sept	158	86	68	4	43.0
9-16 Sept	307	148	140	19	45.6
16-23 Sept	70	31	33	6	47.1
23-30 Sept	63	44	18	1	28.6
30 Sept-7 Oct	44	33	7	4	15.9
Total	995	579	369	47	37.1

Dissection and examination of the trapped female fruit flies revealed the progression of reproductive maturation in their populations. The rate of mature females was only 15% in those trapped during August 10-19th, but it steadily increased to 47.1% one month later, though it decreased to 15.9% during the period between September 30th and October 7th (Table 5). Undoubtedly, the rapid increase in temperature in late August-early September contributed to the acceleration of reproductive maturation in these female fruit flies. The observed decrease in the rate of mature females after this period was probably due to an influx of newly emerged females from the local populations.

4.3.2 Assessment of fruit fly infestation in strawberries

In total, 10,264 strawberries (equivalent to 167.23 kg) harvested from the early season varieties in May were assessed. Among them, 3418, 2866 and 3757 packed fruits were taken from the farms at Chevallum, Wamuran and Elimbah, respectively, and 223 discards from Wamuran. Out of these strawberry samples assessed, only one fruit from Chevallum was found to be infested with one Qfly larva. Based on these results, the upper level of infestation percent is estimated as 0.0462 at a 95% confidence for the samples taken from the strawberries harvested across the three farms prior to winter window (Table 6).

Table 6 Assessment for fruit fly infestation in strawberries harvested prior to the winter window of 2009

Property	Variety	Date picked	No. fruit assessed	Weight of fruit (Kg)	No. fruit infested	No. Larvae / pupae*	Upper infestation level % (95% confidence)
Chevallum	Festival	18/05/2009	3418	48	1	1	0.1388
Wamuran	Ruby Gem	26/05/2009	2866	61	0	0	0.1045
Elimbah	Festival	26/05/2009	3757	58	0	0	0.0797
Elimbah (Discards)	Festival	26/05/2009	223	0.229	0	0	1.3434
Total			**10264**	**167.229**	**1**	**1**	**0.0462**

* The larva did not emerge as adult.

Table 7 Assessment for fruit fly infestation in strawberries harvested during the winter window period of 2009

Property	Variety	Date picked	No. fruit assessed	Weight of fruit (Kg)	No. fruit infested	No. Larvae / pupae	Upper infestation level % (95% confidence)
Bellmere	Festival	10/06/2009	1000	20.1	0	0	0.2996
Bellmere (Discards)	Festival	10/06/2009	549	11.1	1	1	0.864
Wamuran	Ruby Gem	15/06/2009	1079	20.6	0	0	0.2776
Elimbah	Festival	24/06/2009	2057	39.9	0	0	0.1456
			4685	**91.7**	**1**	**1**	**0.1012**
Wamuran	Ruby Gem	7/07/2009	1050	19.8	0	0	0.2853
Bellmere	Festival	7/07/2009	1098	24.4	0	0	0.2728
Elimbah	Festival	16/07/2009	1304	27.4	0	0	0.2297
Chevallum	Festival	15/07/2009	954	28.7	0	0	0.3140
			4406	**100.3**	**0**	**0**	**0.0680**
Bellmere	Festival	4/08/2009	872	21.3	0	0	0.3435
Chevallum	Festival	5/08/2009	1260	30.9	0	0	0.2378
Wamuran	Ruby Gem	10/08/2009	1520	27.5	0	0	0.1971
Elimbah	Festival	10/08/2009	1245	24	0	0	0.2406
			4897	**103.7**	**0**	**0**	0.0612
Total (Jun-Aug)			**13988**	**295.7**	**1**	**1**	**0.0339**
Bellmere	Festival	2/09/2009	926	19	0	0	0.3235
Elimbah	Festival	9/09/2009	1664	25.2	3	8	0.4660
Wamuran	Ruby Gem	10/09/2009	1315	20	1	1	0.3607
Wamuran (Bait Sprayed)	Ruby Gem	9/09/2009	1261	20	4	7	0.7259
			5166	**84.2**	**8**	**16**	**0.2794**
Total (Jun-Sep)			**19154**	**379.9**	**9**	**17**	**0.0820**

Table 8 Assessment for fruit fly infestation in strawberries harvested from the bait-treated blocks after the winter window of 2009

Property	Variety	Date picked	No. fruit assessed	Weight of fruit (Kg)	No. fruit infested	No. Larvae / pupae*	Upper infestation level % (95% confidence)
Bellmere	Festival	29/09/2009	3001	39.7	3	7	0.2584
Elimbah	Festival	30/09/2009	3751	51	418	874	-
Wamuran	Ruby Gem	7/10/2009	3797	51	36	88	1.252
Total			**10549**	**141.7**	**457**	**969**	**-**

*Two fruit fly species were identified from the larvae/pupae detected from the strawberry samples in 2009, with 60% being *B. tryoni* and 40% *B. neohumeralis* during the winter window and 65% being *B. tryoni* and 35% *B. neohumeralis* after the winter window.

The assessment data for fruit fly infestation in strawberries harvested during the winter window period (i.e. between June 1st and September 20th) is presented in Table 7. No fruit fly infestation was found in the 4136 packed fruits harvested in June, though one of the 549 discards from Bellmere had one Qfly larva. In the packed fruit harvested in both July and August, no fruit fly infestation was found in any of the samples from all four strawberry farms. However, a small number of fruit fly infested strawberries were found in 3 of the 4 samples harvested in September. Accordingly, the upper level of infestation percent is estimated as 0.0339 at a 95% confidence for all samples taken from June to August, as compared to 0.2794 that is estimated for the samples during September. By combining all samples from the entire winter window period, the upper level of infestation percent is estimated as 0.0820 at a 95% confidence.

Different levels of fruit fly infestation were found in the strawberry samples harvested from baiting trial blocks on three different farms after September 20th, with more than 10% infestation in one of the samples (Table 8).

5 DISCUSSION

5.1 Seasonal changes in fruit fly activity

The activity and abundance of fruit flies are commonly monitored by using male lure traps, with the assumption that variation in the behavioural response of males to the attractant remains constant under different environmental conditions, including temperature (Fitt, 1981). For this project, cue-lure traps were set up on different commercial farms to monitor the activity of Queensland fruit fly over the strawberry production season of 2008 and 2009. Male trap catches have shown a similar temporal pattern of the fruit fly activity in strawberry cropping areas within south east Queensland. The level of fruit fly activity varied over the production season from May to October. The number of trapped male fruit flies remained low until mid September in 2008 and mid August in 2009 when trap catches started to rapidly increase. The pattern of seasonal changes in the fruit fly activity in strawberry cropping systems is similar, in general, to that recorded from the endemic rainforest habitat (Drew et al., 1984) and other host fruit cropping systems (Lloyd et al., 2003b, 2007; Lloyd et al., in press).

Seasonal changes in the fruit fly activity are apparently related to seasonal fluctuations in environmental temperature. Statistical analyses have shown that trap catches of male fruit flies over the strawberry production season of 2009 were significantly correlated with fluctuations in daily maximum temperature, though not with daily minimum temperature or rainfall. According to the data pooled from the four strawberry farms in the Caboolture-Nambour region, no male fruit flies would be trapped on the days when the maximum temperature was below 21.8 °C. There were more than 30 days with the daily maximum temperature of below 21.8 °C between late May and early August in 2009 (see Figure 8), and the weekly trap catch of male fruit flies was very low, with no flies caught in many cases between late June and mid August. A low level of trap catches continued until August 19th when unseasonably warm temperatures increased the numbers of male and female fruit flies trapped. In 2008, however, no unusual temperature fluctuations occurred during this period of time, and hence the rapid increase in trap catches did not occur until late September.

Systematic trapping of male fruit flies over four different strawberry farms throughout the production season of south east Queensland has also shed a light on the spatial pattern of fruit fly dispersal and foraging behaviour in the strawberry cropping systems. Generally, male fruit fly catches were higher in the traps located close to fruiting or other ornamental trees or in the vicinity of natural vegetation, as compared to those traps located inside strawberry blocks, especially during the early strawberry season. In the early production season when the fruit fly activity was lower, most male catches were obtained from the traps set up in natural vegetation and at the boundaries of strawberry blocks. It was particularly noted that one McPhail trap placed within the canopy of a mulberry tree on one farm caught many more female fruit flies than any of the other McPhail traps. These results suggest that fruit flies may use natural vegetation, especially fruiting trees bordering strawberry patches as shelter and/or breeding habitats from which primarily mature females move to the crop fields to oviposit in strawberry fruit adjacent to the natural vegetation. This behaviour has been observed in melon fly (*B. cucurbitae*) and oriental fruit fly (*B. dorsalis*) (McQuate et al., 2007) in Hawaii. The field collection and assessment conducted in 2006 for fruit fly infestation in a ground-grown strawberry block has provided empirical data to support this.

It is believed that the conclusions drawn from male catches of Queensland fruit fly obtained from cue-lure traps apply equally well to the female flies (Fletcher, 1974). Indeed, the trap catches obtained in 2009 have indicated the temporal pattern of increasing female activity is similar to that of males in south east Queensland during the strawberry production season. However, female traps set up over three different farms did not catch any flies until mid August when the unseasonably warm weather triggered a general increase in fruit fly activity. It is not clear whether the activity of female fruit flies requires relatively higher temperatures than for males or the effectiveness of the orange-ammonia mixture as a female lure decreases under the climatic conditions of early season. The dissection of the trapped female fruit flies showed that the majority of females in the field populations were reproductively immature in the early strawberry production season. Mature female fruit flies accounted for only 15.0% in the first trap catches in mid August, though this percentage increased to 47.1% in mid-late September. Reproductive maturation in female fruit flies is a physiological prerequisite for oviposition, and subsequent host fruit infestation. Therefore, seasonal variability in both the level of fruit fly activity/abundance and the percentage of mature females in the field populations will change the risk of infestation in strawberries. Even though male trap catches suggest that a varying level of the fruit fly activity occurs throughout the strawberry production season in south east Queensland, immaturity or a low rate of reproductive maturation in the female flies minimises the risk of infestation in the early season and winter production of strawberries, especially between June and mid August.

5.2 Fruit fly infestation in strawberries prior to and during the winter window

It is generally agreed that fruit on trees and shrubs is more heavily attacked by fruit flies than on plants close to the ground (Allen, 1981). The ground-grown strawberries may render the fruit unfavourable for oviposition by fruit flies whereas hydroponic strawberries are probably more susceptible to fruit fly attack because they are grown at a height which simulates a tree crop, making them more attractive to female flies. Generally, strawberries are not regarded as a preferred host for fruit flies when they are grown as a ground crop. Field survey data have shown that the fruit of the ground grown strawberry plants is subject

to less infestation by Queensland fruit fly, as compared to those of the hydroponic plants on raised beds, though the experimental data did not demonstrate a statistically significant difference. On the other hand, the data from assessment of strawberry samples taken from different commercial blocks in 2008 and 2009 have shown that the level of fruit fly infestation in strawberries varies, as does the level of fruit fly activity/ abundance, from the early to late production season.

Although all the samples assessed for fruit fly infestation in the strawberries harvested prior to the winter window of 2008 and 2009 were taken from different blocks that were not treated against fruit flies, the level of infestation was very low. In 2008, three samples totalling 8426 packed and 715 discard fruit from different early varieties grown on three different farms were assessed. No fruit fly infestation was found from these samples, and the upper infestation level (%) is estimated as 0.0328% at a 95% confidence. In 2009, a total of 10,041 packed and 223 discard fruit comprising two varieties from three different farms were assessed. Only one of these strawberries was found to be infested with a fruit fly larva, and the upper infestation percent is estimated as 0.0462 at a 95% confidence. These results demonstrate that the risk of natural infestation of strawberries by fruit flies prior to the winter window of south east Queensland is very low.

In response to the concerns with the winter window option for interstate market access, samples were taken from four different commercial farms in June, July, August and September respectively, for assessment of fruit fly infestation in strawberries harvested during the winter window of 2009. As usual, treatment measures were not applied to control fruit flies in strawberries during this period of time. No fruit fly infestation was detected in all the packed fruit from the harvests in June, July and August, though one discard fruit from one farm in early June was found to have a fruit fly larva. Based on the assessment of 13,988 fruit (equivalent to 295.7 kg), the upper infestation percent is estimated as 0.0339 at a 95% confidence for strawberries harvested between June and August. The extremely low risk of fruit fly infestation in strawberries is attributable to low temperatures unfavourable for fruit fly activity, especially maturation and ovarian development in female flies during this period of time. However, small numbers of fruit fly infested strawberries were found in two of the three samples harvested in early September. This can probably be attributed to the abnormally warm temperatures in late August 2009 stimulating an increase in fruit fly activity and reproductive maturation, thereby increasing the risk of infestation during the late period of the winter window.

5.3 Fruit fly infestation in strawberries after the winter window and the efficacy of bait treatments

As climatic conditions, especially temperature, become more favourable for fruit fly activity, strawberries in the late production season of south east Queensland may be subject to a higher risk of infestation than in the early season and during the winter window period. Therefore, the protocol ICA-11 had applied to all strawberries of south east Queensland harvested after September 20th for market access to the Fruit Fly Free Zone of New South Wales, Victoria and South Australia. The ICA-11 protocol requires pre-harvest sprays of strawberry blocks with dimethoate and post-harvest inspection of packed fruit.

Although dimethoate is generally effective against fruit flies, its toxicity has caused environmental and health concerns worldwide. In Australia, this chemical pesticide is

currently under review by the APVMA, and it is uncertain whether the use of dimethoate for treatment of fruit commodities with edible peel, such as strawberries, will be allowed in the near future. In addition, cover sprays over strawberry blocks are not compatible with the biological control of spider mites (*Tetranychus urticae*), an important pest of strawberry plants (Markwell, 1976; Waite, 1988; Waite and Jones, 1999; Oliverira et al., 2007; Fraulo et al., 2008), as it is toxic to released predatory mites. In order to evaluate the efficacy of the bait Naturalure as an alternative to dimethoate sprays, field trials were conducted with late season strawberry varieties on different commercial farms in 2008 and 2009. However, the trial results have shown that the efficacy of the protein bait against fruit fly infestation in strawberries varied between blocks and between years.

In 2008, field trials with the pre-harvest application of the bait Naturalure were planned using three strawberry blocks on different farms, with two samples being taken from each trial block in late September/early October and in late October, respectively, for assessment of fruit fly infestation. These trials were supposed to be repeated in 2009. However, unfavourable weather conditions in the season of both years interrupted the trials to some degree. In 2008, excessive rainfall in the area where field trials were implemented and low market price for strawberries in the season caused the early pull-out of one trial block before the early pick. Assessment of the samples from the remaining trial blocks showed that one of the 8021 strawberries from Wamuran and seven of the 8742 fruit from Bellmere were infested with Qfly larvae and/or pupae. Frequent and heavy rainfalls might have also reduced the baiting efficacy against fruit flies since protein baits are easily washed off. In 2009, the heat wave between late August and early September reduced the fruit productivity and quality of strawberries, leading to foreshortening of the harvest season. As a result, assessment could be done for one sample obtained from each of the three trial blocks in late September/early October. The level of fruit fly infestation in these samples was generally higher, as compared to the fruit samples in 2008, and also two fruit fly species (*B. tryoni* and *B. neohumeralis*) were identified from the detected larvae/pupae. The infestation rate was found to be above 10% in one of the samples, which was obtained from the trial block having a large fruiting mulberry tree in a neighbouring residential property. Unfortunately, no McPhail traps were set up on this farm. These results demonstrate that fruit fly infestation can increase as the fruit fly activity increases if no effective control measures are implemented, and can even reach a significant level where the pest activity is high under favourable conditions. Different levels of fruit fly infestation in the strawberry samples from these trial blocks also suggest that the efficacy of the bait Naturalure as a pre-harvest control measure for strawberries remains to be improved.

Naturalure includes a number of volatile and food-based fruit fly attractants, sugars that act as feeding stimulants and humectants which keep the bait droplets soft and attractive and also includes an organically approved active component (spinosad) that kills fruit flies (http://www.dowagro.com/au/prod/naturalure.htm). Since it was registered for commercial use in Australia in early 2005, Naturalure had been successfully used in the pre-harvest control of Queensland fruit flies in various fruit tree crops, including citrus, custard apple, passionfruit, pome fruit and blueberries (Lloyd et al., 2005). Fruit fly baits are usually applied as spot or strip sprays to the foliage of host trees as this is the natural feeding and foraging site for adult flies (Drew and Yuval, 2000). After consultation with the collaborating growers, and taking into consideration the practice of other operations in strawberry management, the bait in these trials was applied as squirts onto the mulch of strawberry beds on the ground. This application procedure might have lowered the efficacy

of Naturalure against fruit fly infestation in strawberries, especially under high fruit fly pressure.

Queensland fruit fly originally inhabited rainforests, and the adult flies prefer to shelter and forage in trees and shrubs. Previous research demonstrated that fly response to ground application of protein baits was very poor while the tests showed that the Naturalure-baited plywood boards hung at higher positions in a tree canopy attracted a much greater fly response (Lloyd et al., 2005). These boards, set up at an appropriate height, were recommended as a suitable alternative for crops such as cucurbits and strawberries, where foliage baiting would not be suitable. Furthermore, border crops, which act as sheltering and feeding sites for fruit flies (Prokopy et al., 2003), can provide an appropriate site for bait application. For example, the preliminary research of the QPIF Better Berries project have shown the potential of applying the protein bait to a bordering trap crop (lupins) as an alternative to dimethoate cover sprays for fruit fly control in strawberries. Therefore, the efficacy of Naturalure against fruit fly infestation in strawberries can be improved by including the use of border crops and modifying the application method to exploit the biology and feeding behaviour of adult flies. Furthermore, bait treatments should be applied to trees and other windbreak plants around strawberry fields on a farm-wide scale to increase the chance of attracting and killing female flies before they move into strawberry fields. Experience from previous field trials in strawberries and other crops suggests that the application of male annihilation technology (MAT) and hygiene practices to eliminate or treat abandoned fruiting block or residual host fruit on strawberry farms will also benefit the bait treatment by reducing fruit fly pressure.

6 CONCLUSIONS AND RECOMMENDATIONS

Field trial data have shown that the risk of fruit fly infestation in strawberries is extremely low in May and during the winter window period from 1 June to mid August for south east Queensland. Low temperatures at this time of year are unfavourable for fruit fly activity and maturation, though the activity and reproductive maturation of female fruit flies as enhanced by warm temperatures in late August or early September can increase the risk of infestation in strawberries. However, the original project proposal did not plan to provide trial data on the risk of fruit fly infestation in the winter production of strawberries because the winter window option had been well accepted for interstate market access until the detection of fruit fly larvae in the strawberry consignments to Victoria and South Australian in late August/early September, 2009. Field trials to assess the risk of fruit fly infestation in strawberries during the winter window period were conducted only in 2009 in response to Victorian requirements for such trial data in Queensland strawberries. Thus, the project was only able to provide one season data for the winter window option.

The efficacy of current off-plant baiting treatments against fruit flies in strawberries after the winter window period was not adequate, especially when fruit fly activity/abundance was high under favourable conditions. The low attraction of bait spots applied onto plastic mulch to Queensland fruit fly and the high pressure of fruit flies in spring are suggested to be the important factors influencing the efficacy of bait treatments. Therefore, the baiting method should be modified by applying bait sprays onto trees and other windbreak plants surrounding strawberry fields, as well as trap crops (e.g. lupins) wherever practically

feasible, on a farm wide scale. Furthermore, the baiting system should also include the application of MAT and hygiene practices to reduce the fruit fly population abundance.

Building on this project, one or two season trials to assess the risk of fruit fly infestation in strawberries harvested from May to mid August will be able to present an adequate data package and supporting evidence to interstate authorities for negotiation for a new winter window option. Likewise, based on this project, further trials will be required to demonstrate the efficacy of an improved baiting application system as an alternative pre-harvest treatment against fruit flies in strawberries for negotiation of a new ICA protocol with interstate authorities.

7 ACKNOWLEDGEMENTS

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