Final Report

Advanced Stable Fly Management for Vegetable Producers

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Delivery partner:

Department for Primary Industries and Regional Development

Project code:

VG15002

Project:

Advanced Stable Fly Management for Vegetable Producers – VG15002

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Content

Summary

Post-harvest residues of most leafy vegetables rot within days after harvest and provide an ideal environment for stable flies to complete their development. The resultant adult flies that emerge seek blood meals several times a day and significantly affect any livestock nearby. Numerous methodologies have been tried to reduce stable fly development from vegetable crop residues left *in situ* after harvest but have either had limited success or are neither practical nor economically viable for vegetable producers to adopt. The option of burying crop residues and/or compacting the sandy soil above the residues offers a unique physical solution to preventing the emergence of adult stable flies from the residues without the need to use pesticides.

Large-scale field trials at commercial vegetable producers confirmed that burial and compaction of post-harvest residues is the most effective option for controlling stable fly. Compacting sandy soil using a landroller almost totally prevents adult stable fly emergence from the soil. The hard barrier of soil near the surface prevent the newly-emerged stable flies from digging their way to the soil surface. When the adult fly emerges from its pupal case in the soil, their outer exoskeleton hasn't hardened, hence they are quite feeble and unable to dig through compacted soil. By contrast, house flies are bigger and more robust than stable flies, and are not affected by soil compaction (N.B. house flies rarely develop from crop residues).

This project has clearly confirmed the best method for managing and having a major impact on stable fly development from vegetable crop residues. This management involves 2 simple steps:

- Burial of crop residues using either a mouldboard plough, stone burier or a deep, slow rotary hoe; followed by
- Compaction of the sandy soil using a fixed landroller at rates equivalent to $5t/m^2$.

Burying and compacting sandy soil over the crop residues provides key production benefits to growers including: (i) retention of all the organic matter from the residues (ii) less soil wind erosion from moist, compacted sand (iii) no need to use insecticides to control stable flies.

Because compaction prevents stable fly emergence, handling of residues left after harvest does not need to be done immediately, but can be left for up to a week before burying and compaction. By waiting 1 week, any stable fly eggs or larvae in the residues will not emerge at a later point as adult flies. Our research showed that stable flies start laying eggs onto broccoli, lettuce, silverbeet and celery residues within 1-2 days after harvest in summer production months.

There has been considerable engagement with major vegetable producers in areas most affected by stable fly on the uptake of machinery to bury and compact post-harvest residues. Smaller growers can employ the newly approved measure of rotary hoeing their residues on 5 successive days to minimise stable fly. Finally burial of reject produce infested with stable fly larvae was shown to only be effective at preventing adult emergence by burying under at least 1m of soil and/or compacting the soil. We have engaged with local agricultural machinery companies that currently sell or can fabricate landrollers for use by vegetable producers. These range from 2.1m - 6m wide for use on fixed-sprinkler line properties, or from 6m to 12, 18 and 24m wide rollers that could be used on open, centre-pivot irrigated vegetable operations.

A final field day on Stable Fly will be held in December, 2018 (outside the start and finish dates of this project) to promote the findings and use of burial and compaction for handling crop residues.

Public Summary

Burial and compaction of post-harvest vegetable crop residues is the most effective option for controlling stable fly. The residues of leafy vegetable crops rot quickly and are used by stable fly to complete their larval development. The adult stable flies that develop then blood feed several times a day and significantly affect any livestock nearby.

Compacting sandy soil using a landroller almost completely prevents adult stable fly emergence from the soil. The hard barrier of soil near the surface prevent the newly-emerged stable flies from digging their way to the soil surface.

This project identified a simple, non-chemical control option for reducing stable fly development from vegetable crop residues. This management involves 2 simple steps:

- Burial of crop residues using a mouldboard plough, stone burier or a deep, slow rotary hoe; followed by
- Compaction of the sandy soil using a fixed landroller at rates equivalent to 5t/m^2.

Furthermore, burying and compacting sandy soil over the crop residues provides key production benefits to growers including: (i) retention of all the organic matter from the residues (ii) less soil wind erosion from moist, compacted sand (iii) no need to use insecticides to control stable flies.

Although landrollers are not an expensive item, some producers may be unable to use a landroller for economic or other reasons. Our research also showed that smaller growers can employ the newly approved measure of rotary hoeing their residues 5 times on 5 successive days to minimise stable fly.

Local agricultural machinery companies either currently sell or can fabricate landrollers for use by vegetable producers. These range from 2.1m - 6m wide for use on fixed-sprinkler line properties, or from 6m to 12, 18 and 24m wide rollers that could be used on open, centre-pivot irrigated vegetable operations.

Burial of reject produce infested with stable fly larvae was shown to only be effective at preventing adult emergence when buried under at least 1m of soil. The adult fly is still capable of digging its way to the soil surface through up to 1m of loose, dry sand. However, burial to a depth of 1m and compaction of the soil when moist will totally prevent adult stable fly emergence.

A final field day on Stable Fly will be held in December, 2018 (outside the dates of this project) to promote the process of burying and compacting post-harvest residues to increase productivity and reduce stable flies.

Keywords

Stable fly; nuisance fly; livestock; vegetable crop residues; burial; compaction; productivity; landroller

Introduction

The stable fly is a cosmopolitan pest first recorded in Australia in 1881 and in Western Australia in 1912. This fly is now commonly found in Australia often in association with human settlement and wherever livestock are housed and fed. This fly has become an increasingly serious pest of the beef cattle and horse industries around Perth, WA (Cook et al. 2011). When attacked by stable flies, cattle bunch together and their efforts to repel the flies cause reduced feeding and heat stress in summer (Catangui et al. 1997, Mullens et al. 2006, Wieman et al. 1992). Outbreaks of this fly have forced cattle and horse owners to relocate their animals away from affected areas. In addition, human lifestyle has been seriously affected (Cook et al. 1999) with recreational activities and outdoor living severely curtailed.

Stable flies develop from rotting organic matter associated with horticultural production, in particular crop residues left after harvesting vegetable crops (Cook et al. 2011); this includes stalks, leaves and fruit left either in or on the ground after harvesting, or harvested crop waste (i.e., damaged and rejected produce, processing scraps) dumped into open pits or fed to livestock. Simmons and Dove (1942) identified celery crop residues as a source of stable fly outbreaks. Horticulture's expansion into livestock-based regions around Perth favours the development of stable fly throughout most of the year on sandy soils. This fly is a major pest of livestock in agricultural areas along the Swan Coastal Plain where >50% of the state's vegetable production and horticultural exports are grown. Vegetable crop residues left after harvest are the most significant source of stable fly development (Cook et al. 2011). Due to the continual negative impact of stable flies on livestock production and the lifestyle of rural residents, the stable fly became a Declared Pest under the Biosecurity and Agricultural Management Act in 2013. Vegetable growers (amongst others) are required to follow recommended practices outlined in the Stable Fly Management Plan, which is part of this legislation. Growers who do not adhere to these practices may be penalised under the BAM Act.

VG12002 (Managing Biting Flies from Vegetable Crop Residues) showed that a 50-90% reduction in stable fly development was possible through either: 1) ceasing overhead irrigation after harvest; 2) application of the N-fertiliser calcium cyanamide; or 3) applying entomopathogenic fungi that are lethal to flies in the residues. Despite this progress, stable fly development must be reduced to <10 flies/m^2 in order to have a profound impact on their populations, given the scale of vegetable production. If fly numbers remain at current levels, then local shires may limit future horticultural expansion in affected areas.

The current project (VG15002) (Advanced Stable Fly Management Options for Vegetable Producers) focused on 3 key areas for improved mitigation of stable fly:

(1) Use of machinery to deep bury crop waste to prevent flies laying eggs on the residues;

(2) Use of biological agents including predatory beetles, parasitic wasps and fungi; and

(3) Cattle walk through fly traps for the non-chemical removal of flies from affected livestock.

Methodology

Field Experiments:

1) Machinery to Bury Residues followed by Compaction (Celery)

Different agricultural machinery capable of burying post-harvest vegetable crop residues were run through different post-harvest vegetable crop residues namely lettuce, celery, silverbeet and cabbage. The machines used included a Collari® stone burier (2.5m wide) (Figures 1 & 2) that buried the residues to a depth of 20cm below the soil surface, a Mouldboard Plough (Figure 3). The crop residues were initially high speed mulched into smaller pieces prior to burial with the machinery. Three weeks after the residues had been buried, adult fly emergence cages were placed over the treated area to measure the numbers of adult stable flies developing from the buried (Figures 4 & 5). Similarly, a mouldboard plough was run through celery post-harvest residues (1 week old) to bury the residues over a complete vegetable production bay, 250m long and 13.5m wide. After burial of the residues (same day), a landroller (2.3m wide with 1.5t of water was run over half the bay to compact the sandy soil (Figure 3). One quarter of the bay was compacted once, whilst a second quarter had the land roller run over the ground twice (2X Compaction). Two weeks after burial and compaction, adult fly emergence cages were placed randomly along the treatment areas (Figures 4 & 5).

Figure 1. A Collari stone burier going over celery crop residues 1day (LHS) or 7 days (RHS) after harvest

Figure 2. Celery crop residues left after harvesting (L) before being buried with a mould board plough

Figure 3. A mould board plough burying celery residues (L) and a land roller compacting the soil (R)

Figure 4. Adult fly emergence cages (L) on buried vegetable crop residues, and additionally compacted after burial (R)

Figure 5. The trap canister on top of the adult fly emergence cages (L) and a canister with newly emerged stable flies (R)

2) The Effect of Depth of Crop Residue Burial on Adult Stable Fly Development

Several field experiments were carried out to determine the ability of stable fly to access crop residues That were buried at different depths. Figure 6 shows the methodology in a series of pictures where a 150mm PVC tube was pushed into the ground and then fresh crop residues added (standard amount of 1L of residues) into the tube so that the top of the residues was a set distance from the soil surface. In each field experiment, a total of 15 replicate plots were assessed in a totally randomised plot design with 15 replicates placed on the soil surface (0cm). The crop residues were buried to depths of either 0cm 2cm, 5cm, 10cm, 15cm, 20cm, 25cm, 30cm or 35cm. The experiments performed in the field included:

- Experiment 1 (0cm, 2cm, 5cm and 10cm (15th October,2015)
- Experiment 2 (0cm, 10cm and 15cm (with and without compaction) (12th November,2015);
- Experiment 3 (0cm, 5cm, 10cm and 15cm (11th December, 2015);
- Experiment 4 (0cm, 10cm, 15cm and 20cm (with and without compaction (23rd March, 2016)
- Experiment 5 (0cm, 25cm, 30cm and 35cm (Experiment on 15th December, 2016)

Soil was packed back on top of the residues and made flush with the soil surface. In the first field experiment,15 replicates were set up with the PVC tube remaining in the soil, whilst another 15 replicates were set up and the PVC tube then removed and the soil smoothed over. This was to see if the PVC tube enabled the stable flies a means of accessing the residues. For example, they could lay their eggs against the side of the PVC tube and the larvae that hatch could make their way down to the residues using the side of the PVC tube.

Figure 6. Crop Residue Burial Methodology from Top (L) to Top (R), bottom (L) to Bottom (R)

3) Ageing of Crop Residues and Time to Stable Fly Egg Laying

Three different crop residues (celery, lettuce and silver beet) were freshly mulched using a high speed mulcher. Within one hour of mulching, the residues were exposed to stable flies in the field and left to age over the subsequent 5 days. Fifty replicates of 1 litre of each residue type were packed into 150mm diameter PVC tubes pushed into the soil surface with 5cm sticking out (Figure 7 below). Every day after exposure 10 replicate samples of residue from each crop type were placed into a plastic box (25cm x 25cm x 10ch high) and a fine, screen mesh placed over the box to allow for any stable fly eggs and/or larvae in the residues to develop into adult stable flies for later counting and collation (Figure 8).

Figure 7. Crop ageing residues exposed in PVC tubes in a randomised plot design (L) and the Residues of silverbeet within the PVC tube (R)

Figure 8. Aged lettuce residues collected from the PVC tube (L) and then placed in a larger box with a fine mesh lid to capture any flies that subsequently develop from the crop residues (R)

Laboratory Trials:

1) Effect of Depth of Burial on Adult Stable Fly and House Fly Emergence

The effect of depth of pupal burial on **s**ubsequent adult fly emergence was assessed for both stable flies and house flies. Up to 40 stable fly or house fly pupae were placed on a 2cm bed of dry sand and then covered with varying amounts of dry soil. The pupae and soil were set up within PVC tubes (100mm diameter) and stood upright (Figure 9) with the open end covered with fine mesh to capture any adult stable flies that subsequently emerged from the pupae and were capable of emerging at the soil surface (Figure 10).

Figure 9. Stable Fly pupae (n=40) prior to being buried under different amounts of sand in long PCV tubes with a mesh covering to capture any adult flies emerging (R)

Figure 10. PVC pipes of different lengths holding soil from 10-100cm depths above buried fly Pupae (L) and an example of the resultant adult flies that emerged (R)

2) Effect of Compaction on adult House Fly emergence

Both stable fly larvae (late 3rd instars ready to pupate) and stable fly pupae were placed on 2cm bed of soil and then buried under 15cm of soil in clear plastic tubes (Figure 11). Four (4) replicates of 40 larvae and/or pupae were used per replicate5cm (on a bed of 2cm of soil). Soil moisture content of the moist sand was 11.9% (just above field capacity).

Figure 11. Soil with either stable fly pupae (L) or larvae (R) prior to burial under moist sand

Figure 12. The moist sand above the larvae or pupae was either polished (L) or compacted to 2t and 3t/m2 (RHS images) and subsequent adult stable fly emergence recorded

Field Trial: Assessment of the wasp *Spalangia endius* on Suppressing Stable Fly Populations

An assessment on the impact of *Spalangia* wasp on local stable fly populations was made across two cattle feedlots in Gingin, 110km north of Perth where stable flies are found in much higher numbers. The objective was to determine the impact of the small parasitic wasp *Spalangia endius* (2-3mm long) that is known to parasitise stable fly pupae (Figure 1). Specifically, can releases of this wasp reduce stable fly populations on a local scale at and around a cattle feedlot where fortnightly releases of this wasp were carried out over 3 months. Two cattle feedlots about 10km apart were chosen for the trial: 1) Cullalla Feedlot (Cullalla Road) (wasps released) and 2) Fernview Farms (Wannamal West Road) (no wasps released).

Figure 13. ***Spalangia endius*** **wasps (L) used to control stable flies in intensive livestock industries**

Figure 14. Fernview Farm Feedlot (L) and Cullalla Feedlot (R) used to assess *Spalangia endius* against stable fly populations

Outputs

1) Treatment of Post-Harvest Residues

This Included:

a) trials were conducted on the use of machinery to bury vegetable waste, in particular the use of a Mouldboard Plough, which inverts the soil profile, followed up with compaction of the soil using a land roller to stop emergence of stable flies,

b) ageing of crop residues to determine when stable flies first lay eggs in residues left after harvest, and

c) depth of burial of residues and the ability of stable flies to access and lay eggs in the residues

All trials were completed over entire vegetable production bays (3,500m^2 or 0.35ha) with the full co-operation of the vegetable grower and fitting in with their normal commercial operations.

2) Number of field trials and laboratory experiments

A total of 16 field trials were completed across vegetable producers properties during the period of this project (1st October 2015 to 30th September, 2018). In addition to this projects scope, we completed a further 8 laboratory trials during months of the year when stable flies were not active in the field (June-September) on soil compaction and adult stable fly and house fly emergence. These trials were an invaluable link with the larger field replicate plot trials on burial and compaction of vegetable crop residues.

3) Assessment of the parasitic wasp *Spalangia endius* on suppression of stable fly

See Appendix 6 for full details of trial methodology and results. **:** In summary, the releases of *S.endius* wasps at Cullalla Feedlot did not result in the successful parasitism of any filth fly pupae (including stable fly) based on our methodology of exposing 100 filth fly pupae across 2 sentinel stations within the cattle feedlot each week for 4 weeks in succession. The use of this parasitic wasp in this setting would then not be expected to have had any measurable impact on the stable fly populations – in particular the product supplied was below the expectation of 70% parasitised house fly pupae from which the adult *S.endius* emerge in order to parasitise any newly formed filth fly pupae within the vicinity of the feed-lot.

4) Presentations on the research carried out in this project were made to:

- The Serpentine-Jarrahdale Equine Landcare Event (30th April, 2017)
- Stable Fly Action Group AGM (20th September, 2016 and 4th October, 2017)
- WA Commercial Egg Producers Association (14th February, 2017)
- WA Insect Study Group (14th October, 2015)
- Avian Industries (22nd March, 2017)
- Shire of Dandaragan (April 27th, 2017)
- Stable Fly Symposium, Gingin (2nd November, 2017)
- Livestock Industries Group (DPIRD Staff) (3rd November, 2017)
- Shire of Victoria Plains (18th April, 2018)
- Dairy Innovation Day, Benger, WA (3rd May, 2018)
- Stable Fly Regulatory Reference Group (20th September, 2016; 29th March, 2017, 27th

September, 2017, 23rd March, 2018 and 16th October, 2018),

The Stable Fly Regulatory Reference Group that meets biannually over the stable fly issue in WA with representatives from industry (vegetable, cattle, poultry, pig, horse, turf) and government (Shire officers, Environmental Health Officers, Local Government (WALGA)). These meetings are chaired by the Executive Director of Biosecurity and Regulation at DPIRD (formerly DAFWA) where research results are presented by Dr David Cook and discussions are had on the status of the Stable Fly Management Plan and any need for changes/additions.

The Stable Fly Action Group or SFAG meet once a month in Gingin to talk about the stable fly issue. This group has been active since 2005 and they put political pressure on the government of the day, the Minister for Agriculture, and DPIRD over alleviating the stable fly impact in rural communities. Dr Cook attends their meetings regularly (>50% each year) to update research and to provide technical advice on any issues surrounding stable fly. In addition, Dr Cook presents all his research to their Annual General Meeting and has done so since 2008 to the present inclusive. The audience comprises a wide cross-section of those affected by stable fly including livestock producers and rural residents. Vegetable and livestock industry representatives also attend their AGM's.

5) Training of Stable Fly Compliance Officers:

A further 2 Stable Fly Compliance Officers (local government officers) were trained and appointed (April 2017) at the Shire of Capel (Jarred Ramsden & Naomi Milner), whilst doing visits to numerous live stock properties in the Shire and Inspection operations and levels of stable fly development at Capel Farms (broccolini grower). A further three inspectors were trained and appointed to the Shire of Gingin in December, 2017 (Geoff Slater, Susan Koefler and Keven Solkes). Three separate appointees to the full time position of Compliance Officer at DAFWA (DPIRD) were trained and signed off during the lifetime of this project (Renae Gibbs and Matt Bowen), with the current position being held by Bevan Wooldridge.

6) Grower Field Days:

A Vegetable Growers Stable Fly Field Day (2nd February, 2016) titled "Improve Productivity and Eliminate Stable Flies" was held at Bogdanich Farms, Glenrowan Road, Gingin.

A further field day on the use of a mouldboard plough to bury post-harvest residues was held at T & C Do & Sons Farm on Caraban Road, Gingin (22nd February, 2017)

A final field day on the 2 step process of burial and compaction using a land roller will be held at Bogdanich Farms, Glenrowan Road, Gingin in December, 2018

7) Extension work through media and manuals includes:

Media articles in WA grower magazine updating trials funded by this project:

- WA Grower Magazine, Spring 2016, Vol 51 #3
  - Stable Fly Management Plan changes affecting all producers – D Telfer
  - Stable fly and the Rapid Burial of waste – D Cook
- WA Grower Magazine, Summer 2017, Vol 51 #4
  - New provisions and charges for stable fly management
- WA Grower Magazine, Autumn 2017, Vol 52 #1
  - Stable Fly research shows great promise
  - (includes report on International Congress of Entomology presentation in Florida, US)

8) Training Manuals

Updated versions of the "Livestock Producers Manual: Stable Fly Control Versions 2 and 3 (Sept 2017 and August 2018 respectively)" and "Stable Fly Training Manual" for Stable Fly Compliance Officers were produced.

These Manuals included current pesticide registrations catalogued and a revised section on Stable Fly Compliance Thresholds for determining levels of stable fly development from a range of developmental substrates. These Training Manuals are available as downloadable pdf versions on the DAFWA website. Click on the following link to access.

www.agric.wa.gov.au/sites/gateway/files/Livestock%20producer%20manual%202017_0.pdf

9) Presentation on Research Delivered at International Conference

Cook, DF, Telfer, DV, Deyl, RA & Lindsey, J (2016). The race between compliance and research to combat stable flies in Western Australia. Presented at the 25th International Congress of Entomology, Orlando, Florida, US, September, 2016.

Outcomes

Burial and Compaction of Post-Harvest Residues

The combined results from the field trials clearly show that as few as 2-3 stable fly/m^2 were able to emerge from vegetable production areas where post-harvest residues were buried and then compacted with a land roller. By comparison, the previously defined Best Management Practice (BMP) for handling of post-harvest residues and identified from the research in **VG12022** (*Managing Biting Flies from Vegetable Crop Residues*) saw stable fly emergence at around 25-30 stable fly/m^2.

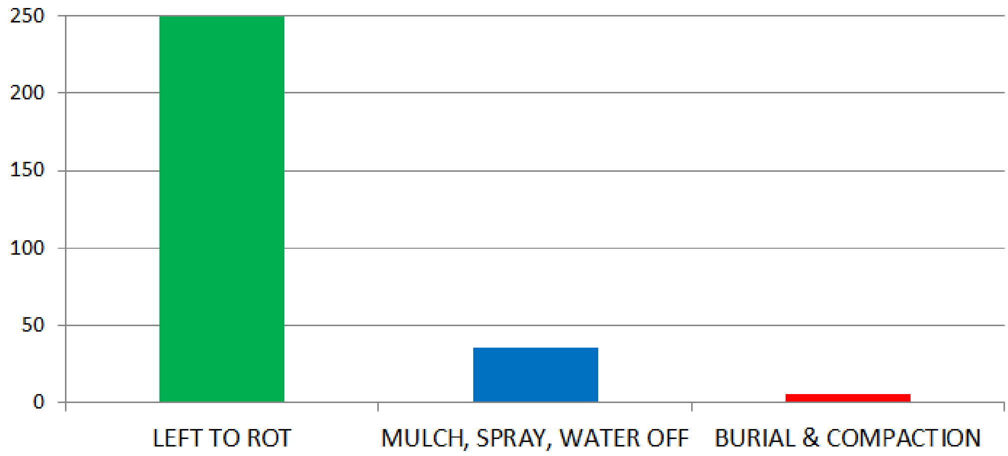


Figure 15. Number of stable flies emerging/m^2 from crop residues buried and then compacted (8 field trail results combined) as compared with either nil treatment of the residues, or applying previous BMP's

Very clear and simple recommendations on the best handling of vegetable crop residues left after harvest, both in terms of production benefits AND to significantly reduce stable fly development.

Burial of the post-harvest residues can be done using either:

(1) a mouldboard plough, which inverts the soil profile down to 45cm deep;

(2) a stone burier or contravator rotary hoe, which places the heavier vegetable residue down to a depth of 20-25cm below a layer of clean, sieved soil, or

(3) deep, slow rotary hoe where the residue is buried to a maximum or approx. 30cm

After burial of the residues, this must then be followed up with compaction using a landroller that will compact the moist, sandy soil at or above 5 tonnes/m^2. The soil above the buried residues should be kept moist to facilitate compaction. This methodology will prevent at least 95-100% of adult stable flies from being able to emerge and dig their way to the soil surface.

Vegetable growers will gain the following production benefits from the burial and compaction of post-harvest residues:

- Total retention of all organic matter from the residues being buried (i.e. green composting)
- Better soil moisture retention
- Less soil wind erosion
- Less time, labour and machinery costs with only 2 operations to deal with post-harvest residues
- No need to apply a pesticide

We have engaged with local agricultural machinery companies that currently sell fixed landrollers and/or manufacturers that have the capability of making fit-for-purpose landrollers for use by vegetable producers. These range in size from 2.1m up to 6m for use on fixed-sprinkler line properties, or from 6m to 12, 18 and 24m wide rollers that could be used on open, centre-pivot irrigated vegetable operations.

Ageing of Crop Residues

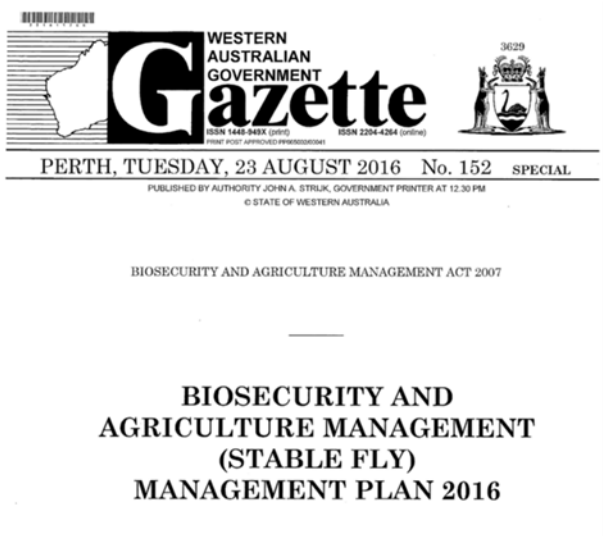
Ageing of crop residue trials demonstrated that stable flies were capable of laying eggs on post-harvest residues within 24-48hrs after harvest was complete (trials on lettuce, celery, silverbeet and cabbage). This time period was shorter than originally thought and means that by delaying burial and compaction of post-harvest residues for 1 week, that this methodology then becomes an effective stable fly killing system, with the buried eggs and/or larvae of the fly unable to successfully complete development into adult flies. By burying crop residues immediately after harvest, this denies stable flies the opportunity to lay eggs on this material and hence the female fly will just move on and lay her eggs elsewhere.

Burial of Infested Waste

Any rotting plant matter and/or animal manures or combination of the two that is infested with stable fly larvae (or any fly larvae for that matter as they are very difficult to distinguish with any great accuracy) MUST be buried under at least 1m of soil if not able to be compacted. IF the ground above the buried material can be compacted, then burial under at least 300mm of soil is recommended prior to compaction with a landroller or similar device.

The research findings from this project have led to some major changes to the previous Stable Fly Management Plan 2013. These changes are:

1. the inclusion of the Shire of Capel in the list of regulated local governments
2. the further restriction of the use of raw poultry manure in the declared shires unless composted to Australian Standard 4454, or is used under the new regulation as an 'Approved Measure' or a licence or 'Prior Approval' to transport raw poultry manure.
3. vegetable waste may be deeply buried by stone burier, mouldboard plough or similar device, or rotary hoed five times in 5 days. This allows horticulture growers good control without the need to turn water off, nor spray insecticides and is a direct outcome from the research funded by HIA.
4. tightening of the feeding of vegetable waste and hay to livestock that may result in breeding of stable flies.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BIOSECURITY AND AGRICULTURE MANAGEMENT ACT 2007

BIOSECURITY AND AGRICULTURE MANAGEMENT (STABLE FLY) MANAGEMENT PLAN 2016

Figure 16. WA Government Gazette Special edition BAM Stable Fly Management Plan 2016

The changes were supported by community, local government and industry representatives over Several Stable Fly Regulatory Reference Group meetings, and were then reinforced and enacted by state government through the Regulatory Gatekeepers Office. The new regulations were enacted on the 23rd August 2016 (published in WA Government Gazette on 23rd August, 2016 (see Figure 16)

Monitoring and evaluation

SF Complaint Numbers and Severity

When either peoples livestock or their amenity was affected by stable flies, they had several options in terms of reporting their concerns to local government (Shires) and/or state government (i.e., DAFWA/DPIRD). This could be made either by a) telephone to their local shire or to PADIS (Pest and Disease Information Section) at DAFWA/DPIRD, or b) through the newly modified Mobile Phone App "MyPestGuide Reporter" or c) direct calls to Don Telfer/David Cook or the DAFWA/DPIRD full time compliance officer.

2015/16 was the first year that the MyPestGuide Reporter Application was made available to the wider community and was promoted as a method for lodging a complaint about stable flies. This App was originally developed by DAFWA (now DPIRD) for growers to send in pictures to identify potential pests of stored grain. This App allows people to use their mobile phones to lodge real-time complaints about stable flies or any other agricultural pest, where they could attach a photo, video or comment, while having their exact location pinpointed by GPS. For further information on the MyPestGuide Reporter App, please see Appendix 9. The MyPestGuide Reporter App was not widely accepted and used widely until the 2016/17 fly season.

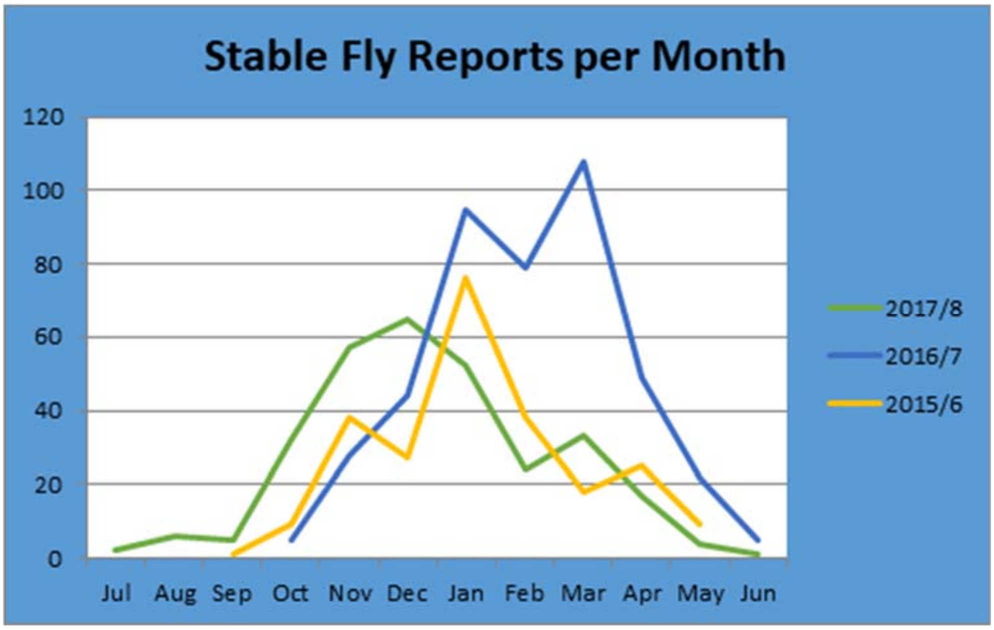

Figure 17. Reports of stable fly bothering livestock and/or residents for each month of the Year from 2015/16 through to 2017/18

The total number of stable fly reports per annum was 241 in 2015/16), 435 in 2016/17, and 298 in 2017/18.

The 2016/17 and 2017/18 seasons were both impacted by unseasonally heavy rains during the peak of stable fly abundance (see Figure 18 and 19), which exacerbated their impact on livestock and human lifestyle in the subsequent 4-6 weeks (allowing for stable flies to lay eggs on moist developmental substrates, the eggs to hatch and develop into newly emerged adult flies).

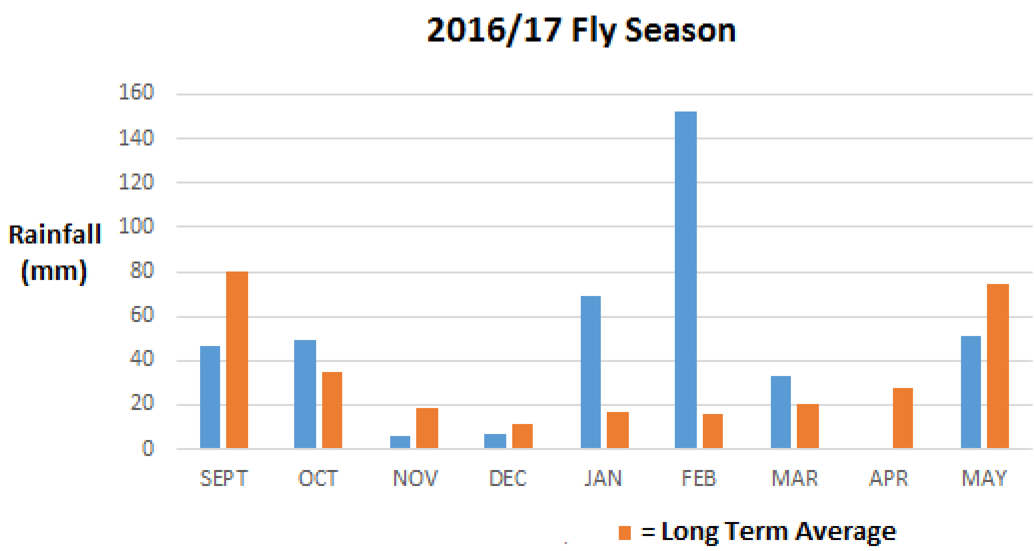

Figure 18. Rainfall in Gingin, WA against long term averages for the 2016/2017 Fly Season

As can be seen from the 2016/17 rainfall (Figure 18), there was extremely heavy and unseasonal rainfall during both January and February 2017, when stable fly numbers are typically at their peak. The rainfall was so significant that it would have soaked through any plant matter on the ground, including hay bales, vegetables fed to livestock, olive pomace, post-harvest reject produce piles, vegetable crop residues, grass clippings etc. that enable stable fly development. This translated into a peak number of stable fly reports in March 2017 (Figure 17).

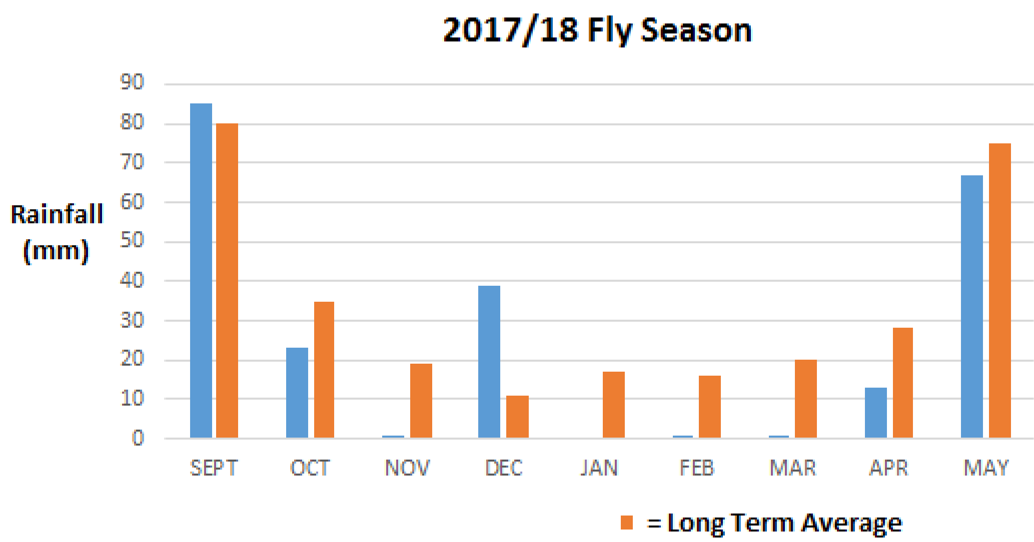

Figure 19. Rainfall in Gingin, WA against long term averages for the 2017/2018 Fly Season

Despite heavy rainfall again in December 2017 (Figure 19), there was no subsequent spike in stable fly reports in the following month (i.e. Jan 2018), but rather a decline in stable fly reports (see Figures 17 and 20). This decline in complaints could be attributed to several factors:

- Greater grower awareness of the stable fly mitigation strategies, including the burial and compaction of their post-harvest residues;
- Both DAFWA/DPIRD and the Shire of Gingin put on a full time stable fly compliance officer to visit

all situations where stable fly development could occur. These officers provided written advice to the landowners on proper management of stable fly development sites, in particular, post-harvest crop residues. In some instances growers were invoiced for the costs of re-inspection and follow-up visits to ensure compliance with the Stable Fly Management Plan 2016.

- The compliance officers also emphasised the research work showed how well soil compaction and deep burial of residues can reduce the emergence of stable flies and improve their productivity
- Much of the poultry litter that may have been illegally used in the past, was now able to be moved to commercial compost sites through changes in the Stable Fly Management Plan (2016)

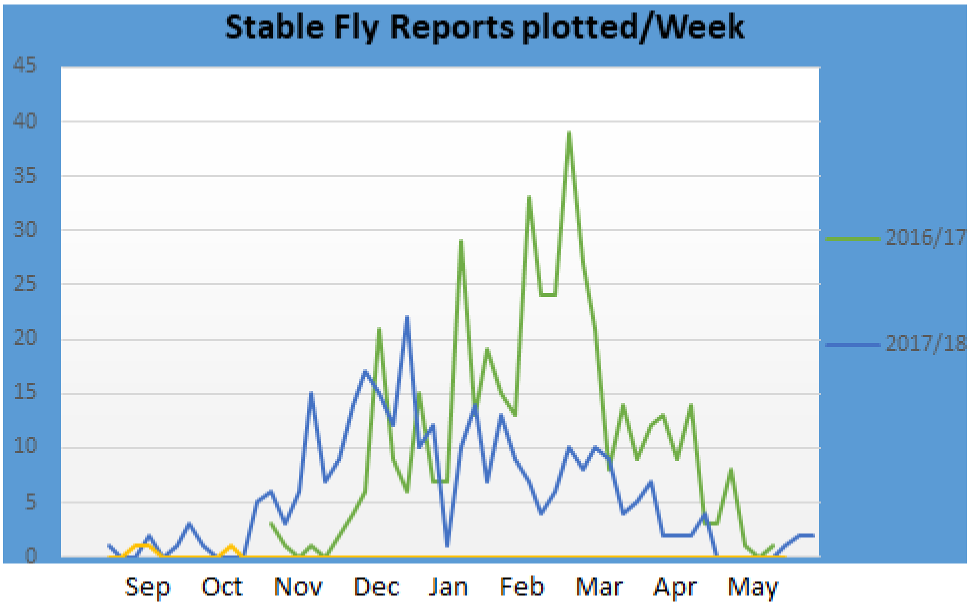

Figure 20. Reports of stable flies bothering livestock and/or residents during each week of The 2016/7 and 2017/18 years

Stable Fly Regulatory Reference Group Meetings

The Stable Fly Regulatory Reference Group Meetings held biannually over the stable fly issue in WA were a significant part of the Monitoring and Evaluation of the research derived as a result of this project. The RRG included representatives from industry (vegetable, cattle, poultry, pig, horse, turf) and government (Shire officers, Environmental Health Officers, Local Government (WALGA)). The RRG Meetings were always chaired by the Executive Director of Biosecurity and Regulation at DPIRD (namely Terry Hill, Kevin Chennell, Mia Carbon and Katherine Clift).

At these meetings, current research results were presented by Dr David Cook and a lot of discussion was generated around the findings and implications within the Group. Also, Don Telfer (Project and Stakeholder Manager) would always give a presentation on the number and location of stable fly complaints. Discussion was held amongst the group on the status of the Stable Fly Management Plan and any need for changes/additions.

Recommendations

Handling of Post-Harvest Residues

That post-harvest vegetable residues on sandy soils be treated in the following manner to reduce the costs of vegegatble production and to severely reduce the ability of stable flies to develop from the residues:

1 week after harvest is complete:
Bury the post-harvest residues using either (i) a mouldboard plough (which inverts the soil profile down to 45cm deep); (ii) a stone burier or contravator rotary hoe, which places the vegetable residue to a depth of 20-25cm below a layer of clean, sieved soil; or (iii) deep, slow rotary hoe where the residue is buried to a maximum or approx. 30cm. After burial of the residues, this must be followed up with compaction of the moist soil

Compaction of Sandy Soils

Compaction can be achieved using a landroller that will compact the moist, sandy soil at or above 5 tonnes/m^2. The soil above the buried residues should be kept moist to facilitate compaction.

The vast majority of vegetable production along the Swan Coastal Plain around Perth is carried out on sandy soils. There is some variation within those sandy soils in terms of both coarse and fine sand amounts as well as the amount of clay and fine sand, which have an influence on the ability to compact the soil (i.e., compactability).

Soils with a greater percentage of clay and fine sand are more easily compacted (eg Cottesloe sands) compared with high coarse sand and low clay levels in Bassendean sands, which will require compaction to equal or greater than 5t/m^2 to severely curtail stable fly emergence.

The methodology of burial and compaction to >5t/m^2 will prevent >95-100% of adult stable flies from being able to emerge at the soil surface.

Vegetable Production Benefits

Vegetable growers will gain the following production benefits from the burial and compaction of post-harvest residues:

- Retention of all organic matter from the residues being buried (i.e. green composting)
- Better soil moisture retention and germination of post-harvest cereal crop
- Less soil wind erosion due to the moist, compacted soil
- Less time, labour and machinery costs with only 2 operations to deal with post-harvest residues
- No need to apply a pesticide

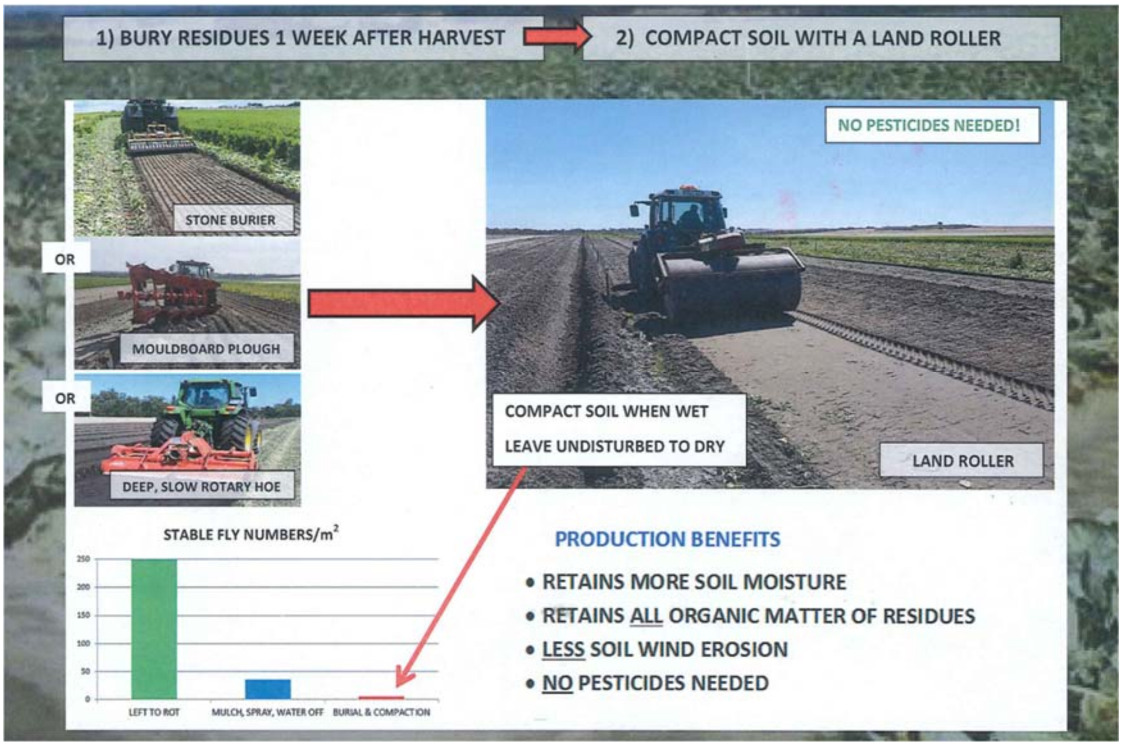

Figure 21. Grower handout summarising the best method for handling vegetable crop residues, where 1) esidues are to be buried 1 week after harvest, and then 2) compacted with a land roller

The research findings from this project have fed into major changes to the previous Stable Fly Management Plan 2013, with included:

- The inclusion of the Shire of Capel in the list of regulated local governments
- The further restriction of the use of raw poultry manure in the declared shires unless composted to Australian Standard 4454, or is used under the new regulation as an 'Approved Measure' or a licence or 'Prior Approval' to transport raw poultry manure
- Vegetable waste may be deeply buried by stone burier, mouldboard plough or similar device, OR rotary hoed five times in 5 days. This allows horticulture growers good control without the need to turn water off, nor spray insecticides. This is a direct outcome from the research during this project
- Tightening of the feeding out of vegetable waste and hay to livestock to reduce these sources from producing stable flies, including feeding the waste in a trough, and circulating around the paddock where the waste is to be located and spread in long, thin lines if in contact with the soil.

Burial of Infested Waste

Any rotting plant matter and/or animal manures or combination of the two that is infested with stable fly larvae (or any fly larvae for that matter as they are very difficult to distinguish with any great accuracy) MUST be buried under at least 1m of soil if not able to be compacted. IF the ground above the buried material can be compacted using machinery, then burial under at least 300mm of soil is still recommended prior to compaction with a landroller or similar device.

Refereed scientific publications

Journal article (Refereed Scientific Publications resulting from this project)

Cook, DF, DV Telfer, JB Lindsey & RA Deyl (2017) Substrates across horticultural and livestock industries that support the development of stable flies, *Stomoxys calcitrans* (Diptera: Muscidae). *Austral Entomology* (Accepted for publication 7th July, 2017) DOI: 10.1111/aen.12282.

Cook, DF, SN Jenkins, LK Abbott, MA D'Antuono, DV Telfer, RA Deyl & JB Lindsey (2018) Amending poultry broiler litter to prevent the development of stable fly, *Stomoxys calcitrans* (Diptera: Muscidae) and other nuisance flies. *Journal of Economic Entomology* (Accepted for publication 12th June, 2018). Manuscript ID ECONENT-2018-0236.

Manuscripts in Preparation

Cook, DF, RA Deyl, JB Lindsey, DV Telfer & IR McPharlin (2018) Compaction of sandy soils to prevent both stable fly (*Stomoxys calcitrans*) and house fly (*Musca domestica*) (Diptera: Muscidae) adult emergence. To be submitted to the *Journal of Economic Entomology* in November, 2018

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Intellectual property, commercialisation and confidentiality

No project IP, project outputs, commercialization or confidentiality issues to report

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Appendices

APPENDIX 1

Field Trials on Agricultural Machinery to Bury Post-Harvest Residues

APPENDIX 2

Assessment of the Ageing of Crop Residues and first Egg Laying by Stable Flies

APPENDIX 3

Assessment of Crop Residue Burial Depth and Stable Fly Development

APPENDIX 4

Entomopathogenic Fungi against Stable Fly

APPENDIX 5

Laboratory Trials (Extra Work outside the Original Research Proposed)

APPENDIX 6

Assessment of the parasitic wasp *Spalangia endius* on suppression of Stable Fly

APPENDIX 7

Cattle Walk Through Trap Development

APPENDIX 8

Vegetable Growers Stable Fly Field Day (2nd February, 2016)

APPENDIX 9

MyPestGuide Reporter Application (Mobile Phone App)

APPENDIX 10

Flyer advertising Stable Fly Field Day, February, 2016

APPENDIX 1

Field Trials on Agricultural Machinery to Bury Post-Harvest Residues

Stone burier machines were run through 3 different post-harvest vegetable crop residues namely lettuce, celery and cabbage residues. The machine used was a Collari stone burier (2.5m wide) (Figure 22 LHS) that buried the residues to a depth of 20cm below the soil surface. The cabbage residues had been high speed mulched prior to being buried with the stone burier. Two (2) weeks after the residues had been buried, adult fly emergence cages were placed over the treated areas to measure the numbers of adult stable flies developing from the residues (Figure 22) over an area that was either just buried or had been additionally compacted from the tractor wheels pulling the stone burier.

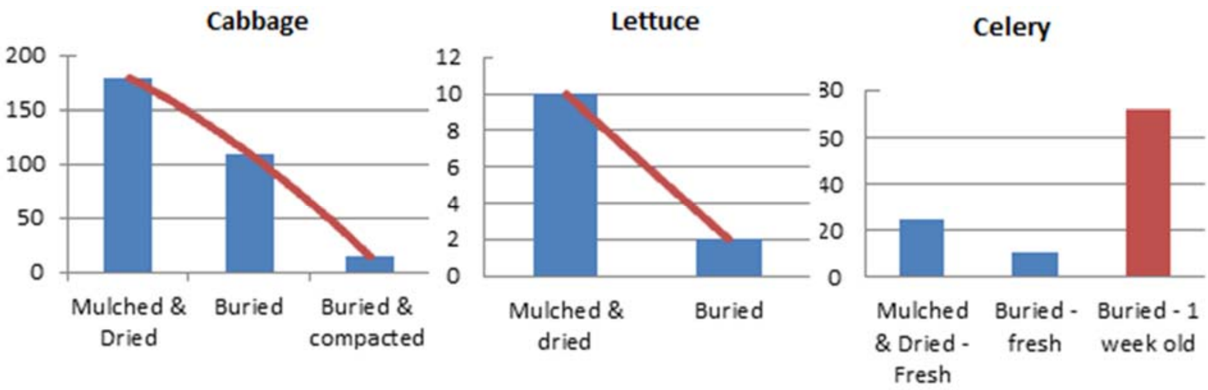

Figure 22. Field Trials on the impact of burial and compaction on cabbage residues, burial of lettuce residues, and burial of fresh *v* 1 week old celery residues on stable fly development. The y-axis is numbers of stable fly/m^2

Residues of cabbage that were buried showed a 45% decrease in stable fly emergence, whereas residues that were buried and compacted by the tractor wheels had 92% less stable fly emergence. No pesticides were applied to the trial site, hence the higher numbers of stable fly from the mulched and dried residues.

Similarly, residues of lettuce that had been mulched and left to dry were compared with residues that were mulched and buried (Figure 22 Centre), where burial resulted in an 80% decrease in stable fly emergence from the soil. Finally, fresh residues of celery that were mulched, dried and buried were half as likely to produce stable flies (Figure 22 RHS), whereas the residues of older celery (1 week) were buried and clearly showed that one week later they were heavily infested with stable fly larvae.

Field Experiments on Machinery to Bury Residues followed by Compaction (Celery)

A mould board plough was run through celery post-harvest residues (1 week old) to bury the residues over a complete vegetable production bay (i.e. 250m long x 13.5m wide) (Figure 1). After burial, a landroller (2.3m wide with 1.5t of water was run over half the bay to compact the sandy soil (Figure 1). All previous trial results (both laboratory and field) had indicated that compaction beyond 2t/m^2 resulted in total prevention of subsequent adult stable fly emergence. One quarter of the bay was compacted once, whilst a second quarter had the land roller run over the ground twice (2X Compaction). Two weeks after the residues were buried and the soil compacted, adult fly emergence cages were placed randomly along the treatment areas (Figure 23).

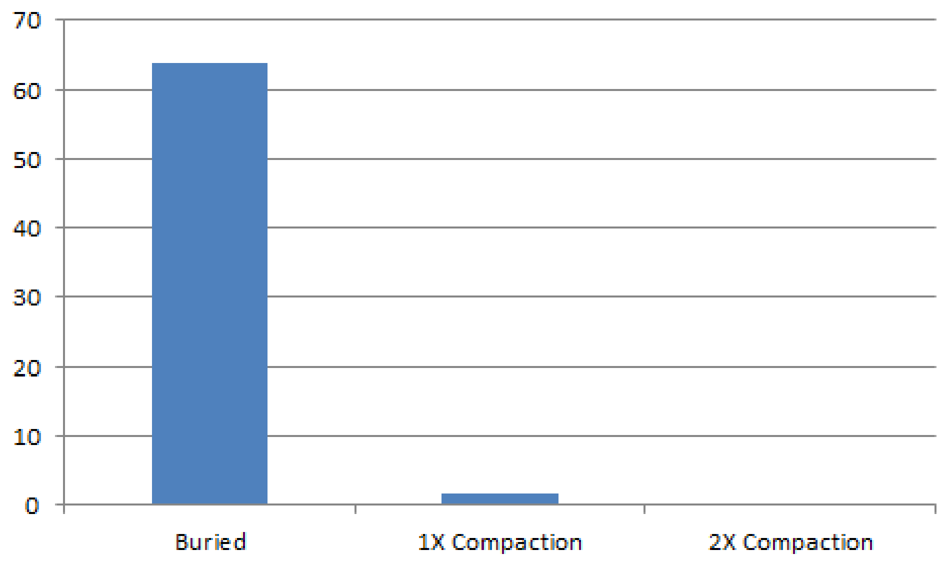

Figure 23. Number of stable flies emerging/m² from celery residues that were either buried, or buried and compacted with a land roller once or twice

APPENDIX 2

Assessment of the Ageing of Crop Residues (first Oviposition by Stable Flies)

All crop residues were struck with some level of stable flies after 2 days exposure, with lettuce in particular being 100% struck within 24hrs (Figure 24). Residues that had stable fly eggs laid on them: within 2 days after harvest, an average of half of the exposed residues had been infested with stable flies.

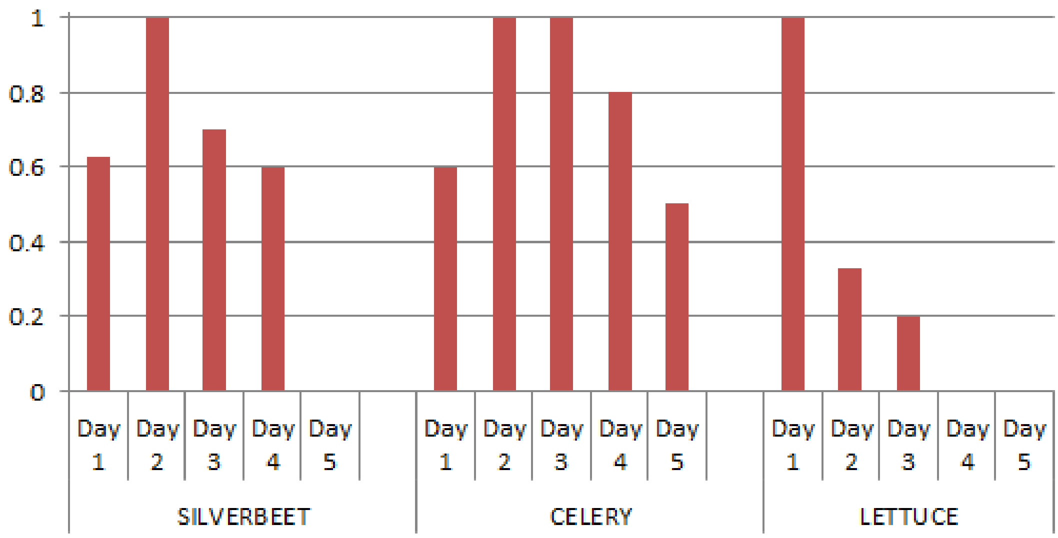

Figure 24. The % of residues where stable flies had laid eggs onto at successive days after harvest for each of silverbeet, celery and lettuce in the field

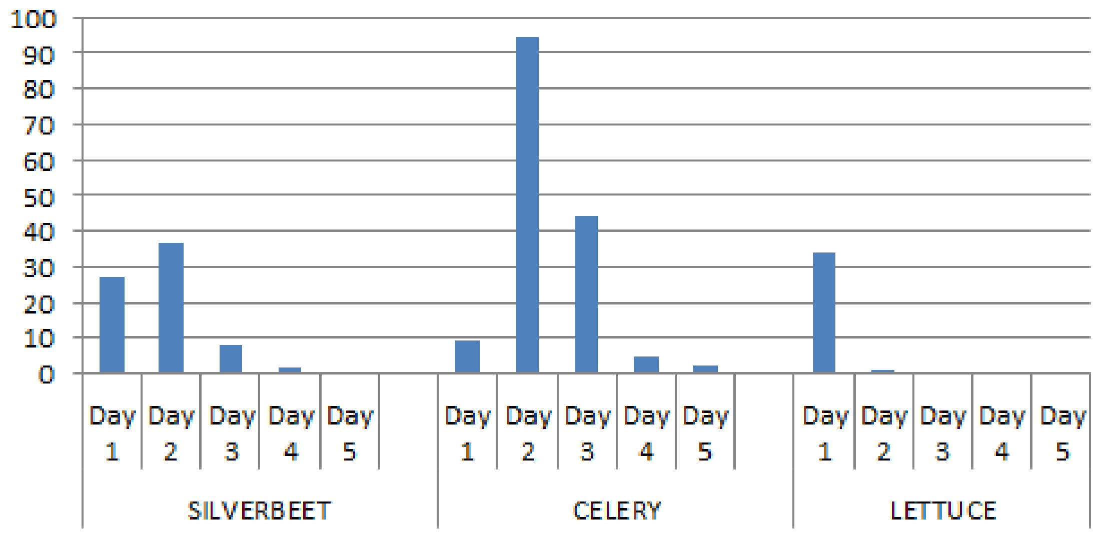

Figure 25. Mean number of stable flies developing on each of celery, cabbage and lettuce residues on successive days after harvest

Ageing of Crop Residue (Silverbeet)

On 11th April, 2016, we set up 3 different crop residues (celery, lettuce and cabbage) to age over a week in the field where they were exposed to stable flies. Every day after exposure 10 replicate samples of residue were placed into a plastic box (25cm x 25cm x 10ch high). A fine, screen mesh was then placed over the box to allow for any stable fly eggs and/or larvae in the residues to develop into adult stable flies for later counting and collation.

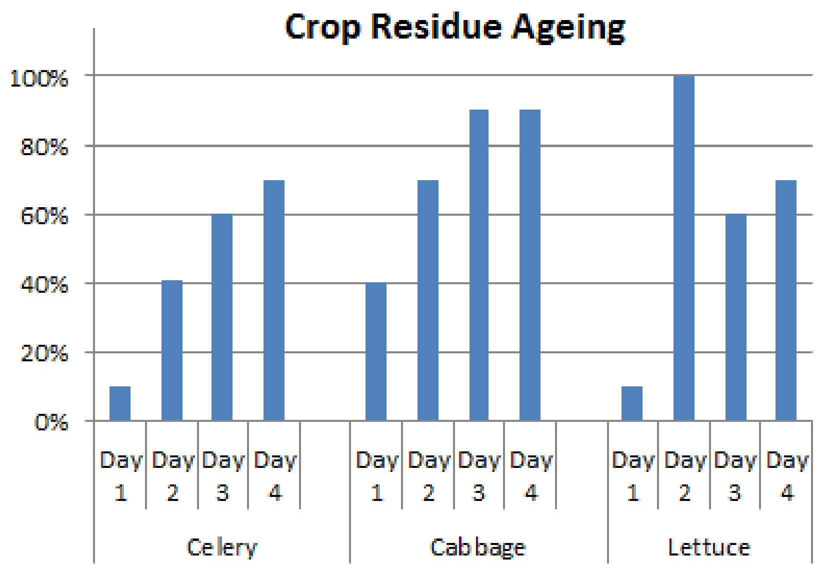

Figure 26. The % of residues where stable flies had laid eggs onto at successive days after harvest for each of celery, cabbage and lettuce in the field

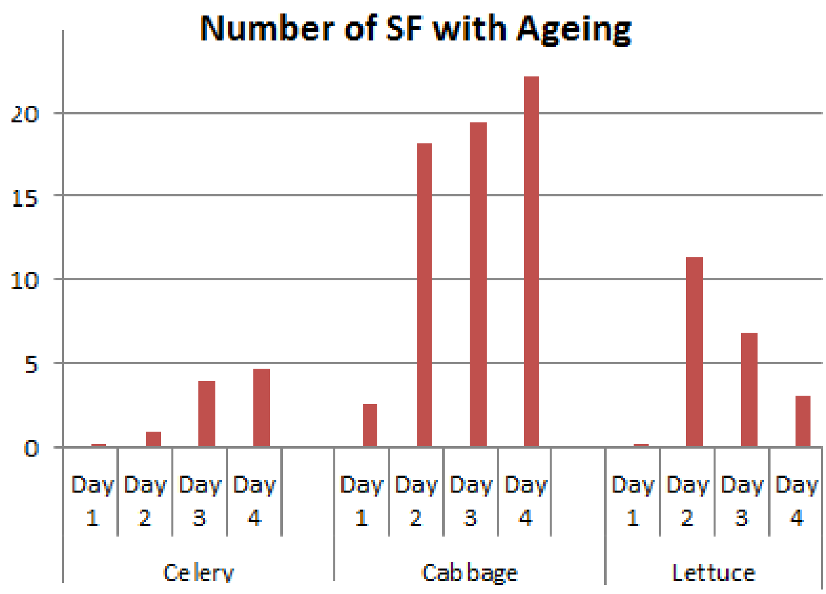

Figure 27. Mean number of stable flies developing on each of celery, cabbage and lettuce residues on successive days after harvest

APPENDIX 3

Assessment of Crop Residue Burial Depth and Stable Fly Development

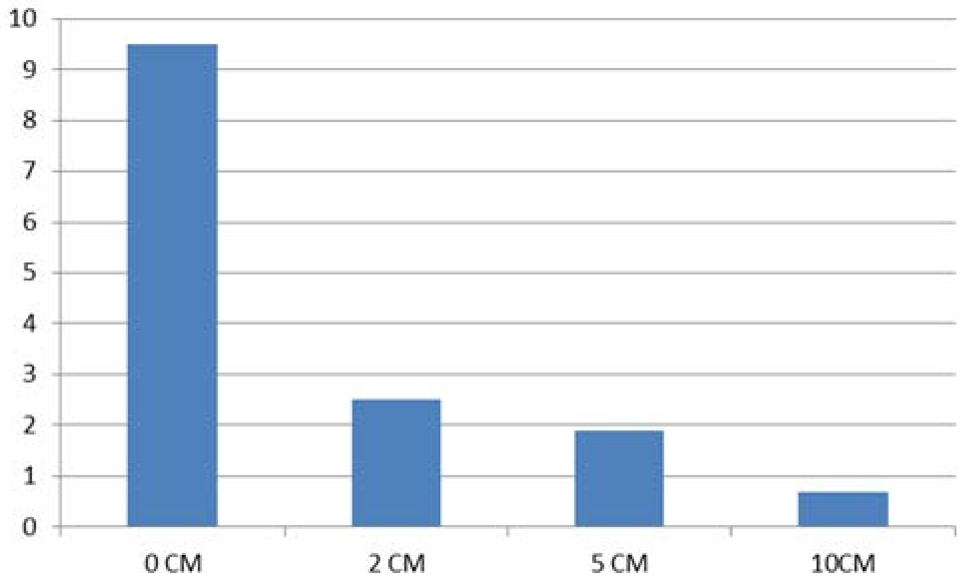

Figure 28. Development of stable flies from crop residues buried in the field at 2, 5 and 10cm without any compaction when stable fly numbers were low (October, 2015)

Burial of residues to even just 2cm below the surface limits stable flies ability to lay eggs onto the residues by an average of 74% (across 15 replicates). As the residues were buried a bit deeper (5cm) there was an 80% reduction in stable fly development, and by 10cm burial depth there was a 93% reduction in stable fly development relative to residues left on the soil surface (0cm). There were several other fly species that accessed the buried residues, in particular the lesser or little house fly (*Fannia cannicularis*) as well as the odd *Helina* species (muscid fly) and *Calliphora dubia* (blue-bodied blowfly)(see Table 1 below)

Table 1. Species of flies recovered in broccoli residues either left exposed on the surface (0cm) or buried under 2, 5 and 10cm of soil for a period of 2 weeks.

Depth (cm)	SF	LHF	HEL	BBB
0	9.5	40.1	0	0
2	2.5	56.4	0.1	0
5	1.9	37.1	0	0
10	0.7	25.0	0.1	0.1

SF=Stable Fly (*Stomoxys calcitrans*); LHF=Lesser House Fly (*Fannia canicularis*); HEL=*Helina* species; BBB=Blue Bodied Blowfly (*Calliphora dubia*).

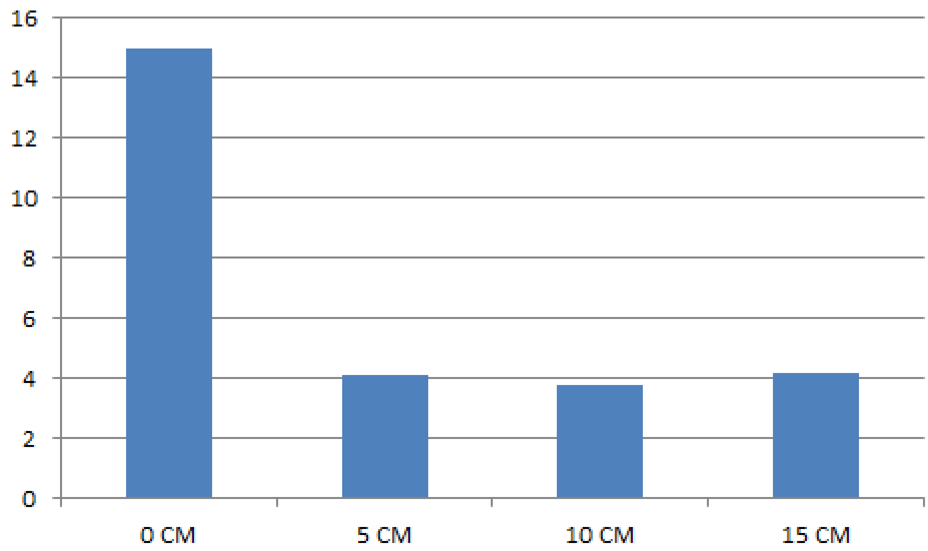

Figure 29. Development of stable flies from crop residues buried in the field at 5, 10 and 15cm without any compaction when stable fly numbers were very high (December, 2015)

Burial experiments in a second field trial in December, 2015 when stable fly numbers present in the field were extremely high, showed that there was still an approximately three-quarters reduction in stable fly development from the residues from 5cm to 15cm burial depths. This rate of reduced stable fly development is equivalent to a pesticide application or turning off all overhead irrigation.

A third field experiment examined the combination of burial AND compaction.

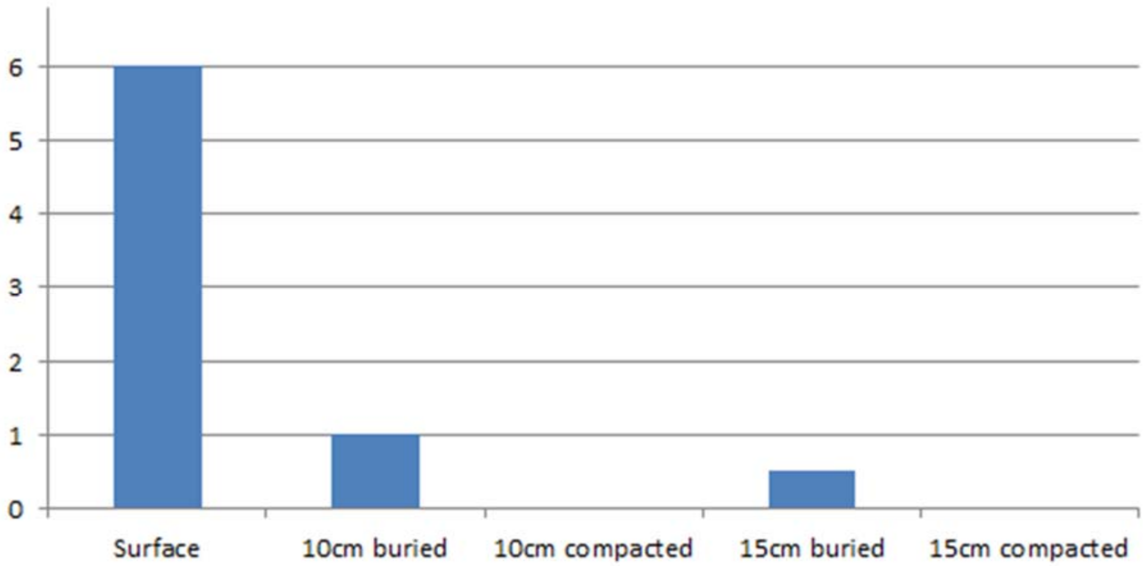

Figure 30. Development of stable flies from crop residues after being buried at 10 or 15cm with or without compaction

APPENDIX 4

Entomopathogenic Fungi against Stable Fly

Already completed trials on 3 crops (as reported in Milestone 103). Entomopathogenic fungi have been identified for use against a range of insect pests, and in particular those insects that spend the great majority of their lifecycle in the soil, such as stable flies. These fungus have the ability to invade the life history stages of stable flies in soil (larvae and pupae) and vegetable crop residues (eggs and larvae) and reduce adult fly emergence. A *Trichoderma* fungus was assessed for its ability to prevent stable fly development in rotting vegetable crop residues. *Trichoderma* occur worldwide in soil, decaying wood and plant matter and are used widely as biopesticides against several insect pests. The impact of *T.viride* on stable fly development was tested in the field when applied either just after planting or 2 weeks prior to harvest to each of celery, cabbage and lettuce crops on a commercial vegetable growing operation in Gingin over the summer months, when stable fly numbers are greatest.

Table 2. Mean ± se of stable flies emerging from a celery crop treated with either (i) the entomopathogenic fungus *Trichoderma viride* after planting, (ii) *T.viride* 2 weeks prior to harvest, or (iii) the synthetic pyrethroid pesticide bifenthrin 2 weeks prior to harvest.

Treatment			
Control	Bifenthrin	*T.viride* Planting	*T.viride* pre-harvest
24.6±5.44	34.7±7.13	22.0±4.62	21.4±4.9
n=30	n=30	n=28	n=29

The application of the entomopathogenic fungus (*T.viride*) had no impact on the development of stable flies from the celery crop residues, when applied either post-planting, 2 weeks prior to harvest, or both (Table 3). The application of bifenthrin reduced adult stable fly emergence by 68%.

Table 3. Mean ± se of stable flies emerging from a cabbage crop treated with either (i) *Trichoderma viride* after planting, (ii) *T.viride* applied after planting AND 2 weeks prior to harvest, or (iii) the synthetic pyrethroid pesticide bifenthrin applied 2 weeks prior to harvest.

Treatment			
Control	Bifenthrin	*T.viride* Planting	*T.viride* (2 applic's)
1.9±0.87	0.6±0.21	3.4±1.96	2.8±1.48
n=29	n=30	n=30	n=30

Entomopathogenic fungi have been identified for use against a range of insect pests, and especially insects that spend the majority of their lifecycle in the soil as larvae and pupae. These fungi have the ability to invade the life history stages of stable flies in soil (larvae and pupae) and ultimately reduce adult fly emergence. Bio-Magic® (a *Metarhizium anisopliae* based fungal product) manufactured by T. Stanes and Co., Ltd (Coimbatore, India) was assessed for its ability to prevent stable fly development in rotting vegetable crop residues. Bio-Magic is a biological insecticide containing spores and mycelial fragments of *M. anisopliae* in a liquid formulation ($1x10^9$ CFU's/ml). The impact of *M. anisopliae* on stable fly development was tested in the field when applied to either: (i) broccoli plants two days after planting; (ii) broccoli crop 2 week prior to harvest, or (iii) broccoli crop residues immediately after harvest was complete. The trial was conducted on a commercial vegetable growing operation in Gingin over the summer months, when stable fly numbers are greatest. Bio-Magic® was mixed at the rate of 3L/500L of water for application to either broccoli plants or post-harvest residues at 1,000L/ha in all 3 treatments.

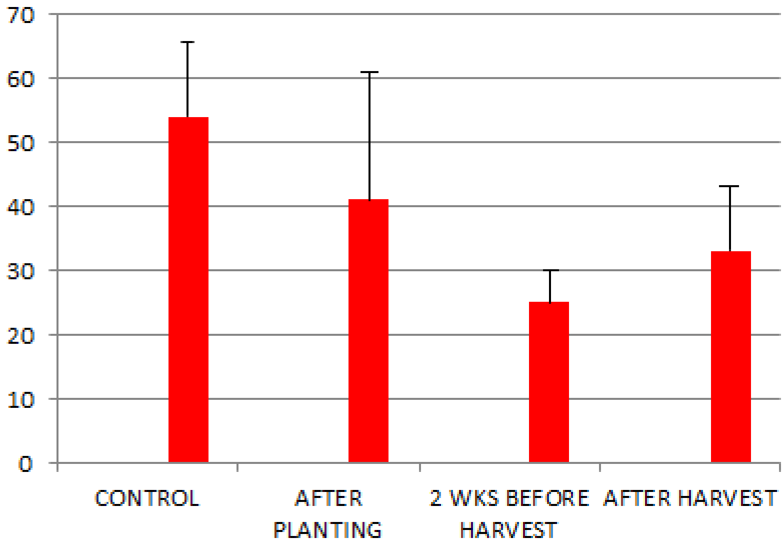

Figure 31. Mean stable flies emerging from a broccoli plants treated with BioMagic® (*Metarhizium anisopliae*) either (i) 2 days after planting, (ii) 2 weeks prior to harvest, or (iii) immediately after harvest was completed

IMPLICATIONS: The application of the entomopathogenic fungus (*Metarhizium anisopliae*) had some impact on the development of stable flies from the broccoli crop residues, especially when applied prior to harvest (54% reduction) and/or post-planting or pre-harvest (38% reduction) (Figure 31).

APPENDIX 5

Laboratory Trials (Extra Work outside the Original Research Proposed)

1) Effect of Compaction on adult House Fly emergence:

We did some further work looking at the same impact of compaction on subsequent emergence of adult house flies from sandy soil. House flies are a significant nuisance fly and it would be useful to compare them with stable flies. Figure 32 below clearly shows that compaction or polishing (smoothing of the surface) of sandy soil had no impact on adult house fly emergence. House flies are a bigger and more robust fly compared with stable flies, so this is not an entirely unexpected result.

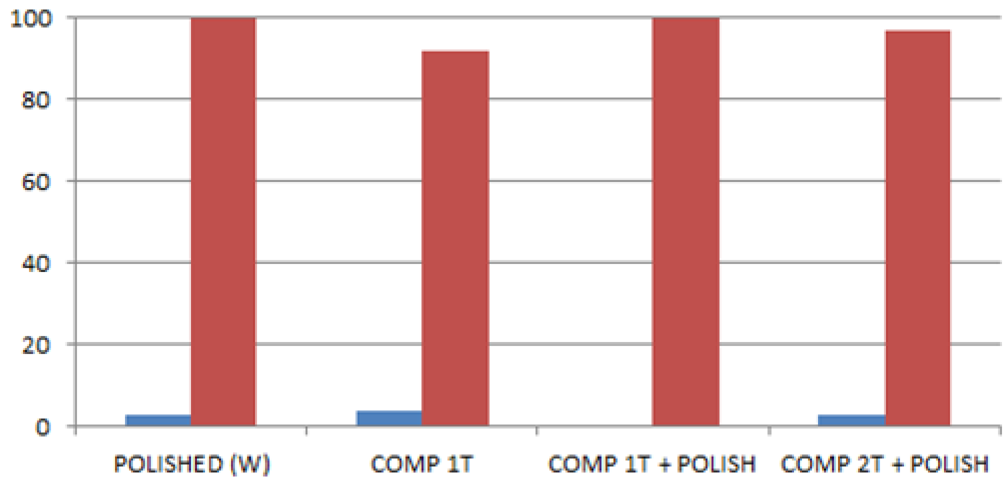

Figure 32. % emergence of adult house flies (red) from soil either polished at the surface or compacted from 1-2t/m^2(LHS) compared with stable flies (blue) (RHS)

2) Effect of Depth of Burial on Adult Stable Fly and House Fly Emergence:

We examined the effect of pupal burial depth on subsequent adult fly emergence between both stable flies and house flies. At depths of 10-30cm, there was no difference in adult emergence. However, as Figure 33 below indicates, burying of stable fly pupae at depths of 70cm or more resulted in less than 50% adult emergence and a dramatic decline in survival to <5% at 90 and 100cm burial. House fly emergence was not as significantly affected by depth of burial, where burial at depths of 80cm or more resulted in less than 50% emergence of adult house flies. At all depths up to and including 80cm, ≈ 30% more house flies emerged at each depth tested compared with stable flies.

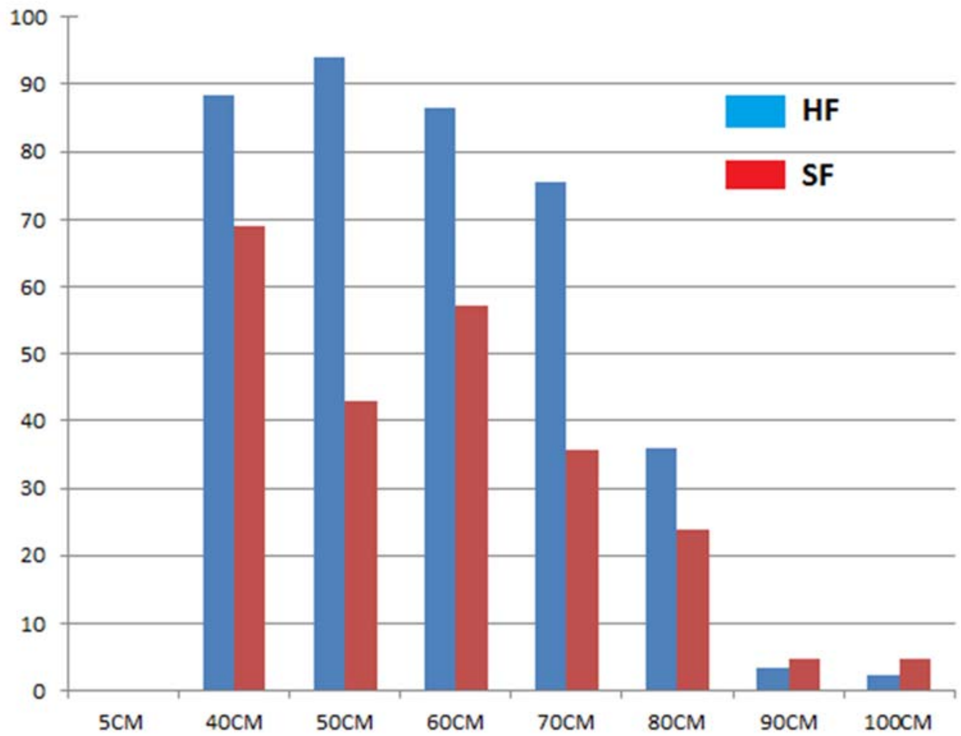

Figure 33. % emergence of adult house flies (HF) and stable flies (SF) from loose, dry sandy soil

3) Influence of Soil Type on Compactability and Adult Stable Fly Emergence

The vast majority of vegetable production along the Swan Coastal Plain around Perth is carried out on sandy soils. However, there is some variation within those sandy soils in terms of both coarse and fine sand amounts as well as the amount of clay and fine sand (Table 4). These have an influence on the ability to compact the soil (i.e., compactability). Soils with a greater percentage of clay and fine sand are more easily compacted.

We wanted to determine which type of sandy soil was the least compactable, so that our recommendations for the amount of compaction required to prevent stable fly emergence had broad application. Four replicate tubes (30cm tall x 15 cm diameter) of each soil type had soil placed in them up to 15cm deep. Fifty viable, stable fly pupae were then placed on the sand and a further 10cm of soil used to cover the pupae. The soil was made up to field capacity prior to filling the tubes and once the soil and pupae were in the tube, they were either (i) left uncompacted, (ii) compacted with a static weight equivalent to 3t/m^2, or (iii) compacted with a static weight equivalent to 5t/m^2. Fine mesh lids were placed over the top of each tube and any adult flies emerging counted.

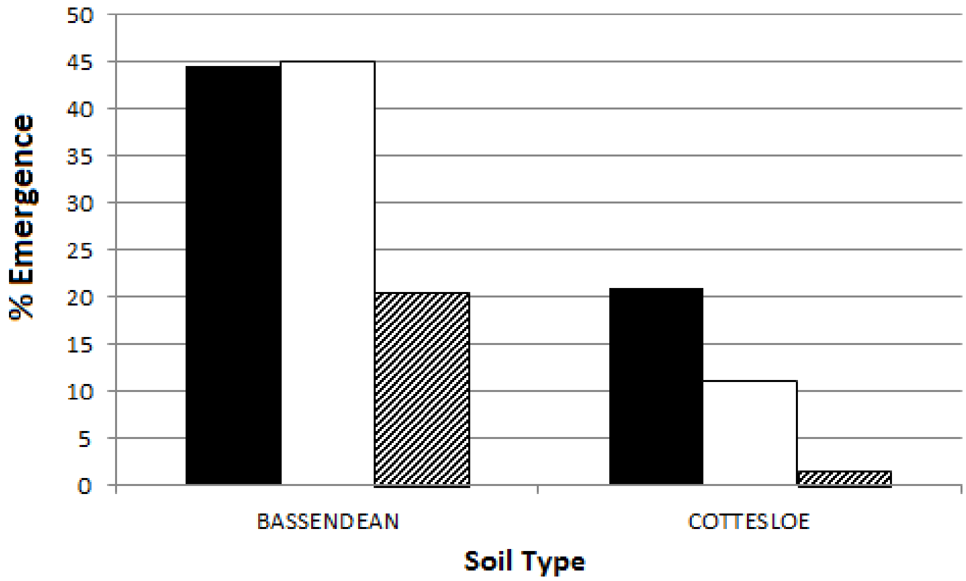

Figure 34. % stable fly emergence from pupae buried under moist Bassendean or Cottesloe sandy soil either left non-compacted (Solid), compacted at either 3t/m^2 (Clear) or 5t/m^2 (Striped)

Adult stable fly were able to successfully dig their way up through 10cm of moist Bassendean sand soil more easily than moist Cottesloe sand (Figure 34). Even with 3t/m^2 compaction, there was no reduction in stable fly emergence relative to non-compacted Bassendean sand. However increasing the level of compaction from 3t/m^2 to 5t/m^2 significantly reduced stable fly emergence in both soil types and in particular from the Cottesloe sands, where adult stable emergence was less than 2%.

Table 4. The percentage of different soil fractions in two soil types typical of vegetable production areas along the Swan Coastal Plain around Perth, WA

Soil Type	**Soil Fraction (%)**			
	Fine Sand	Coarse Sand	Silt	Clay
Cottesloe	27.0	68.5	1.5	3.0
Bassendean	7.0	91.5	0.5	1.0

APPENDIX 6

Assessment of the parasitic wasp *Spalangia endius* on Suppressing Stable Fly

An assessment on the impact of *Spalangia* wasp on local stable fly populations was done across two cattle feedlots in Gingin, 110km north of Perth where stable flies are found in much higher numbers. The objective was to determine the impact of the small parasitic wasp *Spalangia endius* (2-3mm long) that is known to parasitise stable fly pupae. Specifically, can releases of this wasp reduce stable fly populations on a local scale at and around a cattle feedlot where fortnightly releases of this wasp were carried out over 3 months. Two cattle feedlots were chosen for the trial: 1) Cullalla Feedlot (Cullalla Rd) (wasps released) and Fernview Farms (Wannamal West Road) (no wasps released).

S. endius is a parasitic wasp) of both stable fly and house fly (Morgan & Patterson 1977; Morgan 1980; Petersen et al. 1983; Burgess & King 2015) as well as the filth fly *Physiphora aeneae* (Morgan & Patterson 1977). Stable fly populations were measured across the 2 cattle feedlots (10km apart) for 2 weeks prior to the first releases of *S.endius* wasps and for a further 2 months. The *S.endius* wasps were supplied by Bugs for Bugs Pty Ltd, Mundubbera, QLD. Releases of *S.endius* have been done at Cullalla over the past two summers. Anecdotal evidence suggested that the numbers of stable fly had reduced following the wasps introduction, however, there were no measures taken of the stable fly population (using sticky boards or any other trap), or the % of fly pupae that were actually parasitised by *S.endius* wasps.

There has been little research done on the effectiveness of this parasitoid in Australia and continuing community and livestock producer interest in this control option has prompted the need to assess this option in stable fly affected areas around Perth. Research done on cattle feedlots in QLD measured the impact of *S.endius* wasps at around 20% reduction in stable fly, where a regular sanitation and cleaning regime proved just as effective in controlling flies (Urech et al. 2011). However the level of stable fly populations was not nearly as high in QLD compared with what is encountered in around Gingin, WA.

Stable fly monitoring traps (sticky white film over white corflute boards) were set up on 22nd Aug, 2016 around both feedlots (3 x 3 grid of traps) and were counted weekly (films replaced each week). After 2 weeks of monitoring to get a baseline of stable fly numbers at each feedlot, releases of *S.endius* wasps were started at Cullalla Feedlot at 50 wasps/head of cattle (recommended rate) across 20 release stations around the feedlot. Wasp releases were done every 2 wks for 3 months until late Nov, 2016.

Figure 35. Sticky film monitoring board with white sticky film before (L) and 30mins after exposure (R) (captured stable flies can be seen on the sticky film on the RHS)

In addition to monitoring adult stable fly numbers, the % parasitisation of sentinel filth fly pupae was measured. Filth flies include house flies, stable flies and black carrion flies. One hundred filth fly larvae/feedlot (a mixture of 3 filth fly species) were allowed to pupate naturally (put on soil surface with some grass litter to prevent sun exposure) in 10cm deep containers buried to ground level and left exposed at each feedlot at 2 stations (50 larvae/station) every week for 4 weeks.

Any filth fly pupae were recovered one week after placement at the sentinel stations (*S.endius* prefer to parasitise newly-formed fly pupae). Any adult flies and/or wasps that subsequently emerged from the pupae were captured in the laboratory, identified and collated. This measured the % filth fly pupae parasitised by *S.endius* wasps released at Cullalla and any background parasitisation of filth fly pupae at Fernview Farms, where no *S.endius* wasps have ever been released. S.*endius* wasps typically only move up to approx. 100m, so they cannot affect the neighbouring feedlot at Fernview Farms.

Figure 36. Stable fly larvae sentinel traps (LHS) where house, stable and black carrion fly larvae could pupate within the arena (150mm diameter) close-by to *S.endius* release stations (Centre) as shown at Cullalla Feedlot (RHS)

RESULTS

Figure 37. Stable fly trapping board made from corflute (LHS) and exposed at Fernview Farms (August 23-29, 2016) (C) with the monitoring zone delineated (RHS) where stable fly counts were done

Figure 38. Stable fly trapping board from Cullalla Feedlot (Exposed to flies from August 23-29, 2016) (LHS) with the monitoring zone delineated (RHS) where stable fly counts were done

The actual counts on stable fly numbers on each of the 9 trapping boards at each of the two cattle feedlots over 12 weeks of monitoring.

Filth Fly Parasitism by *S.endius*

Tables 1 & 2 indicate the level of parasitism found in sentinel larvae of *S.calcitrans* and other filth flies that were exposed for 1 week at each of Fernview Farms (Table 5) and Cullalla Feedlot (Table 6). At Fernview Farms, only 1 spent pupal case was found from the exposed sentinel larvae to have been parasitised by a micro-hymenopteran pest, of which *S.endius* is one species. It was not possible to determine what species of parasitic wasp had parasitised the filth fly pupae. At Cullalla Feedlot, no filth fly pupae set out as sentinel larvae, were parasitised by any parasitic wasp species over the 4 wks.

Table 5. Numbers of parasitised filth fly pupae from exposures at Fernview Farms

Sampling Date	Filth Flies			No emergence	Parasitised
	SF	HF	BCF		
4/11/16	2	2	32	9	0
	0	0	6	3	0
11/11/16	7	32	2	1	1
	0	5	0	1	0
18/11/16	13	0	7	3	0
	0	1	12	3	0
25/11/16	0	0	8	0	0
	0	0	9	2	0
Total	**22**	**40**	**76**	**22**	**1**

SF=Stable Fly (16%); HF=House Fly (29%); BCF=Black Carrion Fly (55%)

Table 6. Numbers of parasitised filth fly pupae after exposures at Cullalla Feedlot

Sampling Date	Filth Flies			No emergence	Parasitised
	SF	HF	BCF		
4/11/16	5	0	24	5	0
	4	0	5	2	0
11/11/16	1	0	0	1	0
	2	26	9	3	0
18/11/16	0	0	26	7	0
	0	0	23	5	0
25/11/16	0	0	2	8	0
	0	0	9	4	0
Total	**12**	**26**	**98**	**35**	**0**

SF=Stable Fly (9%); HF=House Fly (19%); BCF=Black Carrion Fly (72%)

Discussion: In total, 34 stable fly, 66 house fly and 174 black carrion flies (*Hydroteae rostrata*) were recovered from filth fly pupae exposed at the 2 two cattle feedlots (12% SF, 24% HF and 64% BCF). The percentage emergence of flies from the filth fly pupae recovered was 138/160 (86%) at Fernview and 132/171 (77%) at Cullalla feedlot. Only 1 filth fly pupae (0.3%) from the 327 pupae recovered over the 4 weeks of assessment was found to be parasitised by a parasitic wasp and it was at the feed-lot (Fernview), where no releases of *S.endius* were carried out.

Conclusion: In summary, it would seem that the releases of *S.endius* wasps at Cullalla Feedlot did not not result in the successful parasitism of any filth fly pupae (including stable fly) based on our method of exposing 100 filth fly pupae across 2 sentinel stations within the cattle feedlot each week for 4 weeks in succession. The use of this parasitic wasp in this setting would then not be expected to have had any measurable impact on the stable fly populations – in particular the product supplied was below the expectation of 70% parasitised house fly pupae from which the adult *S.endius* emerge in order to parasitise any newly formed filth fly pupae within the vicinity of the feedlot.

We would like to thank the participating feedlots and their principals for making their businesses Available to us to carry out this research. (1) Cullalla Feedlot - Cullalla Road, Moondah, Shire of Gingin; Angus Graham – Manager; (2) Fernview Farms - Wannamal Road South, Cullalla, Shire of Gingin; Darren Fernie (Owner).

APPENDIX 7

Cattle Walk Through Trap Development

Stable Fly catch rates measured from Cattle Walk Through Traps in Dec (2016) and Feb (2017)

A local grower group (cattle producers and rural residents) has been formed to discuss and test a new version of the Cattle Walk Through Trap. The original concept of a walk through tunnel with lightened exit ports on the sides has been re-configured because of the weaker than expected photopositive response of the adult stable flies and an inability to retain the flies within the tunnel-like trap.

We started looking into an open walk through trap where two air-curtains on either side of the animals would quickly activate as an animal passed and with their wind speed of 25-30m/sec could dislodge the stable flies from the animals sides and lower legs. With the animals walking through a shallow water bath with detergent in the water, the flies blown down into the water would be drawn under the surface (the detergent destroys the surface tension properties of water) where they then drown.

We got some cattle growers to approach their animals with an air blower that pushes air out at several hundred kilometres/hour to see how the blood-feeding flies reacted. Amazingly if they were blood-feeding they would remain attached to the animal, so we had to think around a way of making sure that they retracted their biting mouthpart so that they could be blown off the animals – we considered a range of repellent oils and anti-feedants that could be applied to the animals covered in stable flies just prior to reaching the air curtain. With subsequent testing we have found that simply using soapy water causes the adult flies to cease feeding immediately and drop off the animal. As the cost of 2 air curtains (covering 2.2m) would be over $8,000, we have moved to using jet sprayers (much like an automatic jetting race for treating sheep and cattle) with soapy water and a water bath below the animals. This is a low-cost option and the water can be drained, filtered of adult stable flies (for counting and assessment of number of flies removed/animal) and recycled for use again.

Figure 39. The Cattle Walk Through Fly Trap was built over a water bath, which can be drained and filtered to quantify the number of stable flies removed from the cattle

The prototype spray race and associated water bath for the cattle to walk over was built during the Winter and spring of 2017 for use over the 2017/2018 summer fly season. The numbers of stable fly never reached high enough levels to warrant putting the cattle through the cattle walk through trap, which although good news for the grower, meant that we have not been able to assess the trap fully against stable fly outbreaks.

Figure 40. Final construction of the Cattle Walk Through Fly Trap (LHS), with the side jets triggered as cattle walk on through the race (RHS)

APPENDIX 8

Vegetable Growers Stable Fly Field Day (2nd February, 2016):

The headline of "Improve Productivity and Eliminate Stable Flies" proved to be a positive drawcard for vegetable growers at a Stable Fly Field Day at Bogdanich Farms, Gingin.

Over 20 growers came to see two pieces of agricultural machinery in action and that offer a radical change to how vegetable crop residues are dealt with after harvest (Figure 41). Don Telfer (Stable Fly Project Manager, DAFWA) opened the Field Day and welcomed the growers, shire officers, vegetablesWA representatives and other interested parties.


Figure 41. Growers gather around to see both the Celli Ares (Left) and Collari Stone Buriers

The machinery on display was from Inlon Agrimec Group (NSW) (Gary Surman) and Lovegrove Turf Farms (WA) (Dick Lovegrove) with the Celli Ares 150 and Collari Stone Burier (respectively). Both companies explained the key features of the machines and the different widths, the horse power requirements, blade types, and modifications to the machines that were possible. Dr Cook gave an overview of the research into stable fly management from vegetable crop residues funded by HAL/HIA with local government and vegetablesWA support. He also showed growers some examples of methods used to measure stable fly development (both depth and timing of crop residue burial).


Figure 42. Each stone burier machine burying cauliflower crop residues left after harvest

The machines were run through both finished crops of cabbage and celery. The amount of vegetable matter left after harvest does not get any more than with cabbages and cauliflowers, and handling the large, reject cabbages in particular posed the greatest challenge. Each machine was run through the residues, either after the residues were firstly broken up with a high speed mulcher, or as they were.

Figure 43. Growers assess the ground after a the Celli and Collari machinery handles the vegetable crop residues left after harvest

APPENDIX 9

MyPestGuide Reporter Application (Mobile Phone App)

Recently the Department of Agriculture & Food WA (now DPIRD) released a suite of mobile phone apps, one of which will assist the community with reporting Stable Fly and other pest outbreaks. The new app, called **MyPestGuide Reporter,** is available to download free of charge for both i-Phone and Android smart phones. MyPestGuide Reporter lets anyone reports pests and maps it online.

The second app, called **MyPestGuide Crops** is more often used for identifying and reporting specifically on grains pests in crops. It is suggested that this app is **not** downloaded unless you require information about other horticultural or grain crop pests.

To download the **MyPestGuide Reporter** on your phone, open your preferred I-Phone or Android (Play Store) app downloader, use the search mechanism for Apps looking for '**MyPestGuide Reporter'** and ask it to download. Follow the instructions to set it up. It is helpful if you register your contact details, so that DAFWA/DPIRD can contact you if necessary.

When using the **MyPestGuide Reporter** app on your smart phone, you have the ability to take and submit up to 4 photos. The App will automatically locate the observation site (if the phone's GPS or location remains on), you can describe what you see and where, and it will store the information sent in a folder for you. The report page walks you through attaching photographs, and you can see if the automatic location of the device is on or off. You are able to give an address or other location in the 'Where' text box instead if your GPS is not turned on, or you wish to report an outbreak in a different location to your current one.

To access this App, go to the following link. https://mypestguide.agric.wa.gov.au

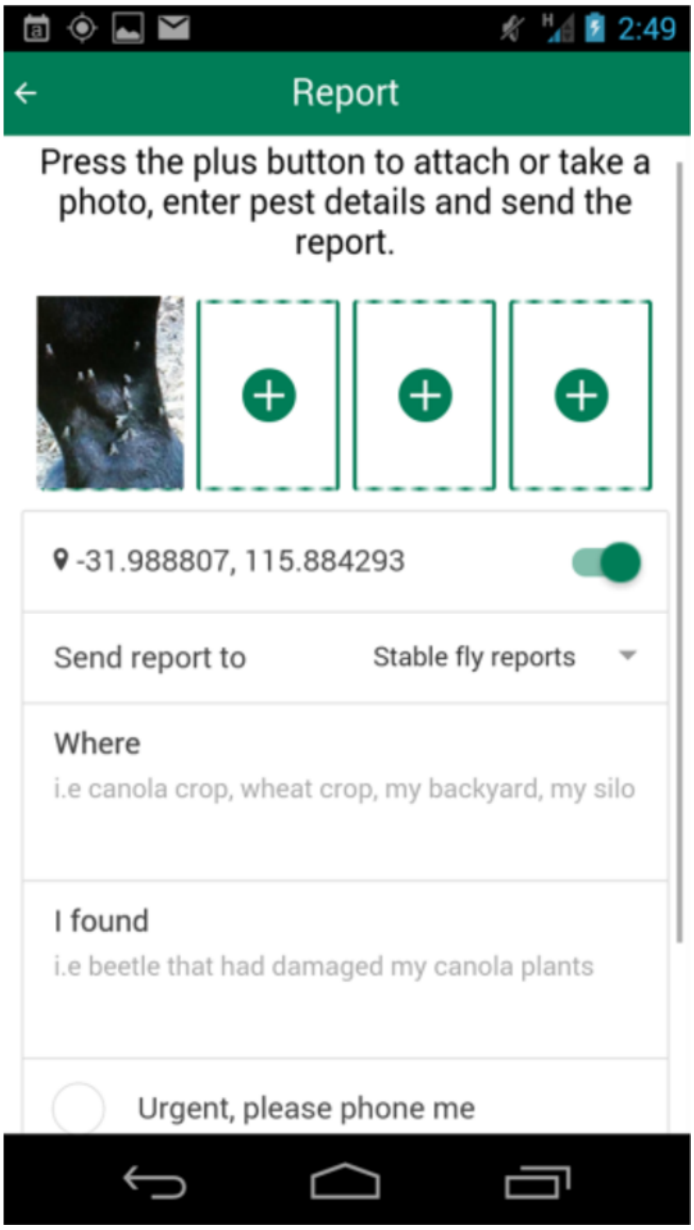

Figure 44. The MyPestGuide Report with an attached photo and GPS Location

One note in sending a report, in the box 'Send report to….' Please click on the arrow, and scroll down to 'Stable fly reports' as it will get to the Stable Fly Group much quicker.

Once you have sent the report to DAFWA/DPIRD, the information is verified by an expert, mapped online as per where the report was sent from based on the location, and discussed if necessary with local shires. (which is why it's important to leave the location turned on). Then the photos and information are securely stored on a DAFWA database allowing the agency to contact you if required as well as send you a message back to onto your device. To obtain the expert feedback the user needs to refresh or download reports in the main menu as this draws the information from the database onto your phone.

DAFWA can also use the information to respond to the report when needed if an exotic pest is found, and to help gather all similar reports and map them together to highlight pest hotspots or pest outbreaks which might impact an industry. You are able to ask for someone to ring you on your mobile as soon as they receive the report, and you can agree to or disallow your report to be shared with others publicly on the online map. However, by sharing this builds up useful information for DAFWA/DPIRD to be able to accumulate a number of similar reports and make them available to the public for example when other countries ask DAFWA/DPIRD if we are free from certain pests or disease, thus keeping our markets open for trade.

Figure 45. The MyPestGuide Reporter Application

For any further questions about the App, please phone: 1800 084 881 or email: mypestguide@agric.wa.gov.au

APPENDIX 10

Flyer advertising Stable Fly Field Day, February, 2016

"IMPROVE PRODUCTIVITY AND ELIMINATE STABLE FLIES!"

We invite all vegetable growers to observe a new machine that buries vegetable crop residues after harvest and prevents stable flies from developing in the residues as they rot. In conjunction with Inlon Agrimec Group and Lovegrove Turf Farms, we encourage you to share in this new procedure, improving your on farm productivity and stopping stable flies.

When: 5th February 2016 10am-2pm

Where: Bogdanich Farms, cnr Gingin Brook Road and Cowalla Road, Gingin

RSVP 30th January 2016

David Cook
Entomologist (DAFWA and Univeristy of WA)
0416 181 162t
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Gary Surman
Inlon Agrimec Group
0419 606 712
gsurman@inlon.com.au

Bury Crop Residues > **Bedform in a Single Pass**

Reduce soil tillage & Machine Use > **Retain Organic Matter**

Remove Stable Flies Breeding Site > **No Need to Spray Pesticides**

GOVERNMENT OF WESTERN AUSTRALIA

Department of Agriculture and Food

inlon AGRIMEC GROUP