The Use of UV-A Light Insect Traps for TPP Control and Monitoring in Glasshouses
Final Report

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Permanent Agriculture and Horticulture Science and Extension

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1. Introduction

The arrival of tomato potato psyllid (*Bactericera cockerelli*, TPP) in 2006 and the need to use insecticides to control it has significantly disrupted the use of biological control agents in tomato and other solanaceae crops under glass. Finding an effective and economical non-chemical means of controlling TPP in protected crops would therefore allow the industry to return to full biocontrol programs, with all the benefits that entails.

Previous research[1] by the Future Farming Centre (FFC) looking at the effect of blocking ultraviolet (UV) light on reducing potato blight also found a strong correlation between reduced UV levels and psyllid yellows on potatoes (Figure 1) (Merfield, 2018).

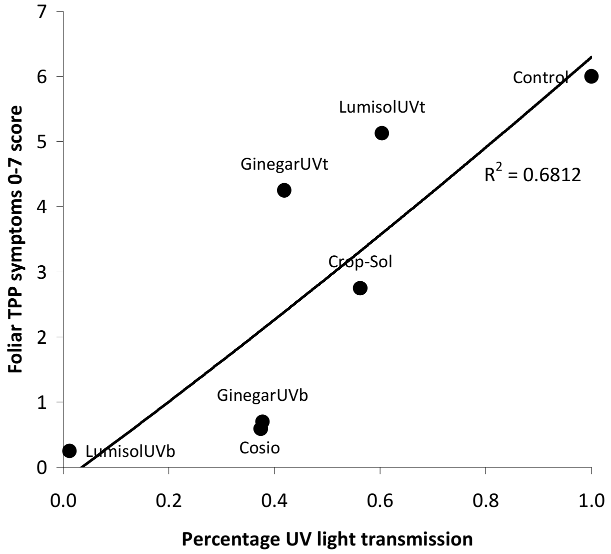

Figure 1. Relationship between the amount of UV light transmitted by the crop covers and psyllid yellows.

These findings indicated that TPP are inhibited by lower UV light levels, i.e., they need UV light to be able to behave normally. It is well established that many insect plant pests most strongly detect light in two wave bands: 1. UVA which orientates them to the sky; and 2. yellow-green which orientates them to possible food sources. This is why most sticky insect traps are yellow. Other research on TPP and other insects' behaviour relating to UV light, e.g., (Antignus, 2000; Raviv & Antignus, 2004; Barghini & Souza de Medeiros, 2012; Paul *et al.*, 2012; Dáder *et al.*, 2015; Dáder *et al.*, 2017) indicated that TPP may be attracted to UV light, and this could therefore be used as a means of trapping and therefore controlling them in glasshouse crops. However, there is no existing research confirming if *B. cockerelli* responds to UV light.

Therefore, in 2017 TomatoesNZ was approached, through its business manager, Helen Barnes, to see if it was interested in exploring the potential of using UV light for control of TPP. It was agreed that the FFC should undertake some preliminary experiments to investigate the attractiveness of UVA light to TPP.

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[1] See www.bhu.org.nz/future-farming-centre/information/crop-management/crop-production/mesh-crop-covers-for-potato-blight-and-pest-control for all FFC TPP and blight research.

2. Experiment 1: UVA light as an attractant for TPP

2.1. Methods

Traditionally research into insect responses to environmental stimuli, such as light, is conducted in the laboratory. However, these are highly artificial environments and it is increasingly considered that much of this kind of research has limited relevance to real-world crop production. Research into solutions for commercial crop productions systems is therefore increasingly being conducted, from the start, in real-world conditions, or as close to it as possible. It was therefore decided to use a small heated glasshouse, approximately six by three meters, at Lincoln University 43°38'42.35"S 172°27'42.44"E, w3w.co/builders.erase.report (Figure 2).

Figure 2. Experimental glasshouse, without mesh cover left prior to the experiment, with mesh cover right during the experiment.

Tomatoes were grown in potting mix in tubs down both sides of the glasshouse. The tomato plants were already infested with TPP from a research culture when they were put in the house. At the north end of the glasshouse, either side of the heating system, two Rentokil, Luminos 3 UV insect light traps with three, F15 T8 365 BL UVA fluorescent tubes, were mounted 80 cm from the ground on plywood sheets, facing into the glasshouse Figure 3. The plywood sheets were to both protect the traps and block the sunlight from behind them.

Figure 3. Experimental setup inside the glasshouse.

Three different coloured glue boards were tested.

- **Yellow** - Glupac GB001 Universal glue board - small, Pelsis Ltd. UK, www.pelsis.com
- **Black** - Glupac GB002 Universal glue board - small, Pelsis Ltd. UK, www.pelsis.com
- **White** - Luminos 3 Glue Board, Stock number 300010, batch 67/7478 produced Jan 2017 - Rentokil Initial Supplies, UK,

The procedure was to randomly chose a glue board colour, then, two boards of the same chosen colour were placed in the traps. Then one trap was randomly chosen to be illuminated, and the other trap turned off. Glue boards were left in the traps for one week, then, changed for another randomly selected colour and another random selection of the trap to be illuminated and trap to be turned off. A total of three replicates was used, i.e., three replicates of each glue board colour, giving a total duration of nine weeks. Trapping started on 28 Nov 2017. The week before, on the 21 Nov 2017, 2500 *Encarsia formosa* wasps were put out to control whitefly (*Trialeurodes vaporariorum*) that was present on the tomatoes.

On the first night of running the traps (21 Nov 2017), a very large number of moths invaded the glasshouse and were caught on the illuminated trap. After various attempts over several days to put mesh over the openings in the glasshouse, such as vents, to block the moths from entering it was decided to cover the entire glasshouse down to the ground with a 0.3 mm mesh (Figure 2) from the previous years field trial (Merfield, 2017). Access to the glasshouse was via a waterproof zip that had been sewn into the mesh for the field trial. While the mesh was highly effective at stopping moth ingress, the mesh also stopped the ingress of any other insects into the glasshouse, both pests and biocontrol agents, and, it also stopped any TPP leaving the glasshouse, in effect making the whole glasshouse a large TPP colony.

Temperature was manually recorded every weekday, except over the Christmas break. Average temperature was 27°C, minimum, 17°C and maximum 44°C.

2.2. Results

The results were completely unambiguous with 99.86% of TPP collected on traps illuminated with UV light (Figure 4). Both newly hatched (brown) and mature (black) adults were caught on the UV traps.

There was no significant effect of glue board colour as the attractiveness of the UV light swamped any colour effect, with very similar numbers of TPP caught on all three colours under UV light ($p=0.717$). However, further testing (see section 3) found that without UV light, yellow was the most attractive colour.

Initial counts of other insects on the traps was abandoned after the second week as numbers were very low, presumably due to the mesh covering the glasshouse keeping other insects out, and their numbers were overwhelmed by TPP. However, during the first two weeks 1 whitefly was trapped on a white UVA illuminated glue boards and 10 whitefly on a black UVA illuminated glue board, but, none on unlit traps. This may indicate that whitefly are also attracted to UVA light, but, the numbers caught were considered low compared to the number of whitefly believed to be on the plants so it may be that the attraction is not particularly strong. In comparison, considering the large number of *Encarsia* that were released, only one was trapped, during the first week on a white UV illuminated glue board. If *Encarsia* was attracted to UVA light, it is expected that larger numbers would of been caught.

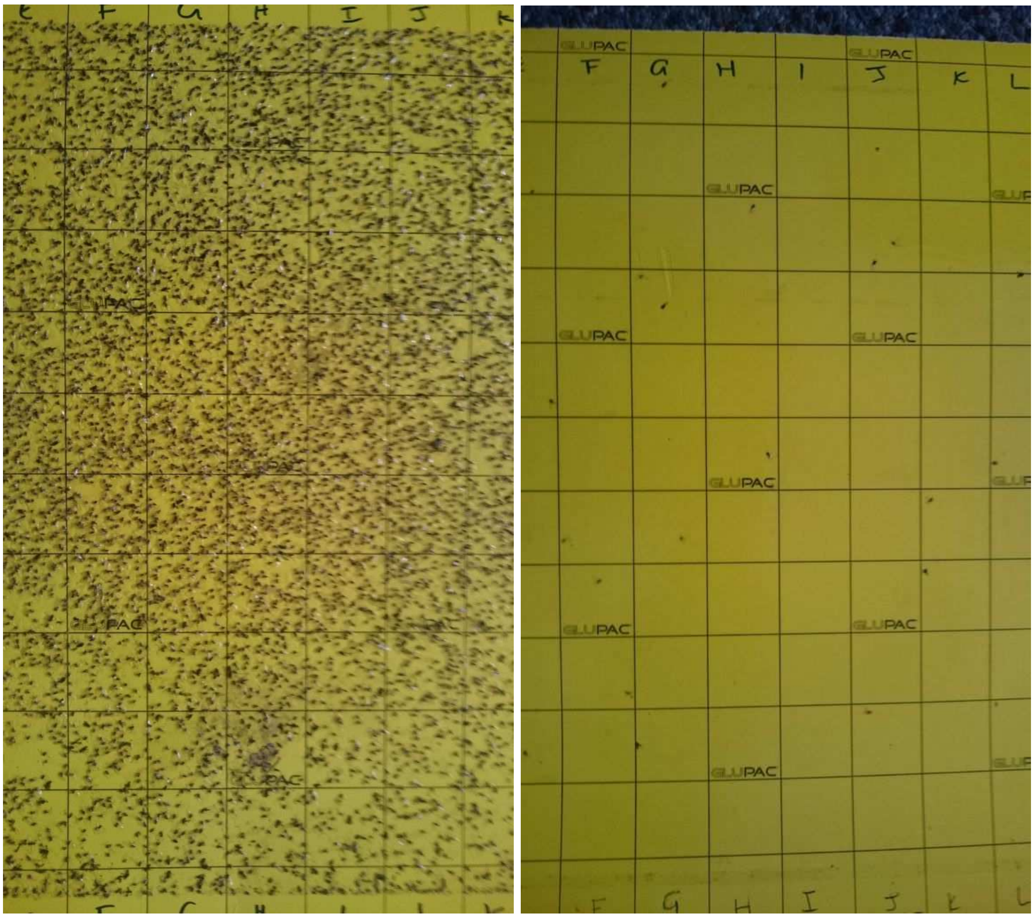

Figure 4. Example of TPP catches on UV illuminated glue board left, and unilluminated glue board right.

2.3. Discussion

2.3.1. UV traps as a control technique

TPP are clearly exceptionally attracted to the UVA lights! However, the hope that this could be used as a means of controlling TPP in a glasshouse situation were not borne out in this experiment, as the TPP populations on the tomato plants were not controlled, but instead built to very high levels. However, there are reasons why this result may not be representative of real-world glasshouse tomato production. First and foremost is the use of the mesh cover over the glasshouse to prevent moths getting in, also prevented any beneficial insects getting in and TPP from getting out, effectively creating ideal conditions for TPP proliferation, i.e., effectively creating a large TPP colony. Therefore even though very large numbers of TPP were caught, the total numbers in the glasshouse overwhelmed the amount that could be caught.

In a commercial situation, it would be expected that the number of TPP on the crop and in the glasshouse at planting would be very small or zero, and that TPP would arrive from outside the house as flying adults. If UV traps could catch these adults as they immigrate into the glasshouse this could reduce the number of adults that reach the crop and lay eggs. If there are sufficient traps it could still be possible for the technique to be a component of an IPM strategy. Clearly this can only be tested in real-world glasshouses not small research glasshouses.

The difference in trap rate between whitefly and *Encarsia* hints at an interesting possibility. As noted above many plant insect pests react most strongly to UVA and yellow-green parts of the light spectrum so they can determine the location of the sky for dispersal and host plants for food. However, predators and parasitoids don't have the same visual requirements, and they often use chemical cues as a means to locate prey, especially over larger distances. There may therefore be a significant difference in the attractiveness of UVA lights to pests vs. their BCAs. If correct there are a number of obvious benefits: beneficials could be used without large number getting trapped, UVA could complement BCA's for pest control by trapping adult pests as often it is juveniles stages that are parasitised, and UVA could also be used for enhanced pest monitoring.

2.3.2. UV traps as a monitoring tool

Despite the inability of the UV traps to control TPP in this experiment, the highly attractive nature of UVA to TPP indicates it has substantial potential as a monitoring tool. The "New Zealand Code of practice for the management of tomato/potato psyllid (TPP) in greenhouse tomato and capsicum crops" (Anon., 2016) states that "It is necessary to monitor TPP populations in order to make informed decisions for their control. Monitoring TPP populations on the plants in the greenhouse is the most reliable and effective method. Yellow sticky traps may give some indication of TPP activity but currently there is insufficient information to relate trap catches with TPP populations in greenhouse crops" (Anon., 2016, page 8). The results of this experiment indicate using UVA light based traps, instead of yellow sticky traps, would increase sensitivity by more than an order of magnitude (approx. 14 times), which could then allow a correlation between trap counts and crop counts, to be established, even at very low TPP populations, .

The Rentokil traps used in this experiment may well be overkill for such a purpose, and they only illuminate in one direction while 360° trapping is more likely to be required. Existing inexpensive traps such as that in Figure 6 could be used, or even, just a UVA fluorescent tube or LED bulb surrounded by UVA transparent plastic cylinder (e.g., cellulose acetate sheets used on overhead projectors) coated with glue could work.

Figure 5. 360° UVA insect light trap

However, a number of questions need answering before the concept can be considered sufficiently rigorous. These include

- The trap design;
- Location of traps; and
- Time of day/night for illumination.

During the experimental stage trap design is not a pressing priority, as long as the traps are sufficient for research purposes. If the research is a success and the technique becomes standard practice commercially produced traps designed to be simple, cheap and robust will be required.

Trap location, for example below crop canopy height and in the glasshouse roof space, may well have different trap rates and trap insects from different sources. For example Al-Jabr & Cranshaw (2007) trapped more TPP above the tomato crop than at the bottom. However, traps below canopy height may trap more insects originating on the plants, while traps in the roof space may trap insects immigrating into the glasshouse through the vents, i.e., different trap heights could be trapping insects from different origins.

3. Experiment 2: Comparison of the attractiveness of different coloured glue boards

From a scientific perspective, it was decided that it would be valuable to know the relative attractiveness to TPP of the different coloured glue boards in the absence of UV light.

3.1. Methods

The three different coloured glue boards were attached to a piece of corflute and hung in the center at the north end of the glasshouse at the same height (80 cm) as the light traps (Figure 6).

Figure 6. Experimental setup for comparing the relative attractiveness to TPP of the different coloured glue boards.

Cards were put out for a week at a time. Four replicates were run (total of four weeks) and the order of the cards on the corflute was randomised for each replicate.

3.2. Results

Yellow was by far the most attractive colour with out of 2062 TPP trapped on all boards 2025 or 98.2% were on the yellow cards. This was as expected as previous research on a range of psyllid species and trap colour had found this result, e.g., (Brennan & Weinbaum, 2001; Al-Jabr & Cranshaw, 2007; Walker *et al.*, 2011; Page-Weir *et al.*, 2012; Walker *et al.*, 2013a; Walker *et al.*, 2013b; Taylor *et al.*, 2014; Lahiri & Orr, 2018). Yellow is also generally the most attractive colour for a wide range of insect plant pests, hence yellow is the standard trap colour.

3.3. Discussion

While the result was as expected, it, provides useful confirmation of trap colour choice and a comparison with the UV experiment, where there was no difference in TPP caught on the different colours as the colour effect was overwhelmed by the attractiveness of the UV light.

4. Experiment 3. Day vs. night capture

The issue of catching moths when using UV traps during hours of darkness, means that using UV traps at night in commercial glasshouses which cannot easily or cheaply be moth proofed, means that to be viable UV traps need to be able to catch psyllids during daylight hours. However, it is possible that sunlight, including its UVA component, (despite the considerable reduction in UV due to filtering by the glass), would swamp the light from the traps such they are no longer attractive. The third and final experiment therefore compared day vs. night time trapping.

4.1. Methods

The same setup as for experiment one was used, except, one trap was illuminated for four hours in the middle of the night and the other in the middle of the day. The trap that was illuminated was randomised between replicates. At the start of the experiment on 21 March 2018 sunrise was 07.30 and sunset 19.42. The middle of the day was therefore 13.30 and middle of the night is 01.30 am. The day trap was thus set to turns on from 11.30 to 15.30, and the night trap from 23.30 to 03.30. The timers were not adjusted for daylight saving which started on the 1 April, to keep them in sync with sun time. Yellow glue cards were used, and they were put out for one week, per replicate, so they had a total of 7 days × 4 hours = 28 hours of illumination. The first trap was put out on the 21 March and the final rep was taken in on 11 April. The number of TPP on the final rep was much lower, indicating that the psyllid population in the glasshouse was rapidly declining, probably due to colder weather and shorter days, even though the glasshouse was heated. Due to low numbers and the variability of the previous replicates, the experiment was stopped.

4.2. Results

The counts from the three reps are given in Table 1.

Table 1. Glue board trap counts from the three replicates of the day vs. night trapping experiment, and their average (p=0.827 LSD=261.7)

Replicate	Day	Night
1	61	133
2	303	130
3	12	47
Average	125	103

Unsurprisingly considering the large variation in counts and neither day or night have consistently higher counts the result was not significant, p=0.827 LSD=261.7.

4.3. Discussion

While there was no significant result, it is clear that TPP can be trapped both in the middle of the day and in the middle of the night. The later result differs from Cameron *et al.*, (2013) who failed to trap TPP in the field during night time. However, Cameron *et al.*, were using unilluminated yellow traps, so it may be that TPP could of been flying at night, but, due to low light levels they did not see the traps and so were not caught. It would be interesting to repeat Cameron's experiment but using illuminated traps.

While TPP were trapped during the middle of the day, the variation between replicates one and two is concerning, which, coupled with the decline in TPP numbers for rep three, means these results should be taken as indicative, rather than authoritative. Also the Rentokil traps have three bulbs and produce a considerable amount of light. It is possible that the intensity of the light is also important (pers. comm. David Ben-Yakir, Department of Entomology, Agricultural Research Organization, Ministry of Agriculture and Rural Development, Israel) and that lower wattage traps may not be as effective.

These results are therefore clearly a starting not an endpoint.

5. General discussion

Overall the results are very positive, and, considered highly surprising by other researchers working on TPP and insect vision, trapping etc. It is hoped that it will therefore be a spring board for a range of further research leading to practical solutions for growers. While the hoped for outcome of control of TPP was not achieved, this is probably a result of the setup, and, replication in real-world tomato glasshouses is needed to determine if control and/or monitoring is achievable.

It may also not be necessary for UV traps to completely control TPP. Previous research has shown a wide range of existing 'wild' biocontrol agents will attack TPP, such as lacewings, ladybirds, hoverfly mites, etc. (Walker *et al.*, 2011; Pugh *et al.*, 2015; Geary *et al.*, 2016) One of the possible reasons for the TPP populations in the experimental glasshouse becoming so large, is that no biocontrol agents could get in due to the mesh crop cover over the glasshouse. Clearly lack of agrichemicals sprays also played a role, but, in organic glasshouse tomatoes which have very few chemical control options, TPP populations of this magnitude are not seen, which indicates that wild biocontrol agents are likely playing a role in moderating the populations in such situations. As Prof. Wratten explained to the TomatoNZ board during their visit to Lincoln on 27 Feb 2018, these agents can be given a considerable boost by supplying resources such as nectar, pollen, habitat and alternative prey, which often means that with this help they can then keep pests, in this case TPP, below economic thresholds. In addition, there has been the release of the classical / introduced biocontrol agent *Tamarixia triozae*, which could be used either as current BCA's are, i.e., as regular inoculations, and/or using a conservation biocontrol approach and providing additional resources to boost their populations and fecundity, as per the other glasshouse research the board viewed during the visit.

Clearly with the large number of moths attracted into the glasshouse due to the UV lights being on at night, using UVA traps during night-time in real-world glasshouses would be impossible. The final experiment comparing day vs. night time trapping, indicates that daytime trapping is possible, but, with the declining TPP populations in the glasshouse with the onset of autumn replication of the research is required to substantiate the result.

One of the issues raised during the boards visit was the immigration of TPP from potato crops, particularly at termination when large numbers of TPP were presumed to be dispersing. While this is an obvious potential source of TPP for glasshouses, there are reasons why the role potato crops may play as a source of infestation for glasshouse crops could be more complex than first appears. In the first instance most potato crops are chemically desiccated with Reglone, the active ingredient of which is Diquat, which is highly toxic including to insects, so it is probable that many of the adult TPP in the crop are killed by the herbicide at the crop's termination. However, potato crops could also be a source of TPP during their life, but, as TPP (or rather the bacteria *Candidatus* Liberibacter solanacearum) is highly damaging to potatoes, potato growers are highly active in controlling it, so TPP populations in commercial crops should not be excessively large, and naturally only reach significant levels in February and March (Merfield, 2013). Finally, there has been limited research actually looking at dispersal from potato crops, the key publication Cameron et al. (2013) found that while TPP were dispersing several hundred meters from a crop, the numbers at that distance were very low, often below one TPP over three days. So unless a glasshouse is within a few hundred meters of a potato crop it is possible that background TPP levels would be as large a source of psyllids as the potato crop. Therefore, it may be prudent to get a better idea of the actual risk potato and other field crops that host TPP are to glasshouse tomatoes. At the same time if potato and field tomato growers switched to mesh crop covers, the problem of TPP emigrating from field crops and into glasshouses, would be completely solved.

6. Conclusions

TPP were highly attracted to the UVA light traps, but at insufficient levels to control them in this experimental setup. It is possible that control could still be achieved in real-world glasshouses, but, even if that is not possible, UVA lights could be a valuable monitoring tool, due to increased sensitivity. However, a reasonable amount of research is required to confirm the effects in commercial glasshouses, in terms of trap design, placement, density, time of day they are illuminated, etc. However, this need not be a massive or expensive undertaking as, existing IPM monitoring counts and staff could be utilised for a project, it could start with small exploratory experiments, which if these produce positive results can be scaled up to create a robust result and workable outcome.

7. Acknowledgments

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