Temperature development and damage rates of onion thrips

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Report to New Zealand Onion Exporters Association
and MAF Sustainable Farming Fund

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CONTENTS

EXECUTIVE SUMMARY

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OBJECTIVES

- Verify temperature development model developed last year in variable ambient temperatures;
- Quantify the damage that thrips cause per day to onion bulbs.

BACKGROUND

Damage caused by onion thrips (*Thrips tabaci*) in export onion consignments has been a serious problem for the New Zealand onion industry since 1997. Understanding the relationship between insects and temperature is a critical component of pest management. Understanding the damage potential of onion thrips is also critical in determining the number of thrips required to cause economical damage, thereby setting appropriate action thresholds. There is a large variation in published results overseas with regards to temperature development of onion thrips, emphasizing the need for research on onion thrip development in New Zealand. A temperature development model was developed last season (2004/05). This season (2005/06), the temperature development model was tested under different variable temperature regimes and the amount of damage thrips cause to onion bulbs was assessed.

METHODS

Onion thrips were placed on leek discs and maintained at one of six variable temperature locations around the Mt Albert Research Centre (MARC) campus. Discs were checked daily and the life stage of each insect recorded. Temperature loggers were to obtain the average daily temperature at each location. The development of each onion thrips life stage was predicted using the model and compared with the observed time it took to complete each life stage.

Either 0, 1, 3 or 5 adult or larval thrips were placed within each of four arenas on onions for 24 h and the amount of damage per individual was calculated. Damage on onions and leeks were also examined using light and electron microscopes to better define and measure damage.

KEY FINDINGS

- The model was able to predict the developmental time of onion thrips with a good level of accuracy;
- In a ‘high thrips’ year (i.e. 1998/99 season), onion thrips were able to develop through 12.5, 10 and 8.7 generations in Pukekohe, Hawke’s Bay and Canterbury, respectively. In a ‘low thrips’ year, the number of generations of onion thrips was reduced by two in each region;

- The appropriate time between sprays within a spray cluster (based on the time required for a newly laid egg to hatch) varied from 8-22 days depending on the month, region and season;
- Adults caused ~20.1 mm^2 of damage per day and larvae caused ~10.7 mm^2 of damage per day;
- The use of a staining solution (1% aniline blue combined with 50% ethanol) to stain areas damaged by thrips did not highlight the damage as well as staining with vivid permanent marker ink combined with 75% alcohol;
- Thrips damage on onions can be observed within 24 hs of the thrips' feeding.

RECOMMENDATIONS FOR THE FUTURE

- Integrate the onion thrip temperature development model in to current internet-based disease prediction models used by the onion industry;
- Discuss the potential of reducing the recommended number of sprays within a spray cluster;
- Focus on research to develop more effective field control of onion thrips by improving spray coverage to deliver well timed, effective insecticides to the sheltered places on onion plants inhabited by mobile onion thrips life stages.

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INTRODUCTION

Damage caused by onion thrips (*Thrips tabaci*) in export onion consignments has been a serious problem for the New Zealand onion industry since 1997. Feeding damage by thrips causes blemishes, shrivelling and skin separation, often resulting in a significant decrease in onion bulb quality. Consignments containing thrips not only lower the market value of the onions, but also infringe quarantine regulations of importing countries.

Understanding the relationship between insects and temperature is a critical component of pest management. By examining the developmental rate of a species over a range of temperatures, a general model can be developed to predict development at any given temperature. Such models have been widely used in insect pest management and have proven to be an important tool for predicting egg hatch and seasonal occurrence of a number of insect populations. A model to predict onion thrips development would be valuable in determining the time required to develop from a hidden life stage (in soil or leaf) to an exposed mobile life stage between spray applications in different regions and different seasons. Understanding the damage potential of onion thrips is also a critical factor in determining the number of thrips required to cause economical damage. Such knowledge can assist in establishing appropriate action thresholds.

Overseas research has examined the development of onion thrips under constant temperatures. Studies have estimated lower thresholds for onion thrips development ranging from about 4°C (Stacey & Fellowes 2002) to 11.5°C (Edelson & Magaro 1988). Such variation in published results is most likely to be the result of differences in food quality, humidity or photoperiod, and emphasises the need for research on onion thrips development under conditions experienced in New Zealand. Temperature development rates of onion thrips feeding on different food sources were investigated last season and there were no significant differences in development rates of thrips reared on leeks, onion leaves or onion bulbs (Jamieson et al. 2005). However, the survival of thrips was lower when feeding on onion bulbs compared with leek and onion leaf discs. Total developmental time (egg to adult) ranged from 51.1 days at 12°C to 10.3 days at 30°C. Lower developmental temperature thresholds for each life stage ranged from 7.34°C for pupae to 9.06°C for eggs and an accumulation of 221 degree days was required to complete development from egg to adult.

This project aimed to test the temperature development model developed last season under different variable temperature regimes and to determine the amount of damage adult and larval thrips cause to onion bulbs.

MATERIALS AND METHODS

Onion thrips used in the following trials were collected from a commercial crop in Pukekohe in February 2000 and reared by Crop and Food Research (Martin & Workman 2006).

TEMPERATURE DEVELOPMENT

Twenty to 30 discs (18 mm diameter) of leek (sheath) were cut using a sharpened metal pipe. Discs were placed in Petri dishes (50 mm diameter) lined with moist filter paper. Three female adult thrips were placed on each disc to lay eggs and the lid was secured. This was replicated six times. The Petri dishes were placed into ventilated plastic containers and maintained at one of six variable temperature locations around the Mt Albert Research Centre (MARC) campus. The adult thrips were removed after 24 h and the discs were checked daily for the presence of thrips larvae. Once larvae emerged, individual thrips were relocated to a fresh leek disc. Twenty leek discs with a single thrips larva were set up for each of the six temperature regimes. Discs were checked daily and the life-stage of each insect recorded Leek discs were replaced every 3-5 days when required. Temperature loggers were also placed into each of the containers to obtain the average daily temperature.

THRIPS DAMAGE

Preliminary observations

A preliminary experiment to determine the appropriate number of thrips, feeding exposure time, and the best technique to quantify damage was set up by caging 0, 5, 10 and 20 adult thrips on to six onions using four feeding arenas.

Feeding arenas consisted of 13-mm diameter non-toxic clear plastic tubing (20 mm in length) that had been sealed at one end using metal mesh. Feeding arenas were attached to fruit using Blu-tack rings. Onions were stored at 21^{o}C for 7 d after which the number of thrips remaining in each arenas was counted. Onion thrips damage was examined on onions using light and electron microscopes to define and measure damage. Two methods of staining the damaged areas were tested. The first involved soaking the damaged areas in a staining solution consisting of 1% aniline blue and 50% alcohol. The alternate staining solution consisted of vivid permanent marker pen ink and 75% ethanol.

Damage trial

A replicated bioassay was set up to determine the amount of damage caused by thrips. Dry skins of onions were removed and adult or larval thrips were caged on to each onion using feeding arenas described above. Either 0, 1, 3 or 5 adult or larval thrips were placed within each of four arenas on each onion. This was replicated 12 times. Onions were stored at 21^{o}C for 24 h and then the number of thrips remaining was recorded before the arena was removed and the area brushed with vivid permanent marked pen ink combined with 75% ethanol. After 0.5-1 h the amount of damage to the onion bulb was recorded.

DATA ANALYSIS

Hourly temperature records were used to calculate the mean daily temperature for each of the variable locations. To calculate the predicted number of days to complete each life stage in Table 1, the temperature development model from Jamieson et al. (2005) was used. The number of degree days was calculated for each day by subtracting the thermal constant from the model for the appropriate life stage from the mean daily temperature.

The developmental threshold temperature (t) is the temperature below which onion thrips are unable to develop. The thermal constant is the number of heat units required for onion thrips to develop to the next life stage. The developmental threshold temperature and thermal constant (K) required for each life stage were derived from the regression equation y-a + bx, where y is the developmental rate at temperature x, a is the y-intercept and b is the slope. The developmental threshold was calculated using the formula t = (y-a)/b, where y is set at 0, to determine the temperature at which development ceases (developmental rate zero). The thermal constant is calculated by K = 1/b

The number of days required to accumulate the required amount of degree days from the model was calculated for each life stage. This predicted number of days to complete each life stage was compared with the actual time observed to complete each life stage.

To calculate the maximum number of generations per year in Table 2, mean daily temperature was calculated from data collected from weather stations at the Hortresearch Pukekohe, Hawke's Bay and Canterbury Research Centres. The accumulated number of degree days was calculated as described above for each year and divided by the model's predicted degree days required from egg to adult.

Similarly, the number of days required to develop through each life stage for each month in Table 3 was calculated by using the average daily temperature over the last eight seasons and starting the temperature development model for each life stage in the middle of the respective month.

RESULTS

TEMPERATURE DEVELOPMENT

The observed and predicted time to develop through each life stage at each variable temperature regime is shown in Table 1. The duration of each life stage was predicted within one day of the observed duration. Overall, the total time from egg to adult was predicted within two days of the observed duration. Therefore the model is a good predictor of onion thrips development over a range of temperatures.

The maximum number of generations for each of the last eight seasons in Pukekohe, Hawke's Bay and Canterbury is shown in Table 2. In a 'high thrips' year (i.e. 1998/99 season) onion thrips were able to develop through 12.5, 10 and 8.7 generations in Pukekohe, Hawkes' Bay and Canterbury, respectively. In a 'low thrips' year the number of generations that onion thrips is able to complete is reduced by two in each region.

The estimated duration of each life stage and recommended time between sprays for each month in an average year in the three regions is shown in Table 3. The recommended time between sprays is based on the time required for a newly laid egg to hatch. Sprays are recommended to be applied in a cluster at 8-22 day intervals depending on the month, region and season. Temperatures used in Table 3 were averaged over the last eight years and average monthly temperatures can vary from year to year, therefore ideally the temperature development model has the potential to run continuously each season, providing up-to-date accurate spray interval information to growers.

Table 1. Observed development times (days) for each life stage of onion thrips in variable conditions and predicted times using temperature development model.

Variable temperature regime[1]		Egg	Larva	Pupa	Egg-Adult
A	Predicted	9.39	8.44	6.95	24.78
(16.7°C)	Observed	10.45	7.69	7.59	25.41
B	Predicted	4.79	4.96	4.89	13.90
(23.8°C)	Observed	4.38	3.70	3.88	11.94
C	Predicted	8.64	8.03	6.51	23.40
(17.8°C)	Observed	8.93	7.40	7.42	23.96
D	Predicted	7.13	6.96	4.96	19.31
(19.7°C)	Observed	7.40	6.21	4.88	18.62
E	Predicted	4.63	4.72	3.89	13.56
(24.3°C)	Observed	3.75	5.27	3.36	12.36
F	Predicted	5.23	5.52	4.47	15.57
(22.2°C)	Observed	4.00	6.13	3.55	13.65
Model	*t (lower temperature threshold)*	*9.06*	*8.25*	*7.34*	*8.11*
	K (degree-days)	*72.53*	*78.78*	*63.61*	*220.95*

[1] **Mean temperatures are given for each regime**

Table 2. Estimated maximum number of generations in the field for each season (1 June to 31 May) between 1998 and 2006 in Pukekohe, Hawke's Bay and Canterbury.

Season	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06
Pukekohe								
Degree-days[1]	2768	2462	2520	2729	2354	2221	2231	2388
No. of generations	12.5	11.1	11.4	12.4	10.7	10.1	10.1	10.8
Hawke's Bay								
Degree-days	2216	1997	1942	1927	1945	1958	1935	1981
No. of generations	10.0	9.0	8.8	8.7	8.8	8.9	8.8	9.0
Canterbury								
Degree-days	1912	1662	1631	1629	1388	1481	1452	1543
No. of generations	8.7	7.5	7.4	7.4	6.3	6.7	6.6	7.0

[1] Total effective temperature

Table 3. Estimated time (days) to complete each life stage and recommended time between sprays for each month in an average year in Pukekohe, Hawke's Bay and Canterbury.

Month	October	November	December	January	February	March
Pukekohe						
Mean temp. (^{o}C)	14.0	15.1	17.4	18.9	19.1	17.9
No. days as egg	14.5	12.3	8.6	7.7	7.2	8.4
No. days as larva	15.3	13.3	9.3	8.3	7.8	9.1
No. days as pupa	10.0	8.4	6.3	5.7	5.4	6.2
Time between sprays (d)	15	13	9	8	8	9
Hawke's Bay						
Mean temp. (^{o}C)	13.4	14.4	17.3	18.1	17.9	16.5
No. days as egg	15.8	14.7	8.5	8.2	8.3	9.7
No. days as larva	16.7	15.6	9.1	8.8	9.0	10.5
No. days as pupa	11.2	9.2	6.2	6.0	5.9	7.0
Time between sprays (d)	16	15	9	9	9	10
Canterbury						
Mean temp. (^{o}C)	11.7	13.0	16.2	16.9	16.8	15.4
No. days as egg	21.6	18.0	10.1	8.9	10.1	11.7
No. days as larva	22.6	19.0	10.9	9.6	10.9	12.6
No. days as pupa	13.6	12.2	6.9	6.6	7.0	7.8
Time between sprays (d)	22	18	10	9	10	12

THRIPS DAMAGE

Preliminary observations

The number of thrips recovered from feeding arenas containing 0, 1, 10 or 20 adults is shown in Table 4. There was a very low recovery rate of live thrips from feeding arenas after 7 d, therefore in the subsequent damage trial, thrips were only left in feeding arenas for 24 h. The entire onion surface within the arenas containing thrips was damaged, also indicating that a shorter time period of exposure was required. Because of the very active nature of onion thrips, it was difficult to place 10 or 20 thrips in the arenas, therefore up to five thrips was used in the damage trial that followed.

Table 4. The mean (± SEM) number of thrips recovered when 0, 1, 10, or 20 adults were caged onto onion bulbs for seven days.

Life stage No. thrips placed in cage	Live thrips recovered from cage	Dead thrips recovered from cage
Adults		
0	0	0.2 ± 0.2
1	0.2 ± 0.2	0.3 ± 0.2
10	2.3 ± 1.0	4.3 ± 1.0
20	3.0 ± 0.5	5.8 ± 0.9
Larvae		
0	0	0
1	0.2 ± 0.2	0.2 ± 0.2
10	1.2 ± 0.3	2.0 ± 0.4
20	1.5 ± 0.7	4.3 ± 0.8

Damage trial

The amount of thrips damage per day is shown in Table 5 and illustrated in Figure 1. Adults caused ~20.1 mm^2 of damage per day and larvae cause ~10.7 mm^2 of damage per day. Staining the damaged area with aniline blue did not highlight the damage as well as staining with vivid permanent marker ink combined with 75% alcohol.

Onion thrips feeding damage is caused by onion thrips' rasping the plant surface and rupturing the outer cells of onions or leeks (Figure 2). The damaged area has drops of fluid from the ruptured cells and/or from thrips (faecal drops). These drops then dry out and feeding damage is seen as shrivelled depressions (Figure 3). Damage is seen within 24 h of the thrips feeding.

Table 5. The amount of damage per day that different densities of adult and larval thrips caused when caged onto onion bulbs.

Life stage No. thrips placed in cage	Mean (± SEM) no. live thrips recovered from cage	Total damage caused by thrips (mm^2)	Mean (± SEM) no.[1] live thrips over 24 h	Mean (± SEM) damage per mean no. live thrips (mm^2)
Adults				
0	0	0.5 ± 0.3	0	-
1	0.7 ± 0.1	15.3 ± 3.0	0.8 ± 0.1	16.7 ± 2.7
3	2.4 ± 0.4	57.3 ± 6.6	2.7 ± 0.2	20.8 ± 1.8
5	3.5 ± 0.4	97.1 ± 6.1	4.3 ± 0.2	22.8 ± 0.8
mean				20.1 ± 1.2
Larvae				
0	0	0.6 ± 0.2	0	-
1	0.3 ± 0.1	8.0 ± 3.3	0.6 ± 0.1	14.8 ± 6.8
3	0.8 ± 0.2	18.5 ± 5.9	1.9 ± 0.1	9.2 ± 2.5
5	2.0 ± 0.3	29.8 ± 6.5	3.5 ± 0.2	8.2 ± 1.6
mean				10.7 ± 2.4

[1] Mean no. live thrips over 24 h was calculated as an average of the number of thrips placed on and the number removed.

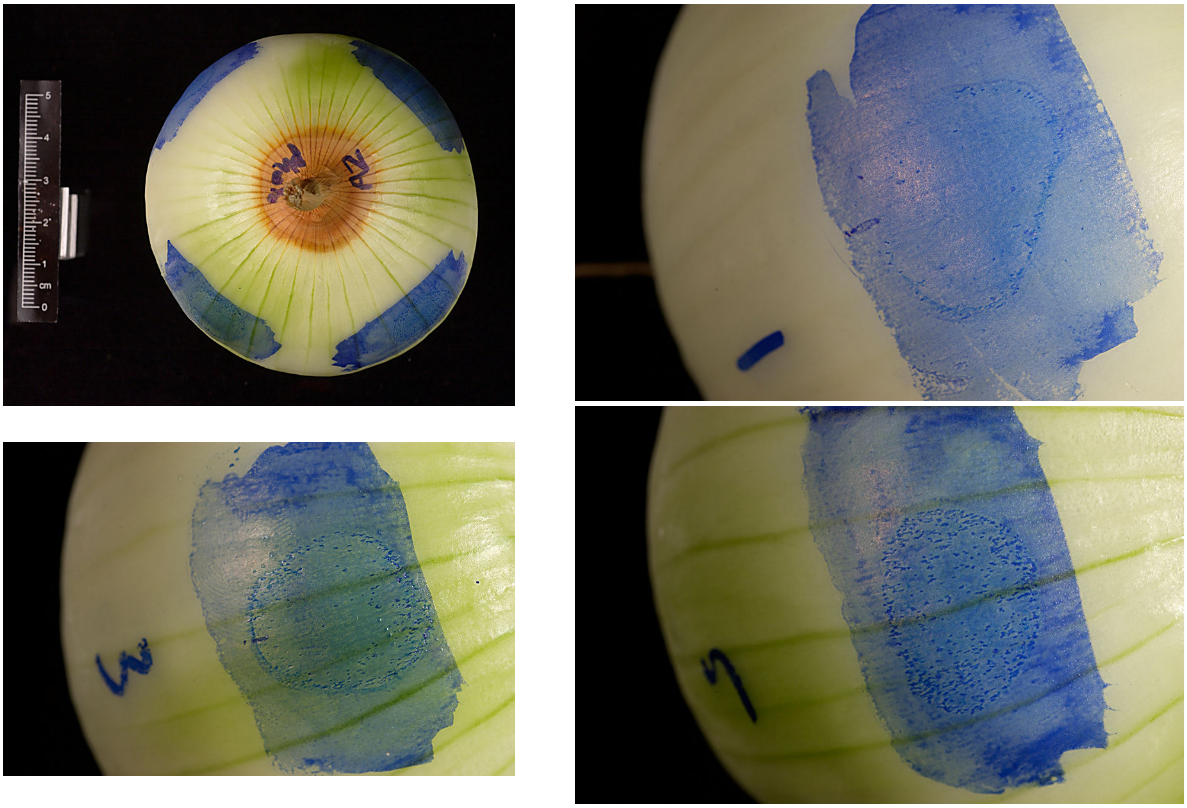
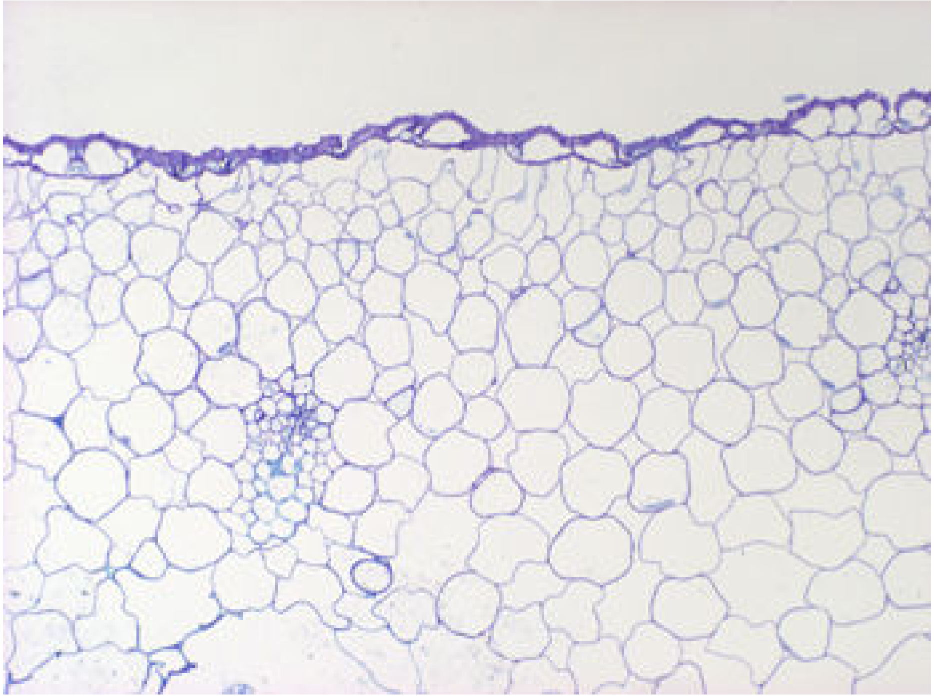


Figure 1. The position of the feeding arenas (top left) and amount of damage, as seen as depressed dark blue dots and lines, that one (top right), three (bottom left) and five (bottom right) thrips cause after 24 h.

(A)



(B)

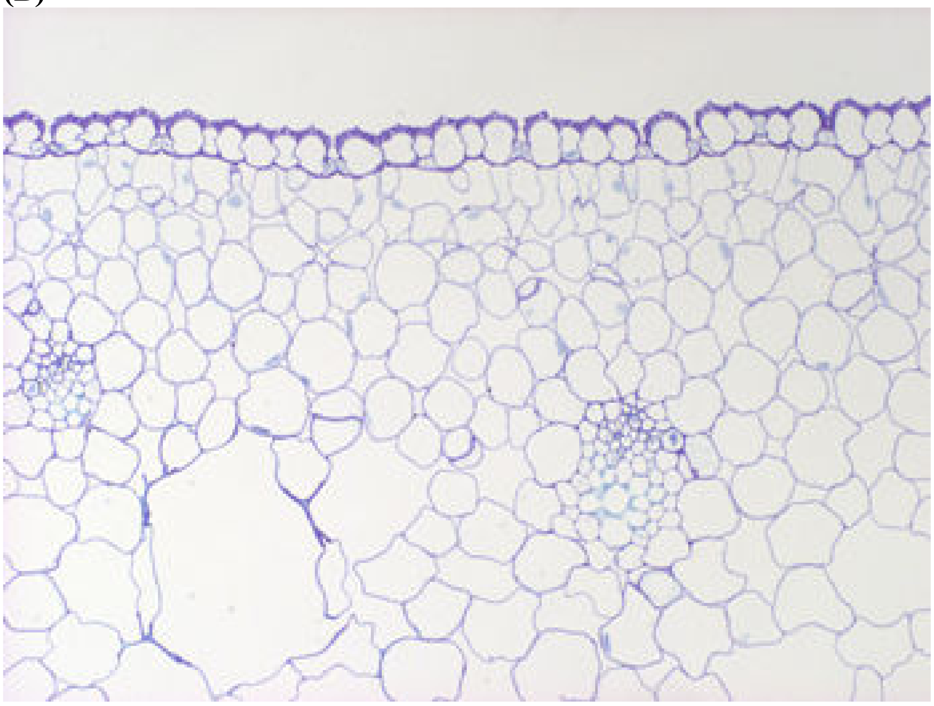


Figure 2. Light microscope image of (A) collapsed cells on the upper surface of a leek exposed to onion thrips feeding; (B) intact cells on the upper surface of a leek not exposed to onion thrips feeding.

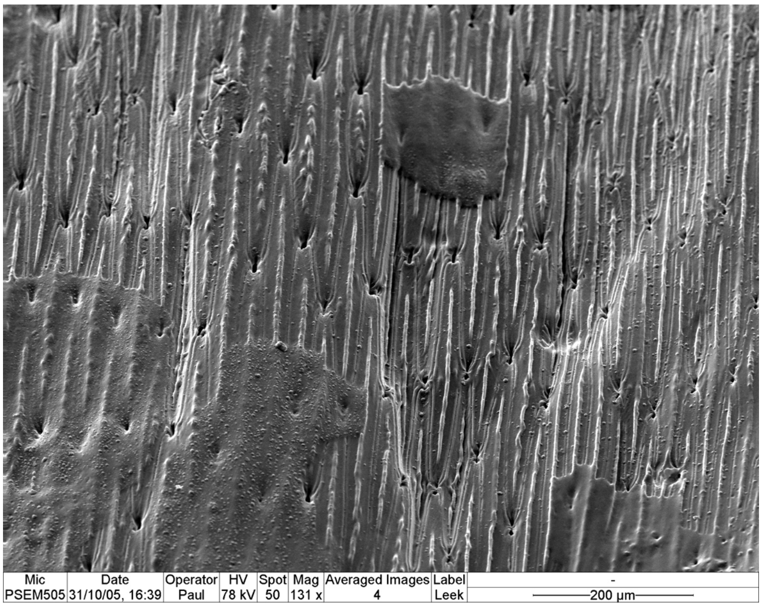


Figure 3. Electron microscope image of a shrivelled area on a leek as a result of onion thrips feeding, with droplets of plant cell contents and/or thrips faecal drops.

DISCUSSION

Insecticides targeting onion thrips in New Zealand are currently applied in clusters of 3-4 applications. The latter spray applications in a cluster target those thrips previously hidden from sprays as eggs beneath the surface of the leaf or pupae in the ground. Knowledge of temperature development rates of onion thrips in New Zealand enables more accurate timing of sprays and therefore has the potential to reduce the number of sprays in each cluster and overall insecticide use in the onion industry.

The temperature development model can track the number of degree days accumulated at any stage during the season and by comparing with previous seasons, growers can determine if the season is likely to be a 'high', 'medium' or 'low' thrips season. If the season is tracking as a 'high' thrips season it is recommended that up to three well timed sprays be applied in a cluster, but if the season is tracking as a 'low' thrips season, two well timed sprays per cluster would probably be adequate. Reduction in the number of applications in spray clusters also reduces the risk of thrips' developing resistance to a product.

An action threshold is the pest population level at which action (e.g. spray applications) needs to be taken to prevent the population from causing economic damage. Action thresholds should be based on the number of insects and exposure required to cause significant economic damage. Based on the amount of damage that thrips cause to an onion bulb as described in this report, it would take 35 or 66 days for a single adult or larva to cause a 15-mm damage band around the entire neck of an average onion. Onions are generally kept for 3-4 weeks prior to shipping, therefore one adult or a couple of larvae have the potential significantly to damage an onion during storage. Approximately 60% of thrips found on stored onion bulbs are from field populations (Chhagan & Jamieson 2006). Therefore, the currently recommended low action threshold of five thrips per 50 onions is justified.

Inadequate control of onion thrips in the field is most likely the result of inadequate timing of spray applications, reduced efficacy of product due to thrips resistance, inefficient spray coverage (unable to reach the sheltered places that mobile onion thrips life stages inhabit) and/or rapid immigration from surrounding fields. A temperature development model has been developed (Jamieson et al. 2005) and subsequently tested and found to be accurate under variable temperatures. It can now be used to deliver information to growers to assist with more accurate timing of spray applications. Research has been carried out to determine the degree to which thrips has developed resistance to products used against onion thrips. Therefore, future research on onion thrips in the field should focus on improving spray coverage to deliver well timed, effective insecticides to the sheltered places on onion plants that mobile onion thrips life stages inhabit.

RECOMMENDATIONS FOR THE FUTURE

- Integrate the onion thrips temperature development model in to current internet-based disease prediction models used by the onion industry;
- Discuss the potential of reducing the recommended number of sprays within a spray cluster;
- Focus on research to develop more effective field control of onion thrips by improving spray coverage to deliver well timed, effective insecticides to the sheltered places on onion plants that mobile onion thrips life stages inhabit.

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