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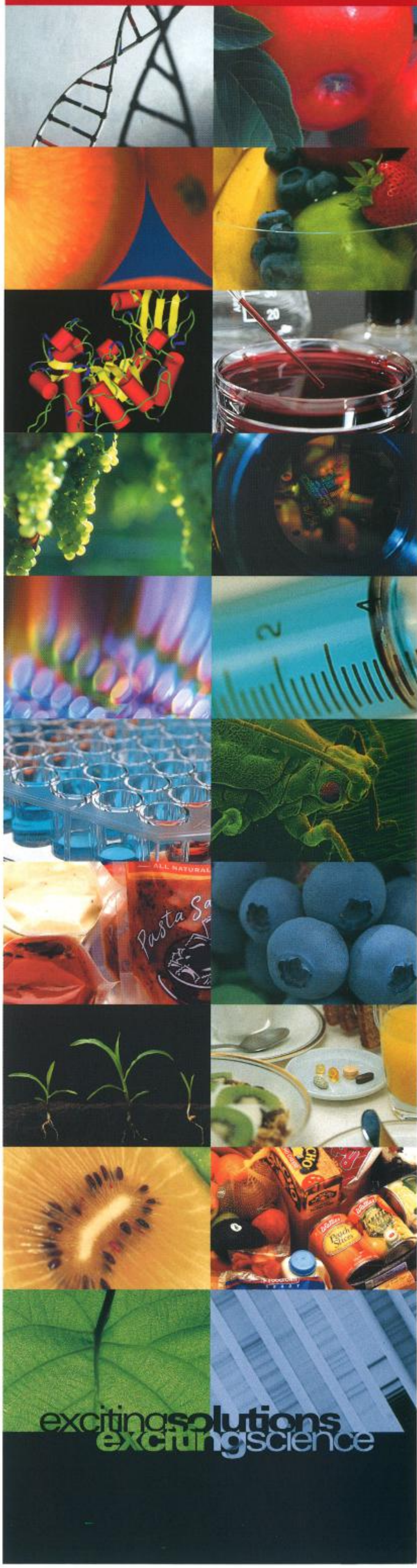
July 2002



Report to the New Zealand Onion Exporter's Association

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Head Office
The Horticulture and Food Research
Institute of New Zealand Ltd
BATCHELAR RESEARCH CENTRE
Private Bag 11 030
Palmerston North
Telephone: (06) 356 8080
Facsimile: (06) 354 0075

L. Jamieson, A. Chhagan, R.A. Fullerton and J.L. Tyson
The Horticulture and Food Research
Institute of New Zealand Ltd
MT ALBERT RESEARCH CENTRE
Private Bag 92169
Auckland
Telephone: (09) 815 4200
Facsimile: (09) 815 4201

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EXECUTIVE SUMMARY

Monitoring onion thrips in export onions.

Lisa Jamieson, Asha Chhagan, Bob Fullerton and Joy Tyson. June 2002

Objectives
1. To monitor onion thrips populations on onions in storage following the use of the two 'best' topping practices identified from last season's research.
2. To monitor temperature conditions in the field and storage facilities and relate them to thrips development.

Background
In the 2000-01 crop year, HortResearch was contracted by the Onion Exporters Association of New Zealand Ltd (OEA) to undertake a series of commercial scale trials to determine the effect of different field-handling practices on the incidence of onion thrips and black mould on onions. The OEA research committee identified the two 'best' field-handling practices as those that would minimise thrips incidence and black mould development on onions at harvest and after ambient or high-temperature storage. The two best treatments were:
1. machine-topped and lifted when plants are green,
2. lifted unclipped when plants are green.

Methods
Eight growers aimed to implement both of these 'best' field-handling practices each on one half of an onion field. Following lifting, the onions were to be left in the field to cure for about 14 days and then harvested. Observations on thrips incidence were made prior to implementing field-handling practices and at various times after onions were harvested and put into storage facilities. Onions were also put into high-temperature/high-relative humidity (HT/HRH) storage and thrips and black mould incidence was assessed.

Key Results
- There was no difference between the two field-handling methods with relation to the numbers of thrips on onions in storage.
- Thrips populations on onions from crops exceeding the spray threshold prior to lifting and harvested early in the season increased in storage.
- Thrips populations on one early season onion crop that did not exceed the spray threshold prior to lifting and harvested early in the season did not increase in storage.
- There was a positive correlation between thrips populations prior to lifting and after 60 days storage on onions harvested early in the season.
- Thrips populations on onions from crops harvested late in the season did not increase in storage.
- The average temperatures in the sheds storing early harvested onions were higher than those in sheds storing late harvested onions.

- Within a shed, temperatures in the top bins within a stack were 1-2°C higher than in the middle or bottom bins of the stacks.
- A thrips development model estimated that the number of generations of thrips developing in storage would be expected to decrease as the season progressed because of decreasing temperatures.
- It is estimated that 3.4 generations of thrips would develop during shipping to Europe, however survival rates are unknown.
- The number of larvae compared to adults decreased throughout ambient storage which suggests that thrips populations are 'aging' and not reproducing well on white onion bulbs.
- Thrips populations did not increase after 30 days at 30°C, >90% RH.

Recommendations and future research priorities

- Continue to manage thrips populations prior to lifting using recommended monitoring and spray thresholds to reduce the likelihood of high populations of thrips developing in storage
- Survey crops harvested early in the season to determine whether there is a relationship between thrips populations on onions prior to lifting and after 60 days storage to enable catagorisation of high risk and low risk crops.
- Determine the cause of thrips population increases in storage. Are they due to field laid eggs hatching or adult thrips migration?
- Develop a thrips damage model and determine the time between thrips feeding and manifestation of bulb damage.
- Investigate cost benefits of shipping onions in low-temperature (10°C) conditions.
- Determine which commercially available onion variety is least susceptible to onion thrips infestation and/or damage.

For further information contact:

Lisa Jamieson
HortResearch
Private Bag 92 169
Auckland
Ph: (09) 815 4200 extn 7073
Fax: (09) 815 4201
Email: ljamieson@hortresearch.co.nz

INTRODUCTION

Onion thrips (*Thrips tabaci*) feed predominantly on the newly emerging inner leaves of onion (*Allium cepa*) plants (Waterhouse and Norris, 1989). Once the leaves become dry, the thrips generally move down into the bulb and feed in the neck area or on the onion bulb scales. Onion thrips possess sucking mouthparts and feed by piercing the surface of plant tissue and extracting the plant fluid. Feeding by thrips on an onion bulb causes shriveling of bulb scales and skin separation, both major causes of rejection by European packers. There is also evidence of a link between onion thrips and black mould (Fullerton et al. 2000, Jamieson et al. 2001) which further downgrades onion value.

Previous research has concentrated on developing a field monitoring and pesticide management strategy to limit the development of resistance by thrips to insecticides. With better field control resulting from that work, research is now aimed at identifying field-handling practices that minimise postharvest infestations of thrips. In the 2000-2001 crop year, trials were carried out on two commercial fields (one early and one late maturing crop) and on small experimental plots in the Pukekohe district. A range of common topping and field handling methods were evaluated on each crop. It was shown that onions lifted in the green stage and hand-clipped had the highest infestation of thrips at harvest at both commercial sites. In addition, onions lifted when plants were dry had the highest proportion of split skins, which were more likely to be infested with thrips and black mould. The two 'best' field-handling practices (minimal thrips incidence and black mould development in storage) were identified as machine-topping then lifted when onion plants are green, and untopped onions lifted green and allowed to dry down and cure in the field.

Thrips development is significantly influenced by temperature. Several models have been derived to predict *T. tabaci* development as a function of temperature on onions. Edelson and Magaro (1988) estimated that 191.1 degree-days were required for development from egg to reproducing adult, with a threshold temperature of 11.5°C. Jimenez and Roscandido (1996) give the developmental threshold of onion thrips on onions as 10.4°C with the estimated degree-days from egg to reproducing adult as 256.4. Although onion field temperatures have been monitored in many onion trials, the temperature conditions in storage sheds are largely unknown.

The objectives of the commercial trial this year were:

1. To monitor onion thrips populations on onions in storage following the two 'best' handling practices as identified from results of the 2000-01 crop year.
2. To monitor temperature conditions in the field and storage and relate this to thrips development.

METHODS

The study was made on commercial crops on eight properties in the Pukekohe, Karaka, Pukekawa and Matamata districts, using crops selected to give a range of harvest dates. It had been intended to use nine commercial fields (3 early, 3 mid-season and 3 late crops) for the study however, only eight were available (4 early, 1 mid and 3 late crops). Fields had identification numbers assigned to them prior to field 5 becoming unavailable, for comparison with parallel sticky trap trials carried out by A. Tomkins. Therefore, field 5 is absent from all tables.

The two best-practice handling methods (treatments) applied were:

1. Machine-topped and lifted when green and field cured,
2. Untopped onions lifted when green and allowed to field cure with tops on.

Growers aimed to implement both practices in the same field, one in each half of the field. Onions were then to remain in the field to cure for about 14 days prior to being placed in storage.

Sampling regime

For each crop, samples of bulbs for assessment for thrips numbers were taken from the field on five different occasions.

The experimental design for field sampling is shown in Appendix 1. Each half of the field (representing one field handling practice) was divided into four plots (replicates). Prior to lifting, 24 onion plants from each replicate were placed into insect proof bags and taken back to the laboratory for assessment, providing a total of 100 onions from each treatment from each crop. At harvest, single bins were collected from the centre rows of each replicate and stored in grower's storage sheds (7 different sheds). The eight bins were generally stored together in two stacks of four bins. Within 2-3 days of being placed in storage, 25 onions from each experimental bin were collected for assessment. Five onions were taken from each corner and the centre of each bin, about one quarter of the way down the bin. Thereafter samples were collected from the experimental bins after 15, 30 and 60 days storage. In addition, a sample of onions was taken after 30 days ambient storage and held at high temperature and humidity (30^{o}C/>90%RH) for 30 days to observe the development of black mould and thrips populations in these conditions.

Harvest and sampling times

The crops were selected to provide a range of maturity dates. The crops and their respective lifting and harvest dates are shown in Table 1. Four of the fields were harvested early in the season, one of them mid-season and three of them late in the season. In some of the fields the onions had matured beyond the green stage and had begun to dry out before they were machine-topped and/or lifted. Furthermore, few growers were able to adhere to the proposed 14-day curing period. Onions were left to cure from between 17 and 74 days due to unfavourable weather conditions or availability of field equipment.

Table 1: Lifting and harvesting dates and condition of tops at lifting for each of the experimental fields.

Field	Harvest category	Location	Date lifted	Top condition at lifting	Date harvested (field to shed)	Time between lifting and harvesting	Onion variety
1	early	Karaka	5 Jan	dry	22 Jan	17 d	Kiwi Gold
2	early	Waiuku	21 Jan	green-dry	7 Feb	17 d	Kiwi Gold
3	early	Pukekawa	9-10 Jan	green	1 Feb	22 d	Kiwi Gold
4	early	Karaka	8 Jan	green-dry	30 Jan	22 d	PLK
6	late	Pukekohe	3-8 Feb	dry	18 Apr	74 d	PLK
7	mid	Matamata	31 Jan	green-dry	26 Feb	26 d	PLK
8	late	Pukekohe	14 Feb	green	11 Mar	25 d	PLK
9	late	Pukekohe	14 Feb	green	21 Mar	35 d	PLK

The dates for sampling from each of the trial crops are shown in Table 2.

Table 2: Sampling dates for each of the experimental fields

			Days after harvest		
Field	Pre-lift	Harvest	15 d	30 d	60 d
1	3 Jan	23 Jan	5 Feb	21 Feb	22 Mar
2	17 Jan	8 Feb	21 Feb	8 Mar	9 Apr
3	3 Jan	1 Feb	14 Feb	28 Feb	2 Apr
4	3-Jan	1 Feb	14 Feb	28 Feb	2 Apr
6	31-Jan	19 Apr	3 May	21 May	18 June
7	31 Jan	28 Feb	14 Mar	26 Mar	26 Apr
8	9-Feb	11 Mar	26 Mar	9 Apr	10 May
9	14 Feb	22 Mar	9 Apr	19 Apr	21 May

Assessment method

After sampling, onions were stored at 12°C and assessed within 5 days of collection. Each onion was dissected and examined under magnification for thrips number (live and dead), life stage (larva, pupa, adult), location of the onion (leaf, neck, scale base), presence of split skin (live onion scale showing over more than 25% of the onion), and presence of black mould. Onion black mould results are presented in a separate report along with soil sample results (Tyson et al. 2002), however relationships between thrips, black mould and split skins are reported here.

High-temperature/high-humidity (HT/HRH) storage

Because one of the proposed experimental fields became unavailable, the resources were redirected to a study of the effects of high temperature and high humidity storage of thrips and black mould in each of the experimental lines. Samples of 100 onions from each field handling regime from each field were collected after 30 days ambient storage and held at HT/HRH (30°C/>90%RH) for a further 30 days. All onions were assessed for black mould (Tyson et al. 2002) and a sub-sample (25 onions) was also assessed for thrips number, life stage and location.

Temperature monitoring

Field temperatures were monitored over the period between lifting and harvest in all but one of the onion fields. Tiny Talk® temperature loggers were placed under the curing onions and did not receive direct sunlight. After harvest these loggers were placed into the centre of one of the eight experimental bins stored at each shed.

In order to determine temperature variations within sheds, Squirrel® temperature loggers were used to monitor temperatures at different positions and heights in stacks of bins. Temperature probes were placed in the bottom, middle and top bin of two stacks of onions and monitored for at least one month. Humidity was also monitored in one of the storage sheds.

Statistical analysis

Analysis of Variance (ANOVA) was used to compare the numbers of thrips for each field-handling treatment for each sampling time. Least Significant Differences were calculated to separate treatments if the ANOVA indicated significant treatment effects ($P<0.05$). All analyses for tables were carried out using the statistics software SAS (release 6.12) (SAS Institute, 1985). The linear regression in Figure 2 was carried out using the graphing package Origin version 5.0.

RESULTS

Thrips numbers from onions within each crop and between crops were extremely variable. Although both live and dead thrips were found, only the live thrips data is presented here.

Effect of field-handling practice

The numbers of live thrips per 50 plants for each of the treatments in eight different fields and for five different sampling times are shown in Table 3. Numbers of thrips varied quite considerably between plots prior to the application of field-handling treatments.

Table 3: Numbers of thrips per 50 unclipped or machine topped onions from each field prior to lifting and at various times after harvest (Mean ± SEM).

Field no.	Treatment	Pre-lift	Harvest	15 d storage	30 d storage	60 d storage
1	Unclipped Machine topped	9.4 ± 4.5 a[1] 3.6 ± 1.5 a	0.5 ± 0.5 a 1.5 ± 0.9 a	0 a 0 a	0.5 ± 0.5 a 2.5 ± 1.3 a	20.0 ± 13.9 a 23.5 ± 10.7 a
2	Unclipped Machine topped	22.9 ± 11.8 a 20.8 ± 7.4 a	1.0 ± 1.0 a 0.5 ± 0.5 a	21.5 ± 13.5 a 16.5 ± 14.6 a	29.5 ± 13.1 a 75.5 ± 33.3 a	112.5 ± 20.0 a 156.0 ± 36.2 a
3	Unclipped Machine topped	0.5 ± 0.5 a 0.5 ± 0.5 a	0 a 0.5 ± 0.5 a	0 a 3.5 ± 2.3 a	1.0 ± 0.6 a 7.0 ± 4.0 a	4.0 ± 2.0 a 7.5 ± 4.9 a
4	Unclipped Machine topped	13.5 ± 8.3 a 47.3 ± 29.1 a	0 a 0.5 ± 0.5 a	9.5 ± 6.4 a 2.5 ± 1.0 a	103.0 ± 51.9 a 28.5 ± 12.0 a	64.5 ± 20.5 a 82.0 ± 12.1 a
6	Unclipped Machine topped	55.1 ± 23.3 a 49.4 ± 7.2 a	2.0 ± 0.8 a 2.0 ± 1.4 a	2.5 ± 1.0 a 0.5 ± 0.5 a	2.0 ± 1.4 a 0 a	0 0
7	Unclipped Machine topped	8.8 ± 7.2 a 3.1 ± 1.3 a	0 a 0.5 ± 0.5 a	0 a 0.5 ± 0.5 a	2.5 ± 1.0 b 8.5 ± 1.7 a	27.0 ± 13.0 a 12.0 ± 8.8 a
8	Unclipped Machine topped	92.6 ± 23.5 a 95.2 ± 20.1 a	24.5 ± 18.3 a 19.0 ± 5.3 a	15.0 ± 6.5 a 12.5 ± 2.5 a	25.5 ± 7.3 a 15.0 ± 6.5 a	3.0 ± 1.2 a 4.0 ± 1.0 a
9	Unclipped Machine topped	80.6 ± 27.8 a 7.28 ± 4.6 b	3.5 ± 2.9 a 0.5 ± 0.5 a	10.0 ± 5.0 a 3.5 ± 1.5 a	17.5 ± 11.8 a 1.5 ± 1.0 a	2.5 ± 1.9 a 1.5 ± 0.5 a

[1]Values within a cell followed by the same letter are not significantly different P>0.05.
Significant differences are highlighted.

A comparison between handling methods within each field, and at each sampling time showed that there were no consistent differences between the number of thrips per 50 bulbs on onions that had been left unclipped and onions that had been machine topped. On only two occasions were there statistically significant differences in the number of thrips in bulbs collected from the parts of the fields subjected to different handling methods. After 30 days storage machine topped onions from Field 7 had a significantly higher number of thrips than unclipped onions. From a commercial point of view the numbers (8.5 and 2.5 thrips per 50 onions) are probably insignificant. In Field 9, variation in number and distribution of thrips within the field resulted in a significant difference in the number of thrips infesting onion plants prior to the application of any handling methods. The difference in thrips numbers in onions from the plots subjected to the two different handling treatments was not observed once onions were placed in storage.

Because there was no effect of field-handling practice on thrips number at any sampling time, data for the two handling practices for each field were pooled for comparisons of the effects of storage times and conditions on thrips numbers.

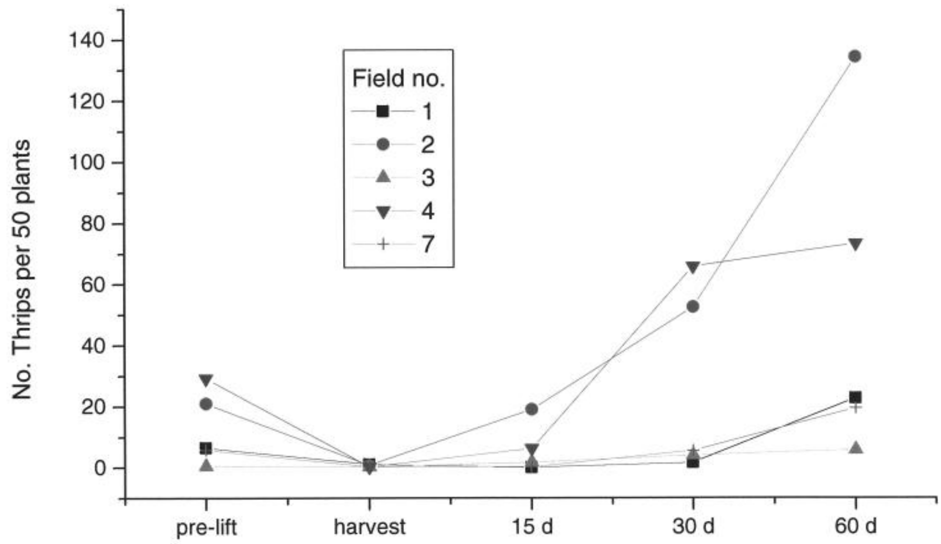
Effect of storage time on incidence of thrips

The patterns of thrips incidence over the sampling period in the early/mid-season crops and the late-season crops were different. Therefore, data from these two groups of crops are presented separately.

Early and mid-season harvests

Thrips numbers at each sampling time for the early and mid-season harvested fields are shown in Figure 1 and Table 4.

Figure 1: Numbers of thrips per 50 onions at different sampling times from early and mid-season harvested fields.



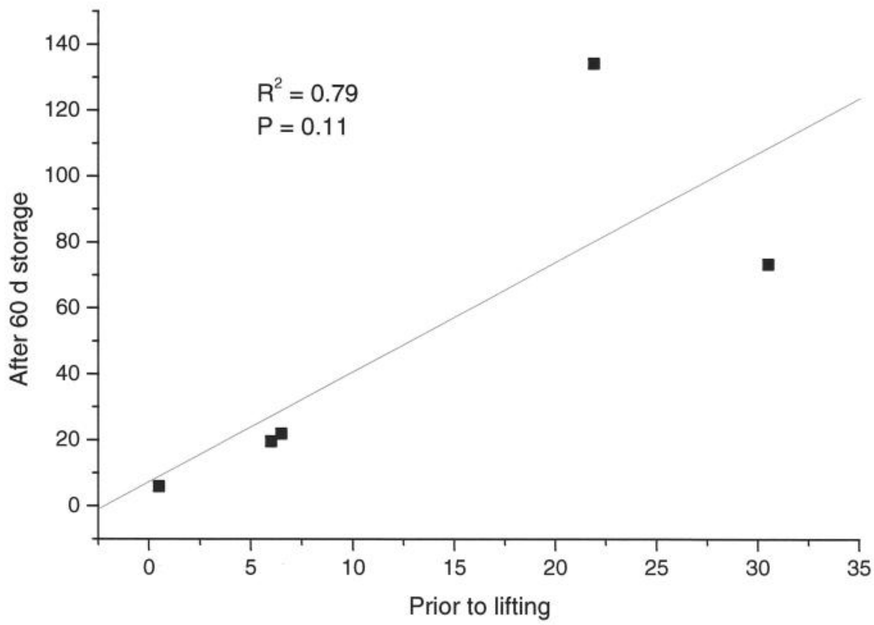
In all cases (apart from Field 3, which had very few thrips at topping) thrips numbers decreased between lifting and harvest and increased between harvest and 60 days ambient storage. After 60 days storage, the numbers of thrips on onions from these fields were significantly higher than the number of thrips on onions prior to topping and/or lifting (Table 4). A linear regression was carried out on the relationship between numbers of thrips prior to lifting and numbers of thrips after 60 days ambient storage (Figure 2). While there was positive correlation (R^2 value > 0.5) there was insufficient data to show a statistical significance (P value > 0.05).

Table 4: Number of thrips per 50 onions at each sampling time for early and mid-season harvested crops.

Sample time	Field no.				
	1	2	3	4	7
Pre-lift	6.5 ± 2.5 b	21.9 ± 6.6 bc	0.5 ± 0.3 a	30.5 ± 15.4 bc	6.0 ± 3.7 b
Harvest	1.0 ± 0.5 b	0.75 ± 0.5 c	0.3 ± 0.3 a	0.3 ± 0.3 c	0.3 ± 0.3 b
15 d storage	0 b	19.0 ± 9.3 bc	1.8 ± 1.3 a	6.3 ± 3.3 c	0.3 ± 0.3 b
30 d storage	1.5 ± 0.7 b	52.5 ± 18.7 b	4.0 ± 2.2 a	65.8 ± 28.4 ab	5.5 ± 1.5 b
60 d storage	21.8 ± 8.2 a	134.2 ± 20.8 a	5.8 ± 2.5 a	73.3 ± 11.5 a	19.5 ± 7.8 a
P value	0.001	0.0001	ns	0.004	0.008

[1]Values within a column with the same letter following are not significantly different P>0.05.

Figure 2: Linear regression of number of thrips per 50 onions prior to lifting vs. after 60 days storage.



Late season harvests

Thrips numbers at each sampling time for the late-season crops are shown in Figure 3 and Table 5. Thrips numbers on onions from these fields decreased after lifting however, unlike those from the early and mid-season fields, did not tend to increase in storage. The number of thrips was significantly higher prior to lifting than at any of the sampling times during storage.

Figure 3: Numbers of thrips per 50 onions at different sampling times from late-season harvested fields.

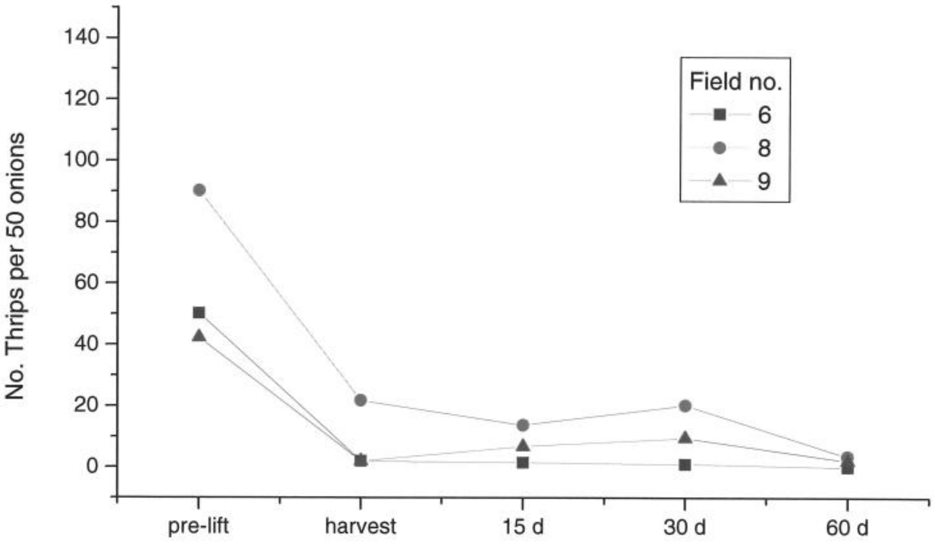


Table 5: Number of thrips per 50 onions at each sampling time for late-season harvested crops.

Sample time	Field no.		
	6	8	9
Pre-lift	52.3 ± 11.3 a	94.0 ± 14.3 a	44.0 ± 19.0 a
Harvest	2.0 ± 0.8 b	21.8 ± 8.9 b	2.0 ± 1.5 b
15 d storage	1.5 ± 0.6 b	11.1 ± 3.2 b	6.8 ± 2.7 b
30 d storage	1.0 ± 0.8 b	20.3 ± 4.9 b	9.5 ± 6.3 b
60 d storage	0	3.5 ± 1.5 b	2.0 ± 0.9 b
P value	0.0001	0.001	0.01

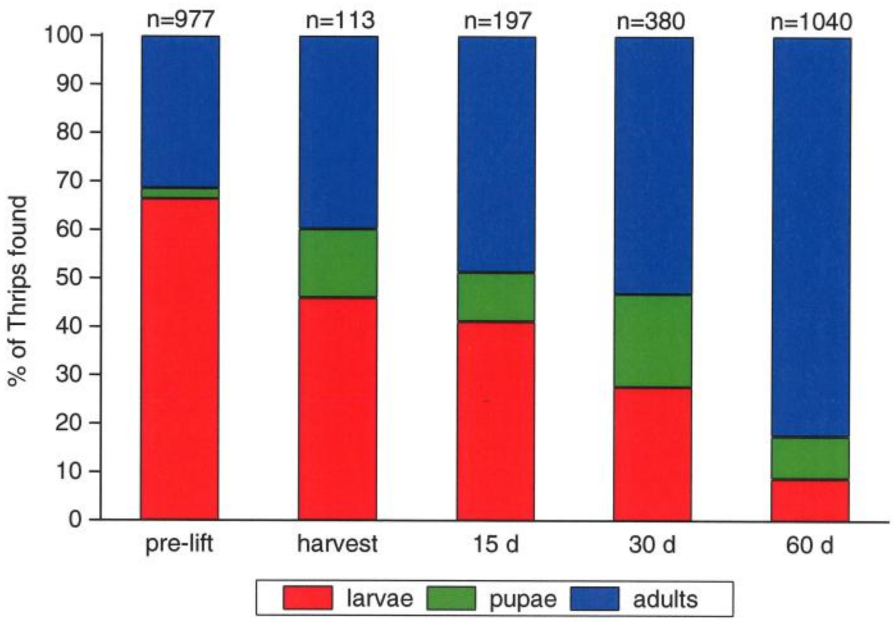
[1]Values within a column with the same letter following are not significantly different P>0.05.

Overall, the results suggest that there is a greater chance of increased thrips populations developing during storage of early maturing onions (prior to mid-March) than in onions harvested later in the season.

Life stages of thrips at different sampling times

The percentage of thrips of each life stage at each sampling time is shown in Figure 4. Prior to lifting, most thrips found were in the larval stage. The percentage of thrips found as larvae reduced as bulbs were harvested and held in storage for increasing time.

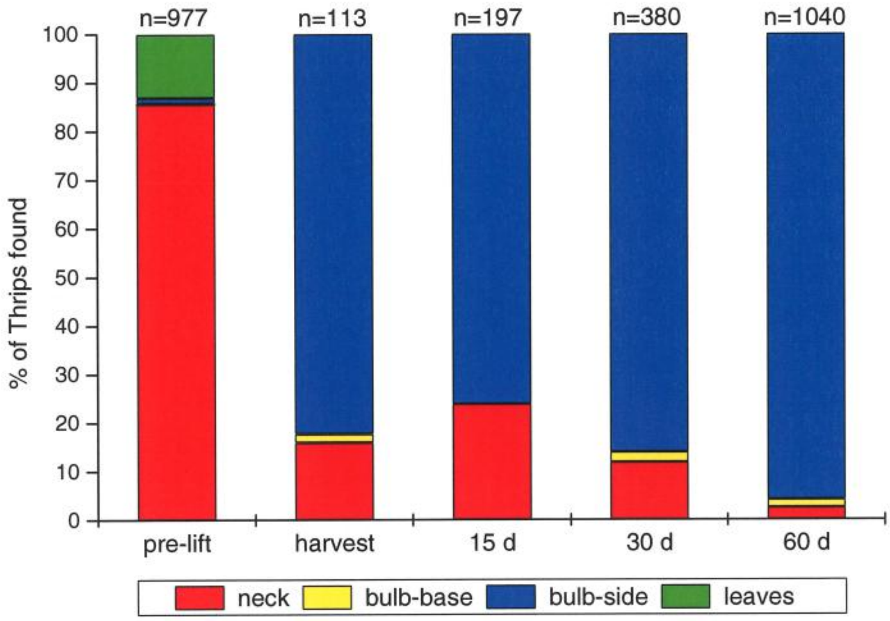
Figure 4: The percentage of thrips of each life stage at each sampling time.



Location of thrips in plants and bulbs

The percentage of thrips at each location on the plant at each sampling time is shown in Figure 5. Prior to lifting, the majority of the thrips were found within the necks of the onions. As the neck dried during curing and storage, the proportion of thrips found within the necks decreased and the proportion found under scales on the side of bulbs increased.

Figure 5: The percentage of thrips found at each location at each sampling time.



Effects of field and storage temperature on incidence of thrips

Temperature conditions in fields and sheds. The minimum, maximum and average hourly temperatures in the monitored onion fields and storage sheds are shown in Table 6. In the field, temperatures fluctuated from a minimum of 9°C to a maximum of 42°C. In the sheds the temperatures were less variable ranging from 14-28°C.

Table 6: The minimum, maximum and average hourly temperature recorded in the monitored onion fields and storage sheds.

Field no.	Time of season harvested	Field temperature during field curing			Storage shed temperature		
		min	max	average	min	max	average
1	early	13.3	31.0	20.4 ± 0.2	17.2	22.8	20.1 ± 0.05
2		13.0	34.7	23.0 ± 0.2	18.4	21.8	19.4 ± 0.02
3		15.5	39.0	21.2 ± 0.2	16.7	24.5	18.6 ± 0.03
4		12.4	30.7	19.6 ± 0.2	17.7	20.9	18.8 ± 0.02
6	late	12.0	37.3	20.3 ± 0.2	14.5	19.1	16.6 ± 0.05
8		9.1	41.9	21.0 ± 0.3	14.9	28.4	17.8 ± 0.07
9		14.0	26.9	19.2 ± 0.1	13.7	27.6	16.5 ± 0.06

The average daily field temperatures over the period of the trial are shown in Figure 6. Average daily storage shed temperatures are shown in Figure 7. Average temperatures measured in sheds holding the early-season harvests were higher than those measured in the late- season sheds.

The temperature profiles (average of two probes at each level – top, middle and bottom) within stacks of bins in two storage sheds are shown in Figure 8. There was a temperature gradient from bottom to top with temperatures in the top bins consistently 1-2°C higher than the bottom bins. Relative humidity, measured in one of the storage sheds, ranged from 57% to 98% with an average of 80%.

Figure 6: Average daily temperatures in the monitored onion fields

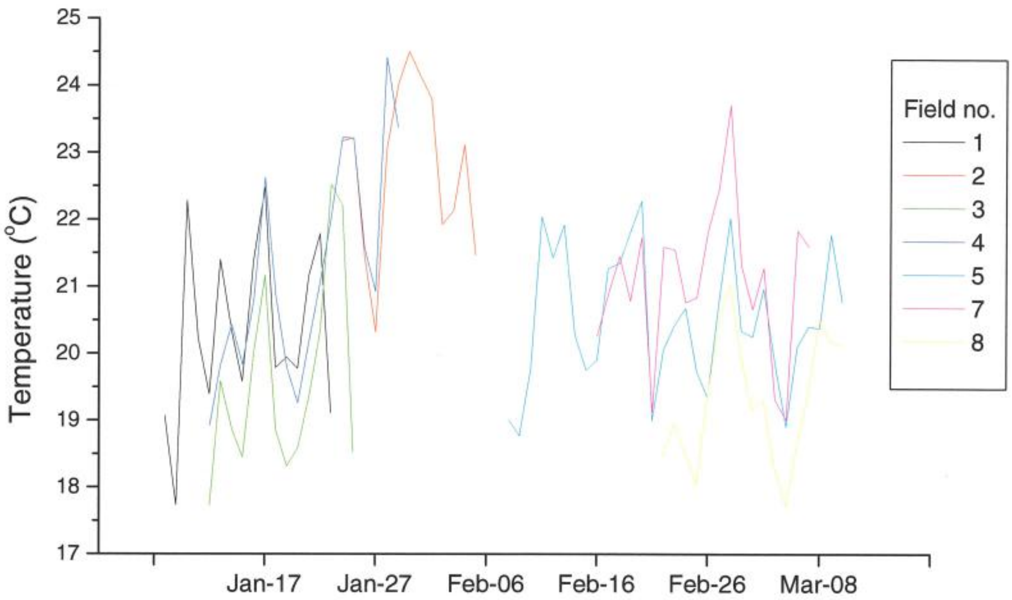


Figure 7: Average daily temperatures in the monitored onion storage sheds.

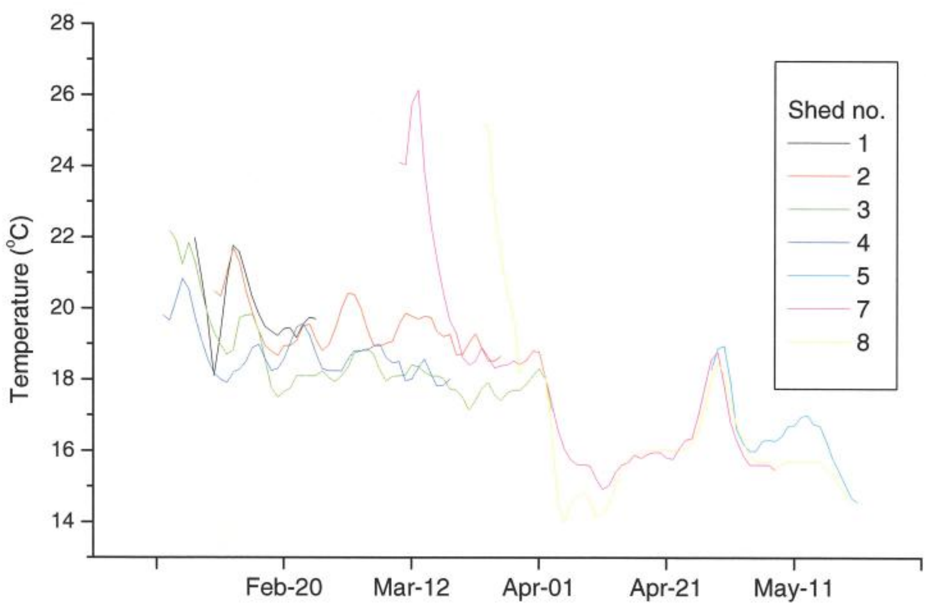
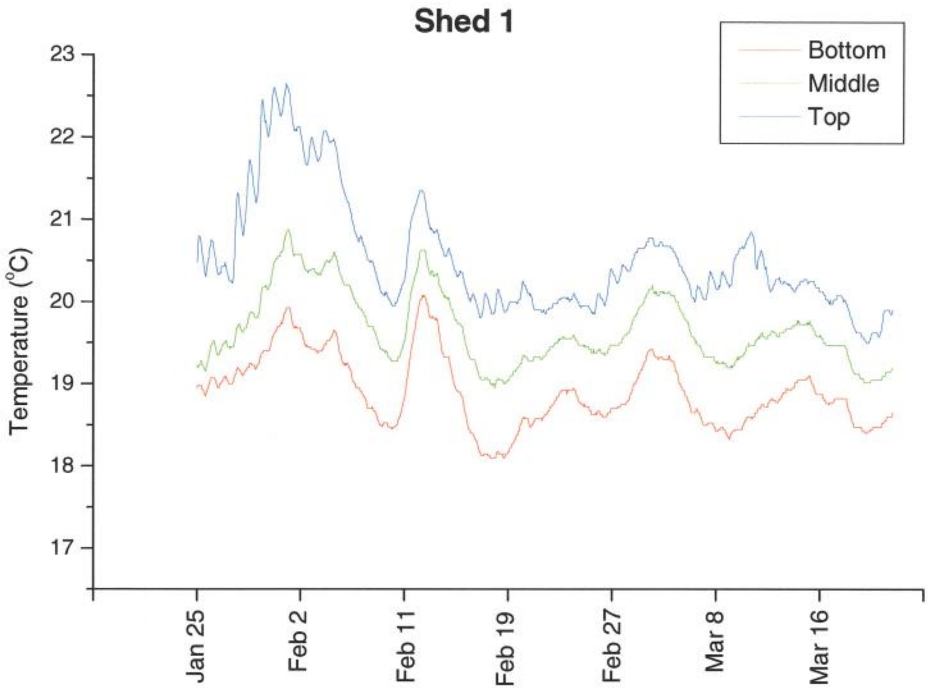
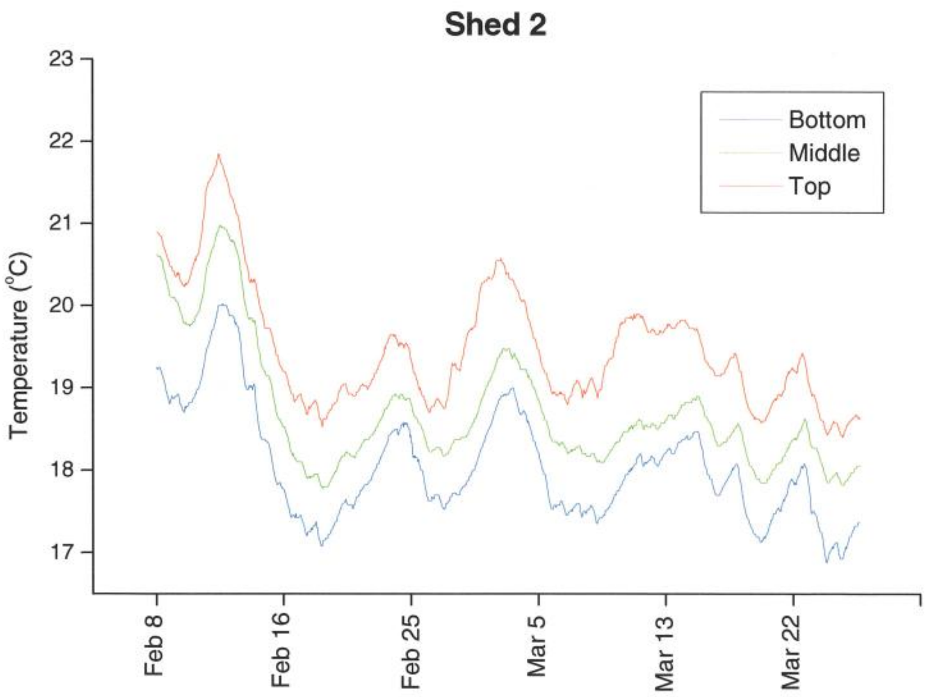


Figure 8: Temperature profiles inside stacked onion bins within two onion storage sheds





Effect of temperature conditions on thrips development. Using the field and storage shed data, the degree-day model of Edelson and Magaro (1988) was used to predict the number of generations of onion thrips in the field and in the storage sheds. The predicted number of generations for each location is shown in Table 7.

Table 7: Predicted number of generations of onion thrips developing in the field and in the storage sheds using a degree-day model (Edelson and Magaro, 1988).

Field no. (time of season)	Field			Storage shed		
	Dates model run	No. days model run	No. generations	Dates model run	No. days model run	No. generations
1 (early)	Jan 5- Jan 22	17	0.8	Jan 23- Mar 22	60	2.8
2 (early)	Jan 21- Feb 7	17	1.1	Feb 8- Apr 9	60	2.5
3 (early)	Jan 10- Feb 1	22	1.0	Feb 1- Apr 2	60	2.3
4 (early)	Jan 8- Jan31	22	1.2	Feb 1- Apr 2	60	2.2
6 (late)	Feb 8- Apr 18	74	2.8	Apr 19- Jun 18	60	1.4
8 (late)	Feb 14- Mar10	25	1.3	Mar 11- May 10	60	1.9
9 (late)	Feb 14- Mar 21	35	1.5	Mar 22- May 21	60	1.6

The predicted number of generations in the field varied according to both the temperature and the length of time the onions remained in the field to cure (17-74 days). Over a 60 day storage period, the model predicted more generations for early harvested crops (average 2.5 generations) than for the later harvested crops (average 1.6 generations) when temperatures are cooler. On average, if onions are to be kept onshore for 60 days after harvest then it is predicted that 2.1 generations would develop on the bulbs in storage prior to export.

The same degree day model was applied to two shipping temperature regimes for a voyage to Europe. Details of the regimes are shown in Appendix 2. The predicted number of generations during shipping is shown in Table 8. It is estimated that 3.4 generations of thrips would develop in a 38 day shipping journey from New Zealand to Europe.

Table 8: Predicted number of generations of onion thrips developing during shipping using a degree-day model (Edelson and Magaro, 1988).

Shipping regime	No. days model run	No. generations
1	38	3.2
2	38	3.6

Overall, these predictions suggest that a total number of thrips generations developing from harvest to arrival in Europe could be as high as 6.4.

Effect of high-temperature/high-humidity (HT/HRH) on thrips incidence

The number of thrips on onions stored at ambient for 30 days, 60 days and 30 days followed by a further 30 days at HT/HRH storage are shown in Table 9.

Table 9: The number of thrips per 50 onions after three different bulb storage conditions (mean ± SEM).

Line No.	Time of season harvested	Storage conditions			P value
		30 days ambient	60 days ambient	30 days ambient + 30 days HT/HRH	
1	early	1.5 ± 0.7 b[1]	21.8 ± 8.2 a	5.0 ± 2.3 b	0.02
2		52.5 ± 18.7 b	134.2 ± 20.8 a	15.3 ± 5.1 b	0.0002
3		4.0 ± 2.2 a	5.8 ± 2.5 a	1.3 ± 0.8 a	ns
4		65.8 ± 28.4 a	73.3 ± 11.5 a	3.8 ± 1.7 b	0.02
7	mid	5.5 ± 1.5 b	19.5 ± 7. a	0.5 ± 0.5 b	0.02
6	late	1.0 ± 11.3 a	0 a	1.0 ± 1.0 a	ns
8		20.3 ± 4.9 a	3.5 ± 1.5 b	0.3 ± 0.3 b	0.002
9		9.5 ± 6.3 a	2.0 ± 0.9 a	4.3 ± 2.2 a	ns

[1]Values within a row with the same letter following are not significantly different P>0.05.

There was an increase in thrips numbers between 30 and 60 days at ambient storage for early/mid-season harvested onions. When onions were removed from ambient storage after 30 days and held at HT/HRH for a further 30 days, thrips numbers declined.

Relationship between onion thrips incidence, split skin and black mould

The inter-relationships of split skins, black mould, thrips and storage conditions are shown in Table 10. Onions with split skins had a higher level of thrips infestation and black mould compared to onions with intact skins following both ambient and HT/HRH storage. Similarly, onions with thrips had a higher incidence of black mould and split skins compared to onions without thrips.

Table 10: The percentage of onions with or without split skins that had thrips or black mould after 30 or 60 days ambient storage or 30 days HT/HRH storage.

	After ambient storage			After HT/HRH storage		
Onions	% with thrips	% with black mould	% with split skin	% with thrips	% with black mould	% with split skin
• with split skin:	59	6	-	29	86	-
• without split skin:	8	2.3	-	3	21	-
• with thrips:	-	2.8	9.3	-	53	7.5
• without thrips:	-	0.7	0.6	-	21	0.6

DISCUSSION

There were no consistent differences between thrips populations after storage on onions from the two 'best' field-handling practices – machine-topped and lifted or lifted unclipped, both when onion plants were green. Results from the field trials in the 2000-01 crop year showed that the number of thrips on onions that had been lifted unclipped from the early-harvested crop was higher after 60 days storage than on those that were machine topped. In the 2001-02 season for onions harvested early in the season there was a positive correlation between number of thrips on onions prior to lifting and number of thrips on onions after 60 days ambient storage. The number of thrips on onions from the early-season crops increased in storage in both the unclipped and machine topped treatments from four of the five early/mid-season crops. All of those fields had thrips numbers above the accepted spray threshold of 5 thrips/50 plants. The onions from the field that had no increase of thrips in storage had initial thrips numbers below the threshold (5 thrips/50 plants). This indicates that onions from early-season fields where thrips numbers are above the threshold are more likely to develop high populations of thrips in storage.

The increase in thrips populations during storage could have been caused by two different mechanisms, which unfortunately cannot be readily discerned from the results of this study. One possible mechanism is that elevated temperatures during storage of early season bulbs result in an increased number of generations and reproductive rate. A second possible mechanism is that thrips numbers increase during storage as a result of migration of adults from other sources (i.e. onions from other bins inside the packhouse or from plants outside the packhouse) rather than reproduction within bulbs.

Thrips populations on onions from crops harvested earlier in the season increased during 60 days storage, however this was not the case from those harvested late in the season. The difference in thrips numbers may be due to the difference in temperature over the two periods. Records of field temperatures indicate that conditions during curing were not markedly different for the early and later harvested crops. However, shed temperature records show that early harvested onions experienced a higher temperature regime over the 60-day storage period than the later harvested onions. As temperature has a strong influence on thrips development, one would assume that the thrips infesting the early-season onions would develop faster that those on the late-season onions. Application of a degree-day development model using the temperature profiles recorded from the stored onions (both field and storage temperatures), indicated the number of generations developing in storage would be greater in the early than the late season crops.

Anecdotal evidence from packhouse operators suggests that there are often more thrips in onions in the top bins in the sheds. Temperature profiles within the sheds show that temperature conditions in the top bins within a stack were 1-2°C higher than in the middle or bottom bins. If temperature is a key driver of thrips development and reproduction, then thrips populations would be higher on onions in the top bins. In a year of higher summer temperatures, it would be expected that the temperature differential between top and bottom of stacks would be even greater.

However, although temperature-driven development and reproduction may well have a role in the differences in thrips numbers, the observed decrease in proportion of larvae when compared to adults throughout ambient storage suggests that thrips populations are 'aging' and not reproducing well on white onion bulbs. Onion thrips egg production and hatch rate are influenced by the nutritional status of the tissues of the food plant and some onion bulbs are not an ideal substrate for thrips development (Martin et al. 2001). This could be a major factor contributing to the increasing proportions of adults. Eggs laid in the field may have hatched in storage but emerging adults laid only low numbers of eggs. Adults migrating into the bins may have been adding to the adult population but laying only few eggs.

If the increase in the thrips population in storage is primarily the result of eggs that were laid in the field, then temperature management in storage may offer a means to limit thrips development. Better passive ventilation or forced air ventilation would reduce the temperature gradients within stacks of bins. Onion thrips do not develop at temperatures under 10°C and low-temperature storage may need to be considered for severely at risk lines, however eggs will begin to hatch once the onions are removed from 10°C. If thrips migration is the major contributing factor to thrips population increase in storage then those lines of onions entering packhouses with high populations of thrips may need to be stored separately or even at low temperature. Any possible migration of adult thrips from outside the packhouse may be managed using repellency or insect proofing technology.

Onions from early harvested crops with thrips numbers above the spray threshold had 20-134 thrips per 50 onions after 60 days. It is difficult to predict the resultant damage during shipping, as there is no damage estimation model available. Martin et al. (2001) have demonstrated that 5-20 thrips feeding on Pukekohe Long Keeper onions for 3-4 weeks did not result in damage that a consumer would notice, however the thrips survival rates were very low. The time between thrips feeding on onion scales and the manifestation of 'feeding scars' and reduced onion quality is unknown. If it takes some time to develop, the damage may be unnoticed in pre-shipment inspections but appear on outturn.

Using a thrips development model and known shipping temperatures, it is estimated that approximately 3.4 generations could develop in the 38-day trip from NZ to Europe. However, the survival of thrips populations in actual shipping conditions is unknown. Results from a simulated shipping trial conducted last year indicated that thrips populations do not increase during shipping. It may be possible to assess the eight lines of onions upon arrival in Europe. If so, the results will be presented in a separate outturn report and will assist in estimating survival of thrips populations during shipping. If it is confirmed that thrips numbers do increase dramatically during shipping, then low-temperature (below 10°C) shipping could be a solution. Kader et al. (1985) classified onions as non-chilling sensitive and recommended that onions be stored at temperatures of 0-5°C. Yokoyama and Miller (2000) showed that exposure to storage period of 6 weeks at 0-1°C resulted in 99.8% mortality and at 5°C resulted in 82.4% mortality. Low-temperature storage prior to export and/or low-temperature shipping would also assist with controlling black mould fungus development on onions. Black mould is a high-temperature fungus, which only germinates at temperatures above approximately 28°C.

Onions were stored at HT/HRH primarily to induce black mould for comparison with soil predictions (Tyson et al. 2002). Thrips numbers were also assessed in these onions. Populations did not increase over the 30-day storage period. Results from 2000-01 indicated that the percentage mortality of onion thrips was higher in HT/HRH storage when compared to ambient storage. That trend was not apparent this year, however other research has found that adult longevity is influenced by temperature, with longevity decreasing with increasing temperature (Murai, 2000). Onion thrips populations generally have a positive correlation with temperature but a negative correlation with relative humidity. The most favourable conditions for onion thrips are 21.1-23.6°C with a relative humidity of 54% (Hamdy and Salem 1994).

CONCLUSIONS

- There was no difference between the two field-handling methods with relation to the numbers of thrips on onions in storage.
- Thrips populations on onions from crops exceeding the spray threshold prior to lifting and harvested early in the season increased in storage.
- Thrips populations on one early season onion crop that did not exceed the spray threshold prior to lifting and harvested early in the season did not increase in storage.
- There was a positive correlation between thrips populations prior to lifting and after 60 days storage on onions harvested early in the season.
- Thrips populations on onions from crops harvested late in the season did not increase in storage.
- The average temperatures in the sheds storing early harvested onions were higher than those in sheds storing late harvested onions.
- Within a shed, temperatures in the top bins within a stack were 1-2°C higher than in the middle or bottom bins of the stacks.
- A thrips development model estimated that the number of generations of thrips developing in storage would be expected to decrease as the season progressed because of decreasing temperatures.
- It is estimated that 3.4 generations of thrips would develop during shipping to Europe, however survival rates are unknown.
- The number of larvae compared to adults decreased throughout ambient storage which suggests that thrips populations are 'aging' and not reproducing well on white onion bulbs.
- Thrips populations did not increase after 30 days at 30°C, >90% RH.

RECOMMENDATIONS

- Continue to manage thrips populations prior to lifting using recommended monitoring and spray thresholds to reduce the likelihood of high populations of thrips developing in storage
- Survey crops harvested early in the season to determine whether there is a relationship between thrips populations on onions prior to lifting and after 60 days storage to enable catagorisation of high risk and low risk crops.
- Determine the cause of thrips population increases in storage. Are they due to field laid eggs hatching or adult thrips migration?
- Develop a thrips damage model and determine the time between thrips feeding and manifestation of bulb damage.
- Investigate cost benefits of shipping onions in low-temperature (10°C) conditions.
- Determine which commercially available onion variety is least susceptible to onion thrips.

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APPENDIX 1: Trial Layout and Field Sampling Regime.

Unclipped		Machine topped	
Rep 2	**Rep 4**	**Rep 2**	**Rep 3**
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X
Rep 1	**Rep 3**	**Rep 1**	**Rep 4**
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X

X = sampling sites (three plants removed)

APPENDIX 2: Shipping Regimes Used to Estimate Number of Thrips Generations Developing in Transit.

Day	Shipping regime 1	Shipping regime 2
1	16.5	18
2	17.5	18
3	18.5	19
4	17.5	20
5	16	21
6	18	21
7	19	22
8	22	22
9	25	22
10	24.5	23
11	25	24
12	26	24
13	27	25
14	26.5	25
15	26	26
16	25.5	27
17	25.5	28
18	27.5	29
19	27	30
20	26.5	31

Day	Shipping regime 1	Shipping regime 2
21	27.5	32
22	27	33
23	28	34
24	27	35
25	27	33
26	27	31
27	26	29
28	25.5	27
29	24	25
30	20.5	24
31	19	23
32	18.5	22
33	17.5	21
34	17.5	20
35	17	18
36	16.5	17
37	16	16
38	15.5	15