New Zealand Institute for Crop & Food Research Limited
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CROP & FOOD RESEARCH
Mana Kai Rangahau

Crop & Food Research Confidential Report No. 404

Onion thrips populations: effects of post-top fall to harvest treatments Milestone 3 (part), project 2.1

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June 2001

A report prepared for the
New Zealand Onion Exporters Association
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Copy 20 of 20

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Contents

1 Executive summary

The effects of four combinations of lifting and topping treatments on the distribution and numbers of onion thrips in bulbs at harvest were studied in a small plot trial at Pukekohe Research Centre, South Auckland. Onions grown for a Vegfed lettuce trial and government (FRST) funded trial were used in this project. Two replicates of each treatment in the lettuce block had high numbers of thrips prior to top fall while the two replicates in the FRST trial had lower populations prior to top fall. The plots were one bed wide and 15 m long.

The treatments were:

- minimal exposure of base plate (onions with roots and top uncut) until harvest,
- lifted at top fall when leaves were green, tops left intact,
- lifted at top fall when leaves were green, tops cut off,
- lifted when tops 50% dry, tops left intact,
- lifted when tops 50% dry, tops cut off.

The populations of thrips in all treatments declined from about 200 thrips per plant at top fall to 0.1 thrips per bulb at harvest, and to 0.03 thrips per bulb after five weeks storage.

At top fall most thrips were on the leaves. Thrips numbers declined substantially within two days of lifting the plants. The thrips on the leaves were mostly larvae. Some may have left the plant to pupate, but it appears that the quality of leaf material was not suitable to support larval thrips.

On lifted plants at top fall, thrips were found at the root bases and in the bulbs, but most thrips were in the neck of plants or associated with split skins on the bulbs.

At 50% dry, no thrips were found on leaves. A few thrips were found at all other sites. There were no statistically significant differences between treatments in the total numbers of thrips per bulb.

The numbers of thrips per bulb were too low to detect any differences between treatments at harvest.

2 Introduction

Earlier research and observations on onion thrips found no clear link between thrips populations before top fall, post top fall treatments and subsequent infestation of, and damage to, onion bulbs by thrips. Thrips were observed to leave crops that had high numbers of thrips prior to top fall. There was some uncertainty about the parts of the onion plants the thrips were inhabiting at top fall and how this affected their ability to infest bulbs at harvest. There were also questions about the effects of the mode of topping (leaf removal), the length of neck and the timing of lifting and topping on the process of bulb infestation. An experiment was designed across areas of both high and low thrips populations on onions to compare the effect of topping and the timing of topping and lifting on the numbers and distribution of thrips in the bulbs at harvest.

The same areas of onion plants were used for the experiment to compare pre-top fall thrips populations, project 1.2.1 (milestone 1).

3 Methods

Onions grown at Pukekohe Research Centre for two other trials were used for this project. The two areas of onions were near each other in Ranges 12 (FRST onion bulb trial) and 14 (Vegfed onion thrips lettuce trial). The planting dates and treatments of the two lots of onions were identical (Appendix I), except that the Range 12 onions had four chlorpyrifos sprays in December and January to hold the thrips populations at a low level in that crop.

There were five treatments to compare the effect of time of topping and lifting:

- minimal exposure of base plate (onions with roots and top uncut) until harvest,
- lifted at top fall when leaves were green, tops left intact,
- lifted at top fall when leaves were green, tops cut off,
- lifted when tops 50% dry, tops left intact,
- lifted when tops 50% dry, tops cut off.

The treatments were replicated four times with two replicates in the onions with high thrips populations (lettuce blocks 1 and 3) and two replicates in onions with low thrips populations grown for bulbs in Range 12. The plots were 15 m long and one bed (five rows) wide. The green treatments were imposed on 30 January 2001 and all treatments were assessed on 1 February. The 50% dry treatments were imposed on 7 February and all treatments were assessed on 8 February. The onions were harvested on

27 February and put into sacks and stored in a shed at ambient temperature.

The tops (onion leaves) were removed with scissors to leave a long neck on each bulb. The cut bulbs were placed on or close to the cut tops.

The pre-harvest assessments were done in the field. Five plants/bulbs were randomly selected from each plot. The numbers and stages of thrips were recorded on each plant at the following locations: base of bulb, around split skins on bulb, leaves, in neck, in the bulb.

At harvest (27 February) and after storage for five weeks (2 April), 20 bulbs per plot were randomly selected, put in paper bags and examined in the laboratory. The number and stages of thrips were recorded on each bulb at the base of the onion, associated with split skins, under the dead skins and on the first live scale, and between each pair of live scales, until there was no connection from the space between the scales with the neck and to the outside of the bulb.

The data from the pre-harvest samples were summarised on a spreadsheet (Appendix II) and analysed using analysis of variance (ANOVA) to compare treatments and infested sites (Appendix III). The data were transformed using the square root transformation before ANOVA could be performed. Friedman's non-parametric test was used to compare treatments for some counts where ANOVA could not be used because its statistical assumptions were violated.

4 Results and discussion

4.1 Treatments applied at top-fall (green top)

There were significantly more thrips on the three treatments where the plants were still rooted than on the two treatments lifted when the tops were green (green lifted and green lifted and topped) (Fig. 1). On treatments where leaves were present, most of the thrips were larvae.

On all treatments most adults and larvae were on the leaves. The neck region had more total thrips than areas of split skins (Fig. 2), although in 50% topped and control plots there were more adult thrips associated with split skins than in the neck of plants.

Thrips were only associated with the bases of the onions and in the bulbs in the two treatments lifted when green. Adults, larvae and pupal thrips were found at the base of these onions.

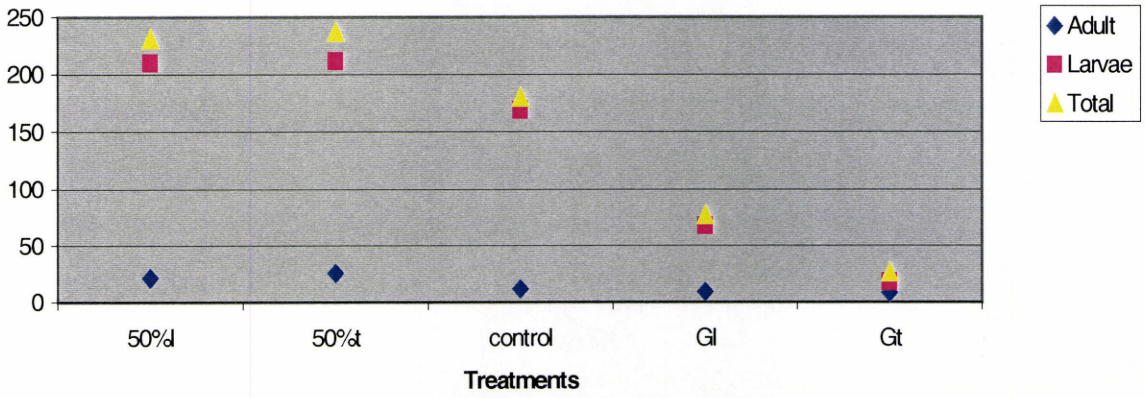

Figure 1: Mean numbers of thrips on onion plants on 1 February, two days after the 'green' treatments.

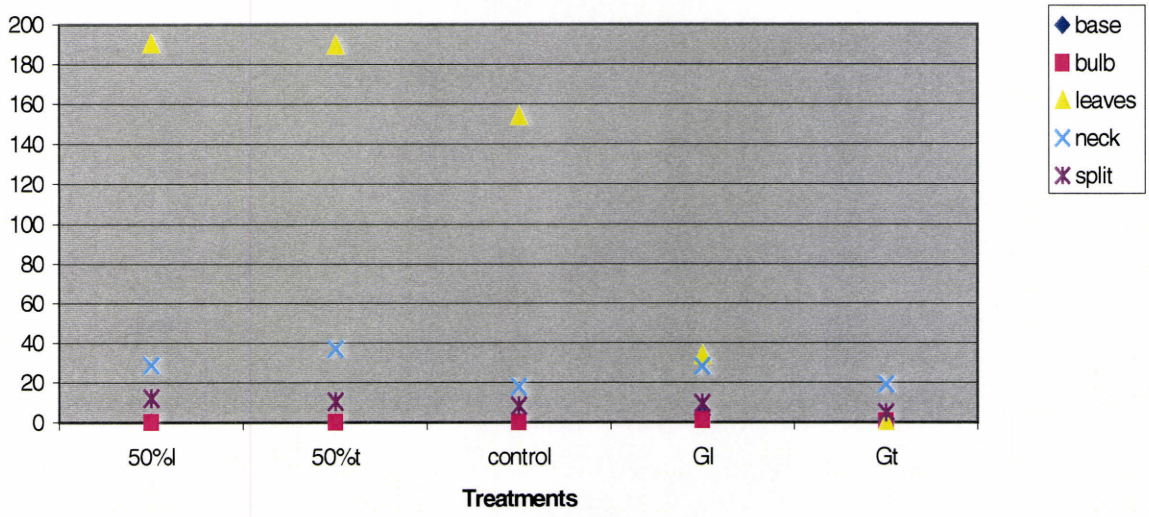

Figure 2: Mean numbers of thrips (larvae and adults) on different parts of onion plants two days after the 'green' treatments.

4.2 *Treatments applied when leaves 50% dry*

When the unlifted plants had leaves 50% dry, the populations of thrips in all treatments had declined substantially and there were no statistically significant differences between the numbers of thrips in each treatment (Fig. 3). There were similar numbers of adult and larval thrips.

On 8 February statistically significant differences in the numbers of thrips occurred on different positions on the onion plant/bulb. There were more thrips in the 'split' and 'neck' than in the other positions. The same was true for adult thrips, but most thrips larvae were in the 'neck'. There were no statistically significant differences among larval counts in the 'split', 'bulb' and 'base' positions, but within the control treatment there were more larval thrips in splits than in onion bulbs.

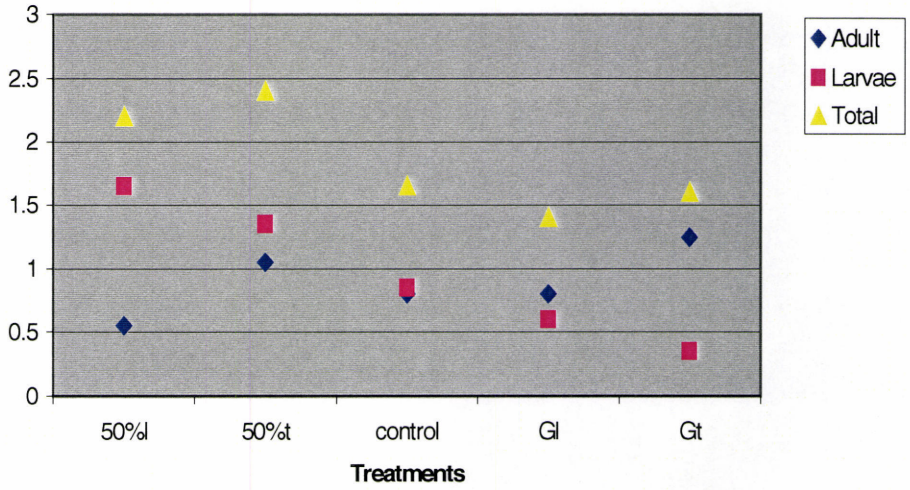

Figure 3: Mean numbers of thrips on onion plants on 8 February, 1 day after the 50% dry treatments.

4.3 Thrips populations at harvest and after storage

The raw data are summarised in Appendix II. Only 8% of bulbs were infested at harvest and less than 2.5% were infested after five weeks storage, with about 0.1 and 0.03 thrips per bulb respectively (Table 1). This is about 1.3 thrips per infested bulb. Adults and larvae were present on both occasions.

The numbers of thrips were too low for statistically significant differences between treatments to be detected.

Table 1: Mean proportion of onion bulbs infested with onion thrips and mean numbers of thrips per onion at harvest (27 February 2001) and after five weeks storage at ambient temperature (2 April 2001). Numbers of bulbs examined per treatment 80 (27 Feb), 100 (2 April).

	Mean proportion of infested bulbs out of 80		Mean proportion of thrips per bulb out of 80	
Treatment	27 Feb	2 April	27 Feb	2 April
Green, lifted	0.05	0.05	0.087	0.08
Green topped	0.125	0.01	0.15	0.01
50% dry lifted	0.05	0.04	0.075	0.05
50% dry topped	0.113	0.01	0.138	0.01
Control	0.75	0.01	0.075	0.01
All treatments	0.083	0.024	0.105	0.032

4.4 *Overall trends*

The overall trend in thrips populations was for numbers to decline rapidly from top fall to harvest and to continue declining during storage (Fig. 4).

Most of the thrips present at top fall were larvae. When the quality of onion leaves declines, through natural senescence or by uprooting the plants, the numbers of larvae drops rapidly. Some of this decline may be due to larvae pupating and becoming adults that migrate from the crop. However, the rapid decline during two days after green plants were lifted, suggests that some larvae walk off the plants or die when the foliage is not of good quality.

Once the base of onions dried, adult or juvenile thrips were no longer found there, even though there were apparently suitable refuges. Many dead thrips were found close to the base of the neck between the dried skins and between the live scales. The thrips appear to have been crushed when the skins tightened as they dried.

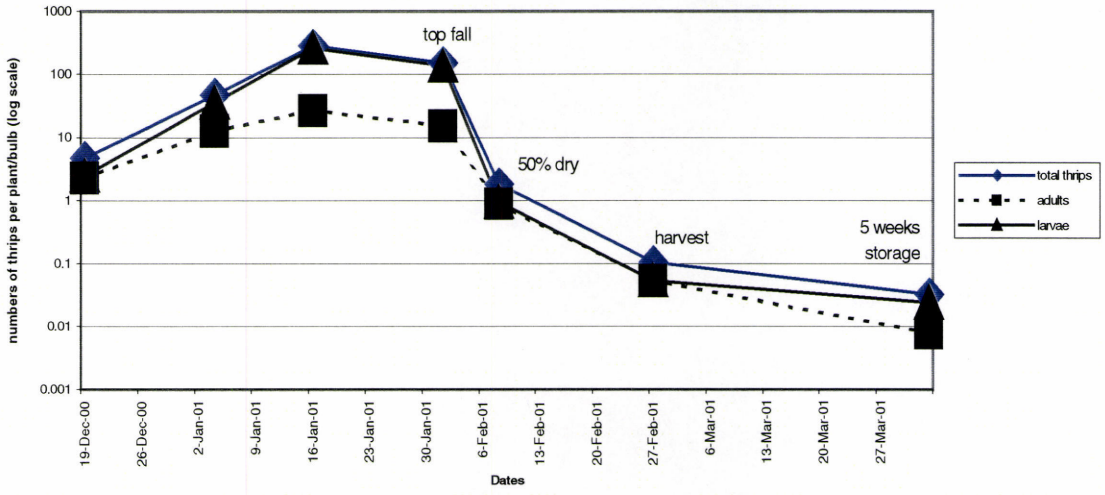

Figure 4: Mean number of thrips per onion plant/bulb from mid December to early April. This graph is the mean of all treatments and the numbers of thrips on untreated plants, i.e. at and before top fall is higher.

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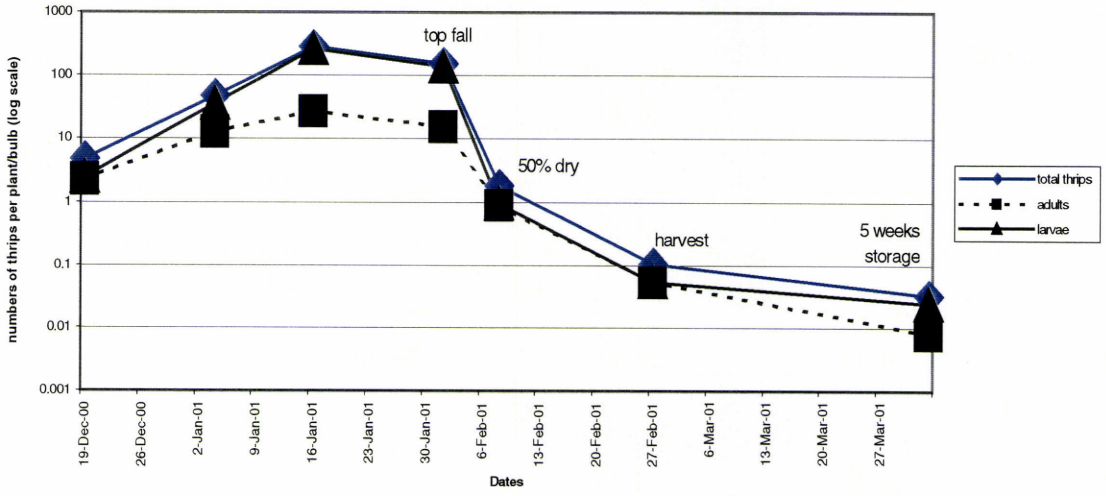


Figure 4: Mean number of thrips per onion plant/bulb from mid December to early April. This graph is the mean of all treatments and the numbers of thrips on untreated plants, i.e. at and before top fall is higher.

5 General discussion and conclusions

While there is evidence that thrips breed on onions and can be found wherever they have access to live onion tissue, Pukekohe Long Keeper onion bulbs do not appear to be suitable for the multiplication of onion thrips. As soon as leaves were no longer of suitable quality, thrips populations declined rapidly. At 50% dry, the neck of each bulb and splits were the places of highest infestation. Both sites tend to become less suitable for onion thrips. As the scale underlying a split dries up it forms a dead skin, which no longer supports the thrips. The neck also appears to become unsuitable for thrips. Thrips need to progress through the neck to the live scale. The spaces between leaves in the neck often contain free moisture which makes movement through it difficult for thrips. When thrips reach the base of the neck, they appear to be able to breed, but the amount of feeding damage was slight and many thrips appear to have been crushed between the shrinking scale and skins.

The overall decline of thrips populations from top fall to harvest was more important than reductions in thrips populations associated with any of the lifting or topping treatments.

6 Acknowledgements

We thank Richard Wood for providing advice on the growing of the onions, Barry Childs for managing the crops and spraying, Lydia Huggard and Jan Elliot for technical assistance, and John Koolaard for biometric analysis of the pre harvest data.

Appendices

Appendix I Onion thrips trials: site management diary

2.5 t /ha 15% super incorporated before sowing

26/7 sow onions (Pukekohe long keeper)

27/7 spray : stomp @ 1.5L/ha

diazinon @ 1.5L/ha

roundup @ 4L/ha

25/8 urea @ 100kg/ha

28/9, 10/10, 13/10, 20/10 Totril @ 300ml/ha

Tribunal @ 300 g/ha

15/10 urea @ 100kg/ha

17/10, 25/10 Manzate @ 2.5kg/ha

27/10 Frontier @ 1.5L/ha

2/11 Manzate @ 2.5kg/ha

10/11, 17/11 Ridomil @ 2.5kg/ha

manzate @ 1.5kg/ha

Methamidophos @ 160 ml/100 l @ 500 l/ha

20/11 C.A.N. 200kg/ha

27/11 Acrobat @ 2.5kg/ha

Methamidophos @ 160 ml/100 l @ 500 l/ha

5/12 , 14/12 Acrobat @ 2.5kg/ha

Manzate @ 1kg/ha

Methamidophos @ 160 ml/100 l @ 500 l/ha

8/12 , 12/12 Totril @ 400ml/ha

Tribunal @ 400ml/ha

23/12 , 29/12 Manzate @ 2.5kg/ha

chlorpyrifos (Lorsban 50% @ 160 ml/100l @ 500 l/ha (Range 12 only)

4/1 , 13/1 Acrobat @ 2.5kg/ha

chlorpyrifos (Lorsban 50% @ 160 ml/100l @ 500 l/ha (Range 12 only)

23/1 Manzate @ 2.5kg/ha

Appendix II Raw data

1. Thrips populations on onions at top fall

Onion small plot trial topfall to harvest
Pukekohe 2001
30-Jan-01 date treated plants at green topfall lifted and topped
1-Feb-01 date sampled plants sampled 5

reps 1-2 high thrips
reps 3-4 low thrips

Summary of treatments mean thrips per plant

	Thrips stages on different parts of plant: onion base			split skin on bulb			leaves			neck			In bulb			total thrips per plant/bulb		
	a	l	total	a	l	total	a	l	total	a	l	total	a	l	total	a	l	
Gt	1	0.6	1.55	1.4	3.6	5	0	0	0	5.9	13.2	19	0.2	0.3	0.5	8.4	17.7	
Gl	2.3	1.6	3.9	1.4	8.4	9.75	1.6	32.3	33.9	3.8	24.5	28	0.3	1.3	1.5	9.3	68	77.3
50%t	0	0	0	4.7	6	10.65	17	173	190	4.6	32.5	37	0	0	0	26	212	237
50%l	0	0	0	3.5	8.8	12.2	13	177	190	4.6	24.3	29	0	0	0	21	210	231
control	0	0	0	2.6	5.9	8.5	7.5	147	154	1.6	16.3	18	0	0.1	0.05	12	169	180

summary of plot data by treatment Green topped and lifted

Rep	Thrips stages on different parts of plant: onion base			split skin on bulb			leaves			neck			In bulb			total thrips per plant/bulb		
	a	l	total	a	l	total	a	l	total	a	l	total	a	l	total	a	l	
1	0.2	0	0.2	0.6	5	5.6				6.2	22	28	0	0	0	7	27	34
2	1	2	3	3.2	8	11.2				6.2	10.6	17	0.2	0.2	0.4	11	20.8	31.4
3	0.4	0	0.4	1.2	0.2	1.4				8.4	10	18	0	0	0	10	10.2	20.2
4	2.2	0.4	2.6	0.6	1.2	1.8				2.6	10	13	0.6	1	1.6	6	12.6	18.6

summary of plot data by treatment Green lifted

Rep	Thrips stages on different parts of plant: onion base			split skin on bulb			leaves			neck			In bulb			total thrips per plant/bulb		
	a	l	total	a	l	total	A	l	total	a	l	total	a	l	total	a	l	
1	2.2	4	6.2	2.4	28	30.4	5.4	110	115	2.8	62	65	0.2	2	2.2	13	206	219
2	4.4	2	6.4	1.4	4	5.4	1	19	20	1.2	16	17	0.2	2	2.2	8.2	43	51.2
3	0.4	0	0.4	1.2	0.2	1.4	0	0	0	8.4	10	18	0	0	0	10	10.2	20.2
4	2.2	0.4	2.6	0.6	1.2	1.8	0	0	0	2.6	10	13	0.6	1	1.6	6	12.6	18.6

summary of plot data by treatment 50 % dry topped and lifted

Rep	Thrips stages on different parts of plant: onion base			split skin on bulb			leaves			neck			In bulb			total thrips per plant/bulb		
	a	l	total	a	l	total	A	l	total	a	l	total	a	l	total	a	l	
1	0	0	0	3.2	2	5.2	15	256	271	3	52	55	0	0	0	22	310	332
2	0	0	0	5.4	8	13.4	9.8	152	162	7	40	47	0	0	0	22	200	222
3	0	0	0	5	7	12	20	142	162	4.2	19	23	0	0	0	30	168	198
4	0	0	0	5	7	12	20	142	162	4.2	19	23	0	0	0	30	168	198

summary of plot data by treatment 50% dry lifted

Rep	Thrips stages on different parts of plant: onion base			split skin on bulb			leaves			neck			In bulb			total thrips per plant/bulb		
	a	l	total	a	l	total	A	l	total	a	l	total	a	l	total	a	l	
1	0	0	0	2.8	11	13.8	2	142	144	0.8	32	33	0	0	0	5.6	185	191
2	0	0	0	2.8	7	9.8	15	230	245	2.4	20	22	0	0	0	20	257	277
3	0	0	0	5.4	7	12.4	24	202	226	10	34	44	0	0	0	40	243	283
4	0	0	0	2.8	10	12.8	12	134	146	4.8	11	16	0	0	0	20	155	175

summary of plot data by treatment control, lifted and topped at harvest

Rep	Thrips stages on different parts of plant: onion base			split skin on bulb			leaves			neck			In bulb			total thrips per plant/bulb		
	a	l	total	a	l	total	a	l	total	a	l	total	a	l	total	a	l	
1	0	0	0	1.6	3.6	5.2	4.6	122	127	1.6	12	14	0	0	0	7.8	138	145
2	0	0	0	2.6	8	10.6	9.2	196	205	0.8	13	14	0	0	0	13	217	230
3	0	0	0	2.4	4	6.4	6.2	170	176	1.4	17	18	0	0	0	10	191	201
4	0	0	0	3.8	8	11.8	9.8	98	108	2.4	23	25	0	0.2	0.2	16	129	145

2. Onion thrips populations when tops were 50% dry

Onion small plot trial topfall to harvest reps 1-2 high thrips
Pukekohe 2001 reps 3-4 low thrips
7-Feb-01 date treated plants at 50% dry lifted and topped
8-Feb-01 date sampled plants sampled 5

Summary of treatments mean thrips per plant

	Thrips stages on different parts of plant															total thrips per plant/bulb		
	onion base			split skin on bulb			leaves			neck			In bulb					
	a	l	total	a	l	total	a	l	total	a	l	total	a	l	total	a	l	total
Gt	0.1	0.1	0.1	0.5	0.1	0.6	0	0	0	0.6	0.15	0.8	0.1	0.1	0.15	1.3	0.35	1.6
Gl	0.1	0	0.05	0.6	0.1	0.65	0	0	0	0.1	0.35	0.5	0.1	0.2	0.25	0.8	0.6	1.4
50%t	0.1	0	0.1	0.5	0.2	0.65	0	0	0	0.5	1.05	1.6	0	0.1	0.1	1.1	1.35	2.4
50%l	0.1	0.2	0.25	0.2	0.4	0.55	0	0	0	0.1	0.7	0.8	0.2	0.5	0.6	0.6	1.65	2.2
control	0.1	0.1	0.1	0.2	0.4	0.55	0	0	0	0.4	0.35	0.7	0.2	0.1	0.3	0.8	0.85	1.65

summary of plot data by treatment Green topped and lifted

Rep	Thrips stages on different parts of plant															total thrips per plant/bulb		
	onion base			split skin on bulb			leaves			neck			In bulb					
	a	l	total	a	l	total	a	l	total	a	l	total	a	l	total	a	l	total
1	0.2	0	0.2	0	0	0				0.4	0	0.4	0	0	0	0.6	0	0.6
2	0	0.2	0.2	0.4	0	0.4				1.6	0	1.6	0	0	0	2	0.2	2.2
3	0	0	0	0.4	0.4	0.8				0.2	0	0.2	0.4	0.2	0.6	1	0.6	1.6
4	0	0	0	1.2	0	1.2				0.2	0.6	0.8	0	0	0	1.4	0.6	2

summary of plot data by treatment Green lifted

Rep	Thrips stages on different parts of plant															total thrips per plant/bulb		
	onion base			split skin on bulb			leaves			neck			In bulb					
	a	l	total	a	l	total	a	l	total	a	l	total	a	l	total	a	l	total
1	0.2	0	0.2	0.2	0	0.2	0	0	0	0	0	0	0	0.4	0.4	0.4	0.4	0.8
2	0	0	0	0.4	0	0.4	0	0	0	0	0.8	0.8	0	0	0	0.4	0.8	1.2
3	0	0	0	0.4	0.4	0.8	0	0	0	0.2	0	0.2	0.4	0.2	0.6	1	0.6	1.6
4	0	0	0	1.2	0	1.2	0	0	0	0.2	0.6	0.8	0	0	0	1.4	0.6	2

summary of plot data by treatment 50 % dry topped and lifted

Rep	Thrips stages on different parts of plant															total thrips per plant/bulb		
	onion base			split skin on bulb			leaves			neck			In bulb					
	a	l	total	a	l	total	a	l	total	a	l	total	a	l	total	a	l	total
1	0.2	0	0.2	0.4	0.4	0.8				0.4	0	0.4	0	0	0	1	0.4	1.4
2	0.2	0	0.2	0.2	0.4	0.6				1.2	1.8	3	0	0.4	0.4	1.6	2.6	4.2
3	0	0	0	0.6	0	0.6				0.2	1.2	1.4	0	0	0	0.8	1.2	2
4	0	0	0	0.6	0	0.6				0.2	1.2	1.4	0	0	0	0.8	1.2	2

summary of plot data by treatment 50% dry lifted

Rep	Thrips stages on different parts of plant: onion base			split skin on bulb			leaves			neck			In bulb			total thrips per plant/bulb		
	a	l	total	a	l	total	a	l	total	a	l	total	a	l	total	a	l	total
1	0	0	0	0.2	0	0.2	0	0	0	0.2	0	0.2	0	0	0	0.4	0	0.4
2	0.2	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.2
3	0.2	0.4	0.6	0.2	0.8	1	0	0	0	0	0.8	0.8	0	0.4	0.4	0.4	2.4	2.8
4	0	0.2	0.2	0.4	0.6	1	0	0	0	0.2	2	2.2	0.6	1.4	2	1.2	4.2	5.4

summary of plot data by treatment control, lifted and topped at harvest

Rep	Thrips stages on different parts of plant: onion base			split skin on bulb			leaves			neck			In bulb			total thrips per plant/bulb		
	a	l	total	a	l	total	a	l	total	a	l	total	a	l	total	a	l	total
1	0	0	0	0.4	0	0.4	0	0	0	0.2	0.2	0.4	0	0	0	0.6	0.2	0.8
2	0	0	0	0.4	0	0.4	0	0	0	0.8	0.2	1	0.8	0.4	1.2	2	0.6	2.6
3	0	0.2	0.2	0	0.6	0.6	0	0	0	0.4	0	0.4	0	0	0	0.4	0.8	1.2
4	0.2	0	0.2	0	0.8	0.8	0	0	0	0	1	1	0	0	0	0.2	1.8	2

3. Onion thrips in onion bulbs at harvest (27 Feb 2001)

Table A: Proportion of onion bulbs infested with onion thrips at harvest (27 February 2001))Number of bulbs examined per treatment; 80.

Treatment	Replicate				Total infested bulbs	Proportion of infested bulbs
	1	2	3	4		
Green, lifted	1	3	0	0	4	0.05
Green topped	1	6	1	2	10	0.125
50% dry lifted	0	2	0	2	4	0.05
50% dry topp	1	2	3	3	9	0.113
Control	2	0	0	4	6	0.75
total	5	13	4	11	33	0.083

Table B: Mean numbers of thrips per bulb at harvest (27 February 2001). Number of bulbs examined per treatment; 80; a = adult, l=larva.

Treatment	Replicate				Total thrips	Mean number
	1	2	3	4		
Green, lifted	2 l	4 a 1 l	0	0	7	0.087
Green topped	1 a	4 a 4 l	1 a	2 a	12	0.15
50% dry lifted	0	4 l	0	1 a 1 l	6	0.075
50% dry topped	1 a	1 a 2 l	3 a 1 l	1 a 2 l	11	0.138
Control	1 a 1 l	0	0	1 a 3 l	6	0.075
total	6	20	5	11	42	0.105

4. Onion thrips in onion bulbs after storage for five weeks (2 April 2001)

Table A: Proportion of onion bulbs infested with onion thrips after five weeks storage at ambient temperature(2 April 2001). Number of bulbs examined per treatment 100.

Treatment	Replicate				Total infested bulbs	Proportion of infested bulbs
	1	2	3	4		
Green, lifted	0	2	0	3	5	0.05
Green topped	0	0	1	0	1	0.01
50% dry lifted	1	2	0	1	4	0.04
50% dry topped	1	0	0	0	1	0.01
Control	0	1	0	0	1	0.01
total	2	5	1	4	12	0.024

Table B: Mean numbers of thrips per bulb after five weeks storage at ambient temperatures (2 April 2001). Number of bulbs examined per treatment; 100; a = adult, l=larva.

Treatment	Replicate				Total thrips	Mean number
	1	2	3	4		
Green, lifted	0	6 l	0	1 a 1 l	8	0.08
Green topped	0	0	1 a	0	1	0.01
50% dry lifted	1 l	2 a	0	2 l	5	0.05
50% dry topped	1 l	0	0	0	1	0.01
Control	0	1 l	0	0	1	0.01
total	2	9	1	4	16	0.032

Appendix III Analysis of onion small trial

1. Data Analysis for 30 Jan/1 Feb

1.1 Comparing positions

1.1.1 Adult Counts

ANOVA was carried out on transformed Adult counts (square root) to compare counts at various treatments and positions. Thus the associated conclusions were drawn from transformed counts, but the mean tables and graphs were based on the original counts.

On 1 Feb, treatments '50%t' '50%l' had significantly more adult insects than 'control' and 'Gt'. There were no significant differences between '50%t' and '50%l' or among 'control', 'Gt' and 'Gl'. The most adult insects were on 'leaves', and insects on 'neck' and 'split' were much more than on 'base' and 'bulb'. The variation among treatment effects mainly occurred on 'leaves'.

Comparing 'Control (i.e.'50%t', '50%l' and 'control') vs Treated ('Gt' and 'Gl')', there was no significant difference in general (i.e. over all positions), but on the 'leaves' there was a significant difference between Control and Treated.

The (back-transformed) mean tables and associated graph are as follows:

***** Tables of means *****

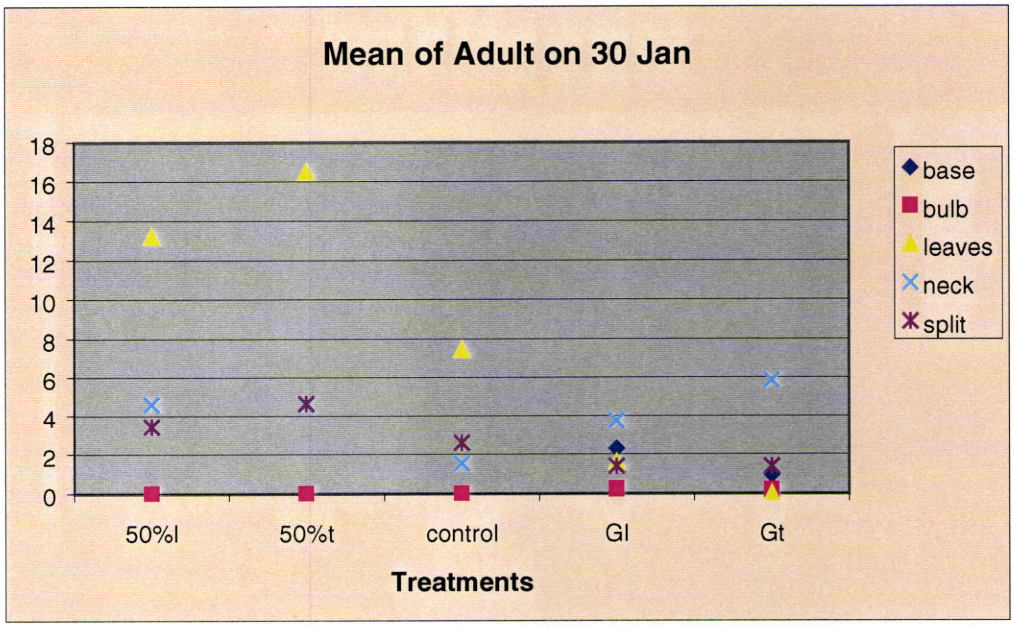
Variate: Adult

Grand mean 3.05

Treat	50%l	50%t	control	Gl	Gt
	4.25	5.15	2.32	1.86	1.68

Position	base	bulb	leaves	neck	split
	0.65	0.09	7.75	4.07	2.70

Treat	Position	base	bulb	leaves	neck	split
50%l		0.00	0.00	13.20	4.60	3.45
50%t		0.00	0.00	16.50	4.60	4.65
control		0.00	0.00	7.45	1.55	2.60
Gl		2.30	0.25	1.60	3.75	1.40
Gt		0.95	0.20	0.00	5.85	1.40



JANUARY 30 DATA - SMALL ONIONS TRIAL
***** Analysis of variance *****

Variate: sqrtAdult

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.9351	0.3117	1.05	
Reps.*Units* stratum					
Treat	4	6.7595	1.6899	5.69	<.001
Green vs Others	1	3.2652	3.2652	10.99	0.001
Position	4	65.0379	16.2595	54.72	<.001
Treat.Position	16	53.9945	3.3747	11.36	<.001
Green vs Others.Position	4	48.9459	12.2365	41.18	<.001
Residual	72	21.3931	0.2971		
Total	99	148.1202			

***** Tables of means *****

Variate: sqrtAdult

Grand mean 1.253

Treat	50%l	50%t	control	Gl	Gt
	1.442	1.657	1.103	1.129	0.935

Position	base	bulb	leaves	neck	split
	0.463	0.145	2.192	1.900	1.567

Treat	Position	base	bulb	leaves	neck	split
50%l		0.000	0.000	3.408	1.965	1.836
50%t		0.000	0.000	4.022	2.119	2.146
control		0.000	0.000	2.700	1.223	1.594
Gl		1.424	0.417	0.831	1.820	1.151
Gt		0.891	0.305	0.000	2.373	1.108

*** Least significant differences of means (5% level) ***

Table	Treat	Position	Treat Position
rep.	20	20	4
d.f.	72	72	72
l.s.d.	0.3436	0.3436	0.7684

1.1.2 Larvae Counts

ANOVA was carried out on transformed larvae counts (square root) to compare counts at various treatments and positions. Thus the associated conclusions were drawn from transformed counts, but the mean tables and graph were based on the original counts.

On 1 Feb, treatments '50%t' '50%l' and 'control' had significantly more larvae than treatments 'Gt' and 'Gl'. There was no significant difference among '50%t', '50%l' and 'control', but there was a significant difference between 'Gt' & 'Gl'. The most larvae were on 'leaves'. There were much more larvae on 'neck' and 'split' than on 'base' and 'bulb'. The variation among treatment effects mainly occurred on 'leaves'.

Comparing 'Control (i.e. '50%t', '50%l' and 'control') vs Treated ('Gt' and 'Gl')', there was significantly different counts for each, both in general, and on the 'leaves'.

The (back-transformed) mean tables and associated graph are as follows:

**** Tables of means *****

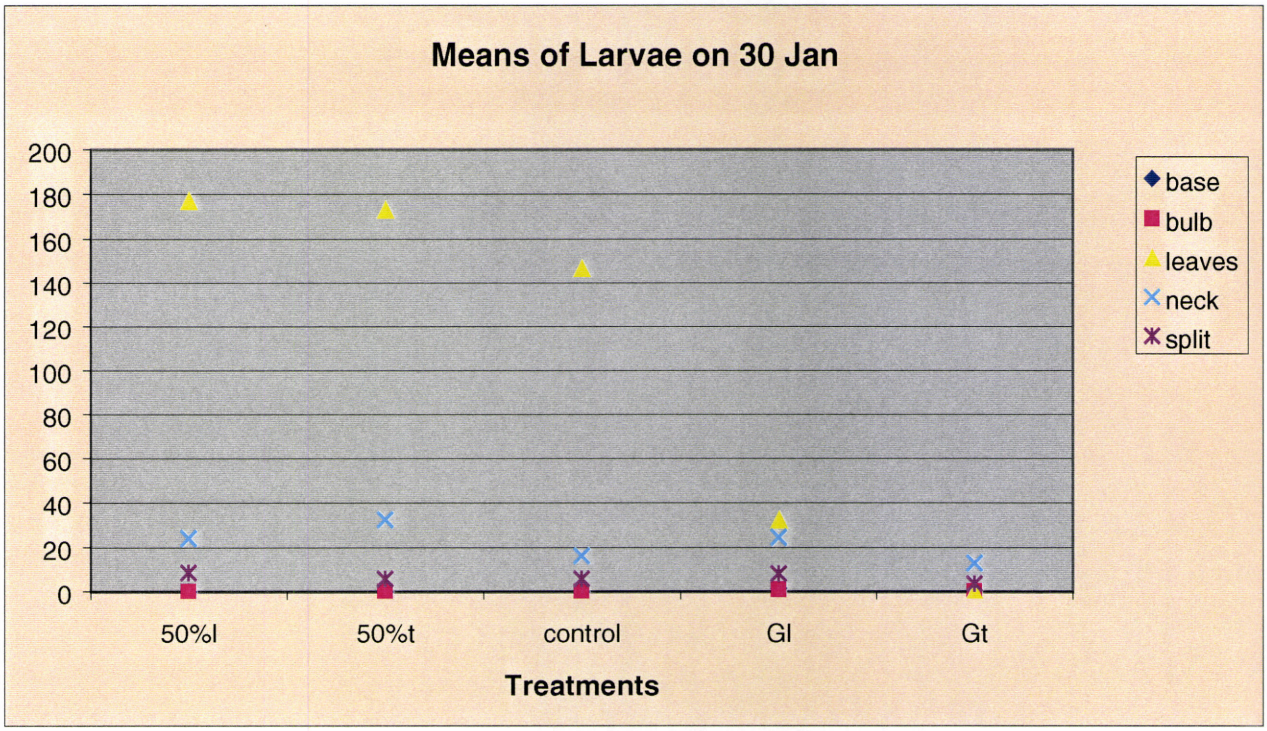
Variate: Larvae

Grand mean 27.0

Treat	50%l	50%t	control	Gl	Gt
	42.0	42.3	33.7	13.6	3.5

Position	base	bulb	leaves	neck	split
	0.4	0.3	105.7	22.1	6.5

Treat	Position	base	bulb	leaves	neck	split
50%l		0.0	0.0	177.0	24.2	8.7
50%t		0.0	0.0	173.0	32.5	6.0
control		0.0	0.0	146.5	16.2	5.9
Gl		1.6	1.2	32.2	24.5	8.3
Gt		0.6	0.3	0.0	13.1	3.6



***** Analysis of variance *****

Variate: sqrtLarvae

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	23.923	7.974	4.25	
Reps.*Units* stratum					
Treat	4	133.211	33.303	17.73	<.001
Green vs Others	1	113.796	113.796	60.59	<.001
Position	4	926.111	231.528	123.27	<.001
Treat.Position	16	486.373	30.398	16.18	<.001
Green vs Others.Position	4	465.219	116.305	61.92	<.001
Residual	72	135.232	1.878		
Total	99	1704.851			

***** Tables of means *****

Variate: sqrtLarvae

Grand mean 3.16

Treat	50%l	50%t	control	Gl	Gt
	4.20	4.20	3.70	2.49	1.22

Position	base	bulb	leaves	neck	split
	0.30	0.29	8.39	4.50	2.32

Treat	Position	base	bulb	leaves	neck	split
50%l		0.00	0.00	13.22	4.82	2.94
50%t		0.00	0.00	13.04	5.56	2.38
control		0.00	0.11	12.00	4.00	2.39
Gl		1.01	0.96	3.71	4.55	2.21
Gt		0.51	0.36	0.00	3.57	1.65

*** Least significant differences of means (5% level) ***

Table	Treat	Position	Treat Position
rep.	20	20	4
d.f.	72	72	72
l.s.d.	0.864	0.864	1.932

1.1.3 Total counts (adult + Larvae)

ANOVA was carried out on transformed Total (adult + larvae) counts (square root transformation) to compare counts at various treatments and positions. Thus the associated conclusions were drawn from transformed counts, but the mean tables and graph were based on the original counts.

On 1 Feb, treatments '50%t' '50%l' and 'control' had significantly more Total insects on onions than the others, and there were no significant differences among '50%t' '50%l' and 'control', or between 'Gl' and 'Gt'. The highest total number of insects were living on 'leaves', and insects on 'neck' and 'split' were much more than on 'base' and 'bulb'. The variation among treatment effects mainly occurred on 'leaves'. This is similar to the conclusions for larvae counts since these make up the bulk of the total count.

Comparing 'Control ('50%t' '50%l' 'control') vs Treated ('Gt' 'Gl')', there were significantly different total counts both overall and just on the 'leaves'.

The back-transformed mean tables and associated graph are as follows:

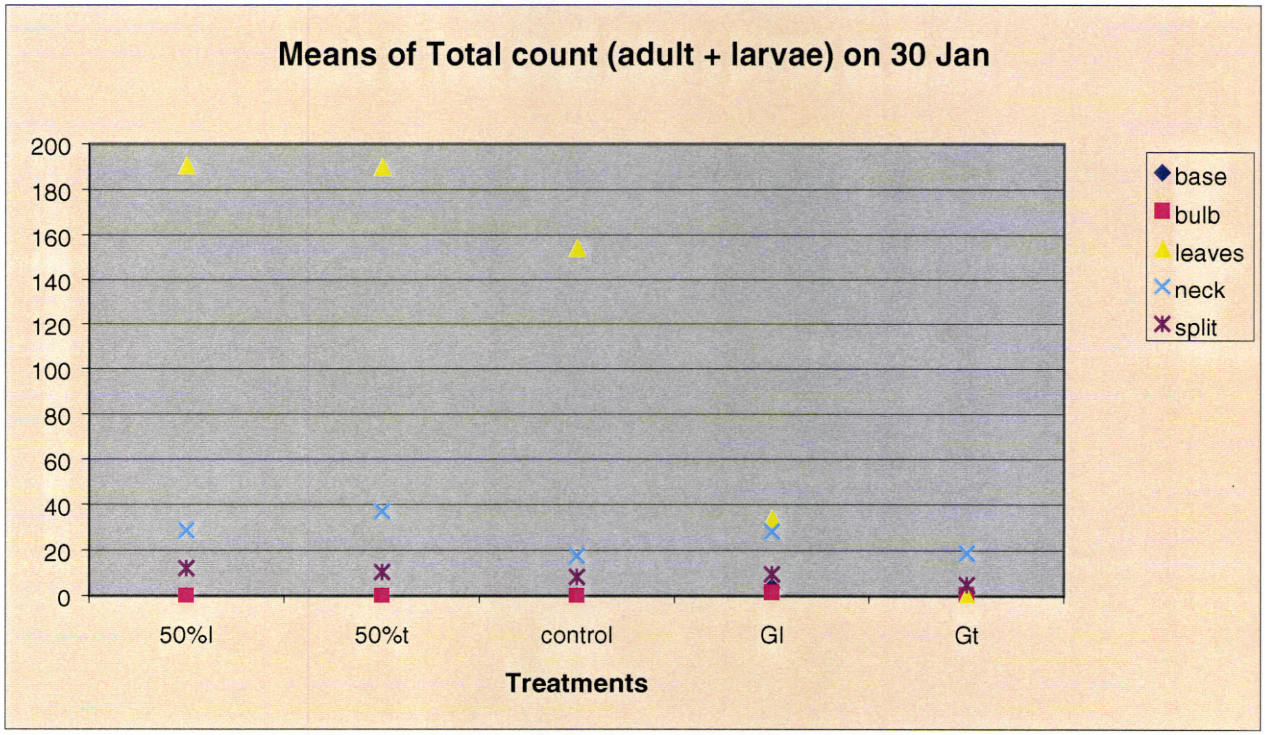
Variate: Total

Grand mean 30.1

Treat	50%l	50%t	control	Gl	Gt
	46.2	47.4	36.1	15.5	5.2

Position	base	bulb	leaves	neck	split
	1.1	0.4	113.5	26.2	9.2

Treat	Position	base	bulb	leaves	neck	split
50%l		0.0	0.0	190.2	28.9	12.2
50%t		0.0	0.0	189.5	37.1	10.6
control		0.0	0.0	154.0	17.8	8.5
Gl		3.9	1.5	33.8	28.2	9.7
Gt		1.5	0.5	0.0	19.0	5.0



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***** Analysis of variance *****

Variate: sqrtTotal

Source of variation      d.f.       s.s.       m.s.     v.r.  F pr.

Reps stratum                3     17.599      5.866     3.01

Reps.*Units* stratum
Treat                       4    126.968     31.742    16.28  <.001
  Green vs Others           1    105.505    105.505    54.11  <.001
Position                    4    961.464    240.366   123.29  <.001
Treat.Position             16    550.305     34.394    17.64  <.001
  Green vs Others.Position
                           4     527.268    131.817    67.61  <.001
Residual                   72    140.376      1.950

Total                      99   1796.713


***** Tables of means *****

Variate: sqrtTotal

Grand mean  3.48

    Treat      50%l      50%t  control        Gl        Gt
               4.49      4.57     3.90      2.86      1.59

 Position      base      bulb   leaves      neck     split
               0.58      0.33     8.69      4.95      2.85

    Treat Position      base      bulb   leaves      neck     split
     50%l               0.00      0.00    13.69      5.27      3.49
     50%t               0.00      0.00    13.67      5.98      3.22
  control               0.00      0.11    12.31      4.18      2.88
       Gl               1.82      1.06     3.80      5.01      2.59
       Gt               1.11      0.47     0.00      4.31      2.06


*** Least significant differences of means (5% level) ***

Table                 Treat    Position       Treat
                                              Position
rep.                     20          20            4
d.f.                     72          72           72
l.s.d.                0.880       0.880        1.968
```

1.2 Comparing treatment sites (areas)

On 1 Feb we find that the most number of total insects (adult+larvae) were found in the '50%t' treatment. The most effect treatment was 'Gt' . Friedman's non-parametric test was used to compare treatments.

The mean tables and associated graph are as follows:

Variate: Adult

Grand mean 15.3

Treat	50%l	50%t	control	Gl	Gt
	21.3	25.8	11.6	9.3	8.4

Variate: Larvae

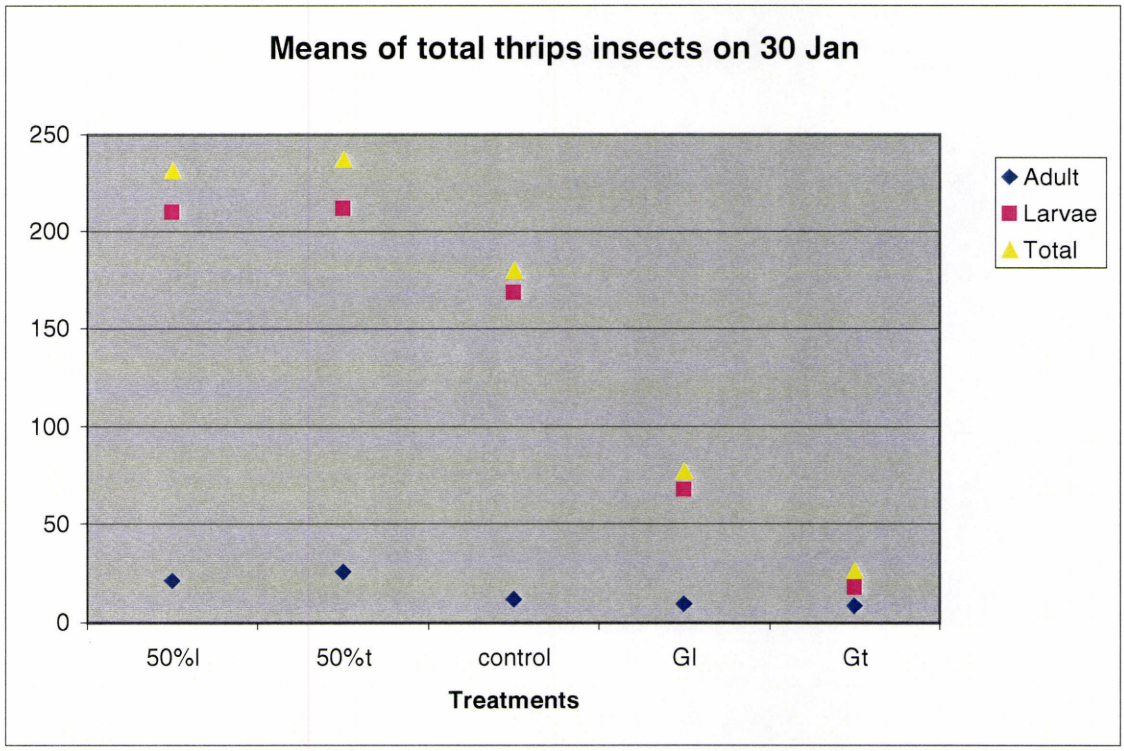
Grand mean 135.

Treat	50%l	50%t	control	Gl	Gt
	210.	212.	169.	68.	18.

Variate: Total

Grand mean 150.

Treat	50%l	50%t	control	Gl	Gt
	231.	237.	180.	77.	26.



In the following 3 analyses, using Friedman's non-parametric test to compare the 5 treatment areas, we can see that there were significant differences among the areas in counts of adults, larvae, and total. The differences existed between counts from the GI and Gt (treated) areas, as compared to counts from the other areas (untreated at 1 Feb). The control area had less insects than 50%l and 50%t, but this difference was not significant.

Friedman Test: Adult versus Treat, Reps

Friedman test for Adult by Treat blocked by Reps

S = 8.65 DF = 4 P = 0.070

S = 9.23 DF = 4 P = 0.056 (adjusted for ties)

Treat	N	Est Median	Sum of Ranks
1	4	9.08	7.5
2	4	8.74	8.5
3	4	25.82	19.0
4	4	19.90	14.0
5	4	11.96	11.0
Grand median	=	15.10	

Friedman Test: Larvae versus Treat, Reps

Friedman test for Larvae by Treat blocked by Reps

S = 10.00 DF = 4 P = 0.040

S = 10.26 DF = 4 P = 0.036 (adjusted for ties)

Treat	N	Est Median	Sum of Ranks
1	4	18.6	5.0
2	4	29.6	9.0
3	4	186.1	16.0
4	4	211.2	17.0
5	4	171.2	13.0
Grand median	=	123.3	

Friedman Test: Total versus Treat, Reps

Friedman test for Total by Treat blocked by Reps

S = 10.00 DF = 4 P = 0.040

S = 10.26 DF = 4 P = 0.036 (adjusted for ties)

Treat	N	Est Median	Sum of Ranks
1	4	27.1	5.0
2	4	35.5	9.0
3	4	210.5	16.0
4	4	227.9	17.0
5	4	184.1	13.0
Grand median	=	137.0	

2. Data Analysis from 7/8 Feb

2.1 Comparing positions

ANOVAs were carried out on transformed counts (square root) to compare counts at various treatments and positions. Thus the associated conclusions are drawn from transformed counts, but the mean tables and graph are based on the original counts.

On 8 Feb, significant differences in counts occurred on different positions. Of the 'Adults' and Total count, more insects were in the 'split' and 'neck' than were in the other positions. Most 'Larvae' were on the 'neck'. There were no significant differences among larvae counts in the 'split', 'bulb' and 'base'; but there were significant differences between 'split' and 'control', and also between 'bulb' and 'control'.

The mean tables and associated graph are as follows:

```
***** Tables of means *****

Variate: Adult

Grand mean  0.187

 Position      base      bulb    leaves      neck     split
              0.070     0.110     0.000     0.330     0.380

Variate: Larvae

Grand mean  0.188

 Position      base      bulb    leaves      neck     split
              0.050     0.170     0.000     0.520     0.220

Variate: Total

Grand mean  0.375

 Position      base      bulb    leaves      neck     split
              0.120     0.280     0.000     0.850     0.600
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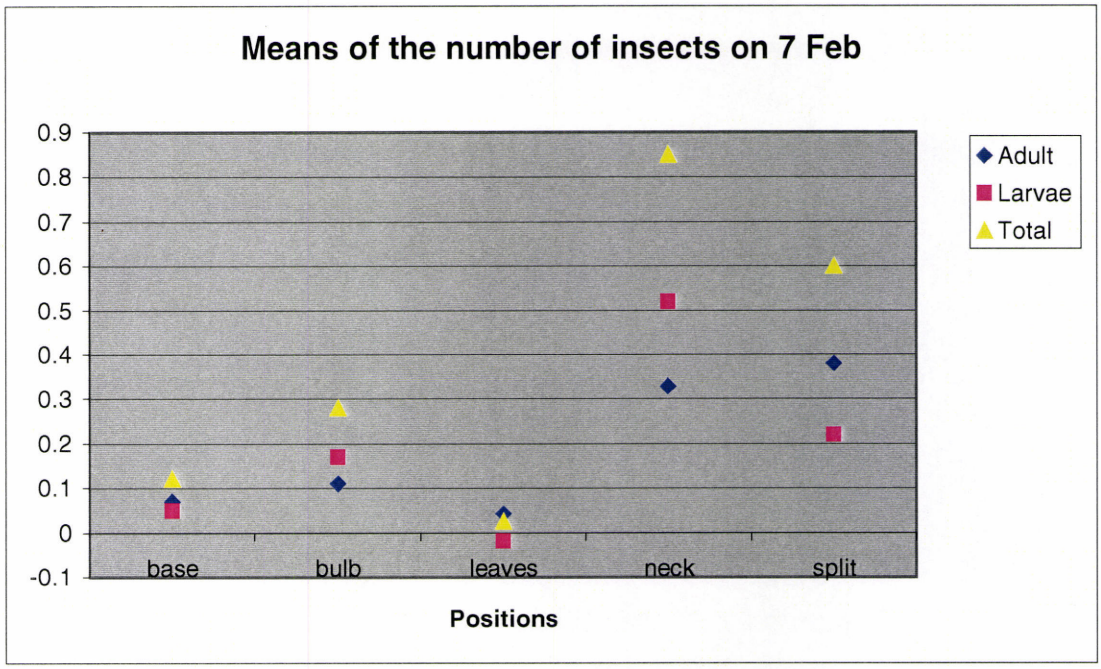

***** Analysis of variance (Feb) *****

Variate: sqrtAdul ANALYSIS OF SQUARE ROOT OF ADULT COUNTS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.06422	0.02141	0.28	
Reps.*Units* stratum					
Treat	4	0.18715	0.04679	0.61	0.657
Green vs Others	1	0.01935	0.01935	0.25	0.617
Position	4	4.06530	1.01633	13.26	<.001
Treat.Position	16	1.29156	0.08072	1.05	0.415
Green vs Others.Position	4	0.19026	0.04756	0.62	0.649
Residual	72	5.51983	0.07666		
Total	99	11.12807			

***** Tables of means *****

Variate: sqrtAdult

Grand mean 0.258

Treat	50%l	50%t	control	Gl	Gt
	0.205	0.307	0.229	0.239	0.312

Position	base	bulb	leaves	neck	split
	0.157	0.147	0.000	0.459	0.529

Treat	Position	base	bulb	leaves	neck	split
50%l		0.224	0.194	0.000	0.224	0.382

50%t	0.224	0.000	0.000	0.656	0.657
control	0.112	0.224	0.000	0.494	0.316
Gl	0.112	0.158	0.000	0.224	0.702
Gt	0.112	0.158	0.000	0.698	0.590

*** Least significant differences of means (5% level) ***

Table	Treat	Position	Treat Position
rep.	20	20	4
d.f.	72	72	72
l.s.d.	0.1745	0.1745	0.3903

***** Analysis of variance (Feb) *****

Variate: sqrtLar ANALYSIS OF SQUARE ROOT OF LARVAE COUNTS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	1.0706	0.3569	3.14	
Reps.*Units* stratum					
Treat	4	0.6299	0.1575	1.39	0.248
Green vs Others	1	0.4729	0.4729	4.16	0.045
Position	4	3.0382	0.7595	6.68	<.001
Treat.Position	16	1.1570	0.0723	0.64	0.844
Green vs Others.Position	4	0.3686	0.0921	0.81	0.522
Residual	72	8.1838	0.1137		
Total	99	14.0794			

***** Tables of means *****

Variate: sqrtLarvae

Grand mean 0.226

Treat	50%l	50%t	control	Gl	Gt
	0.344	0.271	0.232	0.169	0.115

Position	base	bulb	leaves	neck	split
	0.099	0.230	0.000	0.509	0.293

Treat	Position	base	bulb	leaves	neck	split
50%l		0.270	0.454	0.000	0.577	0.417
50%t		0.000	0.158	0.000	0.883	0.316
control		0.112	0.158	0.000	0.474	0.417
Gl		0.000	0.270	0.000	0.417	0.158
Gt		0.112	0.112	0.000	0.194	0.158

*** Least significant differences of means (5% level) ***

Table	Treat	Position	Treat Position
rep.	20	20	4
d.f.	72	72	72
l.s.d.	0.2125	0.2125	0.4752

***** Analysis of variance (Feb) *****

Variate: sqrtTot ANALYSIS OF SQUARE ROOT OF TOTAL COUNTS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Reps stratum	3	0.7710	0.2570	2.22	
Reps.*Units* stratum					
Treat	4	0.1878	0.0469	0.40	0.805
Green vs Others	1	0.1421	0.1421	1.23	0.272
Position	4	9.3230	2.3307	20.10	<.001
Treat.Position	16	1.2768	0.0798	0.69	0.796
Green vs Others.Position	4	0.1628	0.0407	0.35	0.843
Residual	72	8.3492	0.1160		
Total	99	19.9077			

***** Tables of means *****

Variate: sqrtTotal

Grand mean 0.413

Treat	50%l	50%t	control	Gl	Gt
	0.449	0.474	0.409	0.358	0.377

Position	base	bulb	leaves	neck	split
	0.240	0.298	0.000	0.815	0.715

Treat	Position	base	bulb	leaves	neck	split
50%l		0.417	0.512	0.000	0.706	0.612
50%t		0.224	0.158	0.000	1.183	0.805
control		0.224	0.274	0.000	0.816	0.733
Gl		0.112	0.352	0.000	0.559	0.767
Gt		0.224	0.194	0.000	0.810	0.656

*** Least significant differences of means (5% level) ***

Table	Treat	Position	Treat Position
rep.	20	20	4
d.f.	72	72	72
l.s.d.	0.2147	0.2147	0.4800

2.2 Comparing sites (areas)

On 8 Feb we find no significant difference in counts (averaged over all positions) among the 5 treatments for either adults, larvae or both (Total). This is based on results from Friedman's non-parametric test.

The mean tables and associated graph are as follows:

```
Variate: Adult

Grand mean   0.89

    Treat       50%l      50%t   control        Gl        Gt
                0.55      1.05      0.80      0.80      1.25
Variate: Larvae

Grand mean   0.96

    Treat       50%l      50%t   control        Gl        Gt
                1.65      1.35      0.85      0.60      0.35
Variate: Total

Grand mean   1.85

    Treat       50%l      50%t   control        Gl        Gt
                2.20      2.40      1.65      1.40      1.60
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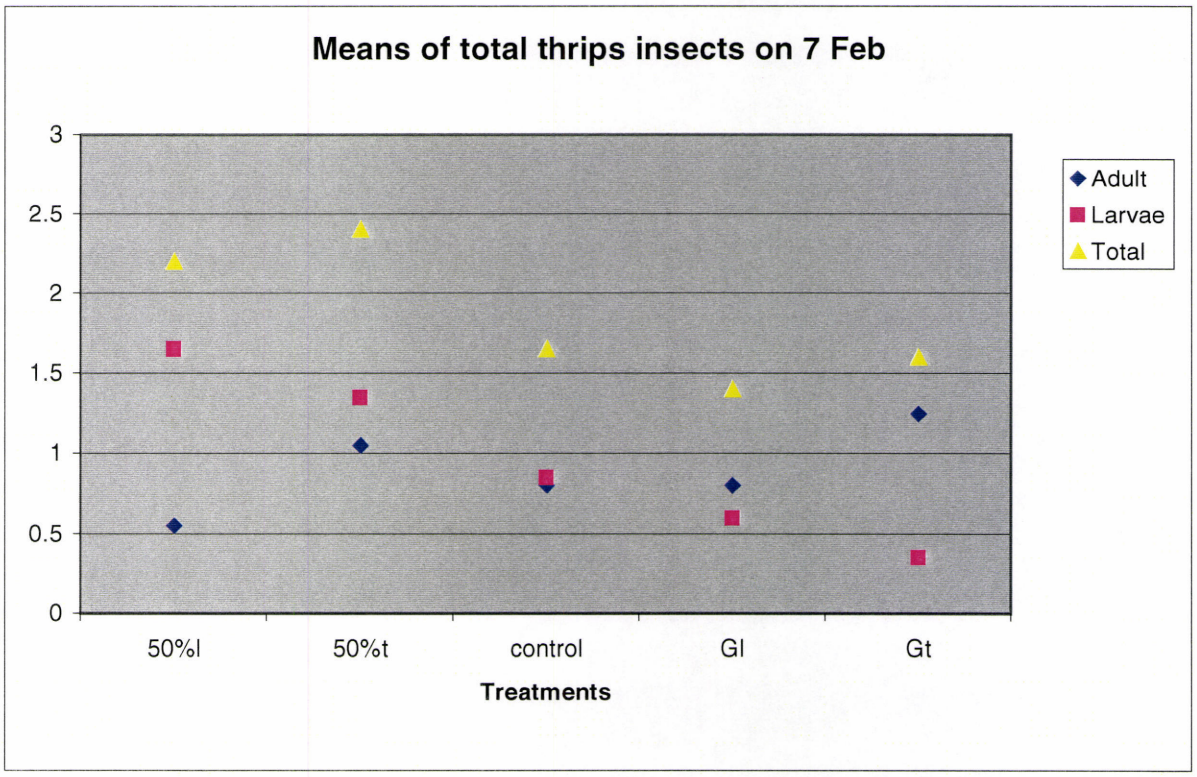

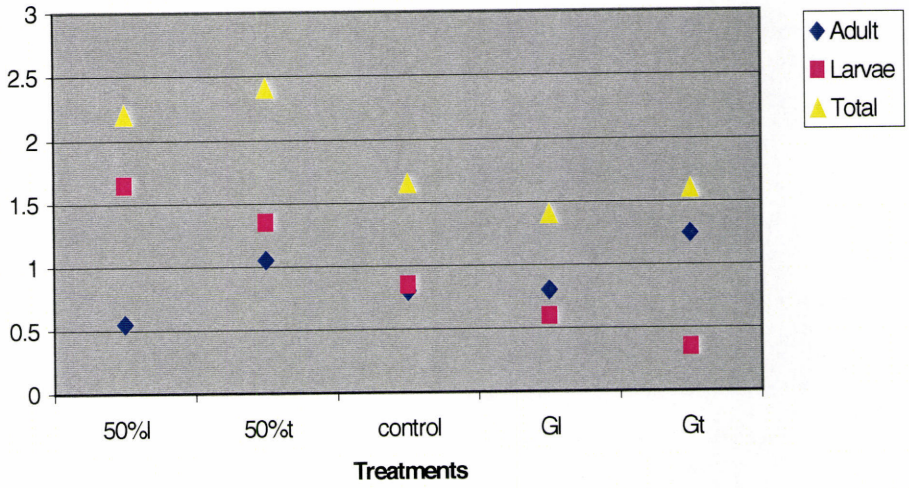

Figure 3: Mean numbers of thrips on onion plants on 8 February, 1 day after the 50% dry treatments.

4.3 Thrips populations at harvest and after storage

The raw data are summarised in Appendix II. Only 8% of bulbs were infested at harvest and less than 2.5% were infested after five weeks storage, with about 0.1 and 0.03 thrips per bulb respectively (Table 1). This is about 1.3 thrips per infested bulb. Adults and larvae were present on both occasions.

The numbers of thrips were too low for statistically significant differences between treatments to be detected.

Table 1: Mean proportion of onion bulbs infested with onion thrips and mean numbers of thrips per onion at harvest (27 February 2001) and after five weeks storage at ambient temperature (2 April 2001). Numbers of bulbs examined per treatment 80 (27 Feb), 100 (2 April).

	Mean proportion of infested bulbs out of 80		Mean proportion of thrips per bulb out of 80	
Treatment	27 Feb	2 April	27 Feb	2 April
Green, lifted	0.05	0.05	0.087	0.08
Green topped	0.125	0.01	0.15	0.01
50% dry lifted	0.05	0.04	0.075	0.05
50% dry topped	0.113	0.01	0.138	0.01
Control	0.75	0.01	0.075	0.01
All treatments	0.083	0.024	0.105	0.032

Friedman Test: Adult versus Treat, Reps

Friedman test for Adult by Treat blocked by Reps (Feb total)

S = 5.35 DF = 4 P = 0.253
S = 5.78 DF = 4 P = 0.216 (adjusted for ties)

Treat	N	Est Median	Sum of Ranks
1	4	1.1300	17.0
2	4	0.9300	12.5
3	4	1.0700	13.0
4	4	0.6700	7.0
5	4	0.7500	10.5

Grand median = 0.9100

Friedman Test: Larvae versus Treat, Reps

Friedman test for Larvae by Treat blocked by Reps (Feb total)

S = 5.20 DF = 4 P = 0.267
S = 5.47 DF = 4 P = 0.242 (adjusted for ties)

Treat	N	Est Median	Sum of Ranks
1	4	0.4600	6.5
2	4	0.6400	11.5
3	4	1.0800	16.5
4	4	1.4000	12.5
5	4	0.7200	13.0

Grand median = 0.8600

Friedman Test: Total versus Treat, Reps

Friedman test for Total by Treat blocked by Reps (Feb total)

S = 2.75 DF = 4 P = 0.600
S = 3.24 DF = 4 P = 0.519 (adjusted for ties)

Treat	N	Est Median	Sum of Ranks
1	4	1.7700	10.0
2	4	1.8300	10.5
3	4	2.3900	16.5
4	4	2.2900	12.0
5	4	1.7700	11.0

Grand median = 2.0100