FINAL REPORT

To:
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Leek and onion: targeting insecticide treatments against *Thrips tabaci*

FV 296

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Grower Summary

FV 296

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targeting insecticide treatments
against *Thrips tabaci*

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Project Leader:	Rosemary Collier Warwick HRI**,** Wellesbourne, Warwick CV35 9EF
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Location of project:	Warwick HRI**,** Wellesbourne, Warwick CV35 9EF
Project co-ordinator:	Gareth Skinner
Date project commenced:	1 June 2006
Date project completed:	31 December 2006
Key words:	*Thrips tabaci*, onion thrips, leek, diurnal periodicity

Signed on behalf of: **Warwick HRI**

Signature:………………..…………………………………… Date: ………………………

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LEEK AND ONION: TARGETING INSECTICIDE TREATMENTS AGAINST *THRIPS TABACI*

Headline

- Improved understanding of thrips distribution within leek crops has been achieved.
- There is insufficient evidence that foliar applications at any particular time of day, or under any particular weather conditions, will improve contact between the insecticide and the thrips.
- Growers are advised to view the results from the Defra-funded project which are included within the action points for growers below.

Background and expected deliverables

One of the reasons for poor thrips control on allium crops is their inaccessibility to contact insecticides, particularly on leek. A number of growers/consultants have asked whether there is a certain time of day when thrips are more likely to be on the upper part of the plant and therefore more accessible to insecticides. Thrips activity and their location on the plant is likely to be affected by time of day, temperature and possibly also by moisture.

The aim of this project was to determine whether there is a time of day, or certain weather conditions, when thrips are more likely to be accessible to foliar sprays of insecticides. This information, in conjunction with information on spray programmes (being addressed in a Defra-funded project 'Thrips control in allium crops'), should help growers to target treatments more accurately.

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Summary of the project and main conclusions

The specific objective of the work was to determine the location of adult and larval *Thrips tabaci* on leek plants at different times of day and under different weather conditions.

A large plot of leek was grown at Warwick HRI, Wellesbourne in 2006 as part of the Defra-funded project on thrips control. The leek seed was direct-drilled on 5 April 2006. The plot was free from insecticides and was close to a source of *T. tabaci* (an overwintered crop of leek).

Once an infestation of thrips became established in the new plot, the distribution of thrips on leek plants was recorded on a number of days throughout the summer. On each sampling day, a random sample of 10 leeks was removed from the plot at intervals (from before dawn until after dusk) and immediately divided into discrete sections which were sealed in polythene bags. The leeks were then taken to a laboratory, stored temporarily in a cool place, and examined to determine the numbers of adult and larval thrips present in each section.

The information from all sampling days was summarised to determine whether a) there was a significant change in thrips distribution over time and b) whether this was related to time of day or to weather conditions (temperature and moisture).

The main conclusions were as follows:

Thrips larvae are confined mostly to the lower parts of the leaves of leek plants and particularly to the area where the leaves branch out from the shaft. Adult thrips are more widely distributed on leek plants, but again are concentrated in the lower leaf area. There are no major shifts in distribution during the day. The overall distributions of adult and larval thrips sampled on six sampling days versus time of day are shown in Figures 1 and 2.

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Figure 1. Distribution of larval thrips on six sampling dates in 2006 – proportion in each zone versus time of day. N.B. branch = zone where most leaves branch out from shaft.

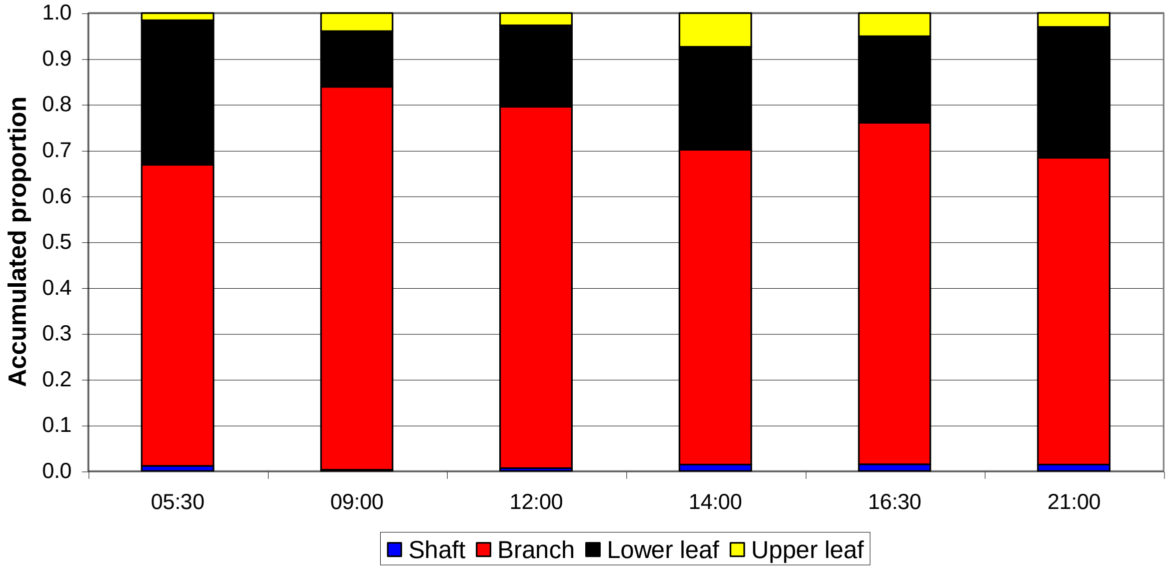
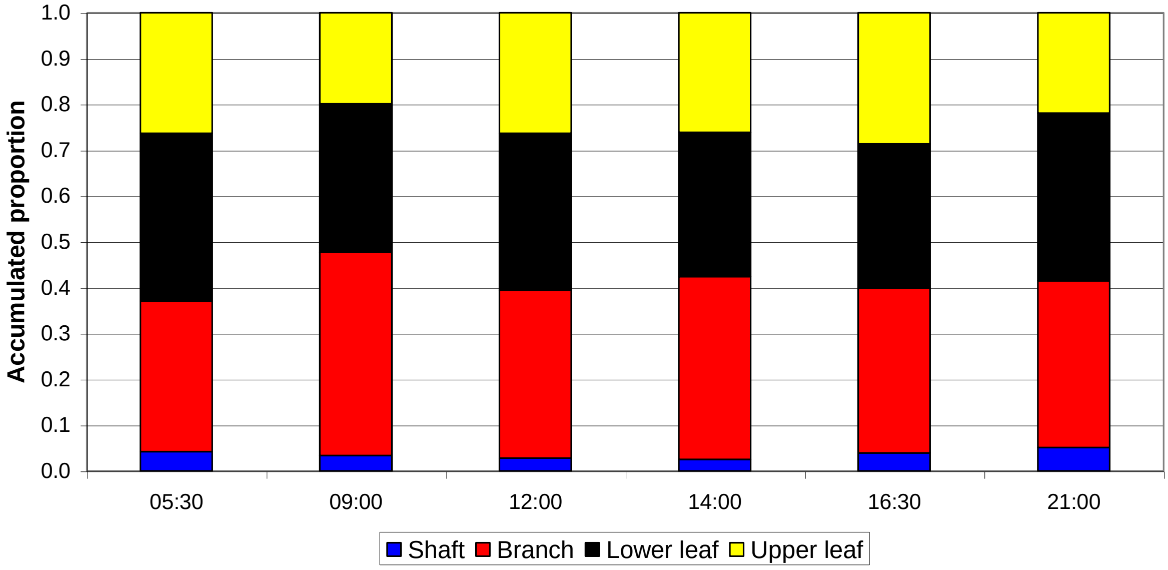


Figure 2. Distribution of adult thrips on six sampling dates in 2006 – proportion in each zone versus time of day. N.B. branch = zone where most leaves branch out.



There is some evidence that thrips may move up the plant in response to an increase in temperature.

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There is also limited evidence that thrips distribution may be affected by rainfall since an increased proportion of adult thrips were found on the upper parts of leaves on days when rainfall was recorded, while the proportions in the other three zones decreased with rainfall (Figure 3). For the larvae there was a decrease in the proportion found where the leaves branch when there was rainfall, and an increase in the other three zones. However, the sample size was small, so these results should be treated with caution.

Figure 3. Distribution of adult thrips on days with or without rain between mid August and mid September – averaged over all sampling dates.

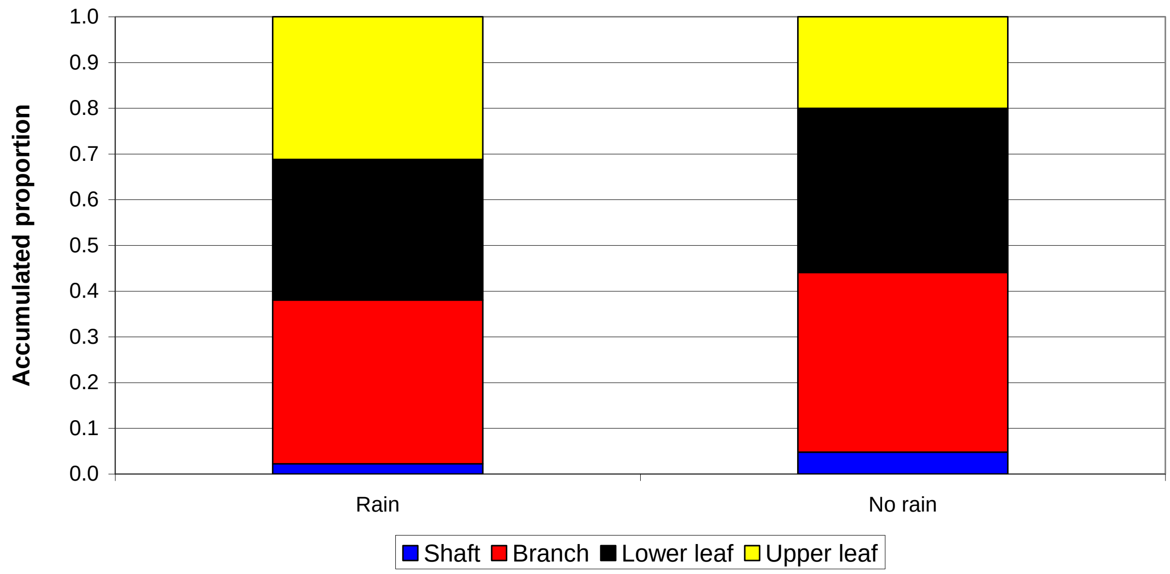

Figure 4. Distribution of larval thrips on days with or without rain between mid August and mid September – averaged over all sampling dates.

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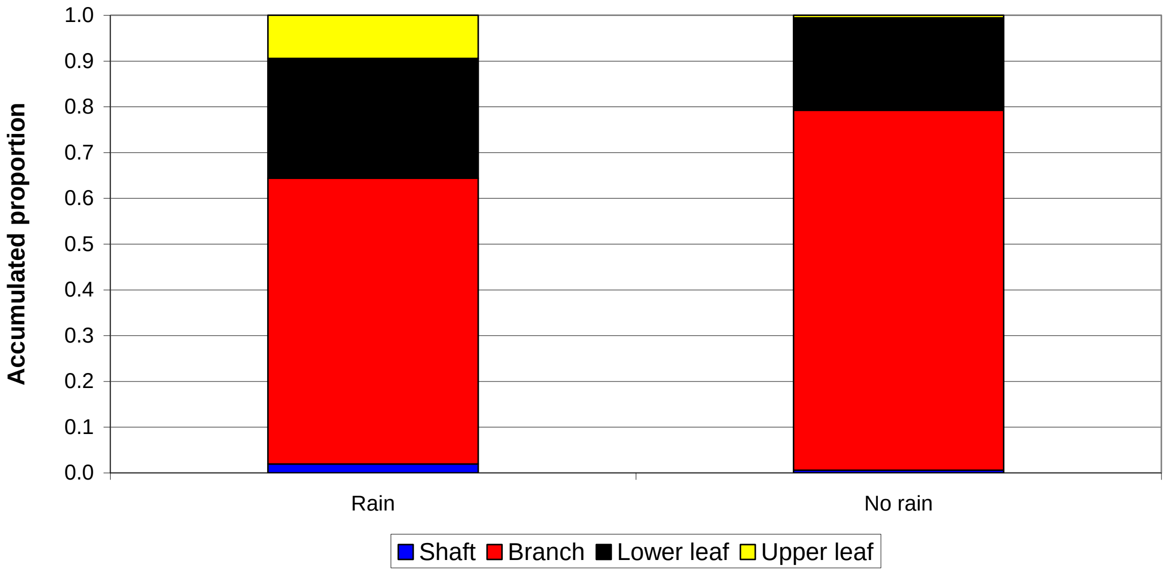

Financial benefits

- There are no direct financial benefits resulting from this project. However, this study has provided growers with an improved understanding of thrips distribution which should be used in conjunction with information on spray programmes (being addressed in a Defra-funded project 'Thrips control in allium crops').

Action points for growers

- Thrips larvae are confined mostly to the lower parts of the leaves of leek plants and particularly to the area where the leaves branch out from the shaft. Adult thrips are more widely distributed on leek plants, but again are concentrated in the lower leaf area. There are no major shifts in distribution during the day. However, there is some evidence that thrips may move up the plant in response to an increase in temperature.

- It is likely, because of the greater proportion of adults on the upper and lower parts of the foliage, that adult thrips are more accessible to insecticides than the larvae and that these should be a target for insecticidal spray treatments.

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However, there is no clear evidence that application at a certain time of day will improve contact between the insecticide and its target pest.

- There is limited evidence that thrips distribution may be affected by rainfall since an increased proportion of adult thrips were found on the upper parts of leaves on days when rainfall was recorded, while the proportions in the other three zones decreased with rainfall. For the larvae there was a decrease in the proportion found where the leaves branch when there was rainfall, and an increase in the other three zones (shaft, upper and lower parts of leaves).

Insecticide trials conducted on leeks in 2004 & 2005 as part of a Defra-funded project:

- Confirmed that Tracer (spinosad) is more effective than pyrethroid insecticides
- Showed that application of Tracer with either sugar or Majestik does not improve its efficacy.
- Identified at least one other product that appears to be as effective as spinosad as a foliar spray and which is likely to have a commercial future in the UK.
- Confirmed that experimental seed treatments provided a useful level of thrips control early in the season.
- Showed that pyrethroids (at least at Wellesbourne) do not control thrips on leek. Resistance to pyrethroid insecticides has since been confirmed in all of the thrips populations sampled from commercial allium crops and tested in summer 2006 (Steve Foster, Rothamsted Research, personal communication).

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SCIENCE SECTION

Introduction

Persistent difficulties with onion thrips (*Thrips tabaci*) control led to a Defra-funded project 'Thrips control in allium crops' (Jan 2004-Dec 2006). The purpose of the project was to develop a strategy for thrips control on allium crops to include the use of novel insecticides, but supported where possible by non-insecticidal techniques. Specific aims of the project were to:

- Evaluate a day-degree forecast and 'action' threshold for timing spray applications.
- Determine the efficacy and persistence of 'new' insecticides applied as foliar sprays and the impact of applying sprays in sugar solutions, with sugar products or other spray adjuvants.
- Determine the efficacy and persistence of potential insecticide seed treatments, so that foliar spray treatments can be targeted subsequently.
- Evaluate the use of entomopathogenic nematodes as part of an integrated programme**.**
- Develop an integrated programme for thrips control on leek.

The insecticide trials done on leek in 2004 and 2005 as part of the Defra-funded project:

- Confirmed that Tracer (spinosad) is more effective than pyrethroid insecticides
- Showed that application of Tracer with either sugar or Majestik does not improve its efficacy.
- Identified at least one other product that appears to be as effective as spinosad as a foliar spray and which is likely to have a commercial future in the UK.
- Confirmed that seed treatments (with any of three compounds) provided a useful level of thrips control early in the season.

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- Showed that pyrethroids (at least at Wellesbourne) do not control thrips on leek. Resistance to pyrethroid insecticides has since been confirmed in all of the thrips populations sampled from commercial allium crops and tested in summer 2006 (Steve Foster, personal communication).

Apart from insecticide resistance, one of the reasons for poor thrips control is their inaccessibility to contact insecticides, particularly on leek. This may be one reason why Tracer fails to provide good levels of control on certain occasions. A number of growers and consultants have asked whether there is a certain time of day when thrips are on the upper part of the plant and therefore more accessible to insecticides. Their activity and location on the plant is likely to be affected by time of day, temperature and possibly also by moisture.

Sites *et al.* (1992) studied the distribution of *Thrips tabaci* on onion plants in Texas, USA. However, temperatures were much higher in Texas (maximum daily temperature 27- 40^{o}C) than in the UK, so that comparisons may be of limited value. A very small study done at Warwick HRI, Wellesbourne in 2005 indicated that it was necessary to repeat observations over a number of days – to separate out the effects of weather from time of day. These observations were pursued in more detail in 2006 in the current project using a plot of insecticide-free leeks that was established as part of the Defra-funded project.

Experimental

The overall aim of the project was to determine whether the weather and time of day affect the accessibility of thrips to insecticides. The specific objective of the work was to determine the location of adult and larval *Thrips tabaci* on leek plants at different times of day and under different weather conditions.

A large plot of leek was grown at Warwick HRI, Wellesbourne in 2006 as part of the Defra-funded project on thrips control. The leek seed (cv Shelton) was direct-drilled on 5 April 2006. The plot was free from insecticides and was close to a source of *T. tabaci* (an overwintered crop of leek).

Once an infestation of thrips became established in the new plot, the distribution of thrips on leek plants was recorded on days with differing weather conditions. On each sampling day, a random sample of 10 leeks was removed from the plot at intervals (from before dawn until after dusk), immediately divided into discrete sections (from the base to the tip of the leaves) and sealed in polythene bags. The leeks were then taken to a laboratory, stored temporarily in a cool place, and examined to determine the numbers of adult and larval thrips present in each section.

Thrips are very small and there can be differences in recording efficiency between individuals (Theunissen & Legutowska, 1992). To try and account for this, all the samples taken on a day were assessed by the same team. This usually consisted of two people, who each assessed half of the sample (5 plants) taken each time. A third person took the samples at the allotted intervals. Altogether, sampling and assessment on each date took approximately 2.5 person days.

The information from all sampling days was summarised to determine whether a) there was a significant change in thrips distribution over time and b) whether this was related to time of day or to weather conditions (temperature and rainfall). Temperature records were taken from a screened temperature logger recording air temperatures continuously at the Wellesbourne site. Obviously, the temperatures recorded by the logger are likely to be different from the temperatures in various locations (microclimates) in the leek crop. However, the logger data were used in the analysis because they provided a consistent record of the relative changes in air temperature over time. Rainfall was measured at the agro-meteorological station at Warwick HRI, Wellesbourne.

Results

Thrips population counts

The population of adult onion thrips that had spent the winter 2005-6 in an overwintered crop of leek produced larvae at the end of April 2006 (Figure 5) which completed their development on the old leek crop. The newly-emerged adults then moved onto the new plots. Regular monitoring showed that thrips numbers were initially low, but started to rise gradually (Figure 6). Both Figures 5 and 6 show that, in general, during the summer period, larvae were more numerous than adults on leek plants.

Figure 5. Numbers of thrips per plant in an insecticide-free leek plot at Wellesbourne from June 2005 to June 2006. The plot was planted in June 2005.

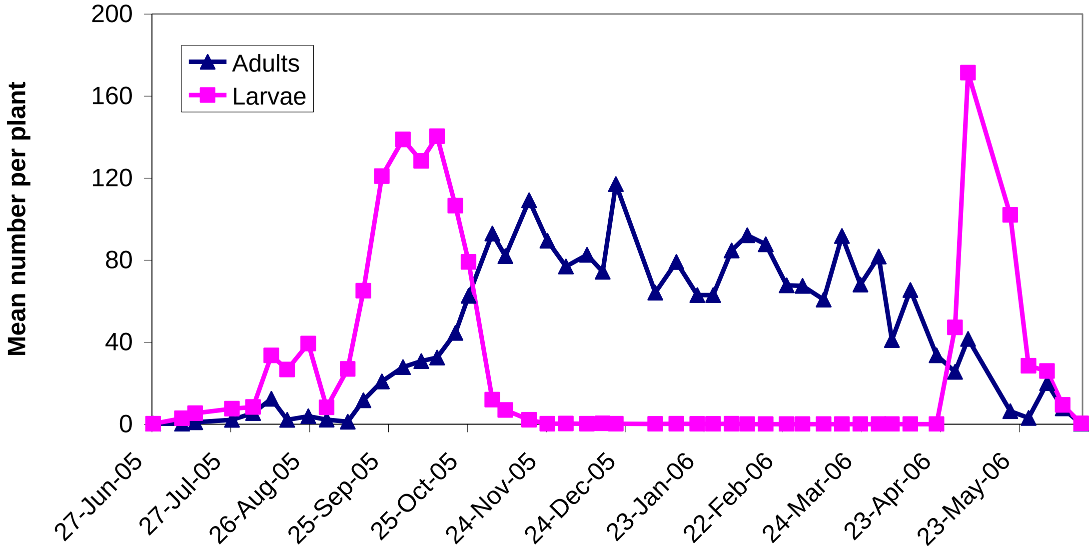
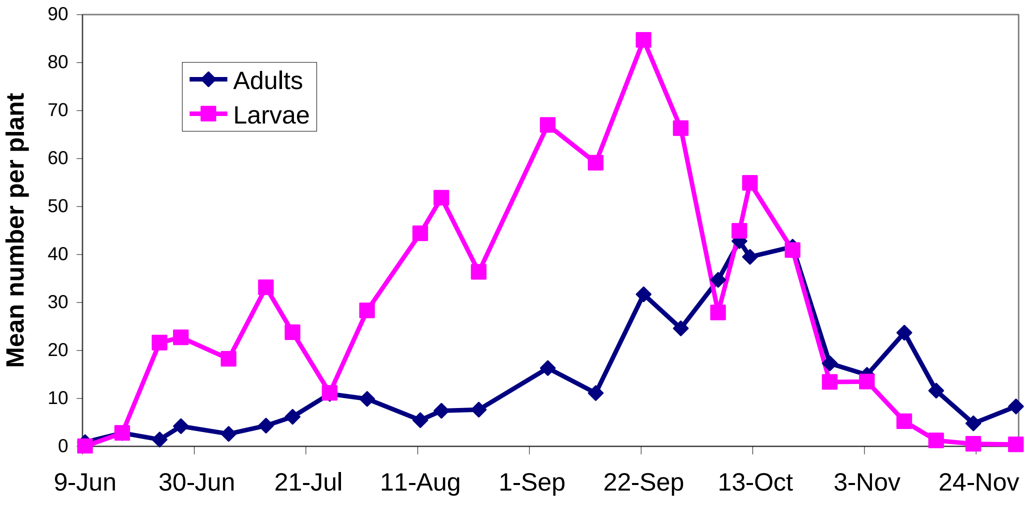


Figure 6. Numbers of thrips per plant in an insecticide-free leek plot at Wellesbourne. The plot was drilled on 5 April 2006.



First sample – 3 August 2006

The first sample was taken on 3 August when there was an average of 15 thrips per plant. For the first sample, each leek was divided into four sections: root zone, shaft, lower part of leaves, upper part of leaves. The count data were analysed using a generalised linear model (GLM) assuming a Poisson distribution and a log link function.

The base model contained the terms position + time + age +time.age, where position = position on plant, time = time of day, age = thrips stage of development (adult or larva). Interactions of position, age and time were added to the model and the accumulated analysis of deviance table for the full model is shown in Table 1. The interaction of position and age (adult or larva) was statistically significant. Figure 7 shows the predicted distribution of adult and larval thrips on 3 August 2006 – averaged over all sampling times.

Table 1. Analysis of thrips distribution data collected on 3 August 2006.

Change	d.f.	deviance	Mean deviance	Deviance ratio	Approx chi probability
+ position+time+age+time.age	**14**	**1904.405**	**136.029**	**136.03**	**<.001**
+ position.time	15	12.912	0.861	0.86	0.609
+ position.age	**3**	**82.607**	**27.536**	**27.54**	**<.001**
+ position.time.age	15	23.374	1.558	1.56	0.077
Residual	440	1049.727	2.386		
Total	487	3073.025	6.310		

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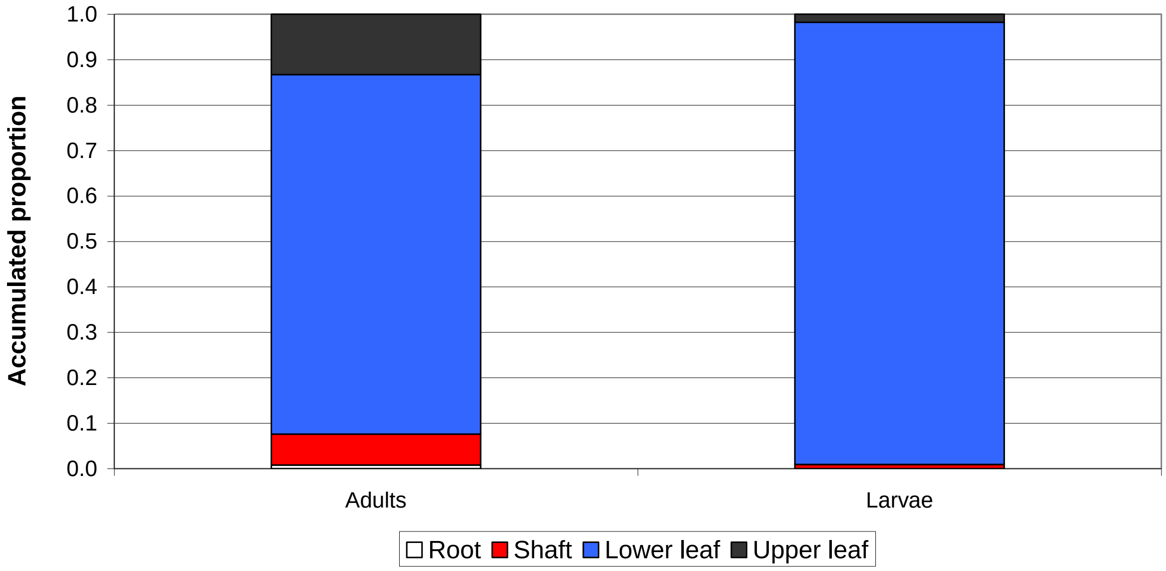
Figure 7. Predicted distribution of adult and larval thrips on 3 August 2006 – proportion in each zone averaged over all sampling times.



Almost all of the thrips larvae were found on the lower parts of the leaves and none were found in the root zone. The adult thrips were more widely distributed, but very few adults were found in the root zone.

Main sampling period (10 August – 13 September 2006)

Following assessment of the first sample, the sampling regions were altered to exclude the root zone and concentrate on the regions where more thrips were found. For the next batch of samples, taken on six dates (10 August, 15 August, 24 August, 7 September, 11 September, 13 September), the regions sampled consisted of: shaft, area where most leaves branch out (branch), lower part of leaves (lower leaf) and upper part of leaves (upper leaf). Adults and larvae were considered separately in the analysis.

Adult thrips

A GLM assuming a Poisson distribution with a log link function was used. There was evidence of over-dispersion and this was accounted for. Over-dispersion occurs when the variation in the data is greater than that predicted by the Poisson model. The accumulated analysis of deviance table for the full model is given in Table 2 and shows that the interaction of position.date was highly significant. The predicted distribution of adult thrips is summarised by date and time of day in Figures 8-11.

Table 2. Adult thrips - accumulated analysis of deviance table for six sampling dates in 2006.

Change	d.f.	Deviance	Mean deviance	Deviance ratio	Approx F probability
+ position + time + date					
+ time.date	**38**	**1468.314**	**38.640**	**14.24**	**<.001**
+ position.time	15	28.737	1.916	0.71	0.780
+ position.date	**15**	**377.683**	**25.179**	**9.28**	**<.001**
+ position.time.date	75	233.840	3.118	1.15	0.186
Residual	1200	3255.978	2.713		
Total	1343	5364.553	3.994		

Figure 8. Predicted distribution of adult thrips on six sampling dates in 2006 – counts in each zone versus date.

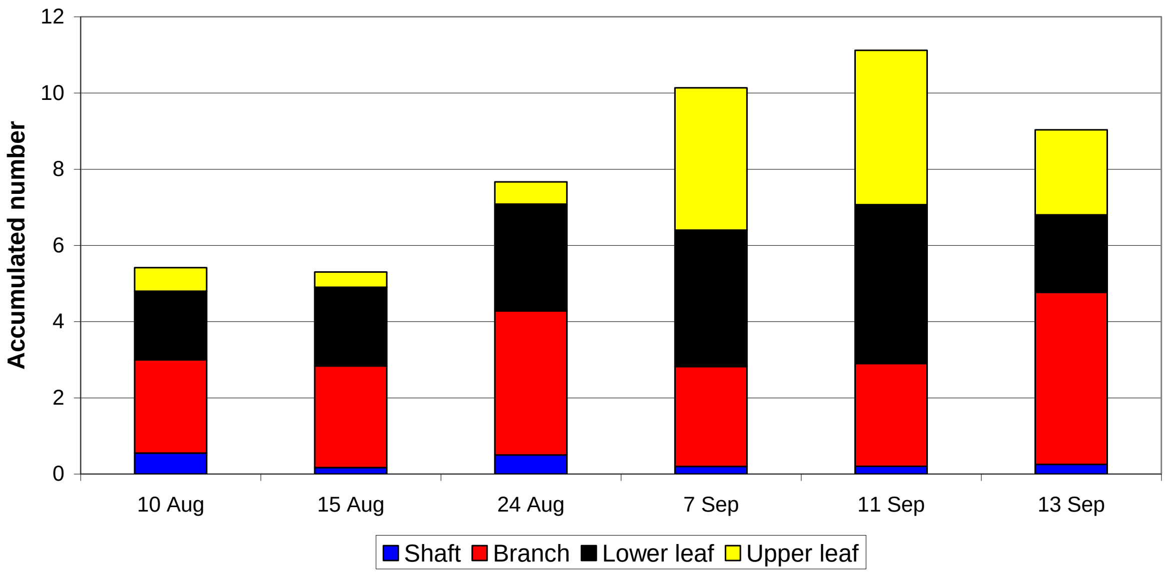


Figure 9. Predicted distribution of adult thrips on six sampling dates in 2006 – proportion in each zone versus date.

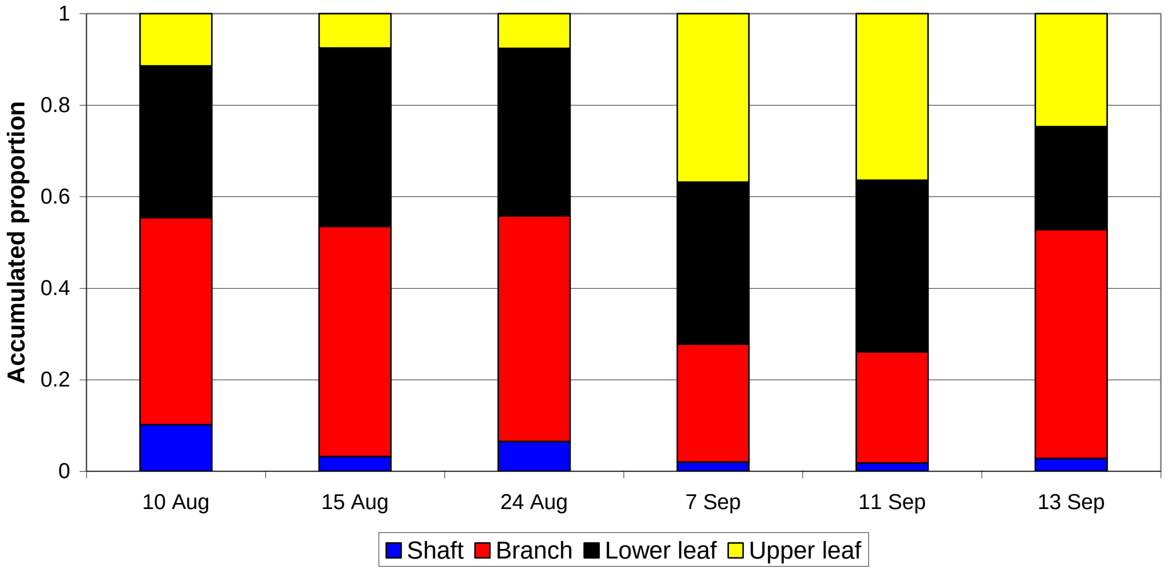


Figure 10. Predicted distribution of adult thrips on six sampling dates in 2006 – counts in each zone versus time of day.

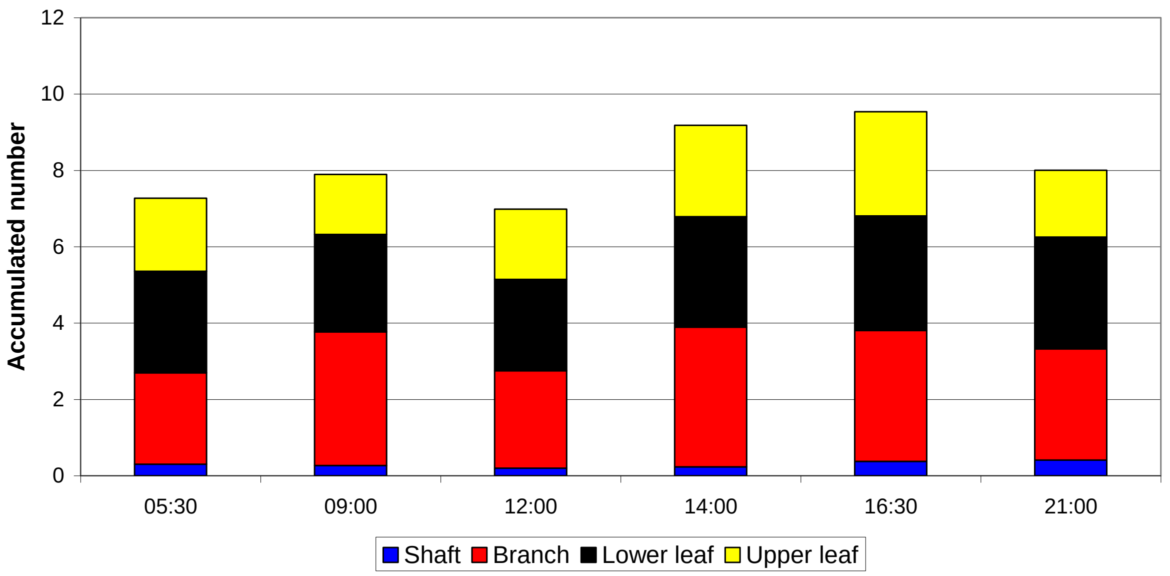
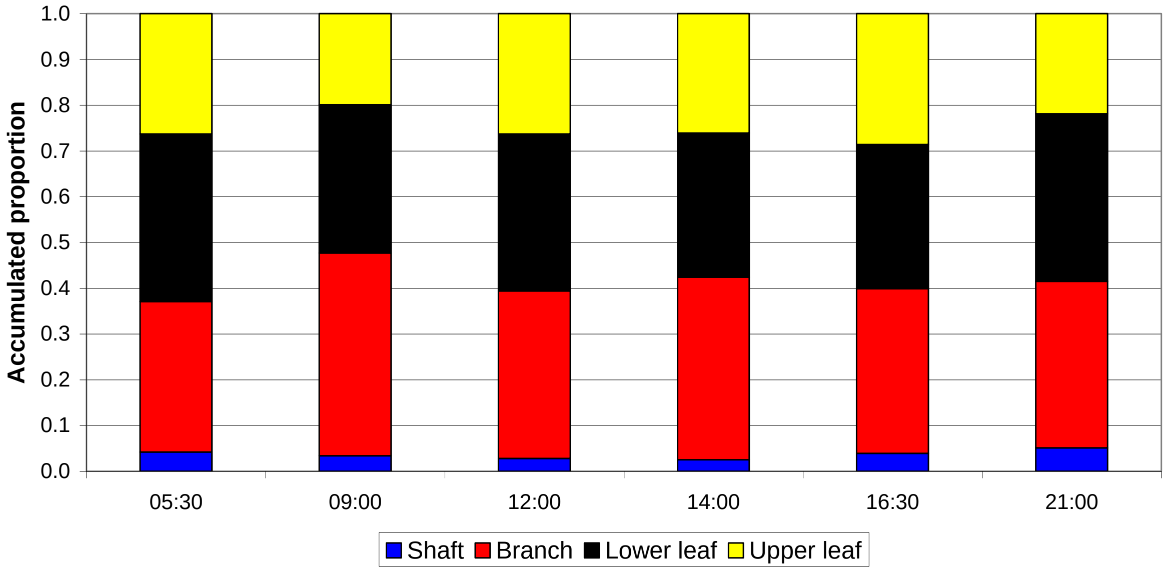


Figure 11. Predicted distribution of adult thrips on six sampling dates in 2006 – proportion in each zone versus time of day.

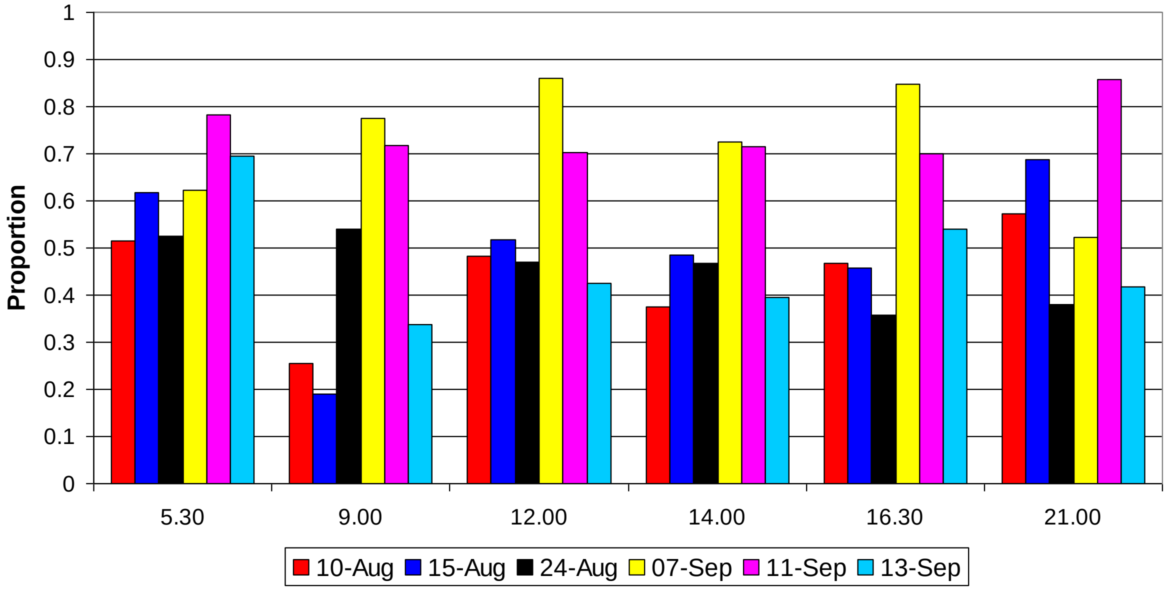


The proportion of adult thrips found on the leaves (upper and lower parts combined) was analysed using a GLM assuming a binomial distribution and a logit link function. The accumulated analysis of deviance (Table 3) suggested there was a significant interaction between date and time. The predicted proportions for adults on the upper and lower parts of the leaves at each sampling date are shown in Figure 12.

Table 3. Adult thrips - accumulated analysis of deviance table for six sampling dates in 2006.

Change	d.f.	Deviance	Mean deviance	Deviance ratio	Approx F probability
+ date	**5**	**212.720**	**42.544**	**15.26**	**<.001**
+ time	5	20.103	4.021	1.44	0.209
+ time.date	**25**	**114.270**	**4.571**	**1.64**	**0.031**
Residual	273	761.172	2.788		
Total	308	1108.264	3.598		

Figure 12. Predicted proportion of adult thrips on leaves (upper and lower parts together) versus sampling date and time.



Larval thrips

A GLM assuming a Poisson distribution with a log link function was used to analyse the counts of larvae. The accumulated analysis of deviance table for the full model (Table 4) shows that the interactions of position with both time and date were highly significant. Figures 13-16 summarise the predicted distribution of larval thrips by date and time of day.

Table 4. Larval thrips – accumulated analysis of deviance table for six sampling dates in 2006.

Change	d.f.	Deviance	Mean deviance	Deviance ratio	Approx F probability
+ position + time + dates					
+ time.date	**38**	**14251.947**	**375.051**	**47.49**	**<.001**
+ position.time	**15**	**368.141**	**24.543**	**3.11**	**<.001**
+ position.date	**15**	**1127.806**	**75.187**	**9.52**	**<.001**
+ position.time.dates	75	675.640	9.009	1.14	0.199
Residual	1200	9477.772	7.898		
Total	1343	25901.305	19.286		

Figure 13. Predicted distribution of larval thrips on six sampling dates in 2006 - number in each zone versus date.

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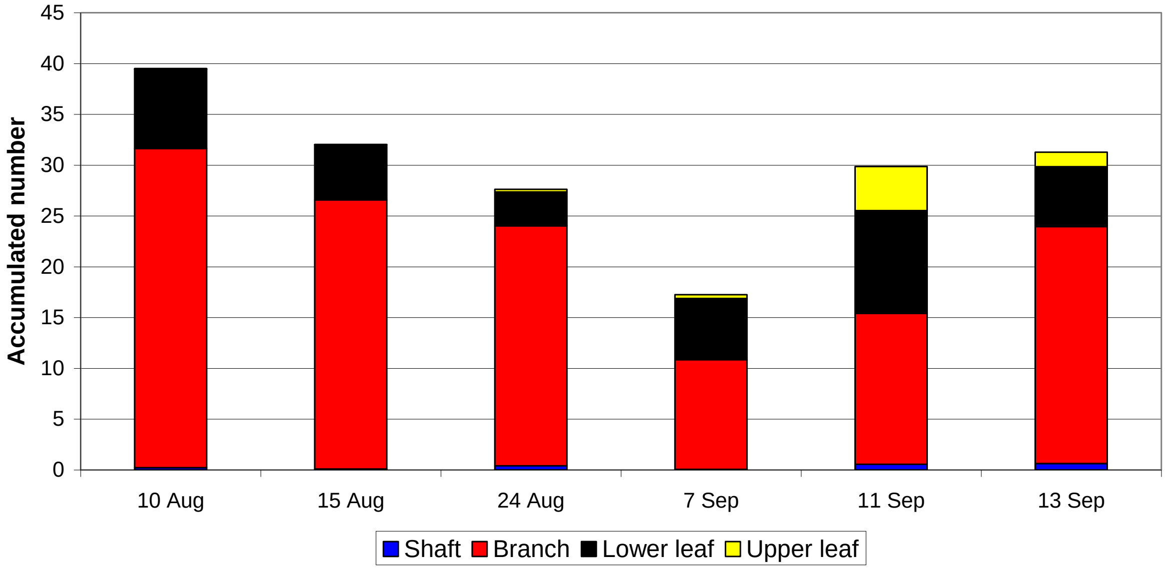
Accumulated number
45
40
35
30
25
20
15
10
5
0
10 Aug
15 Aug
24 Aug
7 Sep
11 Sep
13 Sep
Shaft
Branch
Lower leaf
Upper leaf

Figure 14. Predicted distribution of larval thrips on six sampling dates in 2006 - proportion in each zone versus date.

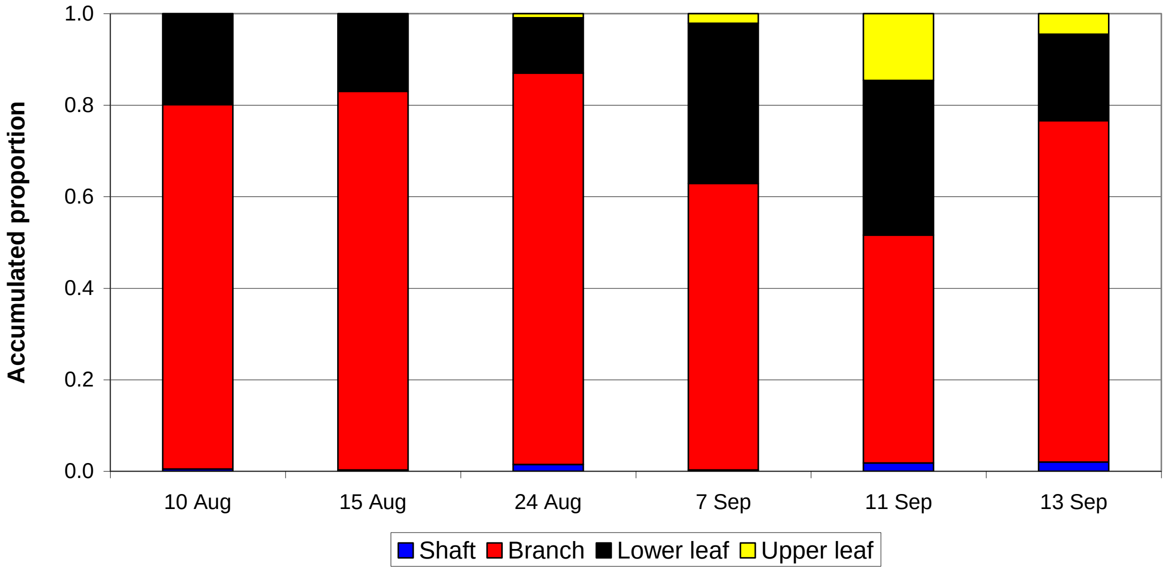

Figure 15. Predicted distribution of larval thrips on six sampling dates in 2006 – number in each zone versus time of day.

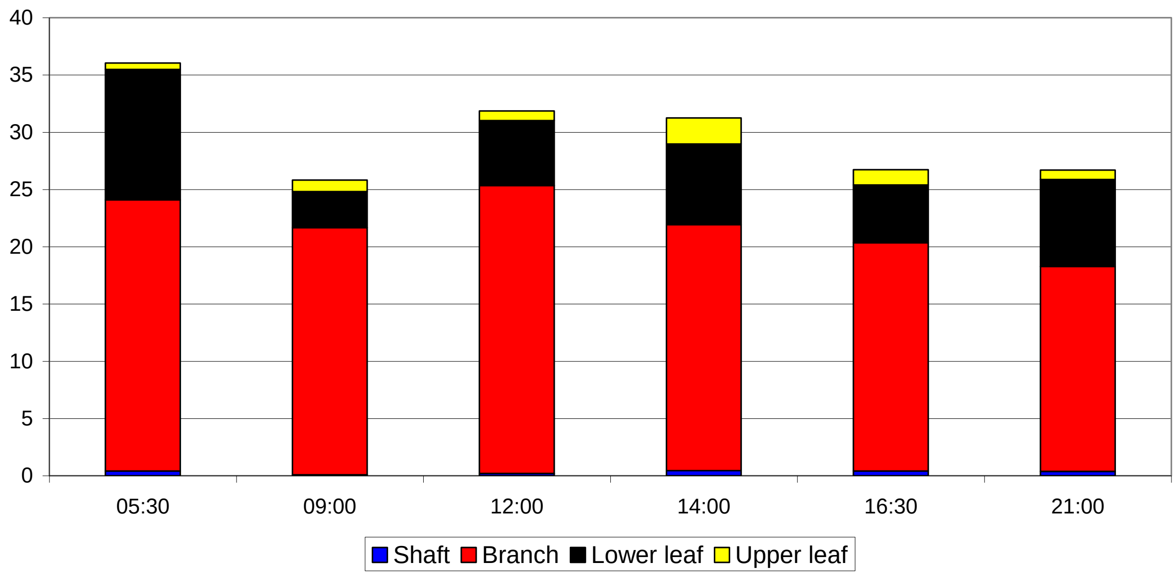

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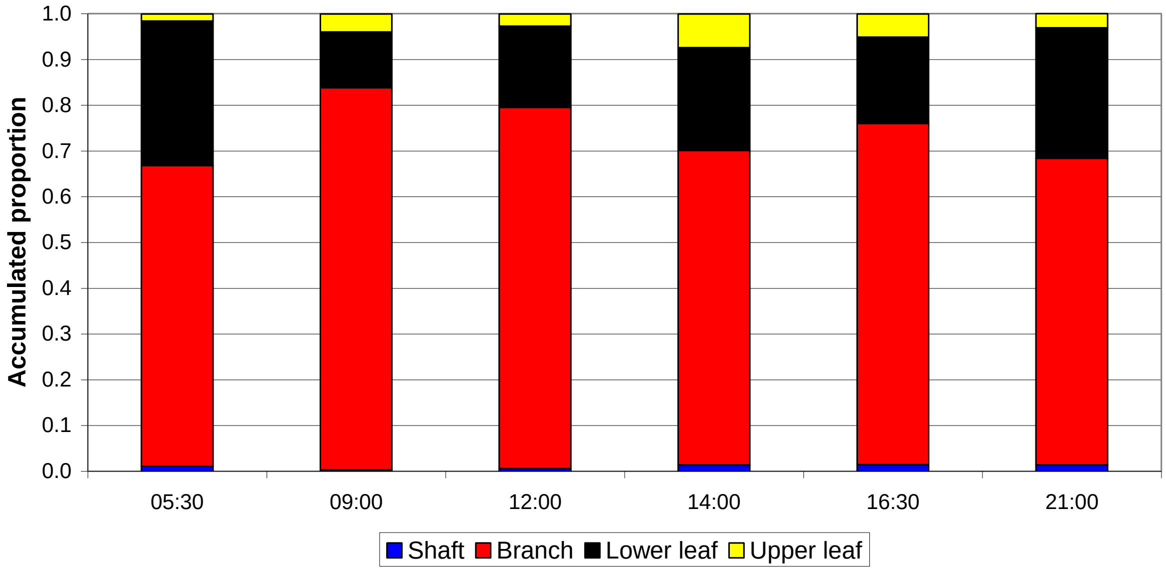
Figure 16. Predicted distribution of larval thrips on six sampling dates in 2006 – proportion in each zone versus time of day.



A GLM assuming a binomial distribution and logit link was used to analyse the proportion of larvae on the leaves (upper and lower parts combined). The accumulated analysis of deviance table (Table 5) shows that date, time and the interaction of date and time were highly significant. A consistently high proportion of larvae were found on the leaves on 11 September, while 24 August had a consistently low proportion. The predicted proportions of larvae on the upper and lower leaves on each sampling date are shown in Figure 17.

Table 5. Larval thrips - accumulated analysis of deviance table for six sampling dates in 2006.

Change	d.f.	Deviance	Mean deviance	Deviance ratio	Approx F probability
+ date	**5**	**715.611**	**143.122**	**16.84**	**<.001**
+ time	**5**	**197.904**	**39.581**	**4.66**	**<.001**
+ time.date	**25**	**582.908**	**23.316**	**2.74**	**<.001**
Residual	281	2387.565	8.497		
Total	316	3883.987	12.291		

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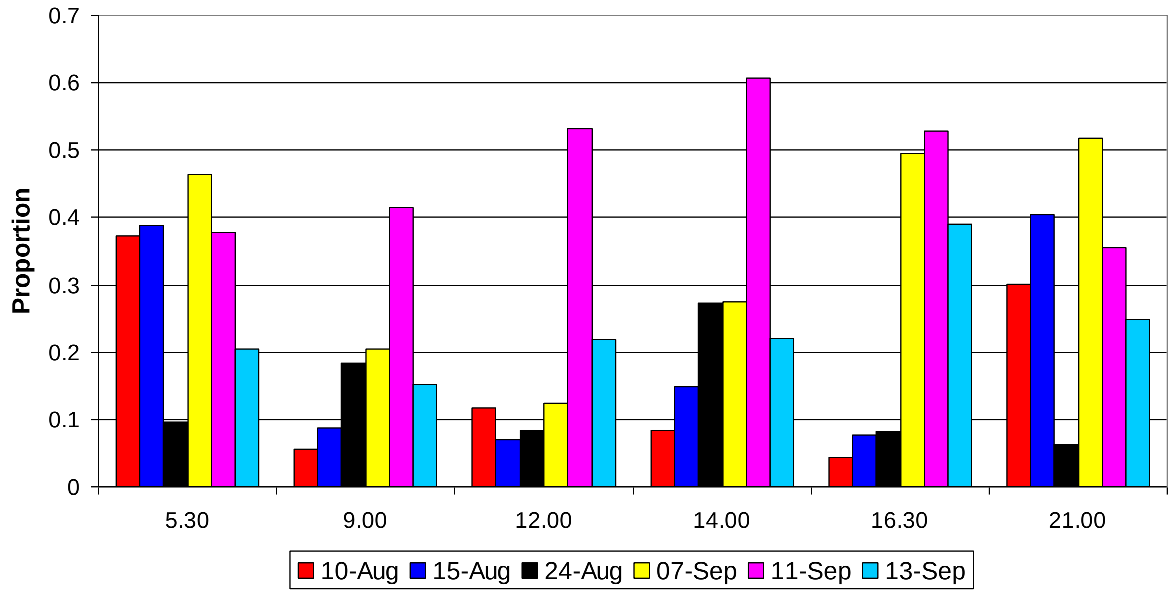
Figure 17. Predicted proportion of larval thrips on leaves (upper and lower parts together) versus sampling date and time.



Correlations with air temperature

The correlations between the proportion of adult thrips in each zone and the temperature were also calculated. A negative correlation suggests that as the temperature increased, the number, or proportion, of adults decreased. A test of the significance of the correlation coefficients suggested that there was a significant correlation between the temperature and the count of adults on the upper leaves and also for the proportion of adults on the shaft (p-value <0.05) (Table 6). Care must be taken when interpreting the significance of the test for the shaft proportions as the values were very small.

Table 6. Correlation coefficients – adult thrips distribution and temperature.

	Upper leaf	Lower leaf	Branch	Shaft
Counts	**0.400**	0.232	0.223	-0.324
Proportions	0.245	-0.110	-0.036	**-0.351**

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Correlations between the predicted counts of larvae (and the proportions), in each position at each sampling time and date, with temperature are given in Table 7. A test of the significance of the correlation coefficients suggested that there was a significant correlation between the temperature and the count and proportion of larvae on the upper leaves and also for the count of larvae on the shaft (p-value <0.05). It should be noted that the predicted counts on both the upper leaves and the shaft are very low, so care needs to be taken in interpreting the significance of these tests.

Table 7. Correlation coefficients – larval thrips distribution and temperature.

	Upper leaf	Lower leaf	Branch	Shaft
Counts	**0.612**	0.041	-0.148	**0.349**
Proportions	**0.597**	0.014	-0.245	0.297

Effect of rainfall

The rainfall was recorded for each of the 6 days and on two days (11 and 13 September), substantial rainfall (>20 mm) fell. The days have been grouped into two classes based on whether rainfall greater than 20 mm was recorded.

The initial analysis for adult thrips assuming a Poisson distribution was repeated with rainfall replacing dates in the model. The accumulated analysis of deviance table for a GLM assuming a Poisson distribution and log link function is given in Table 8. The predicted distribution of adult thrips on days with or without rain is shown in Figure 18. An increased proportion of adult thrips were found on the upper parts of leaves on days when rainfall was recorded, while the proportions in the other three zones decreased with rainfall.

Table 8. Adult thrips - accumulated analysis of deviance table for six sampling dates in 2006.

Change	d.f.	Deviance	Mean deviance	Deviance ratio	Approx F probability
+ position + time + rain					
+ time.rain	**14**	**1206.447**	**86.175**	**27.61**	**<.001**
+ position.time	15	28.737	1.916	0.61	0.866
+ **position.rain**	**3**	**50.484**	**16.828**	**5.39**	**0.001**
+ position.time.rain	15	33.669	2.245	0.72	0.767
Residual	1296	4045.216	3.121		
Total	1343	5364.553	3.994		

Table 8 can be compared with the table created when date is in the model (Table 2). By looking at how the deviances have changed it is possible to determine whether there is additional variation which is not explained by rainfall. In the rainfall model the deviances for the base model, position.rain and position.time.rain are all much smaller than the corresponding terms involving dates rather than rain.

The results from formal tests of the size of the additional variation explained by date relative to rainfall are given in Table 9. The significant results for the base model and the interaction between position and rainfall, suggest that there is extra variation between the dates that is not explained by rainfall.

Table 9. Adult thrips - results from formal tests of the size of the additional variation explained by date relative to rainfall.

Term	Change in df	Change in Deviance	Mean Deviance	Deviance Ratio	Approx F probability
Base model	24	261.867	10.911	4.022	<0.001
Position.rain	12	327.199	27.267	10.050	<0.001
Position.time.rain	60	200.171	3.336	1.230	0.116
Residual mean deviance from the dates model			2.713		

Figure 18. Predicted distribution of adult thrips on days with or without rain between mid August and mid September – averaged over all sampling dates.

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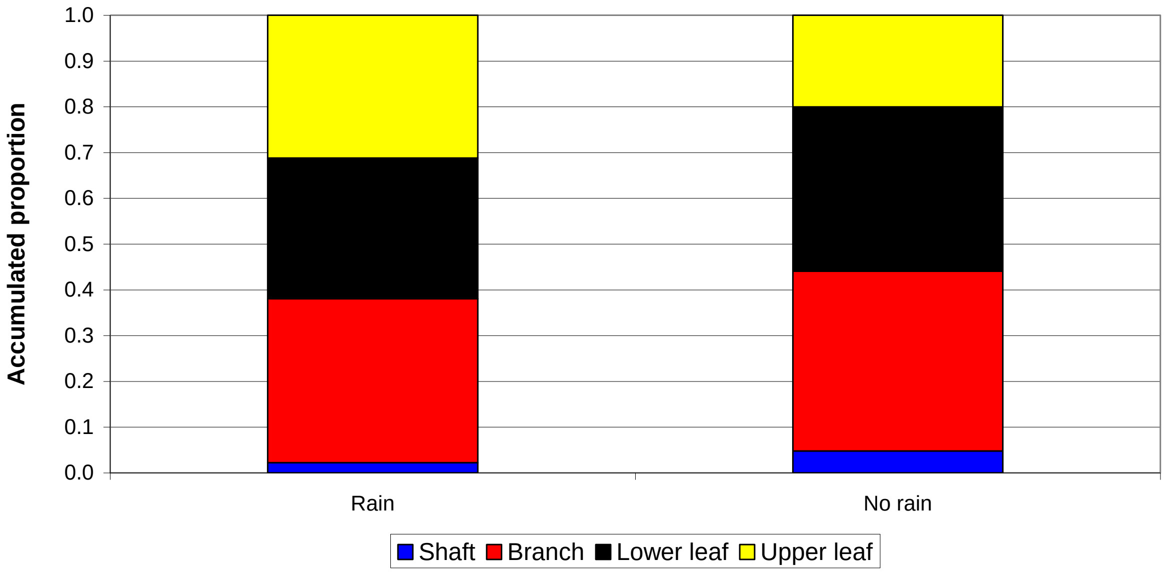


Larval thrips

Using the same rainfall classification as with the adult thrips, the accumulated analysis of deviance table for a GLM assuming a Poisson distribution and log link function for larval thrips is shown in Table 10.

Table 10. Larval thrips - accumulated analysis of deviance table for six sampling dates in 2006.

Change	d.f.	Deviance	Mean deviance	Deviance ratio	Approx F probability
+ position + time + rain					
+ time.rain	**14**	**3273.656**	**948.118**	**108.20**	**<.001**
+ position.time	**15**	**368.141**	**24.543**	**2.80**	**<.001**
+ position.rain	**3**	**638.368**	**212.789**	**24.28**	**<.001**
+ position.time.rain	15	264.438	17.629	2.01	0.012
Residual	1296	1356.702	8.763		
Total	1343	25901.305	19.286		

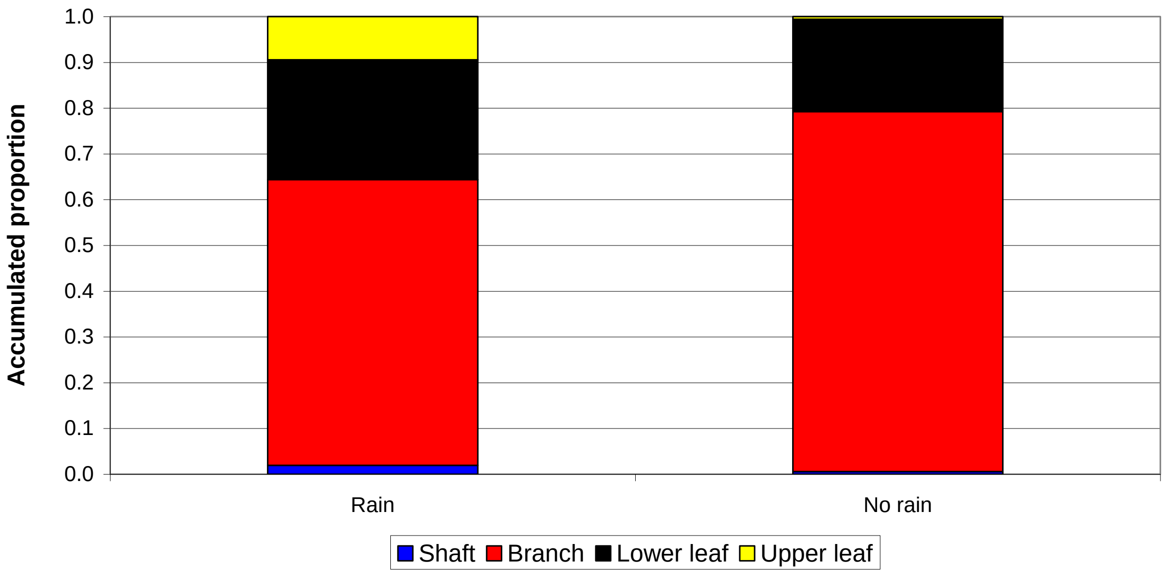
For larvae there was a decrease in the proportion found where the leaves branch when there was rainfall, and an increase in the other three zones (shaft and upper and lower parts of leaves). However, the sample size was small, so these results should be treated with caution. Figure 19 shows the predicted distribution of larval thrips on days with or without rain between mid August and mid September – averaged over all sampling dates.

Comparing Table 10 with the date model (Table 4) suggests that there is extra variation between the dates which is not being explained by rainfall. The results from formal tests of the size of the additional variation explained by date relative to rainfall are given in Table 11. The significant results for the base model and the interaction between position and rainfall, suggest that there is extra variation between the dates that is not explained by rainfall.

Table 11. Larval thrips - results from formal tests of the size of the additional variation explained by date relative to rainfall.

Term	Change in df	Change in Deviance	Mean Deviance	Deviance Ratio	Approx F probability
Base model	24	984.291	41.012	5.193	<0.001
Position.rain	12	489.438	40.786	5.164	<0.001
Positions.times.rains	60	411.202	6.853	0.868	0.753
Residual mean deviance from the date model			7.898		

Figure 19. Predicted distribution of larval thrips on days with or without rain between mid August and mid September – averaged over all sampling dates.



<u>Late season assessments</u>

A further two assessments were taken at the end of the season (28 September and 18 October) and on these occasions two samples were taken – one at 14:00 h and the other at 21:30 h). The plants were separated into two sections, 1) the leaves, above the region where they branch, and 2) the rest of the plant, to see if there were any gross differences in thrips distribution.

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The data were analysed using a GLM assuming a Poisson distribution with a log link. Again there was evidence of over-dispersion and this was accounted for in the model. From the accumulated analysis of deviance table for the full model (Table 11) the key significant interaction is that between position and age (adult or larva).

Table 11. Analysis of thrips distribution data on 28 September and 18 October where the leek plants were separated into two sections – upper leaves and rest of plant.

Change	d.f.	Deviance	Mean deviance	Deviance ratio	Approx F probability
+ position+time+age+date					
+ time.age+time.date+age.date					
+ time.age.date	**8**	**357.439**	**44.680**	**8.98**	**<.001**
+ position.time	1	6.286	6.286	1.26	0.263
+ position.age	**1**	**54.583**	**54.583**	**10.97**	**0.001**
+ position.date	1	14.462	14.462	2.91	0.090
+ position.time.age	1	0.427	0.427	0.09	0.770
+ position.age.date	1	1.881	1.881	0.38	0.540
+ position.time.date	1	7.183	7.183	1.44	0.232
+ position.time.age.date	1	5.525	5.525	1.11	0.294
Residual	144	716.625	4.977		
Total	159	1164.410	7.323		

The predicted counts for the interaction of age and position are given in Table 12. They suggest that significantly more adults than larvae are located on the upper leaves, and for both adults and larvae, more are found on other parts of the plant rather than on the upper leaves.

Table 12. Analysis of thrips distribution data collected on 28 September and 18 October where the leek plants were separated into two sections – upper leaves and rest of plant. Predicted counts for the interaction of age and position.

	Adults	Larvae
Leaves	4.45	2.05
Rest of plant	8.25	10.85

The data suggested that more adults than larvae were located on the upper leaves and for both adults and larvae, more were found on the other parts of the plant than on the upper leaves. Table 13 shows the predicted proportions in each region.

Table 13. Analysis of thrips distribution data collected on 28 September and 18 October where the leek plants were separated into two sections – upper leaves and rest of plant. Predicted proportions in each region of the plant.

	Adults	Larvae
Leaves	0.35	0.16
Rest of plant	0.65	0.84

Finally, the data were analysed assuming a binomial distribution with a logit link function and considering the proportion of thrips located on the upper leaves. The accumulated analysis of deviance table for the full model is given in Table 14.

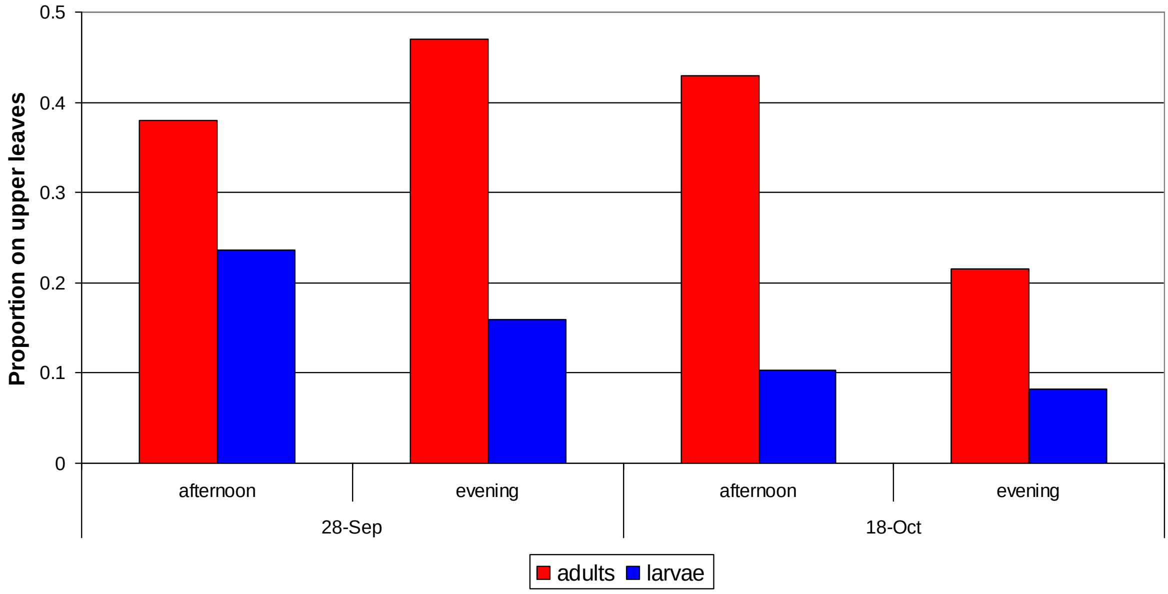
Table 14. Analysis of thrips distribution data collected on 28 September and 18 October where the leek plants were separated into two sections – leaves and rest of plant.

Change	d.f.	Deviance	Mean deviance	Deviance ratio	Approx chi probability
+ date	**1**	**15.395**	**15.395**	**15.40**	**<.001**
+ time	1	2.318	2.318	2.32	0.128
+ age	**1**	**57.618**	**57.618**	**57.62**	**<.001**
+ time.date	**1**	**5.799**	**5.799**	**5.80**	**0.016**
+ age.date	1	3.119	3.119	3.12	0.077
+ time.age	1	0.573	0.573	0.57	0.449
+ time.age.date	**1**	**5.525**	**5.525**	**5.52**	**0.019**
Residual	69	155.331	2.251		
Total	76	245.678	3.233		

The predicted proportion of thrips in each age category clearly showed that a higher proportion of the adult thrips (38%) was found on the leaves compared to larvae (15%).

The predicted proportions for the three-way interaction between time, age and date are shown in Figure 20. In general a higher proportion of thrips were found on the leaves in the afternoon compared to the evening, although this trend was not present on September 28 for adult thrips.

Figure 20. Predicted distribution of thrips in the afternoon and evening on 28 September and 18 October 2006.



Discussion

Sites *et al.* (1992) studied the distribution of *Thrips tabaci* on onion plants in Texas, USA. Temperatures were much higher in Texas (maximum daily temperature 27-40°C) than in the UK, so that comparisons may be of limited value. In addition, their results are difficult to interpret. However, they seem to indicate that as temperatures increased, adult thrips moved upwards in preparation for flight.

The present study has shown that the majority of thrips spend their time on the lower parts of leek foliage, particularly in the region where the leaves branch out. Adult thrips are more widely distributed than larval thrips but still prefer the lower parts of

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the foliage. There is no evidence that either adult or larval thrips make a ‘mass’ migration to the apical parts of the plant at any time of the day. There is evidence that some thrips may move up the plant in response to an increase in temperature.

Since it was a very dry summer, there was limited opportunity to determine whether rainfall affected the distribution of thrips. However, there is also limited evidence that thrips distribution may be affected by rainfall since an increased proportion of adult thrips were found on the upper parts of leaves on days when rainfall was recorded, while the proportions in the other three zones decreased with rainfall. For the larvae there was a decrease in the proportion found where the leaves branch when there was rainfall, and an increase in the other three zones. However, the sample size was small, so these results should be treated with caution.

Conclusions

- Thrips larvae are confined mostly to the lower leaves of leek plants and particularly to the area where the leaves branch out from the shaft.
- Adult thrips are more widely distributed on leek plants, but again are concentrated in the lower leaf area. There are no major shifts in distribution during the day.
- It is likely, therefore, that adult thrips are more accessible to insecticides than the larvae and that these should be a target for insecticidal spray treatments. However, there is no clear evidence that application at a certain time of day will improve contact between the insecticide and its target pest.
- There is evidence that some thrips may move up the plant in response to an increase in temperature.
- There is also limited evidence that thrips distribution may be affected by rainfall since an increased proportion of adult thrips were found on the upper parts of leaves on days when rainfall was recorded, while the proportions in the other three zones decreased with rainfall. For the larvae there was a decrease in the proportion found where the leaves branch when there was rainfall, and an increase in the other three zones (shaft and upper and lower parts of leaves).

However, the sample size was small, so these results should be treated with caution.

TECHNOLOGY TRANSFER

The information from this project will be disseminated to growers together with a summary of the results of the Defra-funded project.

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