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Monitoring saddle gall midge (*Haplodiplosis marginata*) larvae and adult emergence

by

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1. ABSTRACT

The aim of this eight month study was to record development of saddle gall midge larvae and pupae, and the timing of adult emergence. This work was undertaken to determine whether monitoring of soil stages of this pest can provide a useful indication of the risk and timing of adult emergence.

The study had the following objectives:

1. Record numbers of saddle gall midge larvae and pupae by soil sampling at regular intervals.
2. Monitor adult emergence using yellow sticky traps checked at regular intervals.
3. Determine if soil monitoring of larvae and pupae provides a useful early warning of adult emergence.
4. Monitor soil temperature and soil moisture levels at regular intervals.

The work was done at two sites in Buckinghamshire which had previously been affected by the pest. It was funded by HGCA, with additional funding from Dow AgroSciences as part of their Pestwatch campaign.

Saddle gall midge larvae were recorded in every soil sample taken throughout the monitoring period at both sites. Numbers declined by 94% at Wendover and 96% at Cadmore End between February and June 2012. Newly developed (neonate) pupae were first recorded on 10 April at both sites and fully formed pupae at Wendover on 8 May. Numbers of pupae remained low throughout the monitoring period. A small number of pupae were also recorded as being parasitised. Saddle gall midge adults were not recorded on sticky yellow traps until 14 May at either site. Numbers of adults on traps never exceeded 0.5/trap/day. There does not appear to be a simple trigger to initiate pupation and it is likely that further data will need to be collected before any firm conclusions can be drawn.

Soil sampling was an effective method of monitoring saddle gall midge development. It should, therefore, be possible to use soil sampling to give an indication of the likely timing of adult midge emergence. It was interesting that the number of midge developmental stages in the soil declined so significantly during the monitoring period. This could be due to parasitism, predation by other insects or birds, or weather conditions. The biggest drop in numbers of larvae was at the end of April, which coincided with some of the wettest weather. It is also possible that larvae moved back down through the soil profile in response to these adverse conditions. Potential future areas for saddle gall midge research are discussed.

2. SUMMARY

2.1. Introduction

Severe, widespread outbreaks of saddle gall midge occurred in continuous cereals on heavy land in 2010 and 2011, from Wiltshire to the Scottish Borders, with yield losses in the most severe cases reaching 70%. The aim of this study was to record development of saddle gall midge larvae and pupae, and the timing of adult emergence. This work was undertaken to determine whether monitoring of soil stages of this pest can provide a useful indication of the risk and timing of adult emergence. Improved understanding of the risk and timing of saddle gall midge adult emergence will allow more targeted and effective insecticide applications to be made.

The study had the following objectives:

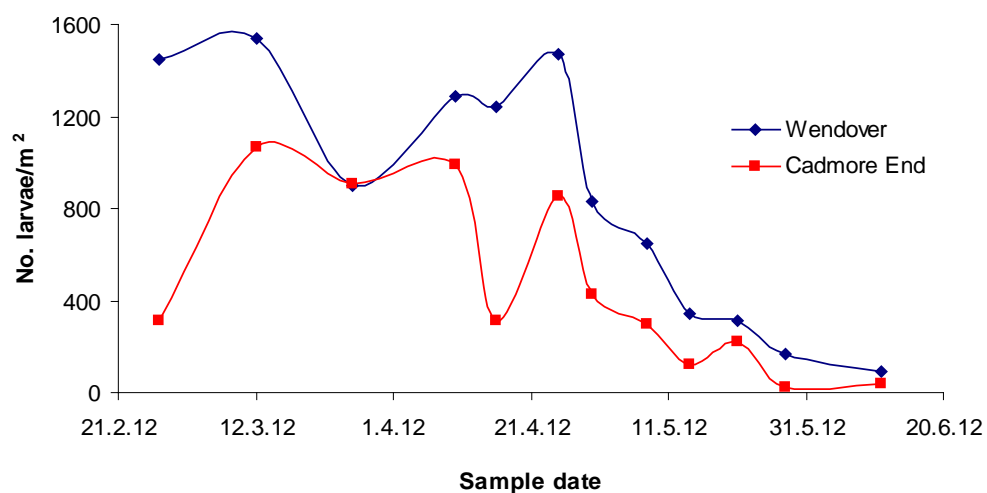
1. Record numbers of saddle gall midge larvae and pupae by soil sampling at regular intervals.
2. Monitor adult emergence using yellow sticky traps checked at regular intervals.
3. Determine if soil monitoring of larvae and pupae provides a useful early warning of adult emergence.
4. Monitor soil temperature and soil moisture levels at regular intervals.

The work was done at two sites in Buckinghamshire which had previously been affected by the pest. It was funded by HGCA with additional funding from Dow AgroSciences as part of their Pestwatch campaign.

2.2. Results

2.2.1. Saddle gall midge development

Saddle gall midge larvae were recorded in every soil sample taken throughout the monitoring period at two sites in Buckinghamshire. Numbers of larvae recorded throughout the monitoring period are summarised in Summary Figure 1 and a photo of larvae is shown in Summary Figure 2. Numbers declined by 94% at Wendover and 96% at Cadmore End between February and June 2012.



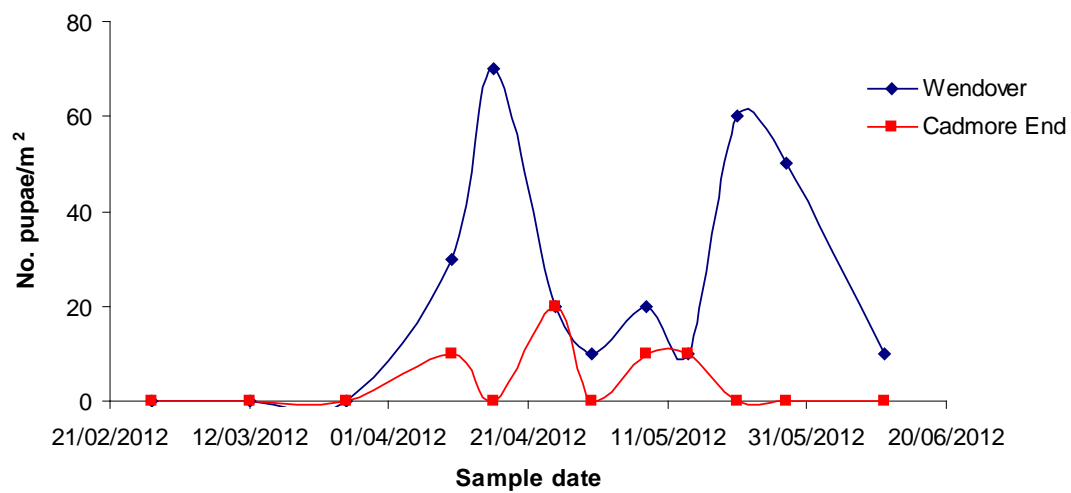
Summary Figure 1. Numbers of saddle gall midge larvae per m² recorded throughout the monitoring period at Wendover and Cadmore End, Buckinghamshire.



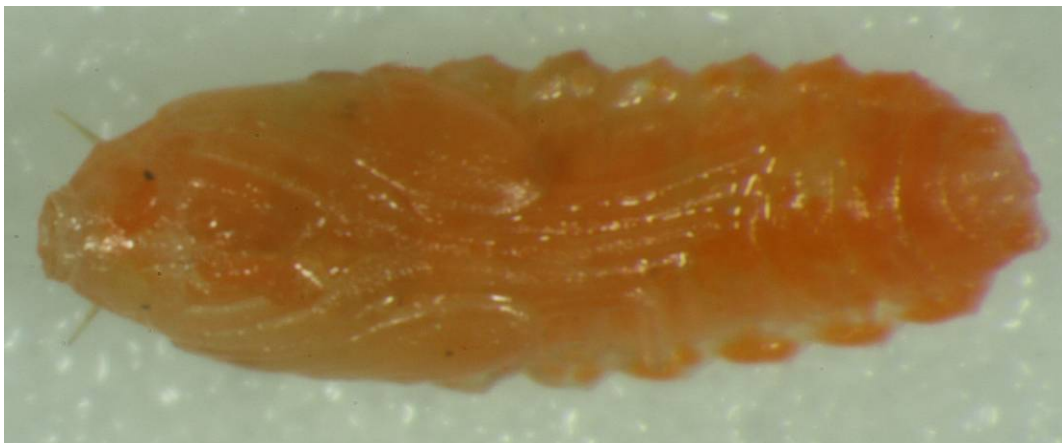
Summary Figure 2. Saddle gall midge larvae on soil surface.

Newly developed (neonate) pupae (Summary Figure 3) were first recorded on 10 April at both sites and fully formed pupae at Wendover on 8 May. No fully formed pupae were recorded at Cadmore End. Numbers of neonate pupae and pupae remained low throughout the monitoring period.

Summary Figure 4 shows a neonate pupa and Summary Figure 5 a fully formed pupa. A small number of pupae were also recorded as being parasitised (Summary Figures 6 and 7).



Summary Figure 3. Numbers of saddle gall midge pupae (neonate and fully developed) per m² recorded throughout the monitoring period at Wendover and Cadmore End, Buckinghamshire.



Summary Figure 4. Newly developed (neonate) saddle gall midge pupa



Summary Figure 5. Fully developed saddle gall midge pupa

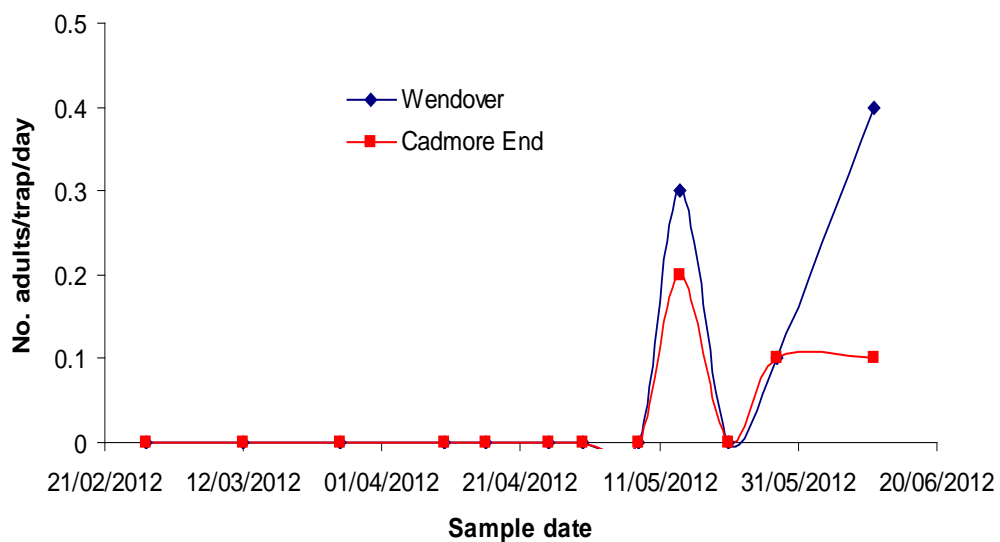


Summary Figure 6. Parasitised saddle gall midge pupa



Summary Figure 7. Emerged saddle gall midge parasitoid

Saddle gall midge adults were not recorded on yellow sticky traps until 14 May at either site (Summary Figure 8). Numbers of adults on traps never exceeded 0.5/trap/day. An adult female midge laying eggs is shown in Summary Figure 9



Summary Figure 8. Numbers of saddle gall midge adults per trap per day recorded throughout the monitoring period.



Summary Figure 9. Saddle gall midge adult laying eggs.

2.2.2. Meteorological data

Relatively cool conditions persisted throughout April and much of May. Following early season warmth in mid- to late-March maximum temperatures did not return to these levels again until mid- to late May. Minimum temperature data showed night time temperatures below 0°C until mid-April. Soil temperatures remained below 10°C until late-April before increasing to approximately 15°C in late-May. There was little rainfall until early-April and then 267mm fell throughout the remainder of the monitoring period. Indeed, over the final 70 days of the monitoring period, rainfall was recorded on 47 days (67% of days). Relative humidity throughout the monitoring period ranged between 59 and 100%. Soil moisture levels declined throughout March, reflecting the lack of rainfall, but rose again during the wet April and May. However, a period of dry, warm weather at the end of May saw soil moisture levels decline before increasing again in early-June.

2.2.3. Midge development and meteorological data

With few pupae and adult saddle gall midge recorded in 2012 there was limited pest development data with which to link the meteorological data. There does not appear to be a simple trigger to initiate pupation and it is likely that further data will need to be collected before any firm conclusions can be drawn.

2.3. Discussion

2.3.1. Monitoring saddle gall midge development

Soil sampling was an effective method of monitoring saddle gall midge development. All stages of pest development except larvae within mud cells were recorded. This included larvae, neonate pupae and pupae. In addition, it was possible to extract pupae which had been parasitised by a hymenopterous parasitoid. It should therefore be possible to use soil sampling to give an indication of the likely timing of adult saddle gall midge emergence. This would provide an early warning of pest activity which could be used to trigger crop monitoring visits to determine when adults are present in the crop and likely to be laying eggs. Yellow sticky traps caught low numbers of saddle gall midge adults but have been used elsewhere to monitor midge emergence successfully.

2.3.2. Meteorological data and saddle gall midge development

In view of the low numbers of saddle gall midge pupae and adults recorded in 2012 it is very difficult to suggest any link between meteorological data and midge development. At the Wendover site there were two peaks in numbers of pupae approximately one month apart in mid-April and mid-May but there was no clear meteorological trigger for pupation. Further years of monitoring and meteorological data will be required to investigate how saddle gall midge development responds to weather conditions.

2.3.3. Saddle gall midge development and impact on crop yield

Despite extremely high levels of the pest in the soil there was limited, if any, crop damage. This suggests that predicting the risk of crop damage from saddle gall midge is more dependent on the timing and number of adult pests that emerge rather than the number of larvae in the soil. It was also interesting that the number of midge developmental stages in the soil declined by 94% at Wendover and 96% at Cadmore End over the monitoring period. Given the small number of pupae, and consequently adults, recorded at each site it seems likely that other factors may be important in explaining the large reduction in larval populations. This could include parasitism, predation by other insects or birds, or weather conditions. The biggest drop in numbers of larvae was at the end of April, which coincided with some of the wettest weather and when soil moisture levels were at their highest. It is also possible that larvae moved back down through the soil profile in response to these adverse conditions.

2.3.4. Further research

It is clear that an improved understanding of the biology and life cycle of saddle gall midge in conjunction with understanding when it infests the crop and the crop's ability to tolerate damage is pivotal to developing a reliable risk assessment for this pest.

The sporadic nature of saddle gall midge damage suggests that in most years insufficient midges emerge to pose a threat to the crop or that the timing of emergence means that any damage has little impact on crop yield. Being able to predict those years in which saddle gall midge is likely to be a threat is crucial in determining a sustainable control strategy.

An evaluation of chemical control options for saddle gall midge is required. The literature suggests there is a limited window for control of this pest before the larvae are protected beneath the leaf sheath.

In summary, future research should concentrate on a number of key areas:

1. Understanding the life-cycle to enable effective monitoring and forecasting
2. Impacts of pest damage on crop yield
3. Chemical control options and insecticide timing
4. Determining economic treatment thresholds

3. TECHNICAL DETAIL

3.1. Introduction

Saddle gall midge is a sporadic, but a periodically and locally-important, pest of wheat, barley, rye and oats in the UK. Severe, widespread outbreaks occurred in continuous cereals on heavy land in 2010 and 2011, from Wiltshire to the Scottish Borders, with yield losses in the most severe cases reaching 70% (A Cotton, pers. comm.). Prior to this, damage was recorded in Britain only in 2004 and in the period from 1967–72 when it was particularly severe. As a result of the recent resurgence of saddle gall midge a review of its ecology and control was published by HGCA in 2012 (Dewar, 2012).

All cereals and most grasses can serve as hosts of saddle gall midge. Wheat and barley are highly susceptible and spring sown crops are at greater risk than those sown in late autumn. Oats are poor hosts and rarely suffer economic damage. Grasses are generally poor hosts with the exception of couch grass (*Elymus repens*). Adult saddle gall midges are red, up to 5mm long and usually appear from late-May onwards. The female lays groups of red eggs in a raft or chain-like pattern on the upper and lower surfaces of leaves. The eggs hatch in 1–2 weeks and the newly hatched larvae move down the leaf to feed on the surface of the stem within the protection of the leaf sheath. Larval feeding results in the formation of galls which appear as saddle shaped depressions, hence the name of the pest. The galls interfere with the flow of nutrients and assimilate to the ear. Larvae are usually fully grown by mid-July when they fall to the ground, enter the soil and overwinter as larvae in mud cells.

The sporadic nature of the pest in the UK means that experience of the problem amongst researchers, agronomists and the farming community is minimal, when compared to commonly occurring pests such as aphids and wheat bulb fly. Golightly and Woodville (1979) provide some information on thresholds and how early-sown crops are less susceptible than late sown. They also propose a monitoring programme to enable improved prediction of potential crop damage. However, there remains a lack of information on the development of soil stages of this pest and subsequent emergence of adults. Understanding the development of the pest in the soil is important if the risk posed by saddle gall midge in a given year is to be understood. In addition, recording, and ideally being able to predict the timing of peak adult emergence, is essential if insecticide applications to control this pest are to be correctly timed.

The aim of this study was to record development of saddle gall midge larvae and pupae, and the timing of adult emergence on a site previously affected by this pest. This work was undertaken to determine whether monitoring of soil stages of this pest can provide a useful indication of the risk

and timing of adult emergence. Improved understanding of the risk and timing of saddle gall midge adult emergence will allow more targeted and effective insecticide applications to be made.

The study had the following objectives:

1. Record numbers of saddle gall midge larvae and pupae by soil sampling at regular intervals.
2. Monitor adult emergence using yellow sticky traps checked at regular intervals.
3. Determine if soil monitoring of larvae and pupae provides a useful early warning of adult emergence.
4. Monitor soil temperature and soil moisture levels at regular intervals.

The work was done at two sites in Buckinghamshire which had previously been affected by the pest. It was funded by HGCA with additional funding from Dow AgroSciences as part of their Pestwatch campaign.

3.2. Materials and methods

In consultation with independent agronomist Andrew Cotton of Cotton Consultancy, a site in Wendover, Buckinghamshire was selected for monitoring. A winter wheat crop in the selected field had been damaged by saddle gall midge in 2011 and winter wheat was again grown in 2012.

Data loggers were positioned within the field on 27 February 2012. These recorded the following information:

- Air temperature - °C
- Soil temperature (10cm depth) - °C
- Relative humidity - %RH
- Rainfall - mm
- Soil moisture – m³.m⁻³

Soil samples were taken at regular intervals from 27 February 2012 until 11 June 2012. On each sampling date, soil was collected from 20 randomly-selected points across the field on a 'W' shaped path. At each sampling point a soil core 10cm long x 5cm wide x 20cm deep was taken using a spade rather than a soil corer as the site was stony. In total the area sampled was approximately 0.1 m² and the total sample weight approximately 10 kg.

By recording the weight of each sample and the area sampled it was possible to express the population of saddle gall midge larvae or pupae per kilogram of soil or per hectare. Midge larvae, pupae and cocoons were extracted from the soil samples using a soil washing/flotation method.

Soil samples were taken every two weeks until saddle gall midge pupae were recorded and then weekly until the end of May with a final sample taken two weeks later in mid-June.

Numbers of adult midges emerging were recorded by placing yellow sticky traps close to the soil surface. Five yellow sticky traps were positioned within an unsprayed area of the field once pupae had been recorded in soil samples. The traps were held just above the soil surface using short canes and were changed each week and numbers of saddle gall midge recorded by carefully viewing the traps under a stereo microscope.

An additional site at Cadmore End, Buckinghamshire, which had a similar pest history, was monitored in the same way as part of Dow AgroSciences funded PestWatch service. The data from this site are included in this report with the permission of Dow AgroSciences but no met data were collected.

3.3. Results

3.3.1. Saddle gall midge development

The first soil sample was collected on 27 February. No overwintering saddle gall midge cocoons were recorded in this first sample at either Wendover or Cadmore End or in any subsequent sample. In contrast, saddle gall midge larvae were recorded in every soil sample. Numbers of larvae recorded throughout the monitoring period are summarised in Figure 1 and a photo of larvae is shown in Figure 2. Numbers of larvae decreased dramatically at both sites over the monitoring period. Numbers declined by 94% at Wendover and 96% at Cadmore End between February and June 2012.

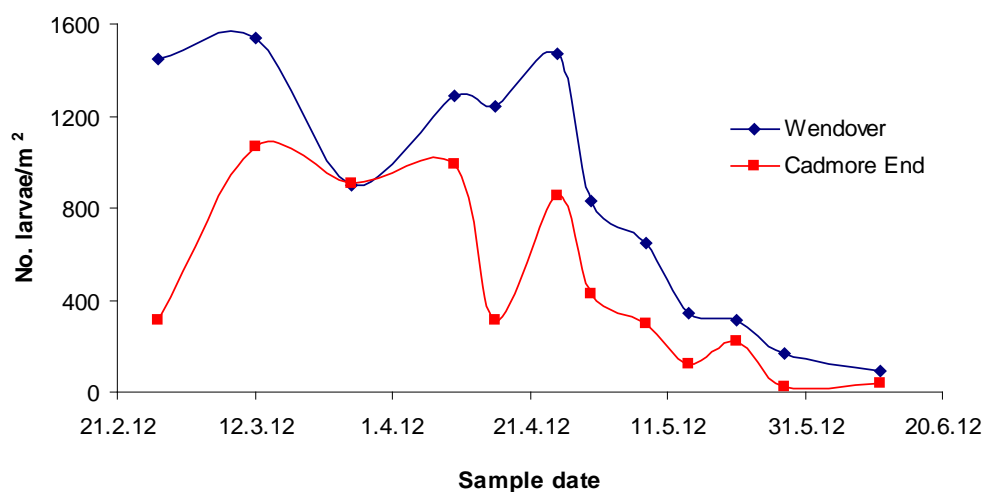


Figure 1. Numbers of saddle gall midge larvae per m² recorded throughout the monitoring period at Wendover and Cadmore End, Buckinghamshire.



Figure 2. Saddle gall midge larvae on soil surface.

Newly developed (neonate) pupae were first recorded on 10 April at both sites while fully formed pupae were not recorded until 8 May at Wendover; no fully formed pupae were recorded at Cadmore End. Numbers of neonate pupae and pupae remained low throughout the monitoring period. When considered together there were two small peaks in numbers of pupae recorded in mid-April and mid- to late-May (Figure 3) at Wendover. Figure 4 illustrates a neonate pupa and Figure 5 a fully formed pupa. Small numbers of pupae were also recorded as being parasitised (Figures 6 and 7).

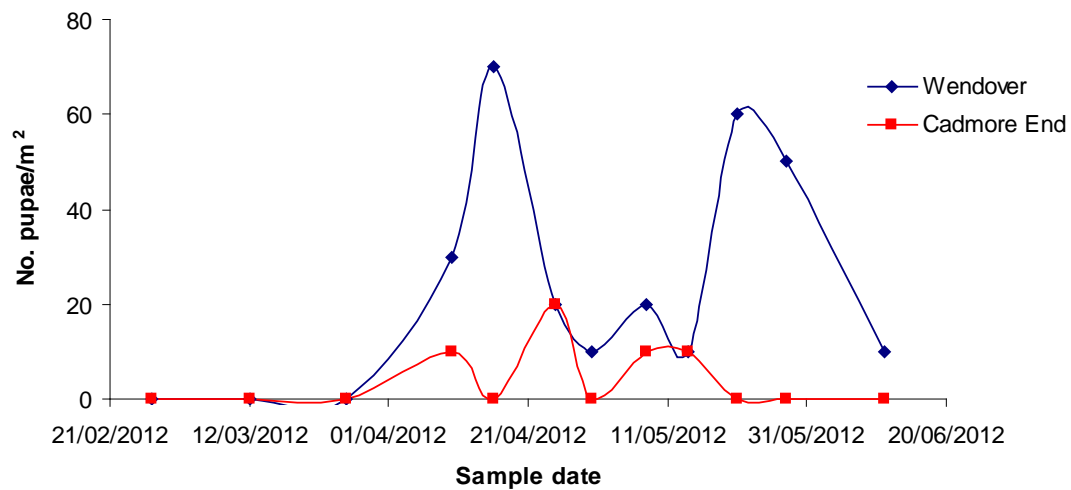


Figure 3. Numbers of saddle gall midge pupae (neonate and fully developed) per m² recorded throughout the monitoring period at Wendover and Cadmore End, Buckinghamshire.

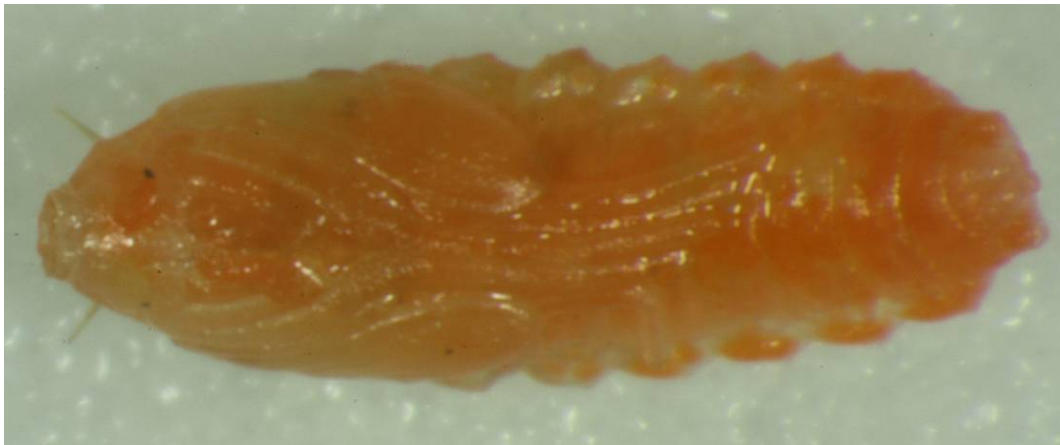


Figure 4. Newly developed (neonate) saddle gall midge pupa



Figure 5. Fully developed saddle gall midge pupa



Figure 6. Parasitised saddle gall midge pupa



Figure 7. Emerged saddle gall midge parasitoid

Saddle gall midge adults were not recorded on yellow sticky traps until 14 May at either site. Numbers of adults remained low until the end of the monitoring period when crops would have been sufficiently developed to be at little risk of economic damage (Figure 8). Numbers of adults on traps never exceeded 0.5/trap/day.

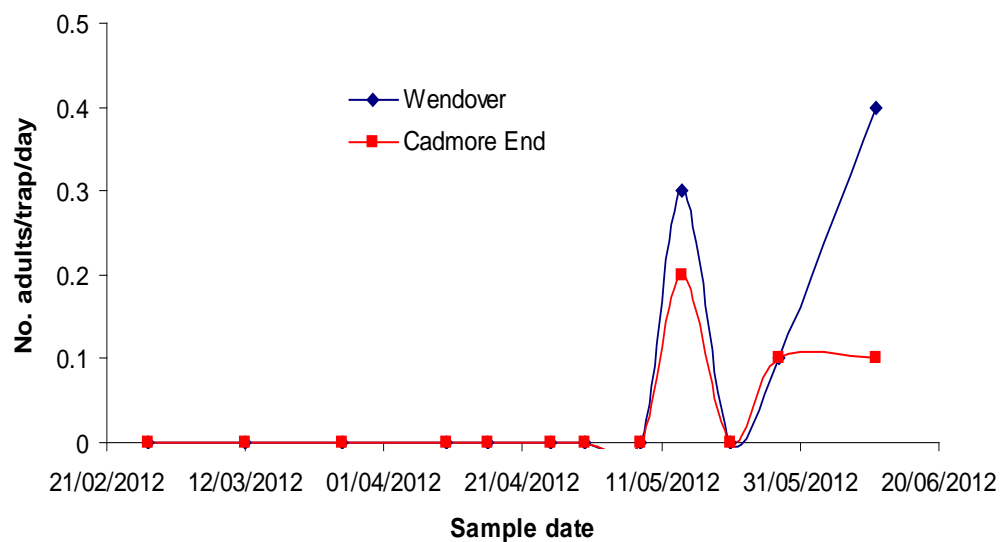


Figure 8. Numbers of saddle gall midge adults per trap per day recorded throughout the monitoring period.



Figure 9. Saddle gall midge adult laying eggs.

3.3.2. Meteorological data

Maximum and minimum air temperatures illustrate the relatively cool conditions that persisted throughout April and much of May (Figure 10). Following early season warmth in mid- to late-March, maximum temperatures did not return to these levels again until mid- to late-May. Minimum temperature data were notable for the presence of night time temperatures below 0°C until mid-April.

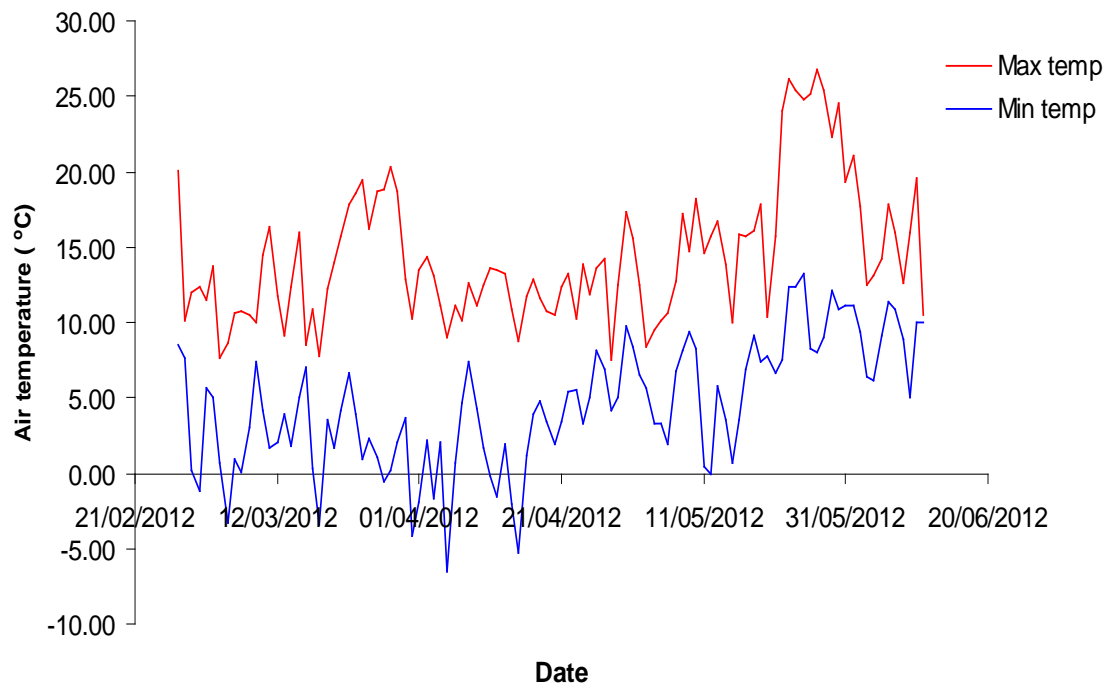


Figure 10. Maximum-minimum temperatures throughout monitoring period.

Soil temperatures remained below 10°C until late-April before increasing to approximately 15°C in late-May (Figure 11).

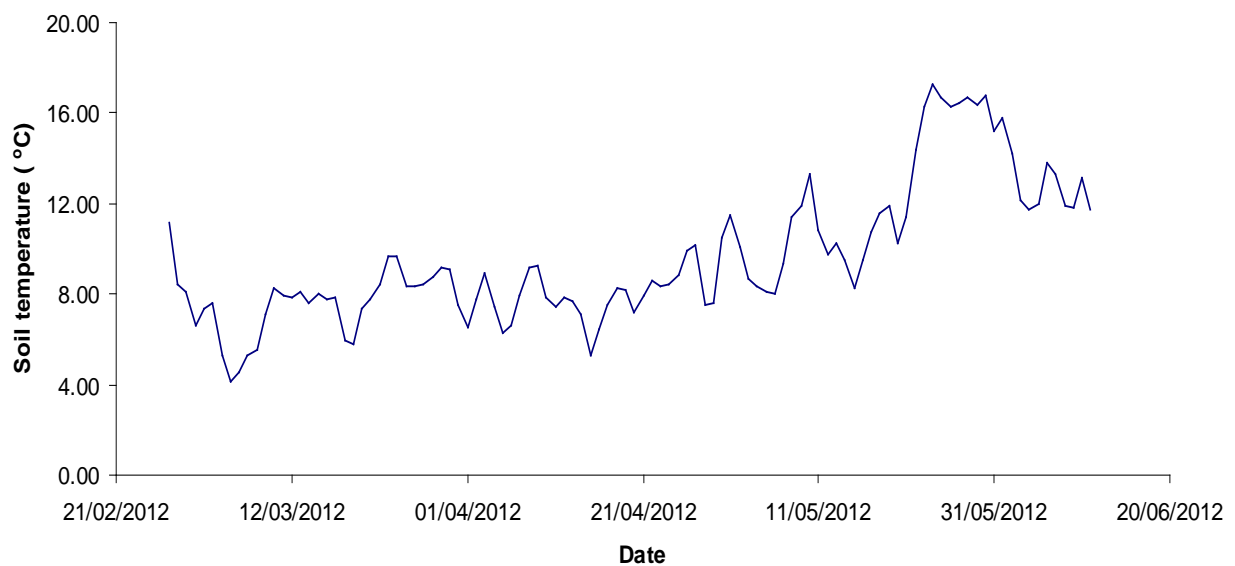


Figure 11. Soil temperatures throughout monitoring period.

The monitoring period was characterised by a lack of rainfall until early-April and then 267mm fell throughout the remainder of the monitoring period (Figure 12). Indeed, over the final 70 days of the monitoring period rainfall was recorded on 47 days (67% of days).

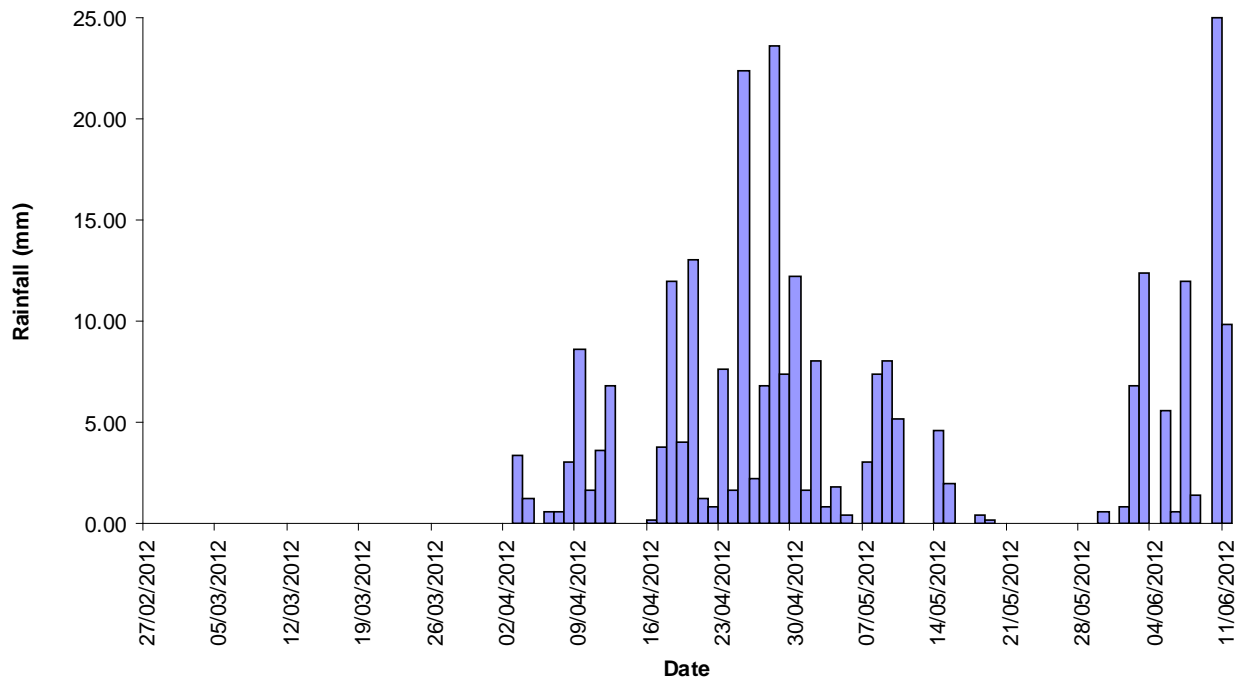


Figure 12. Rainfall throughout monitoring period.

Relative humidity throughout the monitoring period ranged between 59 and 100% (Figure 13).

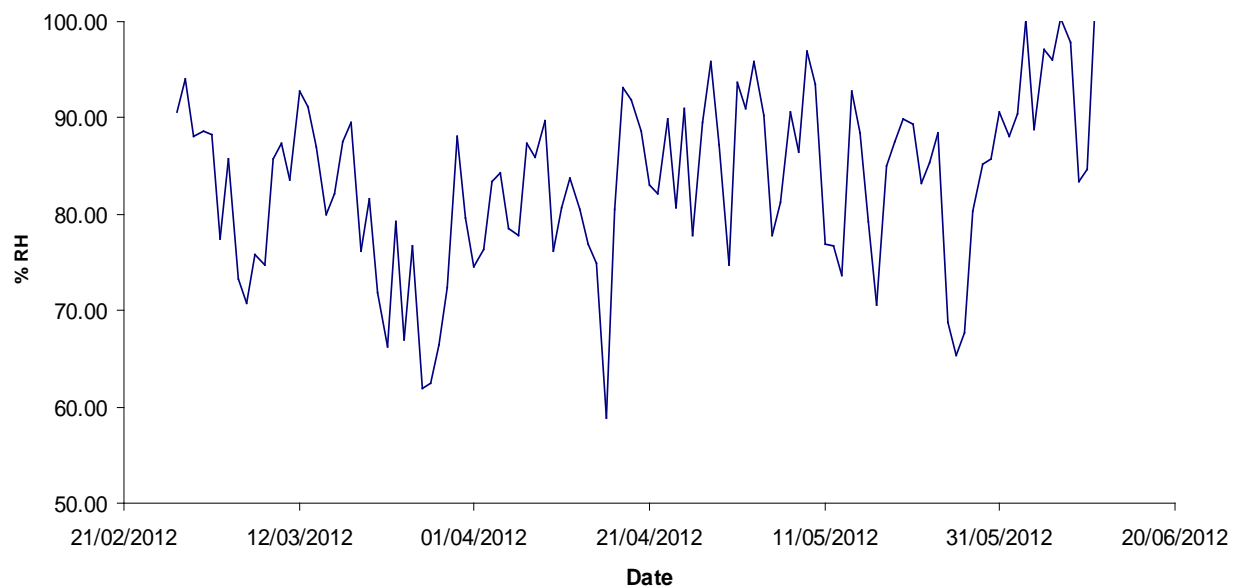


Figure 13. Relative humidity throughout monitoring period.

Soil moisture levels fell throughout March, reflecting the lack of rainfall, but rose again during the wet April and May (Figure 14). However, a period of dry warm weather at the end of May saw soil moisture levels decline before increasing again in early-June.



Figure 14. Soil moisture throughout monitoring period

3.3.3. Midge development and meteorological data

With few pupae and adult saddle gall midge recorded in 2012 there is limited pest development data with which to link the meteorological data recorded. In addition, as pupation was recorded over an extended period with two small peaks at the Wendover site on 16 April and 21 May there does not appear to be a simple trigger to initiate pupation. Taking the two peaks in numbers of pupae recorded it is possible to make the following comparisons:

Table 1. Meteorological data recorded at Wendover during the week before each peak in numbers of saddle gall midge (SGM) pupae.

Meteorological data	Peak SGM pupae 9-16 April	Peak SGM pupae 14-21 May
Max air temperature one week before peak numbers of pupae	8.7 – 13.5°C	10.0 – 17.8°C
Min air temperature one week before peak numbers of pupae	-5.4 – 4.3°C	0.7 – 9.1°C
Soil temperature one week before peak numbers of pupae	5.3 – 9.3°C	8.3 – 11.9°C
Rainfall	20.8mm	7.2mm
Relative humidity	59 – 90%	71 – 93%
Soil moisture	0.36 – 0.42 m ³ .m ⁻³	0.36 – 0.42 m ³ .m ⁻³

Comparison of the meteorological data for the two peaks of midge pupation does not show any clear trigger that might account for the development of pupae and it is likely that further data will need to be collected before any firm conclusions can be drawn.

3.4. Discussion

3.4.1. Monitoring saddle gall midge development

Soil sampling was an effective method of monitoring saddle gall midge development. All stages of pest development except larvae within mud cells were recorded. This included larvae, neonate pupae and pupae. In addition, it was possible to extract pupae which had been parasitised by a hymenopterous parasitoid. It is possible that larvae within mud cells were sampled but the cells were destroyed in the extraction process so that only free larvae were seen. It should therefore be possible to use soil sampling to give an indication of the likely timing of adult saddle gall midge emergence. This would provide an early warning of pest activity which could be used to trigger crop monitoring visits to determine when adults are present in the crop and likely to be laying eggs. Yellow sticky traps caught low numbers of saddle gall midge adults but it is unclear whether this was because few midges emerged or because the traps were ineffective. Yellow sticky traps have been used to monitor midge emergence successfully in Yorkshire and time insecticide sprays (Sam Larwence, pers comm.) suggesting that in 2012 there was limited midge emergence at the monitoring sites.

Chemical control of saddle gall midge is problematic. It is unlikely that sprays will be effective if targeted against larvae in the soil simply because it is difficult to ensure that the insecticide would come into contact with the pest. The preferred option is to control newly hatched larvae as they migrate from the egg to the feeding sites. It should be possible to use soil sampling to give an early warning of when adult midges are likely to emerge. This could be used to trigger crop monitoring visits to determine if adult midges are present or if eggs have been laid. By using soil sampling it would be possible to improve the precision for monitoring saddle gall midge and ensure that time is not wasted unnecessarily looking for the pest long before it is due to emerge. Anecdotal evidence suggests that emergence dates can vary considerably between seasons so some method of monitoring the likely date of emergence will help to guide farmers and agronomists. This is similar to the system used with orange wheat blossom midge where soil sampling can be used to give an indication of when pheromone traps should be set for adult midges at emergence sites.

3.4.2. Meteorological data and saddle gall midge development

In view of the low numbers of saddle gall midge pupae and adults recorded in 2012 it is very difficult to suggest any link between meteorological data and midge development. At the Wendover site there were two peaks in numbers of pupae approximately one month apart in mid-April and

mid-May but there was no clear meteorological trigger for pupation. Further years of monitoring and met data will be required to investigate how saddle gall midge development responds to weather conditions.

There is uncertainty about when saddle gall midge may infest cereal crops as the literature (Gratwick, 1992) indicates that the pest commonly infests cereal crops during late stem extension, whereas more recent observations have shown that infestation can be at the start of stem extension. It is possible that warmer winters trigger earlier pest emergence. Ultimately if it is possible to collect more meteorological and pest monitoring data the potential for a model of saddle gall midge development could be considered.

3.4.3. Saddle gall midge development and impact on crop yield

Despite extremely high levels of the pest in the soil there was limited, if any, crop damage. This suggests that predicting the risk of crop damage from saddle gall midge is more dependent on the timing and number of adult pests that emerge rather than the number of larvae in the soil. This is similar to the situation with orange wheat blossom midge where risk assessment is crucially dependent on the size and timing of adult midge emergence in relation to the susceptible stage of the crop. It was also interesting that the number of midge developmental stages (larvae, pupae and cocoons) in the soil declined by 94% at Wendover and 96% at Cadmore End over the season. This would be expected if adult midges emerged but there were very few pupae recorded and few midges caught on yellow sticky traps. Given the small number of pupae, and consequently adults, recorded at each site, it seems likely that other factors may be important in explaining the large reduction in larval populations. Parasitism was recorded at both sites but numbers of parasitised saddle gall midge larvae/pupae were low. Other forms of mortality may have included predation by other insects or birds as the larvae came close to the soil surface. Weather may also have been important as the biggest drop in numbers of larvae came at the end of April, which coincided with some of the wettest weather and when soil moisture levels were at their highest. However, it remains possible that larvae had come close to the soil surface in early March but had moved back down through the soil profile below the level sampled in April and May. The whereabouts of these developmental stages is important. If they migrated deeper into the soil it would mean that they are still potentially available to invade future crops.

The ability of the crop to tolerate damage depends on the timing of infestation and the cereal species. Yield in barley is primarily limited by the size of its 'sink' (grains per m² Bingham *et al.*, 2007 a & b). Barley usually has sufficient photo-assimilate to fill the grains so its yield is more dependent on the number of grains per m² which is determined early in the life of the crop mainly during tillering. Wheat yield is co-limited by the size of the 'sink' but also the 'source' or the supply of photo-assimilates to fill the grains. Therefore pests that attack cereal crops early, for example up

to stem extension, are likely to have a bigger impact on barley yield than wheat (Ellis *et al.*, 2009, HGCA threshold review, HGCA RD-2008-3563). In contrast, pests which attack crops late in their growth cycle are more likely to be damaging to wheat yield. The HGCA threshold review also demonstrated that cereal crops have a greater capacity to tolerate/compensate for pest damage when they have large numbers of shoots/m² and when pest attack occurs early. Saddle gall midge larvae feed on the stems and restrict the flow of nutrients to the ear. Attack during early stem extension may be expected to reduce barley yield more than wheat yield, whereas attack during late stem extension may affect wheat yield more than barley.

3.4.4. Further research

It is clear from the discussion above that an improved understanding of the biology and life cycle of saddle gall midge in conjunction with understanding when it infests the crop and the crop's ability to tolerate damage is pivotal to developing a reliable risk assessment for this pest.

The sporadic nature of saddle gall midge damage suggests that in most years insufficient midges emerge to pose a threat to the crop or that the timing of emergence means that it has little impact on crop yield. However, this could alter due to climate change. Being able to predict those years in which saddle gall midge is likely to be a threat is crucial in determining a sustainable control strategy.

Finally, an evaluation of chemical control options for saddle gall midge is required. The literature suggests there is a limited window for control of this pest before the larvae are protected beneath the leaf sheath. A method of predicting when to apply insecticide sprays is required to ensure the most effective use of chemicals.

In summary, future research should concentrate on a number of key areas:

1. Understanding the life-cycle to enable effective monitoring and forecasting
2. Impacts of pest damage on crop yield
3. Determining economic treatment thresholds
4. Chemical control options and insecticide timing

Each of these topic areas is discussed in further detail below:

1. Understanding the life-cycle to enable effective monitoring and forecasting

Monitoring midge development in soil and emergence

To-date, only one season's data has been collected on numbers of midge developmental stages in relation to meteorological data at Wendover. This could be repeated at different sites ideally in contrasting climates in both the south and north of England. This should provide contrasting

weather conditions which are likely to influence midge emergence. Data loggers could be used at each site to record air temperature, soil temperature, relative humidity, rainfall and soil moisture.

As in the current project, numbers of midge developmental stages could be assessed by soil sampling. Samples could also be taken at a range of soil depths to determine whether midge larvae move up and down the soil profile in response to weather conditions as may have been the case in 2012.

Model to predict midge emergence

There are no models available for saddle gall midge emergence in the UK but the raspberry cane midge model could be used as a basis for saddle gall midge. ADAS modellers at Wolverhampton could be used to help develop models of midge emergence. Monitoring data could then be used to validate the model.

Comparison of trap types to determine the timing of midge emergence

Very few saddle gall midge adults were caught on yellow sticky traps at either of the monitoring sites in 2012. It seems likely that few adults emerged but it is also possible that yellow sticky traps were ineffective. A range of trapping methods could be compared to determine which is most effective for saddle gall midge.

2. Impacts of pest damage on yield

Monitoring of saddle gall midge in 2012 indicated that despite high levels of pests in the soil there was limited impact on crop yield. It is important to be able to get some indication of the impact of saddle gall midge on the comparative yield of wheat and barley. The impact of the pest on individual tagged plants/tillers could be studied in comparison with uninfested plants/tillers. Both wheat and barley crops could be studied. This will help to indicate the level of tiller infestation required to have a significant impact on crop yield. The potential for the crop to compensate for any damage through extra tillering or increasing the yield from uninfested tillers could also be investigated. The potential for a simple relationship between number of galls and yield loss is another area worthy of investigation.

3. Determining economic treatment thresholds

To-date there is little evidence to suggest that the number of saddle gall midge larvae in the soil is a reliable indicator of significant yield loss. Also assessing the number of galls/tiller is not helpful as by this stage it is probably too late to act. The most promising route for developing reliable thresholds will involve a combination of monitoring adult midge numbers with an understanding of the crop's ability to tolerate damage. Data from research ideas suggested above could be used to identify the level of infestation required to cause yield loss and how this varies depending on cereal

species, tiller numbers, and the growth stage when the crop is infested. Comparison with the levels of tiller infestation observed in the field and yield losses may be used to validate the threshold scheme.

4. Chemical control options and insecticide timing

There are currently no approved products for control of saddle gall midge although a number of insecticides can be applied to cereals at a time likely to coincide with the presence of midges in the crop. There is only a small window during which insecticides are likely to be effective. This is the time from egg hatch until midge larvae move beneath the leaf sheath where they feed. It is important to know which insecticides are likely to be most effective at controlling the pest and how best to time these treatments. What are the best chemical options and when should they be applied? Field experiments could be established to compare a range of insecticides at a range of timings at sites known to have a history of the pest.

3.5. References

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