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Project leader:	Rosemary Collier, Warwick Crop Centre, University of Warwick
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Previous report:	None
Key staff:	Andrew Jukes Marian Elliott
Location of project:	Warwick Crop Centre, Wellesbourne
Industry Representative:	Adrian Jansen, Lingarden Bulbs Ltd
Date project commenced:	1 February 2012
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The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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GROWER SUMMARY

Headline

One novel insecticide and one bio-insecticide showed potential as foliar sprays for the control of large narcissus fly, but further work is required to evaluate them under field conditions.

Background

The large narcissus fly (*Merodon equestris*) is the most important insect pest of narcissus crops in the UK. The larvae feed and grow inside the bulbs. Exports to both EU and non-EU countries are essential to the economy of the bulb industry. Narcissus fly infestation levels as low as 1% may jeopardise the export of bulbs. Current control measures are nowhere near 100% effective, and the control strategy uses just one active ingredient, chlorpyrifos, which is unpleasant to use, may not be available in the longer term and because it is used in the hot-water treatment only protects bulbs for a single season. The aim of this project was to evaluate new insecticides against adult flies in laboratory tests and against larvae in a small field trial. Flies were obtained from infested bulbs growing at Wellesbourne. Insecticides were last evaluated for large narcissus fly control in 2004-5 and several new active ingredients have become available since then and are being evaluated currently for edible crops in a Horticulture LINK project (SCEPTRE). If none of the insecticides are effective then there will be no point in pursuing further field experiments. However, if some of the insecticides are effective then they could be evaluated subsequently in the field. The insecticides to be tested were applied as foliar sprays, the adult flies being the main targets. However, one of the novel insecticides is extremely mobile within plants and it may be that a foliar spray treatment with this insecticide would have some activity against large narcissus fly larvae.

Summary

The aim of this project was to evaluate new insecticides against adult flies in laboratory tests and against larvae in a small field trial.

Obtaining the test insects

Large narcissus flies are currently infesting bulbs in the narcissus plots at Warwick Crop Centre, Wellesbourne. Several thousand bulbs were dug up and screened for narcissus fly damage in winter 2011-12. The infested bulbs were re-buried in field plots that were covered subsequently with large field cages. Adult flies were expected to emerge into these cages during May-July 2012. The aim was to capture flies on the day of emergence and hold them in the laboratory for use in insecticide trials. Capture of the flies depends on their being active, which in turn depends on there being warm sunny weather. The procedure was repeated in winter 2012-13.

Determine whether insecticides applied to narcissus foliage at commercially viable rates kill adult large narcissus flies

The test treatments consisted of three novel conventional insecticides and two bio-insecticides. All novel treatments were coded. Hallmark (lambda-cyhalothrin), which had been identified as most effective insecticide treatment in BOF 53, was used as a standard treatment in one test.

Insecticide solutions were prepared at commercially viable rates. Narcissus foliage at the appropriate stage of development was sprayed with the insecticide treatments, allowed to dry and then the samples of foliage were brought into the laboratory and placed into ‘test’ cages. Samples of untreated foliage were used as control treatments. Adult flies collected from the emergence cages in the field plot were released into the test cages. The flies were supplied with a source of food and water. Fly mortality was recorded over a period of up to seven days. To determine whether fly mortality was increased by the addition of baits (food additives) to the spray solution, the experimental procedure outlined was repeated, but this time the insecticides were applied in a solution containing sugar (1% solution of sucrose) as bait, as an experimental treatment. In a further set of tests, insecticide sprays were applied directly to the flies, which were contained in mesh cages.

Determine whether a very mobile novel insecticide applied as a foliar spray has any activity against narcissus fly larvae

In spring 2013, small plots of *Narcissus* were marked out within one of the larger blocks of narcissus at Wellesbourne (2 rows x 3.3 m). Half of the plots were sprayed with the novel insecticide at an appropriate test rate, whilst the other half were left insecticide-free. All plots were exposed to the local population of large narcissus fly and were also infested at similar rates with eggs obtained from the flies collected for the laboratory tests at a rate of 4 eggs per bulb. Samples of bulbs were taken from each plot in winter 2013-14 and assessed for the presence of large narcissus fly larvae.

Results

In 2012, the first flies were found on 22 May. However, the very wet summer in 2012 limited the number of flies that were collected (they hide when it is cool and wet) and restricted the work that could be undertaken. The field trial, which was originally scheduled for summer 2012, was not undertaken because of the poor weather. In 2013, flies emerged between 31 May and 15 July. Again, fly numbers were relatively low, probably a result of the poor weather in the previous year restricting mating and subsequent egg-laying. Laboratory tests were done in both years using the flies available.

Experiment 1

In Experiment 1, flies were exposed to foliage treated with insecticides, either HDCI 050 or HDCI 051, and there was an untreated control. Neither HDCI 050 nor HDCI 051 caused high knockdown fly mortality.

Experiment 2

In this experiment, flies were exposed to foliage treated with either HDCI 050 or HDCI 051 in a 1% sucrose solution (as an experimental treatment) and there was an untreated control. Flies exposed to HDCI 050 suffered a high level of mortality after 5 days but there was no rapid knockdown.

Experiment 3

In this experiment, flies were exposed to foliage treated with one or other of the two bio-insecticides (HDCI 052, HDCI 054) applied alone or in a 1% sugar solution (as an experimental treatment) and there was an untreated control. HDCI 052 was ineffective when applied in this way, with or without sugar. HDCI 054 was more effective, especially when applied with sugar (Figure 1.1).

Experiment 4

In this experiment, flies were sprayed directly with insecticide solutions. HDCI 050 and Hallmark caused high mortality after 1-2 days. Hallmark had the most rapid effect (Figure 1.2).

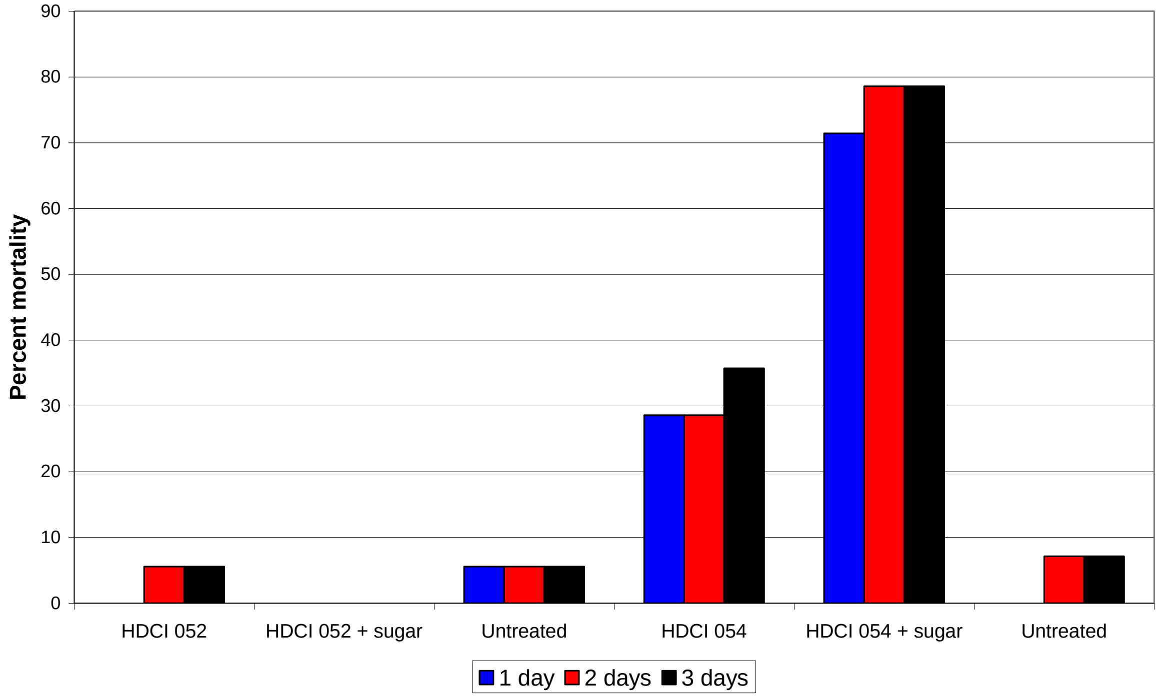

Figure 1.1 Percentage mortality of flies exposed to foliage treated with two novel bio-insecticides alone and in a 1% sugar solution experimental treatment (summarized over 2 tests per bio-insecticide).

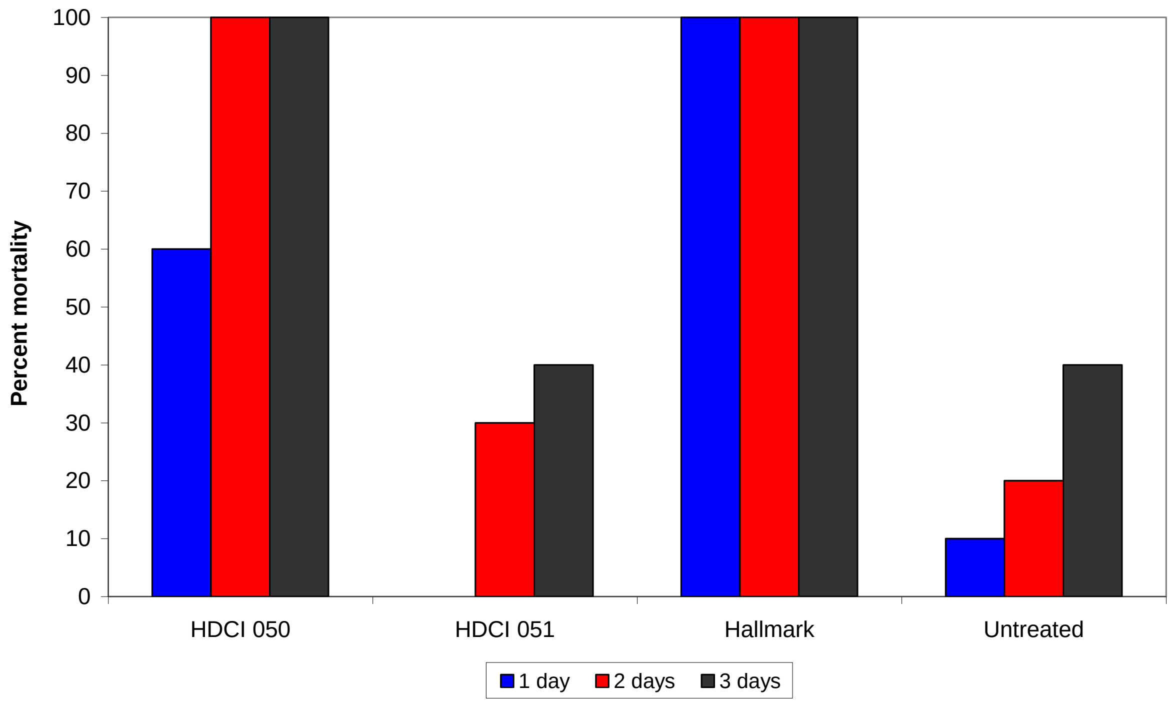

Figure 1.2 Percentage mortality of flies sprayed directly with insecticide solutions.

Experiment 5

In this experiment, flies were sprayed directly with solutions of some of the other novel products. The bio-insecticides HDCI 052 and HDCI 054 caused high mortality after 2 days.

Experiment 6

Overall, an average of 84 and 72 larvae per plot were recovered from the treated and untreated plots respectively. An average of 36% of bulbs was damaged, irrespective of treatment and 21 and 20% of bulbs from the treated and untreated plots respectively contained larvae. There was little difference between the two treatments and since good numbers of insects were recovered it is reasonable to conclude that this treatment was ineffective.

Discussion

Unfortunately the very wet weather conditions had an adverse effect on this project because it was impossible to collect flies in 2012 when the weather was cool and wet. In addition, the weather was so poor that it was not possible to undertake the field trial. An extension to the project was agreed and further work was carried out in 2013-4. It was apparent that the field population of narcissus fly in 2013 had also been reduced by the bad weather in 2012, which would have prevented mating and egg-laying. Overall, the bad weather in 2012 had an impact particularly on the numbers of flies that were available for the insecticide tests in the laboratory in both years. Based on the limited numbers of flies, every effort was made to obtain as much information as possible, but it is recognized that fly numbers were too low to undertake conventional statistical analyses.

In contrast, the numbers of damaged bulbs and larvae recovered from the field trial undertaken in 2013 showed how well large narcissus fly can survive when conditions are favourable, since over one third of the bulbs were damaged and over 900 larvae were recovered. Although this trial worked extremely well, and was appropriate for statistical analysis, there was little point in doing this as there was so little difference between the treatments.

All of the results are summarised in Table 1.1 and include some information on Hallmark from BOF 53 for comparison. In general, addition of sugar to sprays applied to foliage as an experimental treatment increased fly mortality, presumably because it encouraged the flies to probe and take up more of the product. Direct application of an insecticide or bio-insecticide was the most effective way of killing the flies, provided the product had some activity. Overall, assuming that it will be quite difficult to contact many flies directly when applying a field spray, one novel insecticide (HDCI 050) and one bio-insecticide (HDCI 054) show potential for control of large narcissus fly. Further work is required before these insecticides would be suggested as suitable for use on a field-scale.

Table 1.1 Overview of the efficacy of the insecticide and bio-insecticide treatments evaluated in 2012 and 2013.

	Application to foliage	**Application to foliage with sugar (experimental)**	**Direct application**	**Application as field spray**
HDCI 050	No rapid knockdown	Effective (no rapid knockdown)	Effective	Ineffective
HDCI 051	No rapid knockdown	Partially effective	Ineffective	-
HDCI 052 (B)	Ineffective	Ineffective	Effective	-
HDCI 053	-	-	Ineffective	-
HDCI 054 (B)	Partially effective	Effective	Effective	-
Hallmark (lambda-cyhalothrin)	Partially effective (BOF 53)	Effective (BOF 53)	Effective	-

Financial Benefits

Exports to both EU and non-EU countries are essential to the economy of the bulb industry and it is vital that bulbs are not infested. Data from Crane *et al.* (2014) (Farm business survey 2012/13. Horticulture production in England) give an annual value of £11 million for UK bulb exports. The presence of large narcissus fly may also put constraints on bulb sales within the UK, which are worth a further £11 million annually. Narcissus fly infestation levels as low as 1% may jeopardise the export of bulbs. Current control measures are nowhere near 100% effective, and the control strategy is based on one active ingredient, chlorpyrifos, therefore the identification of other pesticides which give control is crucial.

Action Points

There are no action points for growers arising from this work at present.

SCIENCE SECTION

Introduction

The large narcissus fly (*Merodon equestris*) is the most important pest insect of narcissus crops in the UK. Large narcissus flies overwinter as fully fed larvae within narcissus bulbs. In March or April, the larvae leave the bulbs and burrow through the soil to find suitable pupation sites near the soil surface. The adults emerge during May and June. After a period during which they feed and mate, the flies lay their eggs in the soil, close to the base of narcissus leaves, at a time when the leaves on many crops have already senesced. The eggs hatch after several days and the newly emerged larvae crawl down the outside of the plant and enter the bulbs through the basal plate. The larvae feed and grow inside the bulbs. Although more than one larva may enter a bulb, only one survives. The larvae are usually fully-grown by early winter.

In England the narcissus crop covers around 4000 hectares, over 40% of which is grown in south-west England, with an additional several hundred hectares in Scotland and Jersey or grown for galanthamine extraction. Traditionally, Cornwall and the Isles of Scilly have been thought of as those areas most affected by the pest, due to a warmer climate and closer rotations. However, narcissus fly infestations can also occur in eastern England and Scotland. In the UK, narcissus crops remain in the soil for two or sometimes more seasons, which means that they are exposed to two or more periods of infestation by the narcissus fly. Of the insecticide treatments available currently, a pre-planting chlorpyrifos (Spannit) dip, preferably in hot-water treatment, is the most effective and provides high levels of control during the first growing season only. There is no effective insecticide treatment for control of narcissus fly during the second and third growing seasons, although premature defoliation and early-lifting can help to reduce attack.

HDC projects on forecasting and control of narcissus fly (BOF 1, BOF 1a, BOF 1b, BOF 1c & FV/BOF 127) were done during 1987-96. During this period, a wide range of insecticide treatments was evaluated for large narcissus fly control. One insecticide, omethoate, looked particularly promising for use as a foliar spray. However, this insecticide is not now available to UK growers. The use of chlorpyrifos for large narcissus fly control was investigated in Project BOF 24 and resulted in chlorpyrifos receiving off-label approval for use as a bulb dip. During the same period, a forecasting system was developed at HRI Wellesbourne to use weather data to indicate the timing of large narcissus fly emergence, egg-laying and egg hatch. This forecast was developed to target insecticidal treatments against both the adults and the newly hatched fly larvae.

More recently, a number of insecticides were evaluated for control of narcissus fly in projects at Warwick HRI, Wellesbourne (BOF 53, 55). Experiments were done in 2004 to determine which, if any, of the currently approved insecticides, or insecticides likely to achieve approval within the next 2-3 years, were effective against either large narcissus fly adults or larvae. In the laboratory, adult narcissus flies exposed to narcissus foliage treated with Hallmark with Zeon Technology (lambda-cyhalothrin) were affected most severely, Decis (deltamethrin) was less effective, and the two other insecticides tested (Tracer (spinosad), Calypso (thiacloprid)) were ineffective. When a small amount of sugar (10%) was added to the spray solution, as an experimental treatment, to act as bait, all the insecticides were more effective, but Hallmark was still the most active compound. In the following year (2005), experiments were done to determine whether Hallmark (lambda-cyhalothrin) applied with or without sugar bait was effective against large narcissus fly adults under field conditions. In a field trial at Warwick HRI Wellesbourne, the strategy used to infest the plots was successful and 23% of the insecticide-free bulbs were damaged and 8% contained live larvae. However, there was no overall difference between treatments, indicating that neither of the insecticidal control strategies had worked. In un-replicated trials in commercial crops of narcissus, damage levels were lower than at Wellesbourne and relatively low numbers of larvae were found. Two crops were completely unaffected. Overall, there were no striking differences between the treated and insecticide-free plots, although the low level of infestation makes it difficult to compare treatments. The overall conclusion was that the application of foliar sprays of Hallmark, with or without sugar, did not reduce narcissus fly infestations significantly.

Novel insecticides for control of the pest insects of edible crops are being evaluated currently in a Horticulture LINK project (SCEPTRE: http://sceptre.ardentdevelopment.net/) which was devised by the HDC in consultation with growers and researchers. The project is providing researchers with information about, and access to, a range of novel products. These, together with products that have been approved since 2005, provide the test materials for this project. The large narcissus fly is normally a 'low density' pest and field experiments to demonstrate the efficacy of insecticides are difficult to execute and interpret because of the patchy distribution of the fly and the relatively low numbers of infested bulbs. By doing experiments on caged insects or artificial infestations in the first instance, some of this variability is removed.

The reason for carrying out the work at this time is that large narcissus fly was a problem with bulbs harvested in 2011 and 2010. Some stocks lifted in 2011 had up to 25% of bulbs damaged, which leads to a 25% reduction in yield/revenue, plus the costs of sorting. In 2011, the problem was not caused by larvae arising from flies active in 2011. It was particularly bad in bulbs from 2008 plantings, which had a lot of old damage, hollowed out bases and masses of dead tissue around new bulbs. Some of the bulbs also had secondary infestations of small narcissus fly. This suggests that the larvae had infested the bulbs in 2009 or 2010, damaged the growing point and caused the bulbs to split. The research is timely because relatively large numbers of insects should be available from plots of insecticide-free narcissus which have been maintained at Wellesbourne as part of a Horticulture LINK project on bulb scale mite.

The overall aim of this project was to determine which, if any, of the recently approved insecticides, or insecticides likely to achieve approval within the next 2-3 years, are effective against large narcissus fly adults or larvae. If efficacy is demonstrated then field application strategies would require investigation subsequently.

Materials and methods

The aim of this project was to evaluate new insecticides against adult flies in laboratory tests and against larvae in a small field trial. Flies were obtained from infested bulbs growing at Wellesbourne. The insecticides to be tested were applied as foliar sprays and the adult flies are likely to be the main targets. However, one of the novel insecticides is extremely mobile within plants and it may be that a foliar spray treatment with this insecticide would have some activity against large narcissus fly larvae.

Obtaining the test insects

Large narcissus flies are currently infesting bulbs in the narcissus plots at Warwick Crop Centre, Wellesbourne. In winter 2011-12, several thousand bulbs were dug up and screened for narcissus fly damage. This was done before March 2012, as at this time, the larvae start to leave the bulbs to pupate. The infested bulbs were re-buried in field plots that were covered subsequently with large field cages. Adult flies were expected to emerge into these cages during May-July 2012. The aim was to capture flies on the day of emergence and hold in the laboratory for use in insecticide trials. Capture of the flies depends on their being active, which in turn depends on there being warm sunny weather. The process was repeated in winter-spring 2012-13.

Narcissus fly adults were held in 31 cm^3 net covered cages and were supplied with 10% sugar solution, yeast hydrolysate, powdered brewer's yeast and water. The sugar solution was absorbed into cotton wool and presented in a 9 cm Petri dish, whilst the yeast hydrolysate was smeared onto another 9 cm Petri dish and covered with a fine layer of powdered brewer's yeast. Water was presented in a bottle with a wick made of blotting paper.

To collect eggs, flies were supplied with oviposition sites consisting of a Petri dish part filled with sieved field soil onto which some pieces of narcissus foliage were placed. Eggs were separated from the soil by emptying the contents of the Petri dish onto a fine mesh sieve and rinsing thoroughly with water. The eggs were removed using a fine paint brush and placed on damp filter paper held in 9 cm Petri dishes, where they were counted. Eggs were stored in a refrigerator prior to use.

Determine whether insecticides applied to narcissus foliage at commercially viable rates kill adult large narcissus flies.

The test treatments consisted of three novel conventional insecticides and two bio-insecticides (Table 2.1).

Table 2.1 Insecticide treatments used in laboratory tests.

Treatment code	Type of insecticide	Rate applied (product/ha)
Hallmark	Conventional	150 ml
HDCI 050	Conventional	750 ml
HDCI 051	Conventional	175 ml
HDCI 052	Bio-insecticide	3000 ml
HDCI 053	Conventional	200 ml
HDCI 054	Bio-insecticide	2400 ml

Exposure of flies to treated foliage

Insecticide solutions were prepared at commercially viable rates. Narcissus foliage at the appropriate stage of development was sprayed with the insecticide treatments, allowed to dry and then the samples of foliage were brought into the laboratory and placed into 'test' cages (as described above). Samples of untreated foliage were used as control treatments.

Adult flies collected from the emergence cages in the field plot were released into the test cages. The flies were supplied with a source of food and water. Fly mortality was recorded over a period of up to seven days. To determine whether fly mortality was increased by the addition of baits (sugar) to the spray solution, the experimental procedure outlined was repeated, but this time the insecticides were applied in a solution containing 1% sugar (sucrose).

Direct application of sprays to flies

In these tests, insecticide sprays were applied directly to the flies, which were contained within a net covered cage.

Determine whether a very mobile novel insecticide applied as a foliar spray has any activity against narcissus fly larvae.

In spring 2013, small plots of narcissus (2 rows x 3.3 m) were marked out within one of the larger blocks of narcissus at Wellesbourne. Half of the plots were sprayed with the novel insecticide (HDCI 050) at an appropriate test rate on 22 May and 5 June, whilst the other half were left insecticide-free. All plots were exposed to the local population of large narcissus fly and also inoculated with eggs obtained from the flies collected for the laboratory tests, at a rate of 4 eggs per bulb. The plots were inoculated on 13, 19, 26 June and 10 and 18 July. The same number of bulbs per plot was inoculated on each occasion. Samples of bulbs were taken from each plot on 14 January 2014 and assessed for the presence of large narcissus fly larvae.

Results

The very wet summer in 2012 limited the number of flies that were collected and restricted the work that could be undertaken. Figure 2.1 shows daily rainfall and maximum temperature at Wellesbourne in 2012 during period of large narcissus fly emergence. First flies were found on 22 May. Flies hide when it is wet and cool (below 20^{o}C).

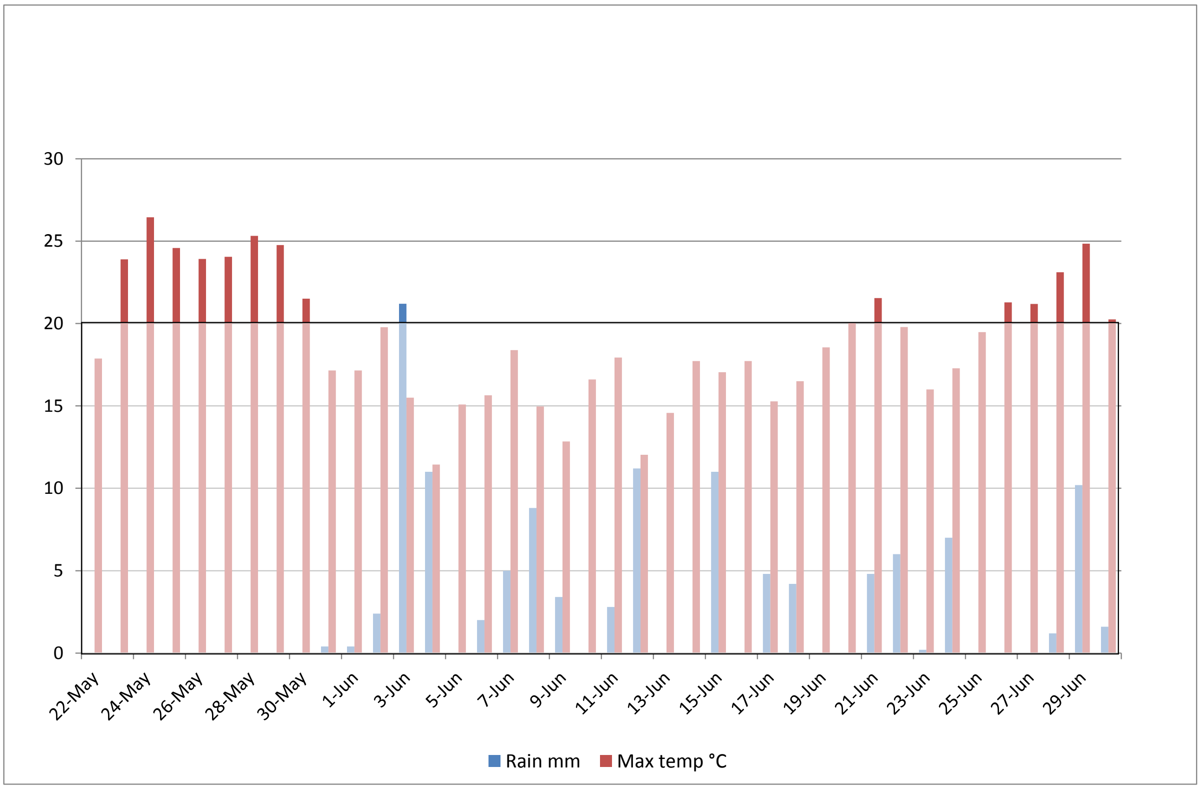

Figure 2.1 Daily rainfall and maximum temperature at Wellesbourne in 2012 during period of large narcissus fly emergence. First flies were found on 22 May. Flies hide when it is wet and cool (below 20^{o}C).

In 2013, flies emerged between 31 May and 15 July (Figure 2.2). Again, fly numbers were not exceptionally high, probably a result of the poor weather in the previous year restricting mating and subsequent egg-laying. The flies that were recovered were used in a series of laboratory experiments and to provide eggs to inoculate the field experiment.

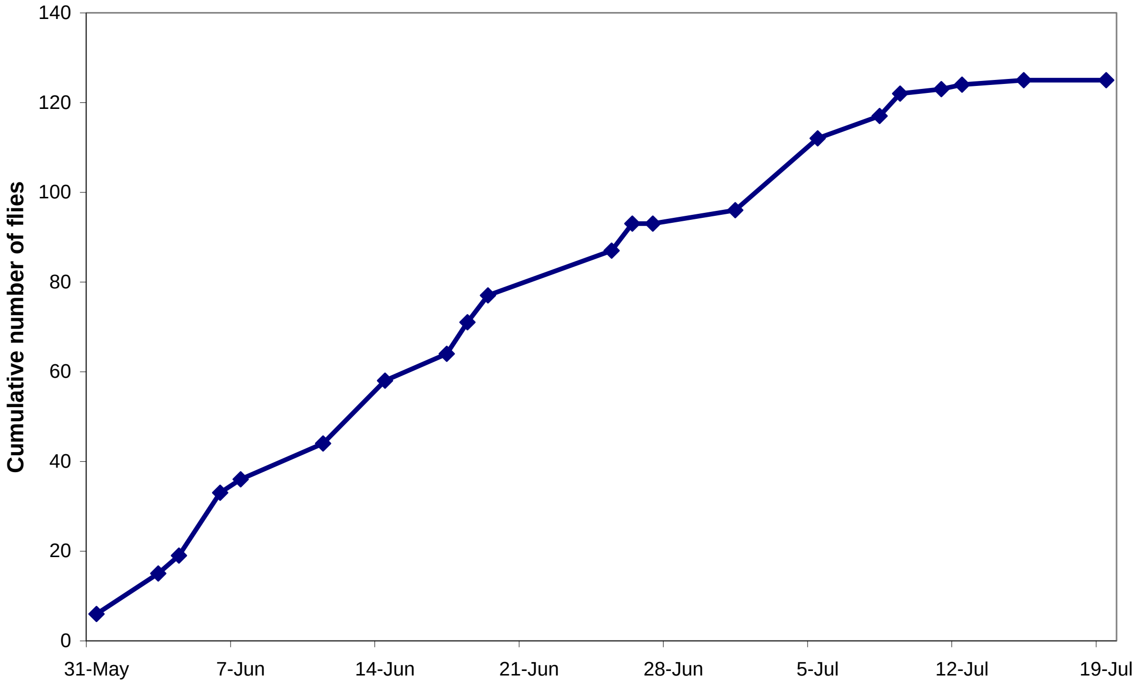

Figure 2.2. Emergence of flies into field cages in 2013 (cumulative number of flies).

Experiment 1

In this experiment, large narcissus flies (2 replicates x 8 flies per treatment) were exposed to foliage treated with either HDCI 050 or HDCI 051 and there was an untreated control. Mortality was assessed after 1 day. The results are shown in Table 2.2. There were no differences between treatments; neither insecticide treatment was effective when applied in this way.

Table 2.2 Percentage mortality after 1 day of flies exposed to foliage treated with two novel insecticides.

Treatment	% mortality
HDCI 050	12.5
HDCI 051	0
Untreated	6.25

Experiment 2

In this experiment, flies (2 replicates x 10 flies per treatment) were exposed to foliage treated with either HDCI 050 or HDCI 051 applied in a 1% sugar solution and there was an untreated control. The results are shown in Table 2.3 and Figure 2.3. HDCI 050 caused relatively high mortality after 4-5 days. HDCI 051 was less effective.

Table 2.3 Percentage mortality of flies exposed to foliage treated with two novel insecticides in a 1% sugar solution.

Treatment	% mortality after		
	2 days	4 days	5 days
HDCI 050	30	75	80
HDCI 051	5	35	45
Untreated	10	15	20

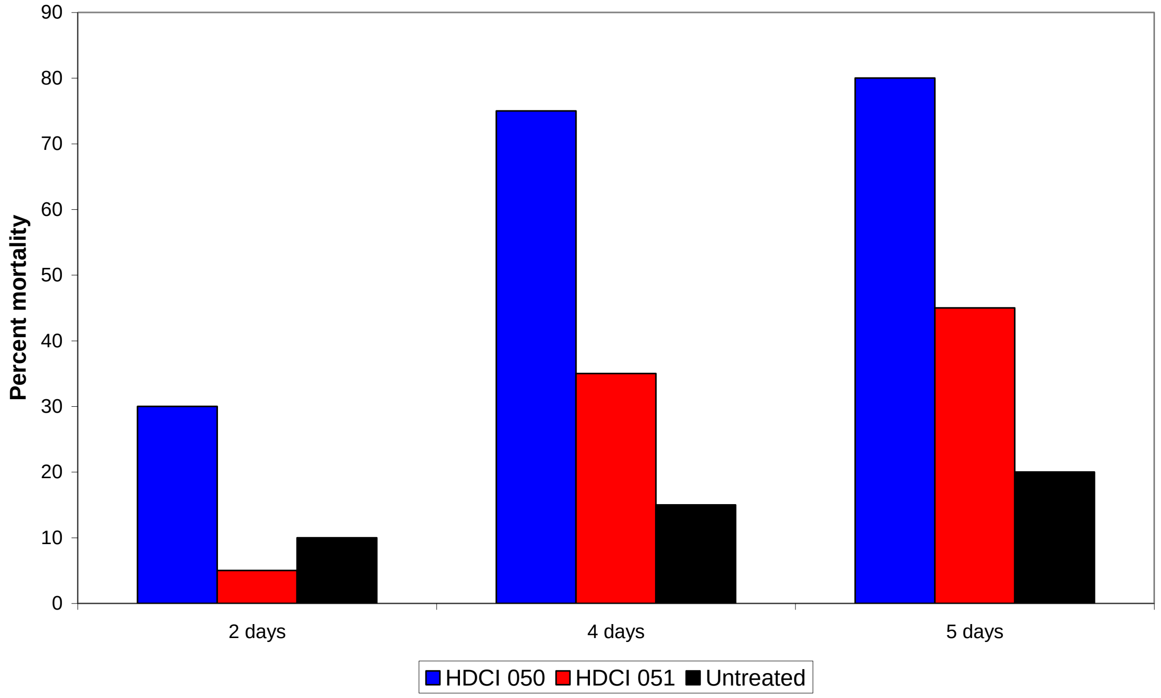

Figure 2.3 Percentage mortality of flies exposed to foliage treated with two novel insecticides in a 1% sugar solution.

Experiment 3

In this experiment, flies were exposed to foliage treated with one or other of the two bio-insecticides (HDCI 052, HDCI 054) applied alone or in a 1% sugar solution and there was an untreated control. There were two tests using each bio-insecticide and 14-16 flies were tested per treatment. The results of the two tests per bio-insecticide are summarised in Table 2.4 and Figure 2.4. HDCI 052 was ineffective when applied in this way, with or without sugar. HDCI 054 was more effective, especially when applied with sugar.

Table 2.4 Percentage mortality of flies exposed to foliage treated with two novel bio-insecticides alone and in a 1% sugar solution.

Test 1						Test 2					
	Percent mortality after:						Percent mortality after:				
Days	1 day	2 days	3 days	6 days	7 days		1 day	2 days	3 days	4 days	7 days
HDCI 052	0	11	11	11	22	HDCI 052	0	0	0	0	14
HDCI 052 + sugar	0	0	0	11	11	HDCI 052 + sugar	0	0	0	0	14
Untreated	11	11	11	22	22	Untreated	0	0	0	0	0
	1 day	2 days	3 days	6 days	7 days		1 day	2 days	3 days	6 days	
HDCI 054	0	0	14	29	29	HDCI 054	57	57	57	57	
HDCI 054 + sugar	43	57	57	71	71	HDCI 054 + sugar	100	100	100	100	
Untreated	0	14	14	14	14	Untreated	0	0	0	0	

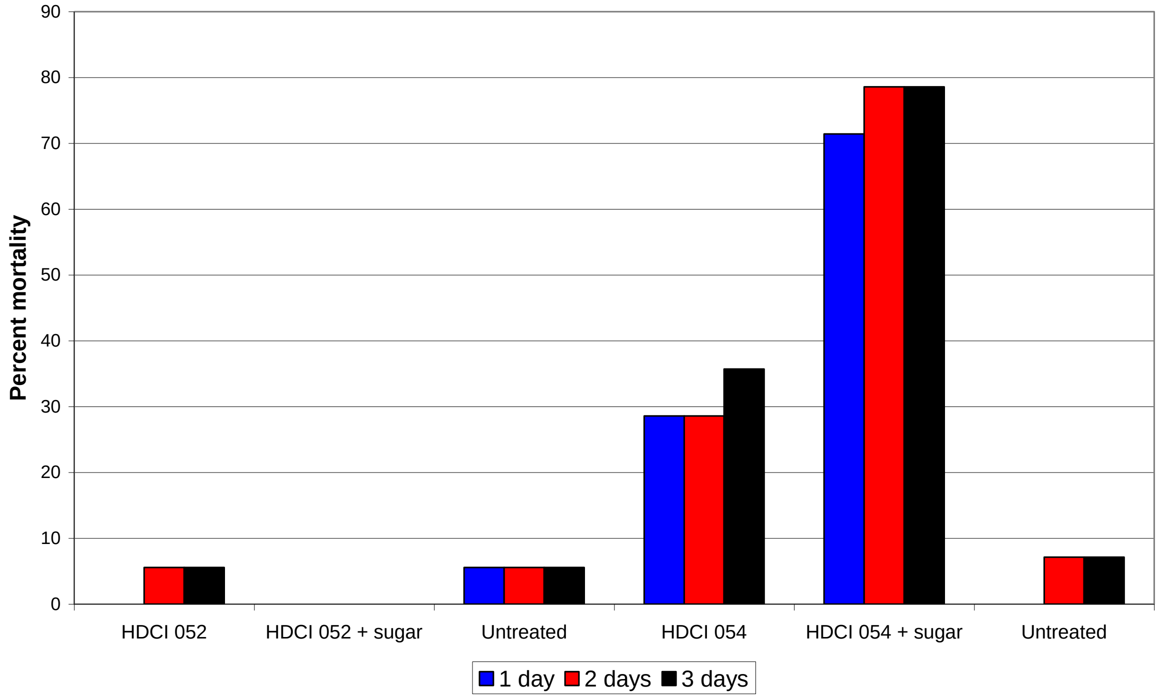

Figure 2.4 Percentage mortality of flies exposed to foliage treated with two novel bio-insecticides alone and in a 1% sugar solution (summarised over 2 tests per bio-insecticide).

Experiment 4

In this experiment, flies (10 per treatment) were sprayed directly with insecticide solutions. Hallmark was included as a standard in the test as we do not have any previous information on this method of application to large narcissus fly. The results are shown in Table 2.5 and Figure 2.5. Both HDCI 050 and Hallmark caused high mortality; knockdown was more rapid with Hallmark.

Table 2.5 Percentage mortality of flies sprayed directly with insecticide solutions.

Treatment	% mortality after		
	1 day	2 days	3 days
HDCI 050	60	100	100
HDCI 051	0	30	40
Hallmark	100	100	100
Untreated	10	20	40

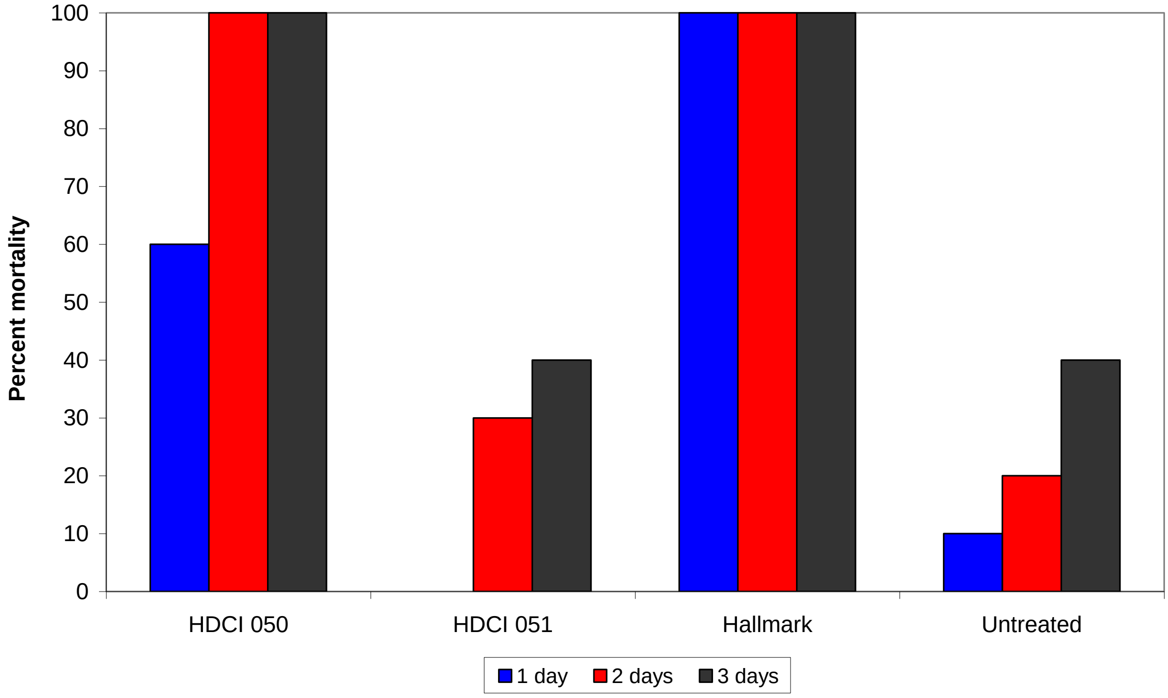

Figure 2.5 Percentage mortality of flies sprayed directly with insecticide solutions

Experiment 5

In this experiment, flies (10 per treatment) were sprayed directly with insecticide solutions of HDCI 053 and the two bio-insecticides (HDCI 052 and HDCI 054). The results are shown in Table 2.6 and Figure 2.6. The mortality of the untreated control flies was quite high in this test and we believe that this may have been due to contamination of the cage with Hallmark in the previous test, which was apparently not removed by washing the cage. Both of the bio-insecticides, HDCI 052 and HDCI 054, caused high mortality within 2 days.

Table 2.6 Percentage mortality of flies sprayed directly with insecticide solutions n.b. (B) = bio-insecticide.

Treatment	**% mortality**			
	1 days	2 days	3 days	4 days
HDCI 052 (B)	43	100	100	100
HDCI 053	14	29	29	43
HDCI 054 (B)	57	86	86	86
Untreated	40	50	50	60

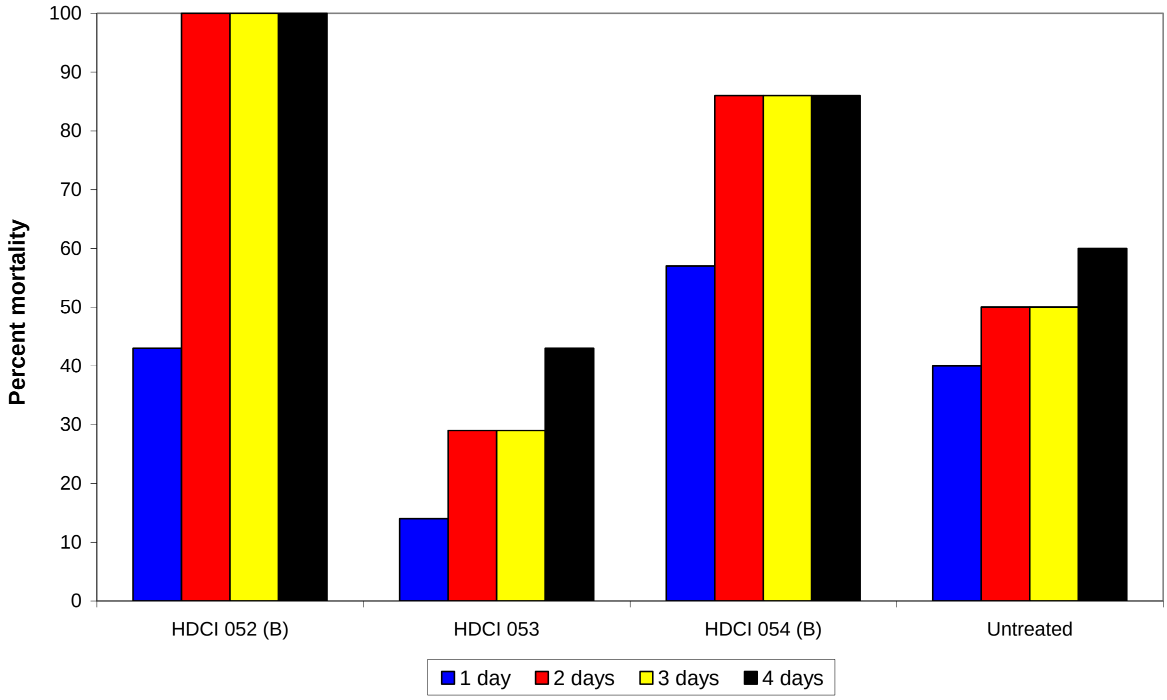

Figure 2.6 Percentage mortality of flies sprayed directly with insecticide solutions n.b. (B) = bio-insecticide.

Experiment 6

The results of the field trial are shown in Table 2.7. Overall, an average of 84 and 72 larvae per plot were recovered from the treated and untreated plots respectively. An average of 36% of bulbs were damaged, irrespective of treatment, and 21 and 20% of bulbs from the treated and untreated plots respectively contained larvae. There was little difference between the two treatments and since good numbers of insects were recovered it is reasonable to conclude that this treatment was ineffective.

Table 2.7 The numbers of undamaged and damaged bulbs and larvae recovered from the plots treated with the experimental insecticide and untreated control plots.

	Number of bulbs					
Code	Undamaged	Damaged	Total	With larvae	% damaged	% with larvae
HDCI 050 a	425	169	594	104	28.5	17.5
HDCI 050 b	229	140	369	88	37.9	23.8
HDCI 050 c	292	175	467	111	37.5	23.8
HDCI 050 d	192	145	337	75	43.0	22.3
HDCI 050 e	145	99	244	47	40.6	19.3
HDCI 050 f	255	107	362	78	29.6	21.5
HDCI 050 Mean	256.3	139.2	395.5	83.8	36.2	21.4
Untreated a	362	143	505	120	28.3	23.8
Untreated b	494	162	656	108	24.7	16.5
Untreated c	80	98	178	44	55.1	24.7
Untreated d	176	112	288	58	38.9	20.1
Untreated e	281	145	426	58	34.0	13.6
Untreated f	96	54	150	30	36.0	20.0
Untreated Mean	248.2	119.0	371.2	71.7	36.2	20.0

Discussion

Unfortunately the very wet weather conditions had an adverse effect on this research project because it was impossible to collect flies in 2012 when the weather was cool and wet. In addition, the weather was so poor it was not possible to undertake the field trial. An extension to the project was agreed and further work was carried out in 2013-4. It was apparent that the field population of narcissus fly in 2013 had been reduced by the bad weather in 2012, which would have prevented mating and egg-laying. This had an impact particularly on the numbers of flies that were available for the insecticide tests in the laboratory in both years. Based on the limited numbers of flies, every effort was made to obtain as much information as possible, but it is recognized that fly numbers were too low to undertake conventional statistical analyses.

In contrast, the numbers of damaged bulbs and larvae recovered from the field trial undertaken in 2013 showed how well large narcissus fly can survive when conditions are favourable, since over one third of the bulbs were damaged and over 900 larvae were recovered. Although this trial worked extremely well and was appropriate for statistical analysis, there was little point in doing this as there was so little difference between the treatments.

The results are summarised in Table 3.1 and include some information on Hallmark from BOF 53 for comparison. In general, addition of sugar, as an experimental treatment, to sprays applied to foliage increased fly mortality, presumably because it encouraged the flies to probe and take up more of the product. Direct application of an insecticide or bio-insecticide was the most effective way of killing the flies, provided the product had some activity. Overall, assuming that it will be quite difficult to contact many flies directly when applying a field spray, one novel insecticide (HDCI 050) and one bio-insecticide (HDCI 054) show potential for control of large narcissus fly. Further work is required before these insecticides would be suggested as suitable for use on a field-scale.

Table 3.1 Overview of the efficacy of the insecticide and bio-insecticide treatments evaluated in 2012 and 2013.

	Application to foliage	**Application to foliage with sugar**	**Direct application**	**Application as field spray**
HDCI 050	No rapid knockdown	Effective (no rapid knockdown)	Effective	Ineffective
HDCI 051	No rapid knockdown	Partially effective	Ineffective	
HDCI 052 (B)	Ineffective	Ineffective	Effective	
HDCI 053			Ineffective	
HDCI 054 (B)	Partially effective	Effective	Effective	
Hallmark (lambda-cyhalothrin)	Partially effective (BOF 53)	Effective (BOF 53)	Effective	

Conclusions

- Of the insecticides tested against large narcissus fly adults, HDCI 050 was effective when applied to foliage in a 1% solution of sugar and also when it was applied directly to flies. Hallmark was also effective using the same approaches to application and caused rapid knockdown when applied to foliage.
- Of the bio-insecticides tested against adults, HDCI 054 was effective when applied to foliage in a 1% solution of sugar. Both HDCI 052 and HDCI 054 were effective when applied directly to flies.
- HDCI 050 did not control fly larvae when applied as a field spray.
- The field trial showed that, in the field, inoculation of *Narcissus* bulbs with fly eggs can lead to a good infestation of large narcissus fly larvae.

Knowledge and Technology Transfer

The results of this work to date were reported at the HDC Daffodil technical seminar on 15 November 2012 at Springfields, Spalding.

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