HDC Project BOF1a & 1b (HRI Work)

FINAL REPORT

Forecasting and control of the

large narcissus fly

Rosemary H. Collier & Stan Finch

Horticulture Research International
Wellesbourne
Warwick
CV35 9EF

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CONTENTS OF REPORT

HDC Project BOF 1b

Narcissus: epidemiology, forecasting and control of large narcissus fly

This original project was separated into a section on forecasting attacks by the pest, that was carried out by Wellesbourne staff, and a section on insecticidal control, that was carried out by ADAS staff based mainly at Starcross, Devon.

The current report is restricted solely to the work carried out at Wellesbourne and includes the trials carried out towards the end of the project to screen narcissus cultivars for their resistance to fly attack.

FINAL REPORT

Forecasting attack by the large narcissus fly (*Merodon equestris*)

INTRODUCTION

The large narcissus fly (*Merodon equestris* (Fab.)) is the major insect pest of bulbs in the UK. Large narcissus flies overwinter as fully-fed larvae within the narcissus bulbs in which they developed. In March-April, the 15-20 mm long larvae move out of the bulb and burrow through the soil until they find suitable sites in whch to pupate. The adults emerge from the soil in May or June and lay their eggs either in the soil close to narcissus bulbs or on senescing narcissus foliage. After several days, the eggs hatch and the newly-emerged larvae burrow through the soil and enter the bulbs via the basal plate. The larvae feed and grow inside the bulbs, destroying their centres. Although several larvae may enter a single bulb, only one survives, and by the onset of winter it is fully-grown and about 15-20 mm long.

In the UK, most narcissus crops are left in the ground for two or three seasons to improve bulb yield and quality. In the past, protecting crops against the large narcissus fly throughout this protracted period was achieved with aldrin, a highly persistent insecticide. However, this insecticide has been withdrawn and the insecticides available currently are much less-persistent. In future, therefore, it seems likely that effective control of the fly during the second and third seasons on well-established crops could prove difficult. Thus information on the timing of large narcissus fly activity under field conditions would be extremely helpful, as it would enable the less-persistent insecticides to be applied at the times they are likely to have maximum impact on the pest.

This report describes the biological information that was collected both to generate and to validate the current system for the forecasting attacks by the large narcissus fly. The report also includes the results of a trial to screen fifteen frequently grown narcissus cultivars for their susceptibility to fly damage.

EXPERIMENTAL

The experimental work was divided into the following three sections:-

1. **DEVELOPMENTAL BIOLOGY** - Field and laboratory experiments were carried out to determine, for each phase of insect development, the relationships between the rate of large narcissus fly development and temperature. Such relationships form the basis of the current forecasting model.

2. **DEVELOPMENT AND VALIDATION OF THE FORECAST** - A computer

model, based on rates of insect development, was produced that enabled the timing of large narcissus fly activity to be forecasted. Field monitoring data on fly activity were then used to validate the accuracy of the computer-generated forecasts.

3. **SCREENING NARCISSUS CULTIVARS FOR RESISTANCE TO LARGE NARCISSUS FLY** - Fifteen narcissus cultivars were screened to determine their relative susceptibility to damage by large narcissus fly larvae.

1. DEVELOPMENTAL BIOLOGY

EXPERIMENTAL

During the summer of 1988 a population of large narcissus fly was obtained from the Agricultural Development and Advisory Service (ADAS) at Starcross, Devon. Additional insects, from the same source, were introduced into the culture in 1989 and 1990. Damaged narcissus bulbs containing partly-developed larvae were potted-up in 15 cm dumpy pots, using a peat-based compost. The pots were then either buried to their rims in an open field plot (winter of 1989-90) or left on the floor of an unheated screenhouse (winter of 1990-91) until the spring, when they were then buried in an open field plot.

Spring emergence and pupal development

During the winter of 1989-1990, pots containing bulbs infested with fly larvae were brought into the laboratory from the field at regular intervals from mid-December 1989 until mid-April 1990. The pots were placed into large trays and each tray was enclosed in a sleeve of Terylene net. All trays were kept in a constant temperature room at 21 ± 2°C. After some time, the larvae left the bulbs to form pupae in the compost and the subsequent emergence of flies was recorded.

During the same winter, additional pots of infested bulbs were brought in from the field on 6 February 1990 and placed in Gallenkamp cooling incubators maintained at 21.5, 19, 16.5, 14 or 11.5°C. Each pot was placed in a sealed polythene bag. The subsequent emergence of flies was recorded. This experiment was repeated during the spring of 1991, at which time additional pots of infested plants were also maintained at 10°C and 15°C. Pots of bulbs infested at Starcross in 1990 were also kept at 16.5°C.

To measure the times required for both pupal development and for the flies to emerge in the spring, pots of infested bulbs were brought in from the field into a controlled temperature room (18h L: 6h D/day temperature 22°C/night temperature 12°C) during February 1991. The soil around the bulbs was sieved daily to extract newly-formed pupae. These pupae were then held individually in small plastic boxes (56 x 36 x 12 m high) in cooling incubators maintained at the standard range of temperatures. The date each fly emerged was recorded.

Table 1 shows the mean time in days at 21 ± 2°C for flies to emerge from bulbs brought in from the field between 20 December 1989 and 19 April 1990. The time for flies to emerge from the samples taken from December through February was 56 days, whereas flies emerged in 20 days from the same taken in April. Throughout the period, the standard deviation was relatively constant (mean of 9 ± 2 days).

Narcissus fly larvae brought in from the field in early February required from 169 days at 10°C to 36 days at 21.5°C to complete post-winter development and emerge as adults. In Figure 1, the data are expressed as the percentage of fly development completed each day and show the effect of temperature on fly development rate in the spring. In 1991 there was no difference in the timing of the emergence of flies from bulbs infested at Wellesbourne and bulbs infested at Starcross. A common regression line was fitted to the data from the springs of 1990 and 1991. The low-temperature threshold of 7.1°C was estimated by extrapolation from this regression line.

Pupal development took from 91 days at 10°C to 19 days at 21.5°C and the low-temperature threshold was 7.2°C. It was estimated, by subtraction, that the time for the overwintering larvae to pupate ranged from 78 days at 10°C to 17 days at 21.5°C.

Egg-laying

Pairs of newly-emerged narcissus fly adults were held in 45 cm^3 Terylene net covered cages and were supplied with 10% sucrose solution, yeast hydrolysate and powdered brewer's yeast and water. The water was presented in a bottle with a wick made from blotting paper and in a plastic dish with a layer of Hydroleca[R] (expanded clay granules) that floated on the surface of the water and prevented the flies from drowning. An oviposition site was also provided which consisted of a plastic dish containing either a small narcissus bulb or some narcissus foliage. Although the flies laid on and around the plant material, most eggs were laid under the edges of the plastic containers.

The fecundity and longevity of single pairs of large narcissus flies were also recorded at a range of temperatures. Newly-emerged flies were confined in pairs in ventilated clear plastic boxes (210 x 105 x 80 mm high) lined with a paper towel, and with the food described above. A small narcissus bulb was provided as an oviposition site. The boxes of flies were maintained both in a controlled temperature room (18h

L:6h D; day temperature 22°C; night temperature 19°C) and in Gallenkamp cooling incubators at temperatures between 11.5 and 24°C. Eggs were removed and counted daily. For each pair of flies, the mean egg-laying time was calculated from the times in days at which the various eggs were laid.

Flies maintained at or below 19°C laid few eggs whereas some females maintained at or above 21.5°C laid more than 100 eggs, usually over a 2-3 day period. However, about half of the females maintained at or above 21.5°C still laid less than 10 eggs during their lifetime. The females that laid more than 10 eggs averaged 69 ± 36 eggs per fly (N = 39).

The mean egg-laying times of flies maintained in constant temperature rooms at 21.5°C and 24°C, and in a fluctuating temperature room at 22°C day/19°C night, were estimated from females that laid more than 10 eggs (Table 2). The mean ranged from 5.9 days in the fluctuating temperature room to 8.6 days in the constant temperature room at 21.5°C.

After being maintained at or below 19°C for at least 2 weeks, batches of flies were transferred to 27°C day temperature: 17°C night temperature, to determine the effect of the higher day temperature. These flies had a mean egg-laying time of 5.2 days (Table 2) and laid 59 ± 23 eggs per female.

Temperatures below 21.5°C could have affected fly development by preventing mating, oviposition, or both. To determine the effects of low temperatures, pairs of newly-emerged flies were kept at 24°C for two days after emergence to encourage mating. The females were then transferred to 16.5°C and most of them laid eggs even though this temperature had previously inhibited egg-laying. Of those that laid more than 10 eggs, the mean batch size was 61 ± 32 eggs (N = 6) and they were laid 14.5 ± 6 days after emergence (Table 2). In a second experiment, females were transferred to 24°C shortly after emergence and males were added from 3-12 days later. With the exception of one female, eggs were laid 2.6 ± 0.4 days after the male had been added (Table 2). Females maintained throughout at 24°C lived for 13.5 ± 5.4 days. In contrast, females maintained at 24°C for 2 days and then transferred to 16.5°C lived for 25.4 ± 8.0 days.

Egg hatching

In each year, at least two replicates of 20-100 newly-laid eggs were placed onto pieces of damp black filter paper and held in plastic boxes (56 x 36 x 12 mm high) in cooling incubators. The eggs were examined at regular intervals to determine when hatching occurred.

Figure 1 shows also the effect of temperature on narcissus fly egg development with a common regression line fitted to the data for 1990 and 1991. Eggs hatched after 37 days at 9°C and after 7 days at 21.5°C. The low-temperature threshold for egg-hatch was estimated to be 6.7°C.

Factors affecting larval establishment

The viability of the eggs in the culture ranged from 61-88%. Therefore, if only one egg was inoculated onto each bulb, many bulbs would not contain larvae. When one, two or four eggs were placed alongside bulbs potted in Levington compost, larvae developed successfully in 41, 76 and 102% of the bulbs, respectively. Figures in excess of 100% indicate that, in some pots, a few larvae established in offsets as well as in the main bulb. It is likely that inoculating three eggs on each bulb may be sufficient, but this treatment was not tested. In similar tests, in which bulbs were inoculated with one or two newly-emerged larvae, fully-grown larvae were found subsequently in 78 and 106% of the bulbs, respectively.

Previous information indicated that bulbs are usually attacked through the tough basal plate. In attempts to increase the establishment of larvae in narcissus bulbs, grooves were cut across the basal plate or holes were drilled through, using a fine scalpel. Some of the bulbs were smeared with the waste products from larvae of the previous season to assess whether bacteria associated with larval feeding help larval establishment. Test bulbs were inoculated with larvae that had emerged from eggs of large narcissus flies maintained in incubators. Larvae were placed on the soil surface alongside each bulb or directly in the cuts made in the base of the bulbs.

None of the treatments increased larval establishment. When larvae were placed directly into the cuts or holes made in the base of the bulbs, the larvae did not enter through the damaged tissues. By carefully paring away the base of the bulbs, it was apparent that larvae initially by-passed the physical barrier of the basal plate by chewing into and up through the roots that had already emerged through the basal plate. Why the larvae move subsequently into the tough basal plate to feed, remains a mystery. When two, four, eight or sixteen larvae were inoculated onto each bulb, only one individual survived within the main bulb. However, if the bulb was large and had a number of offsets, larvae were frequently found in the offsets. No potted 'bulb' contained more than three larvae.

Larval development and diapause

To rear large narcissus fly larvae at a range of constant temperatures, batches of eggs, placed on damp filter papers in Petri dishes were maintained at 21 ± 2°C. The dishes were inspected daily, and newly-hatched larvae placed in pairs on each narcissus bulb potted in peat in 15 cm dumpy pots. Some of the pots of inoculated bulbs were placed in the screenhouse to maintain the culture. Other pots were enclosed in polythene bags and placed either at 11.5 - 24°C or at 21 ± 2°C. Three to six pots, each containing five bulbs, were maintained at each temperature. The initial aim was to determine whether the fly generation time of one year under field conditions, could be shortened under laboratory conditions. If it could, then insects could be available on a more regular basis. The inoculated pots were examined at intervals to follow the development of the fly from the newly-hatched larva through to the adult stage.

Narcissus bulbs that had been inoculated with larvae and maintained in the cooling incubators were examined after 18 weeks. Each larva was dissected from the bulb, weighed and returned to its bulb. Table 3 shows the percentage of larvae surviving and their mean weight at each temperature. The only larvae that were not fully-grown after 18 weeks were those kept at 11.5°C. All other larvae had reached the maximum weight of 0.25-0.30 g. When inspected after 36 weeks, all bulbs maintained at 16.5 - 24°C still contained only larvae. In contrast, approximately 40% of the larvae maintained at 11.5 and 14°C had pupated.

Table 3 also shows the mean time (in weeks) for flies to emerge from infested narcissus bulbs. No flies emerged from the bulbs maintained at 24°C. Larvae reared at 21.5 - 16.5°C, 14°C, and 11.5°C emerged as adults after 45 ± 13 weeks (n = 7), 45 ± 6 weeks (n = 16) and 52 ± 15 weeks (n = 3), respectively.

Pots of narcissi inoculated with young larvae in March and May in 1990 were kept at 21 ± 2°C until 22 August and then transferred to 10°C (12h L: 12h D). By this time, the larvae were 5-7 months old and close to their maximum weight (mean weight 0.26 g). The pots were maintained at 10°C until 18 January 1991 when the temperature was raised to 20°C. The larvae formed pupae after approximately 3 weeks (mean 7 February ± 3 days). Most of the "control" batch of larvae kept at 21 ± 2°C throughout development failed to pupate, but from those that did, flies emerged about five months later; the others remaining as fully-developed larvae.

2. DEVELOPMENT AND VALIDATION OF THE FORECAST

Information collected on the relationships between the rates of fly development and temperature were used to develop a simulation model for forecasting the timing of emergence, egg-laying and egg hatch of the large narcissus fly.

The current model simulates the development of large narcissus fly from early spring (1 February) onwards and is based on equations derived from the biological data described above.

Large narcissus fly development was summarised using equations for the following three phases in the life-cycle of the fly:-

1. Spring development from overwintering larva through to emergence of adults
2. Egg maturation until egg laying (includes a threshold temperature for mating)
3. Egg development

The variation in the rate of development was estimated for each stage from the laboratory experiments and coefficients of variation were 17, 30 and 5% respectively for the three equations.

A threshold temperature for mating was also built into the model, on the assumption that large narcissus fly did not mate on days when the maximum air temperature was below 20°C.

The model was run using weather data (air maximum, air minimum and 09.00 h 10 cm soil temperatures) from the Agro-meteorological stations located closest to the sites where the fly monitoring data were collected. The output included the forecast times of spring emergence, egg-laying and egg-hatching of a population of 500 large narcissus fly. Individual forecasts were compared with the appropriate monitoring data.

Comparison of real and forecast large narcissus fly emergence

Between 1988 and 1992, the emergence of large narcissus fly from bulbs infested the previous summer was recorded at Starcross (1988-92), Wellesbourne (1989-92), Kirton (1990-91) and Cawood (1991). Batches of infested bulbs were planted in field soil and the area enclosed with a Tygan[R] cage or with non-woven fleece. Newly-emerged flies were collected regularly and their numbers were recorded. The simulation model was run for each site/year combination for which fly monitoring data was available, using weather data from the nearest weather station. The model was run on a population of 500 individuals.

Observed and forecast fly emergence at Starcross and Wellesbourne during 1989-92 are compared graphically in Figure 2 and at all sites on a percentage basis in Table 3. The observed and the forecast 10% activity differed by more than one week (8 days) in only one case. The difference between the observed and the forecast 50% activity was greater than one week on two occasions. At one of these sites, Starcross in 1988, the sample of insects (13) was very small whilst at the other site, Cawood, there were some initial difficulties in locating and capturing the insects from within the Tygan[R] cage, and this probably prevented the times of emergence being recorded accurately. The numbers of insects collected at Kirton were too low for any meaningful comparisons.

Comparison of observed and forecast large narcissus fly egg-laying

To test forecasts of the timing of large narcissus fly egg-laying, in May-June 1992, batches of newly-emerged flies were placed each day into 45 cm^3 Terylene net covered cages and supplied with 10% sucrose solution, yeast hydrolysate and powdered brewer's yeast and water. As described earlier, the water was presented in a bottle with a wick made from blotting paper and in a plastic dish beneath a layer of Hydroleca[R] (expanded clay granules). An oviposition site was also provided, which consisted of a plastic dish containing either a small narcissus bulb or some narcissus foliage. The flies were kept in an outdoor insectary screened from rainfall and direct sunlight. The numbers of eggs laid each day were recorded and compared with the forecast. During early June 1992, most eggs were laid from 5-9 days after emergence. On most days during this period the daily maximum temperature in the screenhouse was greater than 21°C and the mean temperature was above 15°C. The forecast, using the slightly lower temperatures recorded in a Stevenson's screen at Wellesbourne, indicated that egg-laying would have occurred approximately 5-10 days after emergence. However, further validation of egg-laying forecasts is essential, to ensure that the timing of egg-laying is predicted accurately in cool years, when the maximum air temperature remains below the threshold for large narcissus fly activity over a period of several days, or even weeks.

3. SCREENING *NARCISSUS* CULTIVARS FOR RESISTANCE TO LARGE NARCISSUS FLY

Narcissus bulb resistance to larval attack was studied using nine frequently-grown narcissus varieties (Divisions 1-4: trumpet, large cup, small cup, double) during 1991 and 1992 and a further six varieties (Narcissus Divisions 5, 6 and 8) during 1992. In the present study, newly-emerged larvae were inoculated during June and July onto bulbs of each variety at the rate of two maggots per bulb. As maggots were produced continuously over a 6-week period, the bulbs were inoculated in mixed batches to minimize variations arising from inoculation date. The bulbs were maintained in 15 cm dumpy pots, five bulbs of one variety per pot, in a screenhouse and were therefore subjected to temperatures close to outdoor conditions.

During December-February, the bulbs were examined individually to determine the percentage of narcissus fly larvae that survived on each narcissus variety. Because overall larval returns were low, for statistical analysis, the data were expressed in terms of the numbers of pots which did not produce larvae. Survival was greater in 1991 than in 1992 and also varied with the time of inoculation, so adjustments were made for the differences between times of inoculation before varieties were compared. Tables 5a and 5b show estimates of the percentage survival on each variety following adjustment for inoculation date. The data were analysed using a generalized linear model with binomial errors and a logit link function.

There was an almost 3-fold range of susceptibility to large narcissus fly larvae. The most resistant varieties were Golden Harvest and Carlton and the most susceptible was Tête a tête.

CONCLUSIONS

1. The large narcissus fly is a low-density pest, as only one individual survives in each bulb regardless of the number of larvae present.
2. The low temperature threshold was near to 7°C for each phase of fly development.
3. The fly overwinters as a larva in an obligatory diapause that is broken only by exposure to low temperatures for several weeks.
4. The fly generation time of one year cannot be reduced by rearing larvae continuously at high temperatures.
5. The threshold for mating is close to 20°C. At sufficiently high temperatures, the flies mate during the first two days of adult life. Once mating has occurred, lower temperatures do not inhibit oviposition.
6. Large narcissus flies normally emerge during May and June, when maximum air temperatures are often below 20°C. Hence, newly-emerged flies may have to wait for several days, or even weeks, before flying and mating.
7. The timing of large narcissus fly emergence varied by more than three weeks from region-to-region and from year-to-year. The spread of emergence also varied considerably.
8. The timing and spread of large narcissus fly emergence at both Starcross (Devon) and Wellesbourne (Warwickshire) was forecasted accurately.
9. The timing of egg-laying was also predicted at Wellesbourne in 1992. However, further validation of egg-laying forecasts is essential, to ensure that the timing of

egg-laying is predicted accurately in cool years, when the maximum air temperature remains below the threshold for large narcissus fly activity over a period of several days, or even weeks.

10. A range of commonly-grown *Narcissus* cultivars differed by as much as three-fold in their ability to support large narcissus fly larvae. However, this range is not considered sufficiently broad to merit starting a breeding programme to produce fly-resistant narcissus.

11. Greater levels of resistance may be present in other *Narcissus* species, but there is insufficient plant material available at present to support a statistically-sound screening programme.

SUMMARY

Eggs, larvae, pupae and adults of the large narcissus fly (*Merodon equestris*) were reared at a series of constant temperatures between 9-24°C. Egg development required from 37 days at 9°C to 7 days at 21.5°C. The low-temperature threshold for development was 6.7°C. Larvae reared at 14-24°C were fully-grown after 18 weeks, but it took much longer for such insects to pupate, and adult flies emerged only after about 45 weeks of development. Large narcissus flies enter diapause during the larval stage and overwinter as fully-fed larvae, forming pupae in the following spring. Post-winter pupation and pupal development took from 169 days at 10°C to 36 days at 21.5°C. Of this, pupal development required from 91 days at 10°C to 19 days at 21.5°C. The low-temperature threshold for post-winter pupation and pupal development was 7.1°C, and for pupal development alone, 7.2°C.

Females maintained at or below 19°C laid few eggs, whereas some females kept at, or above, 21.5°C laid more than 100 eggs (mean 69 ± 36). Approximately half of the females maintained at, or above, 21.5°C laid less than 10 eggs during their lifetime. The mean egg-laying time was 6-9 days. Although temperatures at or below 19°C inhibited mating, once a female had mated, such temperatures did not prevent oviposition.

Emergence of large narcissus flies from the soil alongside infested bulbs was recorded at Starcross and Wellesbourne. Emergence (10%) started earliest at Starcross in 1990 (3 May) and latest at Wellesbourne in 1989 (24 May). The forecast generally predicted 10% & 50% emergence to within 3-4 days. Although the timing of emergence varied considerably from year-to-year, it was predicted accurately by the forecast.

Narcissus bulb resistance to larval attack was studied using fifteen frequently-grown *Narcissus* varieties in 1991 and 1992. There was an almost three-fold range of susceptibility to attack and the most resistant varieties were Golden Harvest and Carlton.

ACKNOWLEDGEMENTS

We thank Steve Tones and Robin Brown of ADAS FCS, Starcross for providing the flies to start the Wellesbourne culture and Marian Elliott and Jan Percival for technical assistance. We thank especially the Horticultural Development Council for supporting this work as part of Project BOF/1.

Table 1. Mean time (in days ± S.D.) for flies to emerge from batches of narcissus bulbs infested with large narcissus fly larvae and brought in from the field between 20 December 1989 and 19 April 1990.

Date samples taken from field	**Mean time for flies to emerge at 21±°C**	**Standard deviation**
20 Dec 1989	56	12
12 Jan 1990	56	9
30 Jan 1990	40	9
21 Feb 1990	53	7
16 Mar 1990	37	7
19 Apr 1990	20	8

Table 2. Mean egg-laying times of large narcissus flies kept at temperatures between 11.5°C and 24°C

Temperature treatment (°C)	No. of insects	Mean egg-laying time (days)	S.D.
21.5	6	8.6	2.8
24.0	14	7.3	2.0
22.0 (day) 19.0 (night)	5	5.9	2.0
11.5 - 19.0 for 2 wk then 27.0 (day) 17.0 (night)	7	5.2	1.2
24.0 for 2 days then 16.5	7	14.5	6.4
24.0 permanently with males added 3-12 days later	6	2.6	0.4

Table 3. Percentage of insects surviving and mean weight of large narcissus fly larvae maintained for 18 weeks at temperatures between 11.5°C and 24°C. The mean times taken to emerge and the percentage of these insects that eventually emerged as flies are also shown.

<table>
<tr><th>Temperature treatment (°C)</th><th>Mean larval weight (g)</th><th>% larvae surviving</th><th>Mean emergence time (wk)</th><th>% emergence</th></tr>
<tr><td>24.0</td><td>0.26</td><td>45</td><td>-</td><td>0</td></tr>
<tr><td>21.5</td><td>0.23</td><td>35</td><td rowspan="3">45 ± 13</td><td>2</td></tr>
<tr><td>19.0</td><td>0.30</td><td>45</td><td>6</td></tr>
<tr><td>16.5</td><td>0.32</td><td>40</td><td>8</td></tr>
<tr><td>14.0</td><td>0.25</td><td>50</td><td>45 ± 6</td><td>26</td></tr>
<tr><td>11.5</td><td>0.14</td><td>50</td><td>52 ± 15</td><td>8</td></tr>
</table>

Table 4. Comparison of observed (O) and forecast (F) timings of 10% & 50% emergence of large narcissus flies in four localities.

Year	Site	Weather data for forecast	Emergence					Egg-laying
			10% (Obs)	O - F (days)	50% (Obs)	O - F (days)	No. flies	Forecast 50% eggs
1988	Starcross	Starcross	15 May	-4	19 May	-12	13	19 Jun
1989	Starcross	Starcross	18 May	3	24 May	0	73	1 Jun
1989	Wellesbourne	Wellesbourne	24 May	3	31 May	0	174	13 Jun
1990	Starcross	Plymouth	3 May	-	16 May	6	407	11 Jun
1990	Wellesbourne	Wellesbourne	13 May	2	24 May	3	124	31 May
1990	Kirton	Kirton	*20 May	-	*31 May	-	-	8 Jun
1991	Starcross	Exeter/ Starcross	20 May	-8	5 Jun	-7	675	27 Jun
1991	Wellesbourne	Wellesbourne	22 May	0	4 Jun	1	73	4 Jul
1991	Kirton	Kirton	*28 May	-	*12 Jun	-	7	4 Jul
1991	Cawood	Cawood	-	-	27 Jun	16	61	4 Jul
1992	Starcross	Plymouth	11 May	4	14 May	-3	223	24 May
1992	Wellesbourne	Wellesbourne	23 May	4	27 May	-1	1726	3 Jun
Median absolute difference between observed and forecast				**3**		**3**		

* Forecast emergence

Table 5. The proportion of narcissus bulbs containing large narcissus fly larvae in December-February following inoculation of 2 newly-hatched larvae/plant in June/July

a) **Divisions 1-4**

Cultivar	Percentage of bulbs infested
Golden Harvest	11
Carlton	11
California	17
Fortune	18
Unsurpassable	18
Golden Ducat	25
Hollywood	26
Dutch Master	27
Ice Follies	27

b) **Divisions 5, 6 and 8**

Cultivar	Percentage of bulbs infested
Minnow	17
Thalia	17
Geranium	19
February Gold	22
Tresamble	30
Tête a tête	33

Fig. 1. Effects of temperature on the rates of egg, pupal and spring development of the large narcissus fly (expressed as the percentage of total development completed each day). Mean development rates for each year (1990 & 1991) are shown separately. Pupal development was measured only in 1991.

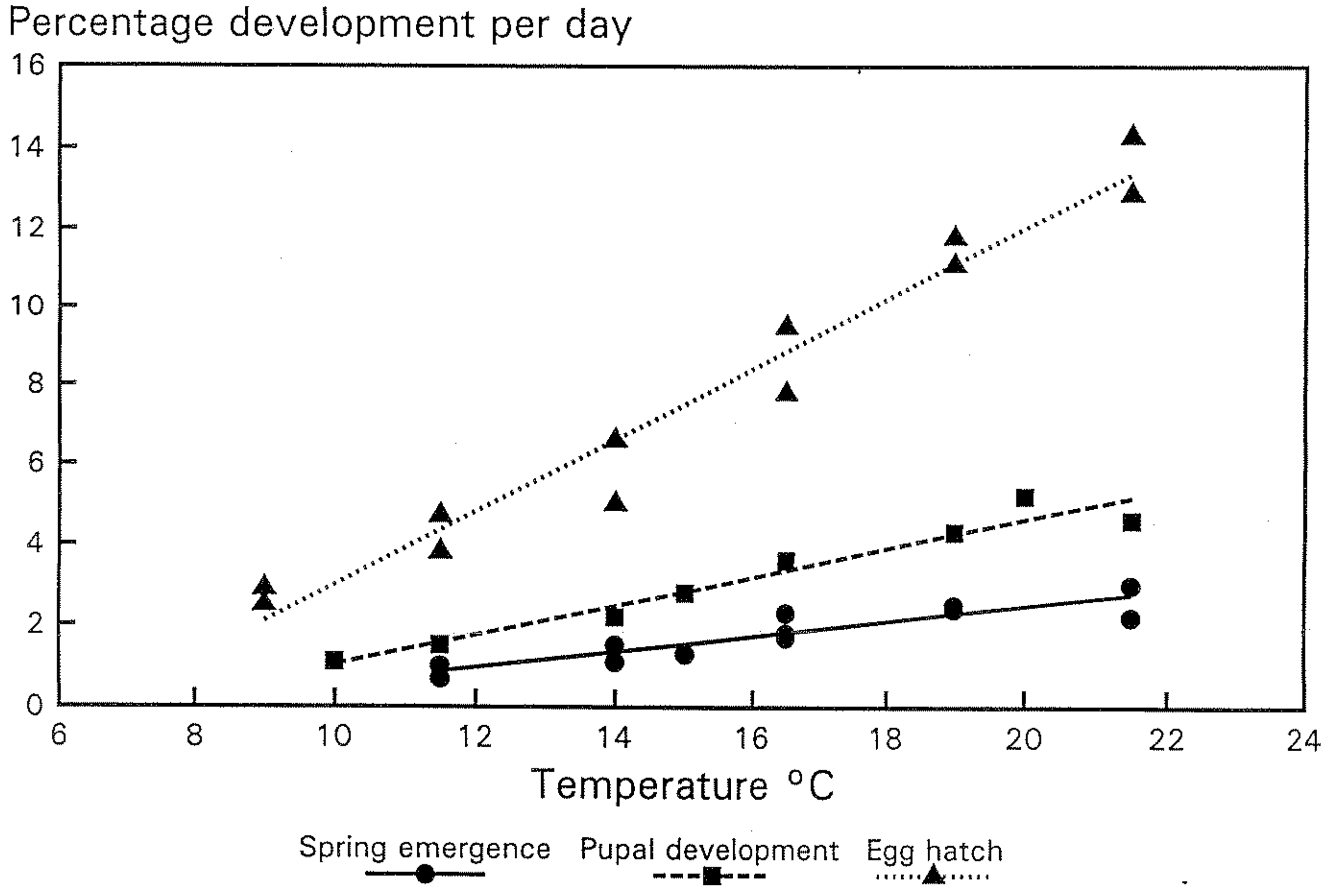

Fig. 2. Observed and forecast large narcissus fly emergence at Starcross and Wellesbourne during 1989 - 1992.