HDC projects **BOF 1c** and **FV/BOF 127 (bulbs)**

FINAL REPORTS

Integrated control of the large narcissus fly

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&

Dissemination of large narcissus fly forecasts

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BOF 1c

Integrated control of the large narcissus fly

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Project specifications

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Practical section for growers

Application

Aims

The work described in this report had two main aims: (1) to identify and, if possible, to develop for industry use, candidate chemical control measures for summer application to control large narcissus fly; (2) to refine and validate the HRI simulation model of large narcissus fly development for the timing of chemical and cultural control measures.

The detailed aims of the work on insecticides were: (1) to determine the optimum application rate and frequency of application for omethoate; (2) to determine whether the time of day at which omethoate is applied has any effect on the degree of control obtained; (3) to subject to exhaustive screening under field conditions, all other promising insecticides with existing UK Approvals for other purposes, and hence to identify other candidate insecticides for future development work.

The detailed aims of the forecasting work were to extend the simulation model to include egg-laying and larval invasion of the bulbs, and to validate and refine the model for all stages of the life-cycle over a three-year period utilising biological data generated at a number of geographically disparate locations, in conjunction with appropriate weather data.

Key results

1. Because of unfavourable early-summer weather in each of the three years, the number of attacked bulbs in untreated plots was relatively low, despite the use of infested guard rows between and around the blocks. Although this limited the extent to which differences between individual treatments could be determined, it is unlikely to have obscured the identification of those treatments with genuine commercial promise.

2. Of the insecticides tested as foliar sprays, imidacloprid (UK479C) and omethoate (Folimat) were the most effective. Esfenvalerate (Sumi-alpha) and triazophos (Hostathion) also had some effect. Imidacloprid probably acts by translocation within the plant, killing the young larvae after invasion. Omethoate worked best as weekly sprays at ca. 1 litre per hectare, which reduced attack by up to two-thirds. Less frequent applications were less effective. Half or quarter rates were ineffective. Applications timed by forecast were as effective as applications timed by calendar. Sprays applied in the evening were no less effective than sprays applied earlier in the day. In 1994, contrary to the findings of previous field experiments, omethoate failed to reduce attack, irrespective of the rate, frequency or timing of application. This failure was associated with unusually cool summer weather in 1994, which noticeably suppressed adult flight activity in crops, but did not inhibit egg-laying on

the crop. This confirms previous observations that omethoate acts against the adult flies. Esfenvalerate, like omethoate, probably acts only on the adult flies. Triazophos probably acts mainly on the larvae, either in the soil before invasion, or by translocation, killing the larvae inside the bulb after invasion.

3. Of the insecticides tested as soil drenches, gamma-HCH (Gamma-col), imidacloprid, and triazophos were the most effective. Chlorpyrifos (Dursban 4), demeton-s-methyl (DSM), pirimiphos-methyl (Blex) and quinalphos (Savall) were also effective. Although any of these insecticides could be acting as a simple insecticidal barrier in the soil around the bulbs, triazophos, and demeton-s-methyl may also act by translocation in the plant, killing the larvae inside the bulb after invasion.

4. Observed and forecast dates of adult emergence were compared for all sites at which emergence had been monitored since 1988. At three out of the four monitored sites, predictions of the 10% emergence date were accurate to within a week, with a mean difference between observed and forecast dates of 3.7 days. Predictions of 50% emergence dates were less accurate, with a mean difference between observed and forecast dates of 6.9 days. Starcross was excluded from the analysis because the Starcross Meteorological Station closed in 1990, and data from Plymouth could not be used because the two sites had previously exhibited large differences in spring temperature in some years.

5. Adult females need air temperatures over 20°C before they can mate. Once mating has occurred egg-laying can occur at temperatures much lower than this. The forecast accurately predicted the time at which egg-laying started, but underestimated the duration of egg-laying, which lasted, in some instances, for more than 14 days.

6. The forecast predicted that egg-hatch at Kirton in 1995 would occur roughly 10 days after the eggs were laid. This is similar to estimates of the interval between egg-laying and egg-hatch derived from field experiments at Starcross in previous years.

Opportunities for application

1. High-volume foliar sprays of possible contact-action insecticides such as esfenvalerate (all Approvals for omethoate in the UK lapsed in 1995) may have a worthwhile effect against the adult flies if applied repeatedly throughout the period of adult fly emergence, but may be ineffective in cooler summers.

2. High-volume foliar sprays of a number of soil-acting systemic or contact organochlorine (gamma-HCH), or organophosphorus (*e.g.*: chlorpyrifos; demeton-s-methyl; dimethoate; pirimiphos-methyl; quinalphos; triazophos) insecticides applied at or around the time of egg-hatch give worthwhile activity against large narcissus fly larvae in some seasons, but are sometimes ineffective, even when applied repeatedly.

3. All forecasts used to time treatments against the large narcissus fly should be generated from temperature data that is accurately representative of the locality concerned.

4. Forecasts of adult emergence can be used to initiate insecticide treatments aimed at the adult flies in localities for which representative daily measurements of soil temperature can be obtained from 1 February.

5. Forecasts of egg-laying can be used to initiate defoliation treatments in localities for which representative daily measurements of soil and air temperature can be obtained from 1 February.

6. Forecasts of large narcissus fly egg-hatch can be used to initiate insecticide treatments aimed at the young larvae, or to predetermine crop-lifting dates to prevent larval invasion of the bulbs, in localities for which representative daily measurements of soil and air temperature can be obtained from 1 February.

7. There may be value in publishing a relatively simple fact-sheet for growers, which would detail the control measures currently available for large narcissus fly, and give practical recommendations on their use.

Summary

Field experiments were done over three years to evaluate different insecticide treatments. Omethoate (for which all UK Approvals lapsed in 1995) applied weekly in May, June and July at a rate of ca. 1.0 litre per hectare, was effective. The time of day at which omethoate sprays were applied had no effect on control. In 1994, contrary to the findings of previous field experiments, omethoate failed to reduce attack, irrespective of the rate, frequency or timing of application. This failure was associated with unusually cool summer weather in 1994, which noticeably suppressed adult flight activity in crops, but did not inhibit egg-laying on the crop. This confirms previous observations that omethoate acts against the adult flies.

Esfenvalerate (Sumi-alpha), and triazophos (Hostathion), applied repeatedly as foliar sprays in May, June and July, reduced attack, but not consistently. Repeated foliar sprays of imidacloprid at very high rates gave highly effective control, but testing has not yet been done at commercially realistic rates.

Like omethoate, esfenvalerate probably acts by direct contact with the adult flies, whereas triazophos could either have direct contact action against the adults, or could act on the larvae before or after invasion. Imidacloprid probably acts systemically on the young larvae after invasion.

Gamma-HCH, chlorpyrifos, demeton-s-methyl, dimethoate, pirimiphos-methyl, quinalphos, and triazophos, were effective as soil drenches applied repeatedly in May, June and July. Applied in this way, these insecticides could either be acting as a protective barrier in the soil around the plant, killing the larvae by contact before invasion, or they could be taken up by the plant through the soil, killing the larvae by ingestion during or after invasion, but before visible damage has occurred.

It is recommended that any future R&D on mid-season insecticide treatments against large narcissus fly should include an exhaustive evaluation both of imidacloprid rates and timings, and of tank mixtures of insecticides with different kinds of activity.

The start of large narcissus fly emergence was predicted to within one week of the observed date in all instances where representative local temperature data were available. Forecasts generated using data from the Meteorological Station at Plymouth were inaccurate at Starcross, despite the geographical proximity of the sites (40 miles). The two localities differ significantly in spring soil temperature.

The threshold for mating was confirmed as lying close to 20°C. Mating is delayed if temperatures remain below this after adult emergence. Egg-laying starts a minimum of 4-5 days after adult emergence, and is not inhibited by temperatures below 20°C once the adults have mated.

The simulation model accurately predicted the start of egg-laying, but underestimated its duration. Some modification is needed to correct this.

The model accurately predicted the interval between egg-laying and larval invasion.

Forecasts of adult emergence can be used to initiate insecticide treatments aimed at the adult flies in localities for which representative daily measurements of soil temperature can be obtained from 1 February.

Forecasts of egg-laying can be used to initiate defoliation treatments in localities for which representative daily measurements of soil and air temperature can be obtained from 1 February.

Forecasts of large narcissus fly egg-hatch can be used to initiate insecticide treatments aimed at the young larvae, or to predetermine crop-lifting dates to prevent larval invasion of the bulbs, in localities for which representative daily measurements of soil and air temperature can be obtained from 1 February.

Science section

Introduction

The large narcissus fly, *Merodon equestris,* is the most important insect pest of narcissus in the UK. Light infestations can prevent the sale of bulbs for export, and heavy infestations can directly reduce the yield, both of bulbs and flowers. This pest is most troublesome in south-west England, but it can also cause serious problems in eastern England and elsewhere in the UK.

Large narcissus flies overwinter as fully-fed larvae within the 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 from May to July. After a period during which they feed, the flies lay their eggs on the foliage at the base of the plants. The eggs hatch after several days, and the newly-emerged larvae crawl down the plant and enter the bulbs through the root canals in the baseplate. The larvae feed and grow inside the bulbs. Although several larvae may enter a bulb, normally only one will survive. The larvae are usually fully-grown by early winter.

In the UK, narcissus crops are usually left down for two, or sometimes three, seasons. In the 1960s, 1970s, and for most of the 1980s, the ubiquitous use of aldrin against large narcissus fly, usually applied as a furrow-spray at planting, less commonly as a bulb-dip before planting, all but eliminated the problem. In 1989, all approved uses for aldrin in the UK were revoked, leaving the industry without an effective control measure against the pest.

Research done at Rosewarne EHS in the 1970s, and at ADAS Starcross and HRI Kirton more recently, showed that immersing bulbs in chlorpyrifos before planting can give highly effective control of large narcissus fly attack in the first season after planting. However, the control obtained does not extend to the second or third seasons after planting. Also, there are practical reasons to do with crop and operator safety, that prevent the use of chlorpyrifos in this way in some circumstances.

R&D (funded by MAFF and by the HDC) in Southwest England between 1987 and 1995, had the aim of identifying possible control measures for use in the second or third seasons after planting, or in the first season after planting in situations where chlorpyrifos cannot be used. Promising results were obtained with a number of non-persistent insecticides applied during the summer, and with various cultural practices including defoliation of the crop by flaming or cutting, and premature bulb-lifting.

Of the insecticides found to be effective when applied in the summer, one (omethoate) was found to work by killing or repelling the flies before egg-laying, and the others (which included carbofuran, dimethoate and disulfoton) were found to work by killing the young larvae, either before, or immediately after, they enter the bulbs.

The crop-defoliation treatments found to be effective (flaming or cutting) are thought to inhibit the narcissus plant's emission of the biochemicals responsible for eliciting egg-laying by the adult female flies.

Lifting the bulbs prematurely, even if they are afterwards left exposed on the soil surface, has the effect of preventing subsequent invasion by newly emerged larvae, probably because the roots quickly dry out and become too hard for the larvae to penetrate once they are removed from the soil.

Each of these different kinds of treatment is effective at a particular stage in the life-cycle, and must therefore be timed accordingly. Omethoate, or any other insecticide effective against the adult flies must be applied repeatedly at suitable intervals throughout the period of adult emergence. Insecticides effective against the young larvae must be timed to achieve a lethal dose either in the bulb itself, or in the surrounding soil, throughout the period of larval invasion. Defoliation treatments must be completed before significant egg-laying has occurred. Premature lifting must be completed before there has been significant larval invasion.

The development and activity of large narcissus fly, like that of other insects, is temperature-dependent. Hence, the adult flies emerge earlier in a summer following a warm spring than in a summer following a cold spring. Also, because the adults are unable to fly and mate at air temperatures below 20°C, egg-laying and larval invasion may be delayed by cool summer weather. Earlier laboratory studies (HRI Wellesbourne) quantified the influence of temperature on larval development and pupation. The findings have been used to construct a simulation model for large narcissus fly adult emergence.

BOF 1c had three main aims: (1) evaluation of chlorpyrifos band-sprays at planting, as a possible alternative to bulb-immersion in the insecticide; (2) screening and development of insecticides for summer application; (3) further development and validation of the large narcissus fly forecasting model for the accurate timing of chemical and cultural control measures.

The work on chlorpyrifos band-sprays was reported in full in the 1995 annual report, and the work done on forecasting in 1993 and 1994 was reported in detail in the 1994 and 1995 annual reports. The final report presented here includes a full account of the work done on summer insecticides since 1993, a detailed account of the work done on forecasting in the 1995 season only, and a review of all the forecasting work done since 1993.

The detailed aims of the work on insecticides for summer application were: (1) to determine the optimum application rate and frequency of application for omethoate; (2) to determine whether the time of day at which omethoate was applied has any effect on the degree of control obtained; (3) to subject to exhaustive screening under field conditions, all other promising insecticides commercially available in the UK, and hence to identify other candidate insecticides for future development work.

The detailed aims of the forecasting work were to extend the simulation model to include equations both for egg-laying and for egg-hatch, and to validate and refine the model for all stages of the life-cycle over a three-year period, utilising biological data generated at a number of geographically disparate locations, in conjunction with temperature data from nearby Meteorological Stations.

Materials and methods

Insecticides

Each of the four field experiments done over the three years was planted in early October, with narcissus bulbs (cv. Ice Follies) that had been hot-water-treated at 46°C for three hours after storage at 30°C for seven days. All experiments were done at ADAS Starcross, a sheltered estuarine site with sandy loam soil (Rudway Series) in south-east Devon.

A large narcissus fly population was maintained at the site in untreated infested blocks of narcissus left in situ from previous years, and by the annual introduction of infested bulbs, which were planted out in rows between and around the field experiment blocks.

Each year, bentazone (herbicide) was applied in early February to control annual dicotyledonous weeds, and chlorothalonil (fungicide) was applied in March, and again in April, to control foliar diseases.

Each experiment consisted of four randomised blocks. The plots were one row wide (0.71 metres) and 2.5 metres long (roughly 100 planted bulbs). This plot size was chosen on the basis of previous findings, to provide acceptable resolution of treatment effects under moderate pest pressure, without unnecessarily increasing the assessment work required in experiments containing large numbers of treatments. Each block was bounded on two sides by guard rows containing infested narcissus bulbs.

The treatments applied in the four field experiments are detailed in Tables 1 to 4.

The bulbs were lifted, cleaned by hand and weighed in mid-August. A random sample of 20 bulbs was removed from the untreated plots and analysed for dry matter content. The remainder were stored between 15°C and 20°C until mid-October, after which they were dissected and examined for evidence of large narcissus fly invasion. Counts were made of all damaged and undamaged bulbs, and of all large narcissus fly larvae present in the bulbs. All larvae recovered undamaged were transferred to fresh unattacked bulbs, which were planted between or around experiment blocks to replenish the site population, or were used in other experiments.

All data were subjected to analysis of variance using Genstat V. Percentage data were analysed raw and were also subjected to arcsin transformation before analysis. The results obtained were similar, and only the analyses of raw data are presented.

Forecasting

Computer simulation model

The simulation model for adult emergence, which is driven by daily soil temperature measurements from 1 February, was modified to include additional equations (accumulated temperature above development thresholds) for: (1) development of the adult females from emergence to the start of egg-laying (incorporating a threshold temperature of 20°C for mating); (2) development of eggs from laying to hatching.

The simulation model was run for each monitoring site (Jersey, Isles of Scilly, Starcross, Kirton) using standard data (maximum and minimum air temperatures, and 10 cm soil temperatures) from the nearest Meteorological Station. Each model run generated a theoretical "population" of 500 individuals for each stage of the life-cycle.

The computer forecasts were compared retrospectively with the field monitoring data.

Monitoring of adult emergence

Adult emergence was monitored each summer at ADAS Starcross and either at HRI Wellesbourne or at HRI Kirton. In 1995, adult emergence was also monitored on Jersey (data supplied by Department of Agriculture and Fisheries, Jersey), and on the Isles of Scilly (data supplied by Trenoweth R&D Ltd.).

At each site, infested bulbs were planted into field plots in the autumn, and the plots were covered in mid-April with emergence cages made either from Tygan^R, mesh (1x1 mm), or from non-woven fleece. The cages were checked daily until the end of July, and all flies evident on each occasion were removed and counted.

Monitoring of egg-laying

Cages at Kirton

During May and June 1995, batches of newly-emerged flies were placed in net cages (23 x 37 x 16 cm high). Food consisting of 10% sucrose solution, yeast hydrolysate and powdered brewer's yeast was provided. Water was presented in a plastic dish beneath a layer of Hydroleca^R (expanded clay granules) to prevent drowning. An oviposition site, consisting of a plastic dish that contained either a small narcissus bulb or some narcissus foliage, was also provided. The cages were kept in an outdoor insectary screened from rainfall and direct sunlight. Daily counts were made of the eggs laid.

Field experiment at Starcross

Field plots (each consisting of a 2.5-metre length of row) of narcissus (cv. Ice Follies) laid out in four randomised blocks were left exposed to natural infestation by the resident population of large narcissus flies at the site, and were then covered with fly-proof netting, to exclude egg-laying females, from different dates (weekly from 8 May to 11 July 1995).

All plots were lifted in mid-August, and the bulbs were stored at a temperature of between 15°C and 20°C until mid-October, after which they were dissected and examined for evidence of large narcissus fly invasion. Counts were made of all damaged and undamaged bulbs, and of all large narcissus fly larvae present in the bulbs.

Monitoring of egg-hatch

Field experiment at Starcross

Field plots (each consisting of a 2.5-metre length of row) of narcissus (cv. Ice Follies) laid out in four randomised blocks were left exposed to natural infestation by the resident population of large narcissus flies at the site, and were then lifted at weekly intervals from 25 May to 28 July.

The bulbs were stored at a temperature of between 15°C and 20°C until mid-October, after which they were dissected and examined for evidence of large narcissus fly invasion. Counts were made of all damaged and undamaged bulbs, and of all large narcissus fly larvae present in the bulbs.

Results

Insecticides

In all three years, sub-optimal summer weather conditions restricted population build-up, resulting in relatively light attacks by large narcissus fly in the untreated plots in each of the four experiments. This made it difficult to distinguish individual treatment effects against the background variability. All findings must be interpreted accordingly.

Omethoate rates and timing, and insecticide screening -1993

Weekly sprays of Folimat reduced the number of infested bulbs by roughly two-thirds (Table 5). Less frequent applications were less effective. The reduced rates were ineffective. Applications timed by calendar or by forecast were similarly effective. Sprays applied in the evening were no less effective than those applied earlier in the day.

None of the chemicals except omethoate reduced infestation.

Omethoate rates and timing - 1994 (a)

Contrary to the findings of previous field experiments, omethoate failed to reduce attack, irrespective of the rate, frequency or timing of application (Table 6).

Insecticide screening - 1994 (b)

Although the general analysis of variance indicated no statistically significant treatment effects, there were markedly fewer infested bulbs in the plots treated with imidacloprid (UK479C) than in any of the other plots, treated or untreated (Table 7).

Insecticide screening and mode of action - 1995

Drenching with insecticide was generally more effective than spraying (Table 8). Of the drenches, gamma-HCH, imidacloprid, and triazophos were the most effective. Chlorpyrifos, demeton-s-methyl, pirimiphos-methyl, and quinalphos were also effective as drenches.

Of the sprays, imidacloprid and omethoate were the most effective. Esfenvalerate and triazophos were also effective.

Forecasting

Adult emergence

In 1995, ten per cent of adults had emerged from the covered plots by 8 May on Jersey, 10 May at Starcross, 12 May on the Isles of Scilly, and 21 May at Kirton (Figure 1). Emergence started 13 days earlier at the earliest site (Jersey) than at the latest site (Kirton).

The forecasts for Starcross were produced using temperature data from Plymouth, because local data were not available. Emergence at Starcross was later than forecast. Weather data collected at Starcross between 1980 and 1989, before the Starcross Meteorological Station closed, showed that in the four months (February-May) before emergence, the mean monthly 30-centimetre soil temperature was higher at Plymouth than at Starcross by 1°C in February, 0.5°C in March, 0.4°C in April, and 0.3°C in May. Emergence would therefore be expected later at Starcross than at Plymouth Forecasts. Forecasts for the two sites in 1989, the last year before the Starcross Meteorological Station closed, predicted that emergence would occur 11 days later at Starcross than at Plymouth.

Excluding Starcross, the predicted dates of 10% adult emergence were accurate to within a week, with a mean discrepancy of 3.7 days (Figure 2). The predictions of 50% emergence were less accurate, with a mean discrepancy of 6.9 days. Since monitoring began, the earliest date of first adult emergence has been 3 May (Starcross, 1990), and the latest has been 24 May (Wellesbourne, 1989).

Egg-laying

Although large numbers of adult females emerged during late May and early June at Kirton, only those that emerged before the brief warm period in late May were able to mate immediately, after which they started laying eggs 4 to 5 days later, in early June (Figure 3). Females that emerged after the warm period in late May had ended were unable to mate until the end of the cold period in early June, and these females were therefore unable to begin laying eggs until 18 June.

The forecast accurately predicted the time at which the two periods of egg-laying started, but underestimated the duration of egg-laying, which lasted for more than 14 days in some instances.

Only 2 to 4 per cent of bulbs in the Starcross field experiment were infested by large narcissus fly larvae (Figure 4). Although adults started to emerge at Starcross in early May (Figure 1) the cool conditions that prevailed throughout May largely prevented mating, and damage occurred only in plots exposed to flies after 29 May.

Egg-hatch

The forecast predicted that egg-hatch at Kirton in 1995 would occur roughly 10 days after the eggs were laid. This is similar to estimates of the interval between egg-laying and egg-hatch derived from field experiments at Starcross in previous years.

Only 2 to 4 per cent of bulbs in the Starcross field experiment were infested by large narcissus fly larvae (Figure 4). Although adults started to emerge at Starcross in early May (Figure 1) the cool conditions that prevailed throughout May largely prevented mating, and damage occurred only in plots lifted on or after 2 June.

Discussion

Insecticides

MAFF-funded work done at Starcross in 1992 showed that the activity of omethoate is mainly against the adult flies, whereas that of dimethoate is mainly against the young larvae. The lack of control obtained with omethoate at Starcross in 1994 (Table 6), was associated with unusually cool weather throughout most of May and June, during which sightings of adult flies in the crop were rare compared with previous years. This suggests that there was insufficient contact effect, either directly on the adults present in the crop, or indirectly through their subsequent contact with the sprayed foliage.

Although the repeated application of omethoate at rates of one litre or more per hectare as a high volume foliar spray has proved highly effective in most years, omethoate is no longer Approved for use in the UK.

The apparent effectiveness of esfenvalerate as a foliar spray in 1995, suggests that, like omethoate, it may have some activity, either directly or indirectly, against the adult flies. Insecticides effective only against the adult flies are likely to be most effective if applied during periods of hot, sunny weather when the adult flies are most likely to be active.

Imidacloprid may be less effective at commercially permissible application rates than at the rates tested in 1994 (Table 7) and 1995 (Table 8). The 1995 findings suggest that, unlike all the other systemic insecticides screened, imidacloprid can be translocated to the site of larval invasion at the base of the bulb after application as a high-volume foliar spray.

The several insecticides that worked better as soil drenches than as foliar sprays could either be providing a protective barrier in the soil around the plant , or they could be taken up into the plant from the soil, killing the larvae after invasion. Insecticides that have shown this kind of activity against the larvae include granules such as aldicarb, carbofuran and disulfoton, and liquids such as chlorpyrifos, dimethoate, demeton-s-methyl, gamma-HCH, pirimicarb, pirimiphos-methyl, quinalphos and triazophos,

Forecasting

Adult emergence

Based on the sites for which representative temperature data have been available, the wide range of emergence dates observed in different localities in the three years of this study has generally been predicted with enough accuracy to ensure that insecticide treatments or other control measures aimed at the adult flies would start before egg-laying.

Egg-laying

The influence of air temperature in governing mating behaviour is crucial to the accurate forecasting of egg-laying. The findings of this study confirm the findings of previous laboratory studies that a measured air temperature of 20°C is an accurate threshold for mating, by which the simulation model for egg-laying can be triggered.

Although the duration of egg-laying predicted by the model was inaccurate, this has no bearing on the timing of the crop defoliation treatments aimed at preventing oviposition, which have a permanent effect as soon as they are applied, and therefore are related solely to the start of egg-laying. The forecasting model could be adjusted to allow for the longer period of egg-laying evident under field conditions.

Egg-hatch

Although there are relatively few data from which forecasts of the duration of egg development can be validated, the field data obtained at Starcross indicate that, within the limits of accuracy of the experiments, the duration of the egg stage was predicted correctly. This can be used to advise either on the application of insecticides aimed at the invading larvae, or on the timing of crop-lifting to prevent larval invasion of the bulbs physically.

Practicability

Observations over several years have shown that the timing of each of these critical stages in the life-cycle of the fly can vary by several weeks, both in different seasons, and in different parts of the country within a season. If treatments cannot be accurately timed to coincide with the appropriate stage in the fly's life-cycle, growers will either be forced to treat crops prophylactically throughout the whole of the potential target period, or will risk failing to control the problem, by treating either too soon or too late.

At present, several insecticides can be used legally by commercial growers against the adult flies, or against the larvae, but none of these is reliably effective. Premature crop defoliation is known to prevent egg-laying, but its effects on crop growth and yield, and on disease incidence, are still unknown, and are the subject of additional research (BOF 37). Premature bulb-lifting has limited practicability, and offers at best a partial solution for final-year crops. The potential benefits of forecasting are therefore limited by the current lack of control measures effective either against the adult flies or against the invading larvae.

The differences in spring soil temperature at Plymouth and Starcross demonstrate the need to use truly representative local temperature data for large narcissus fly forecasting.

Conclusions

1. High-volume foliar sprays, or soil drenches, of some soil-acting organochlorine, organophosphorus or carbamate insecticides applied at or around the time of egg-hatch give worthwhile activity against young large narcissus fly larvae in some seasons, but are sometimes ineffective, even when applied repeatedly.

2. High-volume foliar sprays of other insecticides such as omethoate and esfenvalerate may have some effect against the adult flies if applied repeatedly throughout the period of adult fly emergence.

3. All forecasts used to time treatments against the large narcissus fly must be generated from temperature data that is accurately representative of the locality concerned.

4. Forecasts of adult emergence can be used to initiate insecticide treatments aimed at the adult flies in localities for which representative daily measurements of soil temperature can be obtained from 1 February.

5. Forecasts of large narcissus fly egg-laying can be used to initiate defoliation treatments aimed at deterring egg-laying on the crop in localities for which representative daily measurements of soil and air temperature can be obtained from 1 February.

6. Forecasts of large narcissus fly egg-hatch can be used to initiate insecticide treatments aimed at the young larvae, or premature crop-lifting aimed at preventing larval invasion of the bulbs in localities for which representative daily measurements of soil and air temperature can be obtained from 1 February.

Recommendations

1. Research on insecticidal and cultural control measures against the large narcissus fly should continue to receive appropriate funding until effective and reliable control measures have been developed that will secure the long-term protection of the UK export and domestic retail trade in narcissus bulbs.

2. Future research on insecticides should evaluate: (1) high-volume sprays of imidacloprid at legally applicable rates at different times of application; (2) high-volume spray mixtures of promising insecticides with different actions against large narcissus fly.

3. If insecticides effective against large narcissus fly are identified and developed for industry use by this continued research, Approvals for their use on narcissus should be sought from the Pesticides Safety Directorate.

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Storage of data

All records of the ADAS parts of this study will be archived at ADAS Drayton, and those of the HRI parts will be stored at HRI Kirton, until 31 March 2001.

Tables

Table 1. Treatments applied in the 1993 omethoate and insecticide screening experiment

Each chemical was applied in 400 litres of water per hectare as a 0.3-metre-wide band along the row centres. Except where indicated otherwise, treatments were applied between 11.00 a.m. and 3.00 p.m. on each date of application.

Omethoate treatments triggered by calendar date:

1. Omethoate 50% miscible concentrate (Folimat) at 1.0 litre of product per hectare weekly from the expected start of first emergence until the observed end of emergence (5 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

2. Omethoate 50% miscible concentrate (Folimat) at 1.0 litre of product per hectare fortnightly from the expected start of emergence until the observed end of emergence (6 May, 21 May, 5 June, and 16 June).

3. Omethoate 50% miscible concentrate (Folimat) at 1.0 litre of product per hectare every three weeks from the expected start of emergence until the observed end of emergence (6 May, 27 May, and 16 June).

4. Omethoate 50% miscible concentrate (Folimat) at 1.0 litre of product per hectare every four weeks from the expected start of emergence until the observed end of emergence (6 May, and 5 June).

8. Omethoate 50% miscible concentrate (Folimat) at 0.5 litres of product per hectare weekly from the expected start of first emergence until the observed end of emergence (6 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

9. Omethoate 50% miscible concentrate (Folimat) at 0.5 litres of product per hectare fortnightly from the expected start of emergence until the observed end of emergence (6 May, 21 May, 5 June, and 16 June).

10. Omethoate 50% miscible concentrate (Folimat) at 0.25 litres of product per hectare weekly from the expected start of first emergence until the observed end of emergence (6 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

11. Omethoate 50% miscible concentrate (Folimat) at 0.25 litres of product per hectare fortnightly from the expected start of emergence until the observed end of emergence (6 May, 21 May, 5 June, and 16 June).

24. Omethoate 50% miscible concentrate (Folimat) at 1.0 litre of product per hectare applied between 4.00 p.m. and 6.00 p.m. weekly from the expected start of first emergence until the observed end of emergence (6 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

Omethoate treatments triggered by the HRI forecast:

5. Omethoate 50% miscible concentrate (Folimat) at 1.0 litre of product per hectare weekly from the predicted start of emergence until the predicted end of emergence (6 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

6. Omethoate 50% miscible concentrate (Folimat) at 1.0 litre of product per hectare fortnightly from the predicted start of emergence until the predicted end of emergence (6 May, 21 May, 5 June, and 16 June).

7. Omethoate 50% miscible concentrate (Folimat) at 1.0 litre of product per hectare within four days of each date when the air temperature reaches 19°C from the predicted start of adult emergence until the predicted end of emergence (28 May, 31 May, 5 June, 7 June, 10 June, 11 June, 16 June, 18 June, 21 June and 24 June).

Insecticides other than omethoate:

12. Cypermethrin 10% emulsifiable concentrate (Ambush C) at 0.25 litres of product per hectare weekly from the expected start of first emergence until the observed end of emergence (5 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

13. Deltamethrin 2.8% emulsifiable concentrate (Decis) at 0.25 litres of product per hectare weekly from the expected start of first emergence until the observed end of emergence (5 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

14. Endosulfan 20% emulsifiable concentrate (Thiodan 20) at 1.0 litre of product per hectare weekly from the expected start of first emergence until the observed end of emergence (5 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

15. Fenitrothion 50% emulsifiable concentrate (Dicofen) at 1.0 litre of product per hectare weekly from the expected start of first emergence until the observed end of emergence (5 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

16. Gamma HCH 57% emulsifiable concentrate (Gamma-col) at 1.0 litre of product per hectare weekly from the expected start of first emergence until the observed end of emergence (5 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

17. Heptenophos 50% emulsifiable concentrate (Hostaquick) at 1.0 litre of product per hectare weekly from the expected start of first emergence until the observed end of emergence (5 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

18. Phosalone 35% emulsifiable concentrate (Zolone Liquid) at 1.0 litre of product per hectare weekly from the expected start of first emergence until the observed end of emergence (5 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

19. Pirimiphos-methyl 50% emulsifiable concentrate (Blex) at 1.0 litre of product per hectare weekly from the expected start of first emergence until the observed end of emergence (5 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

20. Triazophos 42% emulsifiable concentrate (Hostathion) at 1.0 litre of product per hectare weekly from the expected start of first emergence until the observed end of emergence (5 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

<u>Other chemicals:</u>

21. Sulfur 80% dispersible powder (Thiovit) at 10.0 kg of product per hectare weekly from the expected start of first emergence until the observed end of emergence (5 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

22. Codacide (95% adjuvant oil) at 5.0 litres of product per hectare weekly from the expected start of first emergence until the observed end of emergence (5 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

23. Fyzol 11E (99% adjuvant oil) at 5.0 litres of product per hectare weekly from the expected start of first emergence until the observed end of emergence (5 May, 13 May, 21 May, 27 May, 5 June, 10 June 16 June and 24 June).

<u>Controls:</u>

25. Untreated (control)

26. Untreated (control)

27. Untreated (control)

Table 2. Treatments applied in the 1994 (A) omethoate experiment

Each insecticide spray was applied in 400 litres of water per hectare as a 0.3-metre-wide band along the row centres. Except where indicated otherwise, treatments were applied between 11.00 a.m. and 3.00 p.m. on each date of application.

1.	Omethoate 50% miscible concentrate (Folimat) at 1.12 litres of product per hectare weekly from the observed start of emergence until the observed end of emergence (13 May, 25 May, 6 June, 9 June 16 June, 27 June and 6 July).
8.	Omethoate 50% miscible concentrate (Folimat) at 1.12 litres of product per hectare weekly from the observed start of emergence until the observed end of emergence (5 May, 21 May, 2 June, and 15 June).
2.	Omethoate 50% miscible concentrate (Folimat) at 1.12 litres of product per hectare fortnightly from the observed start of emergence until the observed end of emergence (13 May, 25 May, 9 June 16 June and 27 June).
3.	Omethoate 50% miscible concentrate (Folimat) at 1.12 litres of product per hectare on the third day after the air temperature first reached 19°C starting from the observed start of adult emergence, and repeated on the third day after each successive occasion on which the air temperature reached 19°C, until the observed end of adult emergence (9 June and 16 June).
4.	Omethoate 50% miscible concentrate (Folimat) at 0.56 litres of product per hectare weekly from the observed start of emergence until the observed end of emergence (13 May, 25 May, 6 June, 9 June 16 June, 27 June and 6 July).
5.	Omethoate 50% miscible concentrate (Folimat) at 0.56 litres of product per hectare fortnightly from the observed start of emergence until the observed end of emergence (13 May, 25 May, 9 June 16 June and 27 June).
6.	Omethoate 50% miscible concentrate (Folimat) at 0.28 litres of product per hectare weekly from the observed start of emergence until the observed end of emergence (13 May, 25 May, 6 June, 9 June 16 June, 27 June and 6 July).
7.	Omethoate 50% miscible concentrate (Folimat) at 0.28 litres of product per hectare fortnightly from the observed start of emergence until the observed end of emergence (13 May, 25 May, 9 June 16 June and 27 June).
9.	Untreated (control).
10.	Untreated (control).

Table 3. Treatments applied in the 1994 (A) insecticide screening experiment

Each insecticide was applied in 400 litres of water per hectare as a 0.3-metre-wide band along the row centres between 11.00 a.m. and 3.00 p.m. weekly from the observed start of adult emergence until the observed end of emergence (13 May, 25 May, 6 June, 9 June 16 June, 27 June and 6 July).

Insecticides

1. Alpha-cypermethrin 11% emulsifiable concentrate (Fastac) at 0.2 litres of product per hectare.
2. Bifenthrin 12% emulsifiable concentrate (Talstar) at 0.075 litres of product per hectare.
3. Carbaryl 45% soluble concentrate (Thinsec) at 1.0 litre of product per hectare.
4. Chlorfenvinphos 24% emulsifiable concentrate (Birlane 24) at 1.5 litres of product per hectare.
5. Chlorpyrifos 41% emulsifiable concentrate (Dursban 4) at 1.0 litre of product per hectare.
6. Cypermethrin 10% emulsifiable concentrate (Ambush C) at 0.2 litres of product per hectare.
7. Deltamethrin 10% emulsifiable concentrate (Decis) at 0.2 litres of product per hectare.
8. Endosulfan 20% emulsifiable concentrate (Thiodan 20) at 1.0 litre of product per hectare.
9. Esfenvalerate 2.5% emulsifiable concentrate (Sumi-alpha) at 0.2 litres of product per hectare.
10. Fenitrothion 50% emulsifiable concentrate (Dicofen) at 1.0 litre of product per hectare.
11. Gamma-HCH 57% emulsifiable concentrate (Gamma-col) at 1.0 litre of product per hectare.
12. Heptenophos 50% emulsifiable concentrate (Hostaquick) at 1.0 litre of product per hectare.
13. Imidacloprid 70% wettable powder (UK479C) at 0.2 kg of product per hectare.
14. Lambda-cyhalothrin 5% emulsifiable concentrate (Hallmark) at 0.2 litres of product per hectare.
15. Malathion 57% emulsifiable concentrate (Malathion 60) at 2.1 litres of product per hectare.

16. Nicotine 7% emulsifiable concentrate (XL All Insecticide) at 4.0 litres of product per hectare.

17. Demeton-s-methyl 58% emulsifiable concentrate (DSM) at 0.42 litres of product per hectare.

18. Pirimicarb 50% soluble grains (Aphox) at 0.56 kg of product per hectare.

19. Pirimiphos-methyl 50% emulsifiable concentrate (Blex) at 1.0 litre of product per hectare.

20. Quinalphos 25% emulsifiable concentrate (Savall) at 1.0 litre of product per hectare.

21. Rotenone 5% emulsifiable concentrate (Liquid Derris) at 0.5 litres of product per hectare.

22. Trichlorphon 80% soluble powder (Dipterex 80) at 1.75 kg of product per hectare.

23. Triazophos 42% emulsifiable concentrate (Hostathion) at 1.25 litres of product per hectare.

Controls

24. Untreated (control).

25. Untreated (control).

26. Untreated (control).

27. Omethoate 50% miscible concentrate (Folimat) at 1.12 litres of product per hectare.

Table 4. Treatments applied in the 1995 insecticide screening experiment

Each insecticide was applied in 400 litres of water per hectare as a 0.3-metre-wide band along the row centre, between 11.00 a.m. and 3.00 p.m. every three to five days from the observed start of adult emergence until the observed end of emergence (5 May, 10 May, 15 May, 19 May, 22 May, 26 May, 30 May, 2 June, 5 June, 8 June, 13 June, 16 June, 20 June, 23 June, 27 June, 30 June, 4 July, 7 July, 10 July, 14 July, 17 July). Drenching was done by applying 10 millimetres of water through a hand-held watering can immediately after spraying, before the insecticide had dried on the foliage.

Foliar sprays

1. Omethoate 50% miscible concentrate (Folimat) at 1.12 litres of product per hectare.
2. Alpha-cypermethrin 11% emulsifiable concentrate (Fastac) at 0.2 litres of product per hectare.
3. Chlorfenvinphos 24% emulsifiable concentrate (Birlane 24) at 1.5 litres of product per hectare.
4. Chlorpyrifos 41% emulsifiable concentrate (Dursban 4) at 1.0 litre of product per hectare.
5. Deltamethrin 10% emulsifiable concentrate (Decis) at 0.2 litres of product per hectare.
6. Endosulfan 20% emulsifiable concentrate (Thiodan 20) at 1.0 litre of product per hectare.
7. Esfenvalerate 2.5% emulsifiable concentrate (Sumi-alpha) at 0.2 litres of product per hectare.
8. Fenitrothion 50% emulsifiable concentrate (Dicofen) at 1.0 litre of product per hectare.
9. Gamma-HCH 57% emulsifiable concentrate (Gamma-col) at 1.0 litre of product per hectare.
10. Heptenophos 50% emulsifiable concentrate (Hostaquick) at 1.0 litre of product per hectare.
11. Imidacloprid 70% wettable powder (UK479C) at 0.2 kg of product per hectare.
12. Imidacloprid 70% wettable powder (UK479C) at 0.4 kg of product per hectare.
13. Lambda-cyhalothrin 5% emulsifiable concentrate (Hallmark) at 0.2 litres of product per hectare.
14. Malathion 57% emulsifiable concentrate (Malathion 60) at 2.1 litres of product per hectare.

15. Nicotine 7% emulsifiable concentrate (XL All Insecticide) at 4.0 litres of product per hectare.

16. Demeton-s-methyl 58% emulsifiable concentrate (DSM) at 0.42 litres of product per hectare.

17. Pirimicarb 50% soluble grains (Aphox) at 0.56 kg of product per hectare.

18. Pirimiphos-methyl 50% emulsifiable concentrate (Blex) at 1.0 litre of product per hectare.

19. Quinalphos 25% emulsifiable concentrate (Savall) at 1.0 litre of product per hectare.

20. Rotenone 5% emulsifiable concentrate (Liquid Derris) at 0.5 litres of product per hectare.

21. Trichlorphon 80% soluble powder (Dipterex 80) at 1.75 kg of product per hectare.

22. Triazophos 42% emulsifiable concentrate (Hostathion) at 1.25 litres of product per hectare.

Soil drenches

23. Chlorfenvinphos 24% emulsifiable concentrate (Birlane 24) at 1.5 litres of product per hectare.

24. Chlorpyrifos 41% emulsifiable concentrate (Dursban 4) at 1.0 litre of product per hectare.

25. Gamma-HCH 57% emulsifiable concentrate (Gamma-col) at 1.0 litre of product per hectare.

26. Imidacloprid 70% wettable powder (UK479C) at 0.2 kg of product per hectare.

27. Imidacloprid 70% wettable powder (UK479C) at 0.4 kg of product per hectare.

28. Demeton-s-methyl 58% emulsifiable concentrate (DSM) at 0.42 litres of product per hectare.

29. Pirimicarb 50% soluble grains (Aphox) at 0.56 kg of product per hectare.

30. Pirimiphos-methyl 50% emulsifiable concentrate (Blex) at 1.0 litre of product per hectare.

31. Quinalphos 25% emulsifiable concentrate (Savall) at 1.0 litre of product per hectare.

32. Rotenone 5% emulsifiable concentrate (Liquid Derris) at 0.5 litres of product per hectare.

33. Trichlorphon 80% soluble powder (Dipterex 80) at 1.75 kg of product per hectare.

34. Triazophos 42% emulsifiable concentrate (Hostathion) at 1.25 litres of product per hectare.

Controls

35. Untreated (control).

36. Untreated (control).

37. Untreated (control).

38. Untreated (control).

39. Untreated (control).

40. Untreated (control).

Table 5. Larval infestation in plots sprayed with different insecticides in 1993

Treatment	% bulbs infested
Omethoate treatments triggered by calendar date:	
Folimat 1.0 l/ha at midday weekly by calendar	4.4
Folimat 1.0 l/ha in the evening weekly by calendar	5.6
Folimat 1.0 l/ha at midday fortnightly by calendar	7.4
Folimat 1.0 l/ha at midday 3-weekly by calendar	8.3
Folimat 1.0 l/ha at midday 4-weekly by calendar	7.4
Folimat 0.5 l/ha at midday weekly by calendar	6.7
Folimat 0.5 l/ha at midday fortnightly by calendar	14.4
Folimat 0.25 l/ha at midday weekly by calendar	11.0
Folimat 0.25 l/ha at midday fortnightly by calendar	14.9
Omethoate treatments triggered by the HRI forecast:	
Folimat 1.0 l/ha at midday weekly by forecast	1.9
Folimat 1.0 l/ha at midday fortnightly by forecast	5.3
Folimat 1.0 l/ha at midday by temperature and forecast	6.7
Insecticides other than omethoate:	
Ambush C 0.25 l/ha at midday weekly by calendar	13.5
Decis 0.25 l/ha at midday weekly by calendar	9.5
Thiodan 20 1.0 l/ha at midday weekly by calendar	11.6
Dicofen 1.0 l/ha at midday weekly by calendar	10.0
Gamma-col 1.0 l/ha at midday weekly by calendar	16.7
Hostaquick 1.0 l/ha at midday weekly by calendar	17.3
Zolone Liquid 1.0 l/ha at midday weekly by calendar	18.0
Blex 1.0 l/ha at midday weekly by calendar	13.5
Hostathion 1.0 l/ha at midday weekly by calendar	10.6
Other chemicals:	
Thiovit 10.0 kg/ha at midday weekly by calendar	13.3
Codacide 5.0 l/ha at midday weekly by calendar	13.5
Fyzol 11E 5.0 l/ha at midday weekly by calendar	12.2
Controls:	
Untreated	9.1
Significance of F-test (P)	0.002
Standard error of mean	5.34
Standard error of difference	3.77

Table 6. Larval infestation in 1994 experiment (A) in plots sprayed with omethoate

Treatment	% bulbs infested
Folimat 1.12 l/ha at midday weekly by calendar and observation	4.6
Folimat 1.12 l/ha at midday fortnightly by calendar and observation	1.5
Folimat 1.12 l/ha at midday three days after each occurrence of 19°C	2.7
Folimat 1.12 l/ha in the evening weekly by calendar and observation	3.6
Folimat 0.56 l/ha at midday weekly by calendar and observation	4.8
Folimat 0.56 l/ha at midday weekly by calendar and observation	2.5
Folimat 0.28 l/ha at midday weekly by calendar and observation	3.4
Folimat 0.28 l/ha at midday weekly by calendar and observation	4.0
Untreated (control)	2.4
Significance of F-test (P)	0.36

Table 7. Larval infestation in 1994 field experiment (B) in plots sprayed weekly with different insecticides

Treatment	% bulbs infested
Test insecticides:	
Alpha-cypermethrin (Fastac)	3.4
Bifenthrin (Talstar)	9.7
Carbaryl (Thinsec)	7.4
Chlorfenvinphos (Birlane 24)	4.3
Chlorpyrifos (Dursban 4)	6.9
Cypermethrin (Ambush C)	4.5
Deltamethrin (Decis)	4.6
Endosulfan (Thiodan 20)	6.5
Esfenvalerate (Fastac)	3.5
Fenitrothion (Dicofen)	5.0
Gamma-HCH (Gamma-col)	6.2
Heptenophos (Hostaquick)	4.0
Imidacloprid (UK479C)	0.9
Lambda-cyhalothrin (Hallmark)	6.9
Malathion (Fastac)	6.8
Nicotine (XL All Insecticide)	4.6
Demeton-s-methyl (DSM)	5.2
Pirimicarb (Aphox)	3.0
Pirimiphos-methyl (Blex)	5.3
Quinalphos (Savall)	9.4
Rotenone (Liquid Derris)	7.1
Trichlorphon (Dipterex 80)	4.5
Triazophos (Hostathion)	5.4
Controls:	
Omethoate (Folimat)	2.1
Untreated (control)	5.6
Significance of F-test (P)	0.38

Table 8. Larval infestation in 1995 insecticide experiment

Treatment		% bulbs infested
Sprays:	Omethoate (Folimat)	0.7
	Alpha-cypermethrin (Fastac)	5.9
	Chlorfenvinphos (Birlane 24)	4.0
	Chlorpyrifos (Dursban 4)	3.5
	Deltamethrin (Decis)	3.3
	Endosulfan (Thiodan 20)	4.3
	Esfenvalerate (Sumi-alpha)	1.7
	Fenitrothion (Dicofen)	3.5
	Gamma-HCH (Gamma-col)	7.8
	Heptenophos (Hostaquick)	4.6
	Imidacloprid (UK479C) 0.2 kg	0.9
	Imidacloprid (UK479C) 0.4 kg	0.2
	Lambda-cyhalothrin (Hallmark)	3.9
	Malathion (Malathion 60)	6.1
	Nicotine (XL All Insecticide)	2.6
	Demeton-s-methyl (Fastac)	2.6
	Pirimicarb (Aphox)	3.5
	Pirimiphos-methyl (Blex)	4.8
	Quinalphos (Savall)	2.9
	Rotenone (Liquid Derris)	6.8
	Trichlorphon (Dipterex 80)	2.4
	Triazophos (Hostathion)	2.0
Drenches:	Chlorfenvinphos (Birlane 24)	3.4
	Chlorpyrifos (Dursban 4)	1.7
	Gamma-HCH (Gamma-col)	0.2
	Imidacloprid (UK479C) 0.2 kg	0.0
	Imidacloprid (UK479C) 0.4 kg	0.8
	Demeton-s-methyl (Fastac)	1.8
	Pirimicarb (Aphox)	1.2
	Pirimiphos-methyl (Blex)	1.8
	Quinalphos (Savall)	0.9
	Rotenone (Liquid Derris)	4.3
	Trichlorphon (Dipterex 80)	2.0
	Triazophos (Hostathion)	0.5
Controls:	Untreated	4.7
Significance of F-test (P)		0.001
Standard error of mean		2.83
Standard error of difference		1.37

Figures

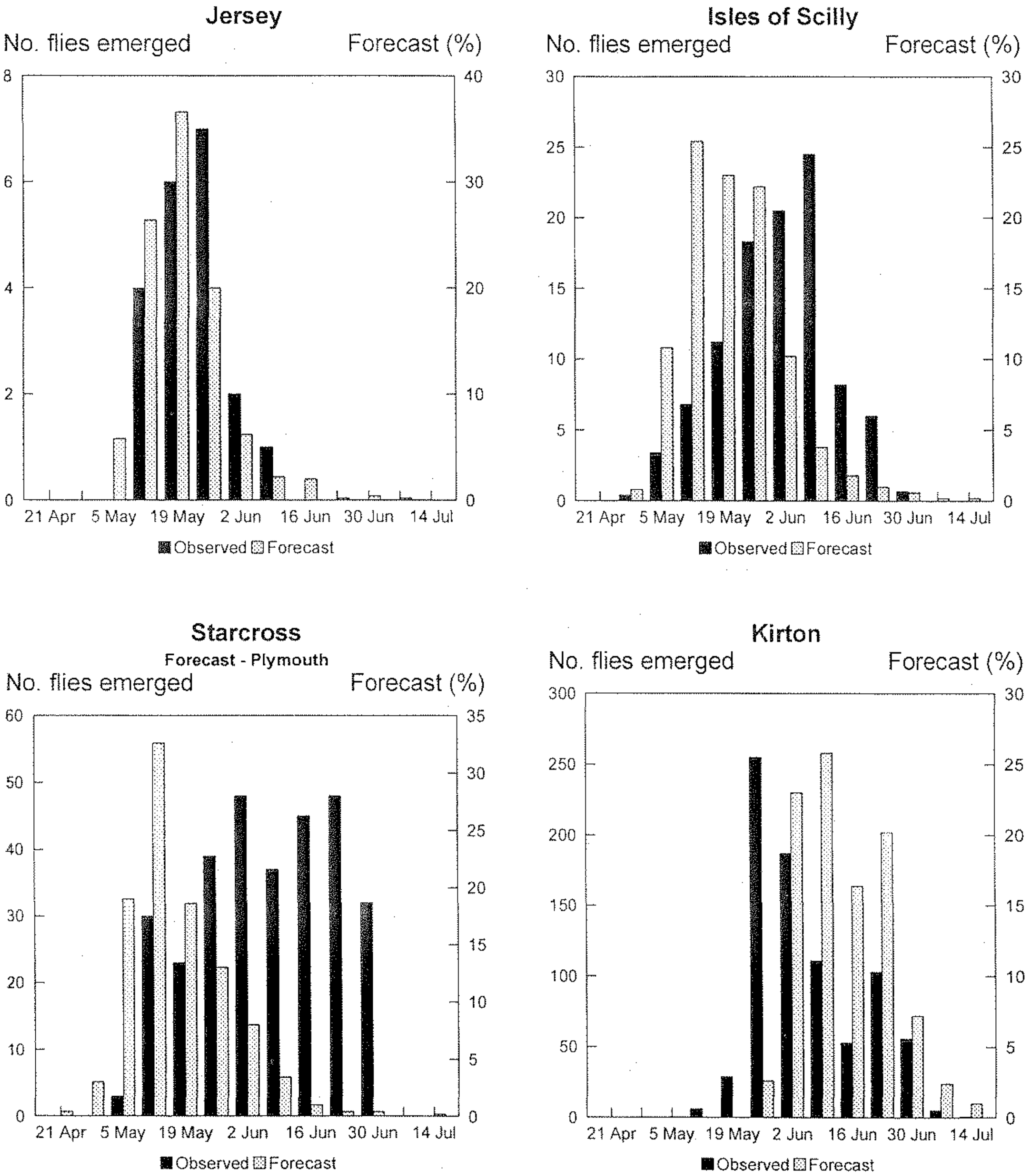


Figure 1. Observed and forecast times of adult large narcissus fly emergence in 1995.

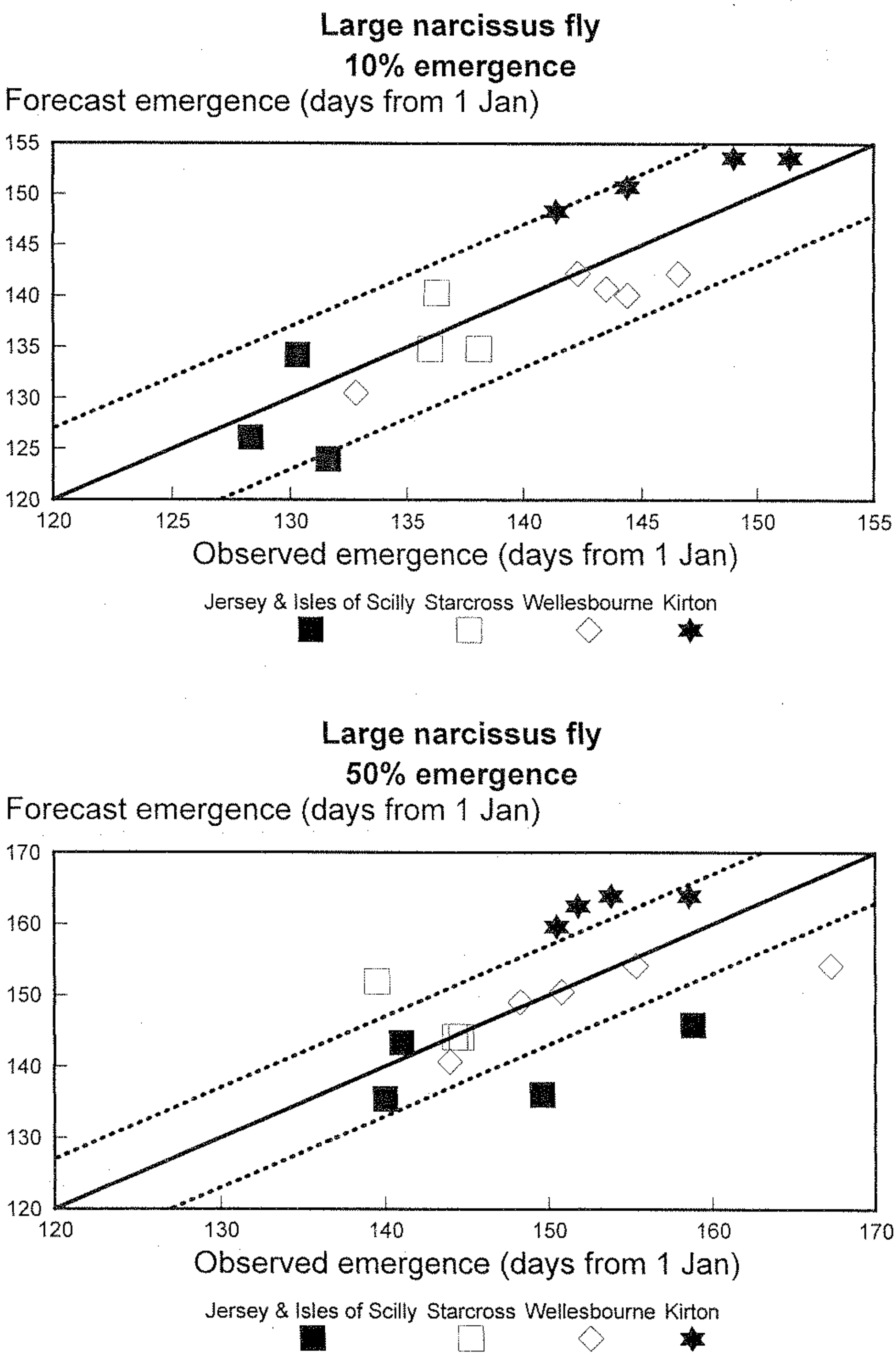


Figure 2. Observed and forecast times of adult large narcissus fly emergence from 1988 to 1995.

Fitted lines: ____ Forecast = Observed
- - - - Forecast = Observed ± 7 days

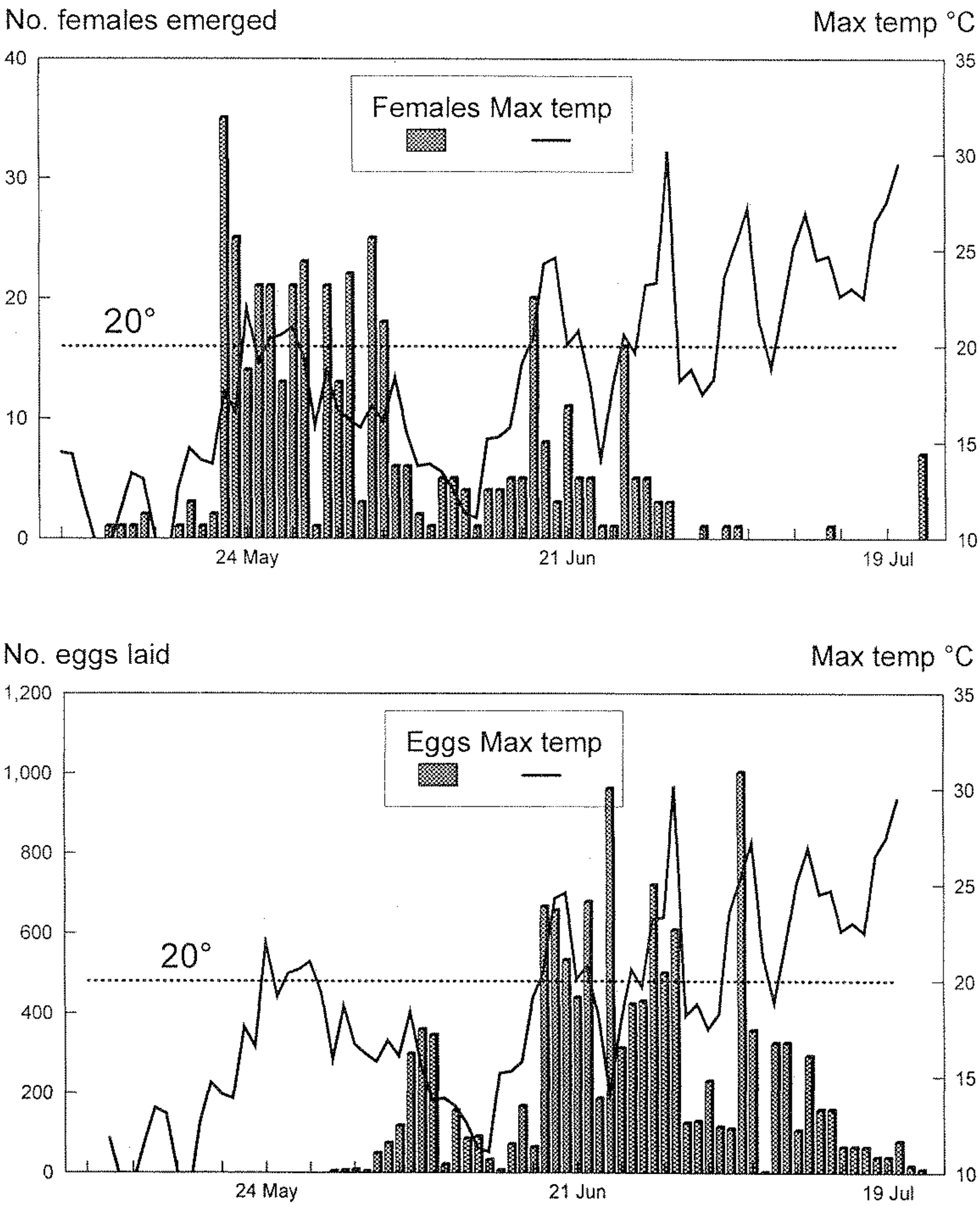
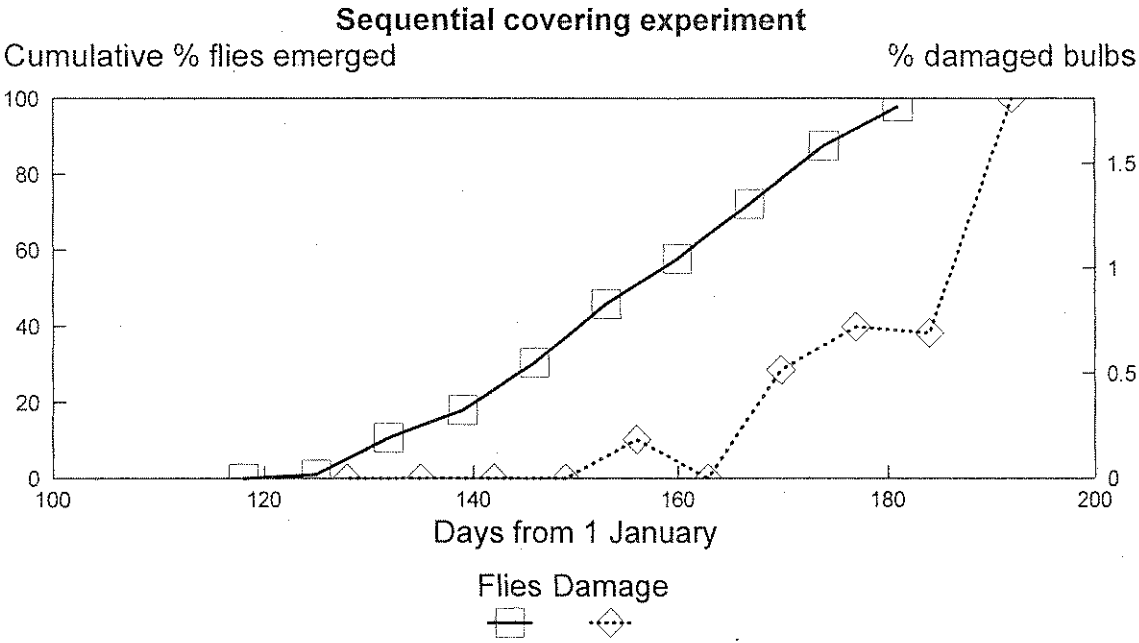


Figure 3. Observed times of female large narcissus fly emergence and egg-laying at Kirton in 1995.



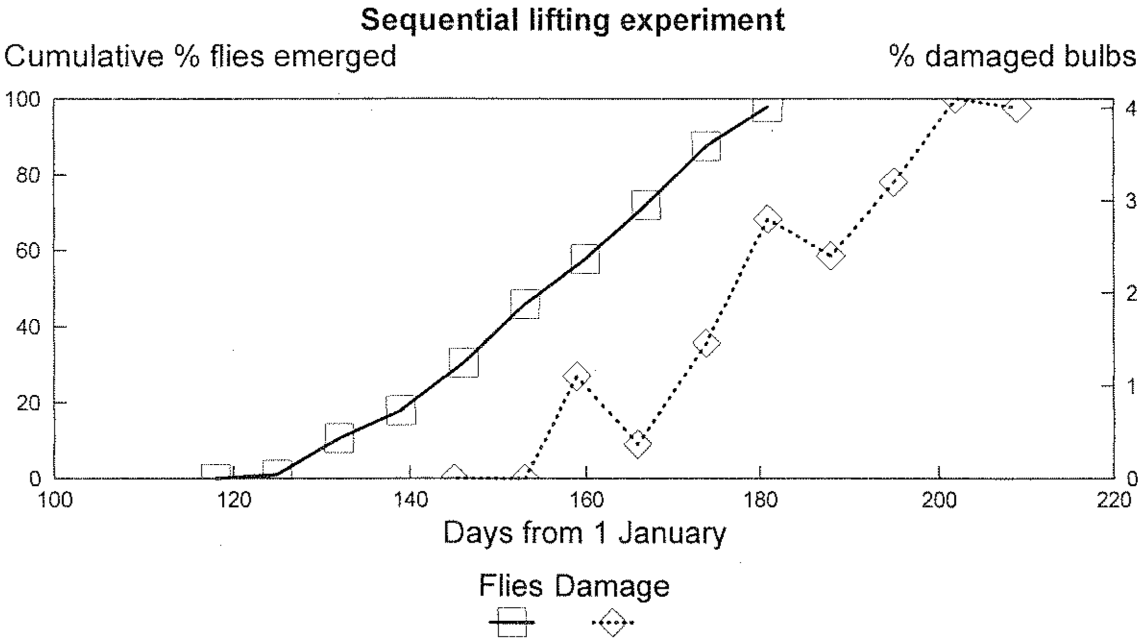


Figure 4. Observed times of large narcissus fly emergence, egg-laying and egg-hatch at Starcross in 1995.

FV/BOF 127

Dissemination of large narcissus fly forecasts

Rosemary H Collier and S Finch

Project specifications

Project number:	FV/BOF 127
Project title:	Dissemination of forecasts for large narcissus fly
Project leader:	Dr S Finch
Project location:	HRI Wellesbourne
HDC Co-ordinator:	Mr A Whitlock
Duration:	1 April 1993 to 31 March 1996
Key words:	bulb, control, forecast, insecticide, large narcissus fly, *Merodon equestris*, narcissus

Practical section for growers

Application

Aims

Using standard soil and air temperature data it is now possible to predict with accuracy when adult large narcissus flies will emerge from the soil in different localities, when the eggs will be laid, and when the eggs will hatch. Weekly forecasts have been issued free on request to growers each summer since 1993.

The aim of the work described in this report was to assess by postal questionnaire the current utilisation of, and future demand for, the large narcissus fly forecasts, and also to determine the industry's willingness to pay directly for them.

Key results

Of the 300 levy payers to whom a questionnaire was sent, 124 (40%) replied. A wish to receive pest forecasts in future was expressed by 89% of respondents, but only 27% indicated a willingness to pay for them.

Opportunities for application

Alternative indirect methods of financing the future production and dissemination of pest forecasts should be considered.

Summary

Weekly large narcissus fly forecasts were issued free to any HDC levy payers who requested them in the summers of 1993, 1994, and 1995. In 1995 the forecasts were sent to more than 60 growers.

A questionnaire about the HRI insect pest forecasts (large narcissus fly, cabbage root fly, carrot fly, pollen beetle) was sent in July 1995 to 300 HDC levy payers. Of the 124 respondents (40% response), 89% indicated that they would like to receive pest forecasts in future, but only 27% expressed a willingness to pay for them.

At present, the potential impact of the large narcissus fly forecasts is limited by the lack of effective chemical control measures for use either against the adult flies or against the invading larvae. As new methods are developed through the continuing programme of industry-funded and MAFF-funded R&D, the demand for the forecasts can be expected to strengthen.

Because most growers are unwilling to pay directly, the forecasts are unlikely to be viable unless a suitable indirect method of financing their production and dissemination can be found.

Science section

Introduction

It is now possible to predict, using standard temperature data for any given locality, when adult large narcissus flies will emerge from the soil, when the eggs will be laid and when the eggs will hatch.

Predicting the period of adult emergence will enable insecticide treatments aimed at the adult flies to be timed correctly. Predicting the start of egg-laying will enable crops to be defoliated on the latest possible date before egg-laying starts. Predicting the start of egg-hatch will enable insecticide treatments aimed at the invading larvae to be timed correctly, and allow bulbs to be lifted on the latest possible date before larval invasion starts.

To date, the production and dissemination of the forecasts to growers has been funded by the HDC on behalf of the industry. The perceived value to users, and the strength of future demand is unknown. If there is a genuine demand by the industry for forecasting to continue, an appropriate method of managing and financing this activity will be needed.

Materials and methods

Simulation model

The simulation model was run in 1993, 1994, and 1995 using weather data from 12 of the existing Meteorological Stations: four in eastern England, seven in south-west England, and one in west Wales.

Dissemination of forecasts to growers

Each week from early April to early July in each year, large narcissus fly forecasts were sent free to all HDC levy payers who requested them.

Questionnaire on pest forecasts

In July 1995, 300 HDC levy payers were sent a questionnaire about the future production and dissemination of the insect pest forecasts for carrot fly, cabbage root fly, large narcissus fly and pollen beetle. The questionnaire was anonymous, and each was accompanied by a stamped addressed envelope.

Results

Replies to the 300 questionnaires sent out were received from 124 levy-payers, comprising 113 growers, 5 corporate members and 6 consultant members. The replies are summarised in the following tables.

The responses made by vegetable growers to do with the forecasts for carrot fly, cabbage root fly and pollen beetle have been included for completeness.

Large narcissus fly forecast (66 sent each week)

Respondents	No.	%
Who received the forecasts	28	
Who want to know when crops are attacked	29	104
Who have narcissus fly on their farm	19	68
Who have difficulty controlling pest	16	57
Who apply pre-planting treatments	4	14
Who monitor the pest	15	54
Who apply post-planting treatments	11	39
Who thought forecasts helped pest control	16	57
Who based spray decisions on the forecast	12	43

Carrot fly forecast (127 sent each week)

Respondents	No.	%
Who received the forecasts	52	
Who want to know when crops are attacked	54	104
Who have difficulty controlling pest	28	54
Who apply pre-planting treatments	36	69
Who monitor the pest	31	60
Who apply post-planting treatments	42	81
Who thought forecasts helped pest control	42	81
Who based spray decisions on the forecast	37	71

Cabbage root fly forecast (212 sent each week)

Respondents	No.	%
Who received the forecasts	83	
Who want to know when crops are attacked	83	100
Who have difficulty controlling pest	37	45
Who apply pre-planting treatments	73	88
Who monitor the pest	43	52
Who apply post-planting treatments	48	58
Who thought forecasts helped pest control	46	55
Who based spray decisions on the forecast	36	43

Pollen beetle forecast (37 sent each week)

Respondents	No.	%*
Who received the forecasts	16	
Who want to know when crops are attacked	44	275
Who have difficulty controlling pest	23	144
Who monitor the pest	25	156
Who apply post-planting treatments	31	194
Who thought forecasts helped pest control	9	56
Who based spray decisions on the forecast	8	50

Some responses were >100% because some brassica growers receiving only the cabbage root fly forecast also replied to questions about pollen beetle.

All pest forecasts

Respondents	No.	%
Who have a farm computer system	61	49
Who use weather records from:		
Local weather information	71	57
Meteorological Office	65	52
On farm sources	52	42
Radio/TV	89	72
Who think Met Office data are appropriate for forecast	64	52
Who would like HRI to run forecasts with their own data	23	19
Who would like to run their own forecasts	21	17
Who would like more background information	58	47
Who would prefer forecasts just before the start of pest activity	72	58
Who would like to receive forecasts in 1996	110	89
Who would be prepared to pay for the forecasts	34	27

Assessment of how easy the forecasts were to understand

	1 (very easy)	2	3	4	5 (very difficult)
No.	50	32	24	5	3
%	44	28	21	4	3

Assessment of whether growers found the forecasts useful

	1 (very useful)	2	3	4	5 (not useful)
No.	33	29	34	13	6
%	29	25	30	11	5

Maximum sum growers willing to pay for forecasts

	<£30	£30-50	£50-75	£75-100
No.	4	34	9	

Growers who would prefer forecasts to be sent by post or fax

	Post	Fax	Either
No.	62	38	9

Growers who would like forecasts sent automatically or on request

	Automatically	Request
No.	99	7

Other pests for which growers would like forecasts

	No.
Aphids	11
Cabbage aphid	9
Peach potato aphid	5
Lettuce root aphid	8
Caterpillars	9
Diamond-back moth	6
Silver Y moth	2
Cutworms	7
Onion fly	1
Vine weevil	1

Other information required with forecasts?

Growers who completed this section of the questionnaire indicated that in addition to the forecasts they would welcome further information on the range of insecticide treatments currently available and the likely levels of attack by the various pest species.

Discussion

Although the results indicate an already strong demand for the whole suite of pest forecasts, including those for large narcissus fly, the unwillingness of most growers to pay directly will prevent implementation unless a suitable indirect method of financing can be found.

At present, the potential impact of the large narcissus fly forecasts is limited by the lack of effective control measures for use either against the adult flies or against the invading larvae. As new methods are developed through the continuing programme of industry-funded and MAFF-funded R&D, the demand for the forecasts can be expected to strengthen further.

Conclusions

1. There is a positive industry demand for the pest forecasts, which can be expected to strengthen further as new control measures for large narcissus fly are developed.

2. An acceptable indirect method of financing the production and dissemination of the forecasts is essential to the industry-wide uptake of the forecasts by growers.

Recommendations

1. An indirect method of financing the pest forecasts should be sought urgently.

2. If an acceptable indirect method of financing is found, it should be implemented as quickly as possible so that the forecasts can be issued in 1996.

Acknowledgements

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Storage of data

All records of the work will be stored at HRI Kirton until 31 March 1997.