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Contract Report C90/0442
Bulbs: Integrated Control of the
Large Narcissus Fly 1990-1993
Undertaken for the Horticultural
Development Council (BOF1b)

PRINCIPAL WORKERS

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AUTHENTICATION

The work summarised in this report was done under my supervision according to the procedures described, and this report is a true and accurate account of it.

.... Mike Lole
Contract Manager
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Date ...6/10/93...

CONTENTS

BULBS : INTEGRATED CONTROL OF LARGE NARCISSUS FLY

SUMMARY

Field experiments were undertaken in 1991 on a mineral soil in Dorset, and in 1991 and 1992 on a peat soil on the Somerset Levels. The Dorset experiment was abandoned after one year due to low pest pressure.

Weekly or fortnightly sprays of omethoate in May and early June, during the main period of adult fly emergence, but before the start of egg-laying, greatly reduced large narcissus fly attack. The application of carbofuran (granules), disulfoton (granules) or dimethoate (sprays) had no significant effect. Insect-parasitising nematodes, and sprayable oils also were ineffective.

These findings suggest that omethoate works by killing or repelling the adult flies, whereas dimethoate, like carbofuran and disulfoton, works by systemic uptake, killing the larvae inside the bulbs after invasion. Omethoate has been consistently effective when applied during the period of adult fly emergence. The systemic insecticides have sometimes given good control, but have often failed to work, even when applied repeatedly at high rates throughout the summer. This inconsistency is thought to be due to natural variability in the duration of root activity during the summer, and the influence that this must have on the amount of insecticide taken up by the narcissus bulbs during the senescence period.

Carbofuran, disulfoton and dimethoate should no longer be recommended against the large narcissus fly. In the short-term, omethoate is the only insecticide that should be recommended for field application against this pest during the summer.

Further work is needed to determine the optimum application rate, timing and frequency of application of omethoate, and to evaluate other insecticides seen as possible alternatives.

INTRODUCTION

Recent research has identified a number of insecticides, including carbofuran, dimethoate, disulfoton and omethoate, that can give some control of large narcissus fly attack when applied to the growing crop during egg-laying and larval invasion. The action of carbofuran and disulfoton, both of which are systemic granular insecticides, has been shown to be the result of their uptake by the narcissus plant, the young larvae being killed inside the bulbs after invasion but before significant damage has been caused. The mode of action of dimethoate and omethoate could be similar to that of the granules, but it is possible also that these liquid insecticides applied as foliage sprays have some activity against the adult flies, although there is no experimental evidence for this.

As a group, these insecticides have proved to be extremely inconsistent in effect, often failing to control attack. This inconsistency is now known not to be due to simple differences in soil moisture content. For carbofuran and disulfoton the explanation is thought to be connected with the plant-physiological processes governing insecticide uptake by the roots, and particularly with their influence on the duration of root activity before the onset of root senescence. Factors that could influence this include cultivar, depth of planting, bulb age, soil organic matter content, and seasonal weather conditions. If dimethoate and omethoate are active against the adult flies, it is possible that the observed variability in control has simply been the result of variable spray timing in relation to adult fly emergence and activity.

No biological control agents have yet been tested against large narcissus fly. However, the recent exploitation of several species of insect-parasitic nematodes against vine weevil and sciarid larvae has suggested that a preliminary screening of these agents should be undertaken. The main difficulty is obtaining adequate exposure of the fly larvae, whose time is spent almost entirely inside the bulb, to the nematodes, whose activity is probably limited to the soil moisture film.

No field assessment has yet been made of any of the synthetic insect growth regulators (IGRs) or of any oil-based sprays with possible repellent or other activity against large narcissus fly.

The aims of the work described in this report were as follows.

1. To evaluate the activity of carbofuran, disulfoton, dimethoate and omethoate more fully.

2. To make a preliminary assessment of the activity of parasitic nematodes, an IGR, and a selection of sprayable oils.

MATERIALS AND METHODS

Sites

In autumn 1990, a field experiment was set up on a mineral soil in Dorset, on a farm with a history of large narcissus fly problems. The original intention was to run a single experiment at this site until the work was completed in 1992, replanting half of it in 1991. However, because fly incidence at the Dorset site was found to be too low to provide meaningful results, a replacement site was sought in summer 1991. The replacement site was located on peat soil on the Somerset Levels, in a crop of narcissus (Cheerfulness) discovered at the time to be heavily infested with large narcissus fly.

Experimental Strategy

One of the main practical constraints in designing the experiments stemmed from the need to plant all the plots in early autumn, before the data from the previous year's work had become available, and hence with only a generalised idea of the treatments to be applied. The reason for doing so was to avoid the 12-month delay that would otherwise have been necessary between successive experiments.

Because a key objective of the investigation was to evaluate treatment effects on bulbs of different ages, the 1991 season was used to make a pilot comparison of treatments on a proportion of the plots, after which all destructively sampled plots were replanted. A comprehensive evaluation of treatments was then undertaken in 1992 using both the replanted plots and an equal number of plots that had remained unharvested since planting.

Design and layout

Dorset:

Design:	2-way factorial: Factor 1: Cultivar Factor 2: Insecticide/other
Replicates:	6
Block size:	10 rows (7.1m) x 15m
Plot size:	1 row (0.71m) x 15m
Sub-plot size:	1 row (0.71m) x 2.5m

Somerset:

Design:	Randomised blocks
Replicates:	4
Block size:	12 rows (8.52m) x 10m
Plot size:	1 row (0.71m) x 10m

Treatments

Dorset 1990/1:

Cultivar:

1. Hollywood
2. Golden Ducat
3. Dutch Master
4. Fortune
5. Hollywood
6. Carlton
7. Ice Follies
8. California
9. Unsurpassable
10. Golden Harvest

Dorset 1991/2:

Treatments not allocated.

Somerset 1991:

1. Carbofuran 5% granules @ 1.25 g per m row as a 0.1-m-wide band along the row centres on 18 June

2. Disulfoton 10% (pumice) granules @ 1.08 g per m row as a 0.1-m-wide band along the row centres on 18 June

3. Phorate 10% (pumice) granules @ 1.28 g per m row as a 0.1-m-wide band along the row centres on 18 June

4. Dimethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres on 18 June, 28 June and 11 July

5. Omethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres on 18 June, 28 June and 11 July

6. Horticultural white spraying oil @ 16 l per ha in 1600 l water per ha as a 0.1-m-wide band along the row centres on 18 June, 28 June and 11 July

7. Vamoose insect repellent oil (formulation unknown) @ 40 l per ha in 1600 l water per ha as a 0.1-m-wide band along the row centres on 18 June, 28 June and 11 July

8. Fyzol 11E adjuvant oil @ 5 l per ha in 240 l water per ha as a 0.1-m-wide band along the row centres on 18 June, 28 June and 11 July

9. Foliage cut off at ground level and the soil surface raked and rolled on 18 June

10. Foliage covered with non woven fleece sheet dug in to a depth of 0.1 m on 18 June

11. Heterorhabditis sp. and Steinernema sp. in equal numbers @ 40,000 nematodes in 1000 l water per m row as a 0.1-m-wide band along the rows on 18 June

12. Untreated (control)

Somerset 1992:

1. Carbofuran 5% granules @ 1.25 g per m row as a 0.1-m-wide band along the row centres on 13 May

2. Carbofuran 5% granules @ 1.25 g per m row as a 0.1-m-wide band along the row centres on 3 June

3. Carbofuran 5% granules @ 1.25 g per m row as a 0.1-m-wide band along the row centres on 1 July

4. Carbofuran 5% granules @ 1.25 g per m row as a 0.1-m-wide band along the row centres on 13 May and 3 June

5. Carbofuran 5% granules @ 1.25 g per m row as a 0.1-m-wide band along the row centres on 3 June and 1 July

6. Carbofuran 5% granules @ 1.25 g per m row as a 0.1-m-wide band along the row centres on 13 May, 3 June and 1 July

7. Disulfoton 10% (pumice) granules @ 1.08 g per m row as a 0.1-m-wide band along the row centres on 13 May

8. Disulfoton 10% (pumice) granules @ 1.08 g per m row as a 0.1-m-wide band along the row centres on 3 June

9. Disulfoton 10% (pumice) granules @ 1.08 g per m row as a 0.1-m-wide band along the row centres on 1 July

10. Disulfoton 10% (pumice) granules @ 1.08 g per m row as a 0.1-m-wide band along the row centres on 13 May and 3 June

11. Disulfoton 10% (pumice) granules @ 1.08 g per m row as a 0.1-m-wide band along the row centres on 3 June and 1 July

12. Disulfoton 10% (pumice) granules @ 1.08 g per m row as a 0.1-m-wide band along the row centres on 13 May, 3 June and 1 July

13. Dimethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres weekly from 13 May to 28 May

14. Dimethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres weekly from 3 June to 25 June

15. Dimethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres weekly from 1 July to 22 July

16. Dimethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres weekly from 13 May to 25 June

17. Dimethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres weekly from 3 June to 22 July

18. Dimethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres weekly from 13 May to 22 July

19. Dimethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres fortnightly from 13 May to 28 May

20. Dimethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres fortnightly from 13 May to 28 May

21. Dimethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres fortnightly from 13 May to 28 May

22. Dimethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres fortnightly from 13 May to 28 May

23. Dimethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres fortnightly from 13 May to 28 May

24. Dimethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres fortnightly from 13 May to 28 May

25. Omethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres weekly from 13 May to 28 May

26. Omethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres weekly from 3 June to 25 June

27. Omethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres weekly from 1 July to 22 July

28. Omethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres weekly from 13 May to 25 June

29. Omethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres weekly from 3 June to 22 July

30. Omethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres weekly from 13 May to 22 July

31. Omethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres fortnightly from 13 May to 28 May

32. Omethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres fortnightly from 13 May to 28 May

33. Omethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres fortnightly from 13 May to 28 May

34. Omethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres fortnightly from 13 May to 28 May

35. Omethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres fortnightly from 13 May to 28 May

36. Omethoate 38% ec @ 1.7 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres fortnightly from 13 May to 28 May

37. Triflubenzuron 15% sc @ 0.5 l per ha in 1000 l water per ha as a 0.1-m-wide band along the row centres weekly from 3 June to 22 July

38. Heterorhabditis sp. and Steinernema sp. in equal numbers @ 20,000 nematodes per m row in 1000 l water per ha as a 0.1-m-wide band along the rows weekly from 3 June to 22 July

39. Untreated (control)

40. Untreated (control)

All granular insecticides were applied by sprinkling with inert ballast material from a hand-held pepper-pot applicator. All sprays were applied using an Oxford Precision Sprayer operated at 3kPa pressure.

Assessments

All lifted bulbs were cleaned by hand, and air-dried until they were free of surface moisture. In 1992, the first-year (replanted) bulbs were then weighed. None of the original farm planted bulbs were weighed after lifting, because there were no individual plot records of planting weights from which final bulb yields could be estimated. All bulbs were stored in an unheated building for a minimum of eight weeks, after which they were dissected and examined. Counts were made of all damaged and undamaged bulbs and of the large narcissus fly larvae present in the bulbs.

At Somerset in 1992, the percentage leaf area remaining unsenesced in each plot was estimated by eye weekly from 13 May to 10 June, after which no further assessments were possible due to excessive weed growth in the plots.

Statistical analyses

All yield and damage assessment data were subjected to analyses of variance using Genstat V.

RESULTS

Dorset

No large narcissus fly adults were evident at the site on any occasion, and no larvae were found in a sample of 600 of the untreated Hollywood bulbs lifted in August 1991. No insecticide treatments were applied in 1992, and the experiment was aborted.

Somerset

Table 1. Larval damage in 3rd-year bulbs at Somerset in 1991

Treatment	Percentage of bulbs attacked
Carbofuran 18 Jun	10.4
Disulfoton 18 Jun	8.0
Phorate 18 Jun	22.0
Dimethoate 18 Jun + 28 Jun + 11 Jul	10.0
Omethoate 18 Jun + 28 Jun + 11 Jul	5.1
White oil 18 Jun + 28 Jun + 11 Jul	11.4
Vamoose 18 Jun + 28 Jun + 11 Jul	10.0
Fyzol 11E 18 Jun + 28 Jun + 11 Jul	14.6
Cut/raked/rolled 18 Jun	13.3
Fleece cover 18 Jun	6.1
Nematodes 18 Jun	16.7
Untreated (control)	16.3
SED (16 degrees of freedom)	6.81
CV(%)	80.3

Due to late acquisition of the site, all treatments were applied too late to be more than partly effective, and there were no significant ($p<0.05$) between-treatment differences.

Table 2. Larval damage to bulbs at Somerset in 1992

Treatment	Percentage of bulbs attacked 1st-year	4th-year
Carbofuran 13 May	49.5	13.1
Carbofuran 3 Jun	48.2	16.6
Carbofuran 1 Jul	47.3	11.4
Carbofuran 13 May + 3 Jun	39.7	11.7
Carbofuran 3 Jun + 1 Jul	50.3	5.3
Carbofuran 13 May + 3 Jun + 1 Jul	39.4	5.4
Disulfoton 13 May	42.8	14.5
Disulfoton 3 Jun	44.0	13.4
Disulfoton 1 Jul	36.7	6.6
Disulfoton 13 May + 3 Jun	34.8	7.2
Disulfoton 3 Jun + 1 Jul	50.1	7.9
Disulfoton 13 May + 3 Jun + 1 Jul	32.9	9.9
Dimethoate weekly 13 May to 28 May	33.8	9.5
Dimethoate weekly 3 Jun to 25 Jun	36.0	13.4
Dimethoate weekly 1 Jul to 22 Jul	44.4	14.3
Dimethoate weekly 13 May to 25 Jun	34.4	9.6
Dimethoate weekly 3 Jun to 22 Jul	36.9	6.0
Dimethoate weekly 13 May to 22 Jul	26.2	4.5
Dimethoate 2-weekly 13 May to 28 May	44.5	16.7
Dimethoate 2-weekly 3 Jun to 25 Jun	41.9	12.7
Dimethoate 2-weekly 1 Jul to 22 Jul	44.3	9.3
Dimethoate 2-weekly 13 May to 25 Jun	31.4	7.3
Dimethoate 2-weekly 3 Jun to 22 Jul	46.8	3.2
Dimethoate 2-weekly 13 May to 22 Jul	35.4	14.1
Omethoate weekly 13 May to 28 May	9.2 *	1.0
Omethoate weekly 3 Jun to 25 Jun	31.6	4.3
Omethoate weekly 1 Jul to 22 Jul	51.2	9.6
Omethoate weekly 13 May to 25 Jun	4.7 *	1.2
Omethoate weekly 3 Jun to 22 Jul	38.2	3.2
Omethoate weekly 13 May to 22 Jul	2.9 *	1.7
Omethoate 2-weekly 13 May to 28 May	6.3 *	7.5
Omethoate 2-weekly 3 Jun to 25 Jun	34.3	6.5
Omethoate 2-weekly 1 Jul to 22 Jul	40.7	6.7
Omethoate 2-weekly 13 May to 25 Jun	2.8 *	5.3
Omethoate 2-weekly 3 Jun to 22 Jul	39.6	8.8
Omethoate 2-weekly 13 May to 22 Jul	16.1 *	5.3
Teflubenzuron weekly 3 Jun to 22 Jul	39.8	20.2
Nematodes weekly 3 Jun to 22 Jul	42.2	26.8*
Untreated (control)	55.7	6.4
Untreated (control)	42.9	10.5
SED (116 degrees of freedom)	7.45	5.54
CV(%)	29.5	85.0

* indicates treatment means differing ($p<0.05$) from the untreated control means by more than the least significant difference (SED x t)

In the analysis of variance, between-treatment differences in the 1st-year bulb experiment were very highly significant ($p<0.001$) and those in the 4th-year bulb experiment were highly significant ($p<0.006$).

In the 1st-year bulb experiment, of the four insecticides tested, only omethoate significantly reduced attack, by between 62 and 93 per cent, but only when applied before 3 June. Fortnightly spraying was roughly as effective as weekly spraying. None of the other three insecticides had any discernible effect on attack, irrespective of the timing or frequency of application.

In the 4th-year bulb experiment, although the relative lightness of attack in all plots prevented the drawing of any statistical distinctions between most of the individual treatments, consistently fewer bulbs were attacked in plots to which omethoate had been applied before 3 June than in all other plots.

Table 3. Foliage senescence at Somerset in 1992

Date	Percentage green leaf area	
	1st-year bulbs	4th-year bulbs
13 May	96	90
20 May	90	85
28 May	50	80
3 June	40	75
10 June	10	70

The foliage of the first-year bulbs senesced much more rapidly than that of the fourth-year bulbs.

Table 4. Final bulb yield and bulb weight increase in 1st-year (replanted) bulbs at Somerset in 1992

Treatment	Bulb yield (t/ha)	% increase in bulb weight
Carbofuran 13 May	23.2	65.1
Carbofuran 3 Jun	24.8	76.2
Carbofuran 1 Jul	25.5	81.3
Carbofuran 13 May + 3 Jun	25.8	83.2
Carbofuran 3 Jun + 1 Jul	24.9	76.8
Carbofuran 13 May + 3 Jun + 1 Jul	28.0	98.9
Disulfoton 13 May	27.0	91.6
Disulfoton 3 Jun	28.8	104.7
Disulfoton 1 Jul	23.6	67.9
Disulfoton 13 May + 3 Jun	25.9	84.3
Disulfoton 3 Jun + 1 Jul	25.3	79.8
Disulfoton 13 May + 3 Jun + 1 Jul	24.2	71.7
Dimethoate weekly 13 May to 28 May	26.1	85.3
Dimethoate weekly 3 Jun to 25 Jun	27.1	92.5
Dimethoate weekly 1 Jul to 22 Jul	26.4	87.6
Dimethoate weekly 13 May to 25 Jun	25.1	78.5
Dimethoate weekly 3 Jun to 22 Jul	26.6	89.1
Dimethoate weekly 13 May to 22 Jul	26.0	84.6
Dimethoate 2-weekly 13 May to 28 May	26.1	85.5
Dimethoate 2-weekly 3 Jun to 25 Jun	26.6	89.2
Dimethoate 2-weekly 1 Jul to 22 Jul	27.8	97.8
Dimethoate 2-weekly 13 May to 25 Jun	23.5	67.3
Dimethoate 2-weekly 3 Jun to 22 Jul	26.9	90.9
Dimethoate 2-weekly 13 May to 22 Jul	25.2	78.8
Omethoate weekly 13 May to 28 May	28.0	98.8
Omethoate weekly 3 Jun to 25 Jun	25.2	78.9
Omethoate weekly 1 Jul to 22 Jul	22.7	61.3
Omethoate weekly 13 May to 25 Jun	31.1	120.8
Omethoate weekly 3 Jun to 22 Jul	25.1	78.7
Omethoate weekly 13 May to 22 Jul	29.3	108.3
Omethoate 2-weekly 13 May to 28 May	27.1	92.9
Omethoate 2-weekly 3 Jun to 25 Jun	25.2	79.1
Omethoate 2-weekly 1 Jul to 22 Jul	24.0	70.6
Omethoate 2-weekly 13 May to 25 Jun	27.5	95.2
Omethoate 2-weekly 3 Jun to 22 Jul	28.1	100.1
Omethoate 2-weekly 13 May to 22 Jul	25.7	82.4
Teflubenzuron weekly 3 Jun to 22 Jul	24.4	73.3
Nematodes weekly 3 Jun to 22 Jul	26.8	90.8
Untreated (control)	23.3	66.0
Untreated (control)	23.7	68.5
SED (105 degrees of freedom)	2.63	18.66
CV(%)	12.4	27.1

There were no significant between-treatment differences in final yield or in percentage bulb weight increase in the first-year replanted bulb experiment in 1992.

DISCUSSION

The failure of the systemic granular insecticides carbofuran and disulfoton to control attack at Somerset in 1992, in contrast to the partial control given by the same treatments in MAFF-funded experiments at Starcross in the same year, suggests that there may have been an inhibitory effect on the action of these insecticides due to the high organic matter content of the soil at this site.

Carbofuran and disulfoton have each given highly effective control in some previous experiments, but in the majority of instances have failed to reduce attack significantly. This variability is known not to be due to differences in soil moisture content, or to differences in treatment timing in relation to large narcissus fly activity, but is thought to be due largely to differences in the time at which root activity and associated insecticide uptake is switched off by the narcissus plant in different crops in different seasons.

The striking difference in effectiveness of the early-season sprays of dimethoate and omethoate suggests that omethoate works largely or wholely by killing or repelling the adult flies, thus preventing oviposition on the crop, whereas dimethoate probably works in the same way as carbofuran and disulfoton, killing the larvae after invasion of the bulbs. Taking all the evidence of the last five years into account, dimethoate has performed with broadly the same inconsistency as carbofuran and disulfoton, whereas omethoate has been effective whenever it has been applied repeatedly from before the start of egg-laying, and has been ineffective whenever spraying has started after egg-laying.

Because the time at which egg-laying starts can vary by several weeks both from place to place each year, and from year to year in any one place, and because the duration of the egg-laying period is also variable, accurate forecasting of both these elements is essential if omethoate sprays are to be timed to achieve maximum effect without unnecessary applications.

The discovery that omethoate works by killing or repelling the adult large narcissus flies, suggests at least the possibility that some other insecticides may have similar activity. Several promising candidates have been screened in the past. However, in the absence of any precise knowledge of oviposition phenology these treatments were probably applied at inappropriate times. In view of the commercial uncertainty over the future of omethoate, there is now a strong argument for undertaking a systematic re-evaluation of possible alternatives. Of these, the synthetic pyrethroids are among the most promising candidates, and also are likely to have a relatively secure commercial future.

It is now known, from recent MAFF-funded work, that oviposition by the adult female large narcissus fly is triggered by a volatile chemical stimulus produced by the narcissus plant, and that this stimulus can be disabled by charring the foliage. The lack of control given by repeated sprays of white oil or "Vamoose" insect repellent, suggests that topically applied oils have no effect, either on the release of the essential plant volatiles concerned, or on the ability of the insect to detect them.

The much heavier attack incurred by the first-year bulbs than by the fourth-year bulbs at Somerset in 1992 (Table 2), may reflect a difference in the amount of oviposition-stimulating chemical produced by plants of different ages or at different stages of development. The difference observed in the rate of loss of green leaf area by bulbs of different ages (Table 3) suggests that production of the chemical concerned may be greatest in rapidly senescing plants.

The synthetic insect growth regulators are effective only against immature insects. Only the first instar large narcissus fly larva would normally be exposed to possible contact with such insecticides, during it's movement over the bulb surface between hatching from the egg and invading the bulb through one of the root canals. This larval invasion period is of very short duration. The amount of insecticide retained on the surface of the outer scale leaves is likely to be minute. The failure of triflubenzuron to prevent larval attack may therefore be due simply to inadequate target contact, rather than to any intrinsic lack of insecticidal activity against the large narcissus fly larva. If this is the reason, then it is unlikely that other chemically and biologically similar members of this group of insecticides would be effective against this pest.

The significance ascribed to the difference in 1992 between the number of attacked bulbs in those plots treated with nematodes and the untreated plots (Table 2) is unexplained, and is probably the result of a Type 1 error in the analysis of variance (the occurrence of differences due entirely to random variation that are genuinely but incorrectly identified as significant in the analysis).

The failure of the entomophilic nematodes to reduce attack could have been due simply to inadequate target contact, as with triflubenzuron, in that the nematodes would be confined entirely to the soil moisture film, with which only the first-instar larvae can come into contact, and then only briefly if at all. The results suggest that there is little or no penetration of the bulbs by the nematodes, at least during the normal pre-lifting period. It is possible that the nematodes might gain access to the larvae inside the bulbs during the autumn, once a respiration hole has been bored through the baseplate, as would be the case in infested first-year bulbs not due for lifting until the following year. However, although this might reduce the risk of a further attack in the following year, it would fail to prevent serious first-year damage, and would therefore contribute little or no improvement in ultimate bulb marketability.

CONCLUSIONS

1. Those insecticides that work systemically by killing the young larvae after invasion of the bulb (carbofuran; disulfoton; dimethoate), are largely ineffective, irrespective of the timing and frequency of application.

2. The poor control often obtained with these insecticides is probably due to the plant root system switching off before enough of the insecticide can be taken up into the bulb.

3. The activity of some of these insecticides may be inhibited further in soils of high organic matter content.

4. The systemic insecticides should no longer be recommended for large narcissus fly control.

5. Omethoate, which works by killing the adult flies, has proved highly effective if applied weekly or fortnightly throughout the adult emergence period, and is the only insecticide that should now be recommended for summer use.

6. The synthetic insect growth regulator triflubenzuron is ineffective as field sprays.

7. The entomophilic nematodes Steinernema sp. and Heterorhabditis sp. are ineffective as field drenches.

8. Sprayable oils are ineffective as field sprays.

RECOMMENDATIONS

1. Field experiments should be done to determine the optimum rate, timing and frequency of omethoate application. Treatments should include spray timings derived using the HRI forecasting model.

2. Because the commercial future of omethoate is now uncertain, there is an urgent need to screen and evaluate other insecticides that might be active against the adult flies.

3. Additional field data on large narcissus fly emergence, oviposition and egg-hatch should be collected so that the HRI forecasting model can be fully validated.

4. Further to recent complimentary MAFF-funded research, chlorpyrifos should be more fully evaluated as a band-spray applied to the exposed bulbs in the open ridge before planting, which might provide a possible alternative to pre-panting immersion treatments for the protection of crops in their first season after planting.

5. Controlled-release formulations of appropriate systemic insecticides should be screened as band applications at bulb planting.

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STORAGE OF DATA

All records of the work will be stored at ADAS Starcross for a period of one year from the issue of this report.