Project Title:	Vining Peas: Monitoring and control of pea midge (*Contarinia pisi*)
Project Number:	FV 58a
Project Leader:	Dr. A. J. Biddle, Processors and Growers Research Organisation Great North Road Thornhaugh Peterborough PE8 6HJ
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Key workers:	Dr. A. J. Biddle, PGRO Dr. Ylva Hillbur Swedish University of Agricultural Sciences Alnarp, Sweden
Co-operator	Mr. R. Davies Oecos Ltd 11a High Street Kimpton. Herts
Location of Project:	Processors and Growers Research Organisation Great North Road Thornhaugh Peterborough PE8 6HJ Tel: 01780 782585 email: anthony@pgro.co.uk
Project co-ordinator:	Mr Ralph Pinder
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Key Words:	vining peas, pea midge, (*Contarinia pisi*) monitoring, sex pheromone, traps

CONTENTS

PRACTICAL SECTION FOR GROWERS

Commercial benefits of the project

It is estimated that around 15% of the UK vining pea crop is produced in areas where pea midge is known to be a sporadic or regular problem. The value of the crops in these areas amount to around £6 million farm price and represent 6000 ha. Yield loss by pea midge varies year by year but because of the sporadic nature and potential yield loss, a significant proportion of this area is treated with insecticide almost as a routine. The current method of control of pea midge is large scale prophylactic spraying of peas at the early bud stage in those areas where pea midge is known to be a pest. The present system of warnings is based on time consuming and limited soil sampling to detect the pupation of overwintering midge cocoons. This is very expensive to operate and is subject to local variations in pest intensity and emergence conditions. Crop inspections over a wide area are also very time-consuming adding extra cost and workload to growers and consultants.

All major freezing companies contract peas produced from assured crops, following the principles of integrated crop management. Prophylactic and badly timed insecticide use is inconsistent with these production criteria. A monitoring system will identify the time of midge emergence from the previous years field and alert growers as to the risk of migration into the current seasons peas. This will reduce the use of prophylactic sprays and will enable optimum timing of application.

The monitoring of emerging midge will allow the study of factors which may affect midge emergence, winter survival and predation rates. This will provide information on the likely level of infestation in any locality in any season. At present the only criterion available for such an estimate is the level of infestation of the crop in the previous year.

The results will lead to the introduction of a monitoring system based on a trapping system which can be used by growers or crop consultants on an on-farm basis.

Action point for growers

- Use pheromone traps specific to catching pea midge to enable fields to be assessed for potential risk.
- Traps should be placed in last year's pea field by the third week of May.
- Monitor traps at least twice weekly
- Assess midge numbers on each occasion using an assessment key supplied with the trapping system
- When a peak has been identified, i.e. more than 500 per trap, inspect local pea crops as they reach the enclosed bud stage
- Treat susceptible peas in the late afternoon to maximise effective control
- Growers can obtain the pheromone traps from Oecos Ltd, High Street, Kimpton, Hitchin, Herts,SG4 8QP

Background and objectives

Pea midge are members of the Cecidomyiidae group of gall midges. The adults are small and gnat-like with a body length of 2-3mm, yellow-grey in colour with fine wings and long legs and antennae. Large populations can develop in areas of intensive pea production. During June to July, adults emerge from the soil of the previous year's infested pea crop and after mating, the females fly to nearby pea crops which are just at the beginning of the flowering period. The insects shelter inside the protective leaves of the growing point and lay eggs in batches of 20 or more on the developing flower buds. After 4-5 days, they hatch and the white, legless larvae burrow into the bud and feed at the base of the ovary. The flower fails to develop a pod and may become distorted and gouty in appearance. The new plant growth is stunted due to the production of shortened internodes and the top of the plant may develop a "nettle-head". In periods of wet weather, damaged plant tissue becomes colonised by saprophytic fungi which add to the overall effects of the midge damage.

Vining peas are more susceptible to high levels of damage due to the varietal characteristic of determinacy which exposes a greater proportion of developing flower buds to damage. In this way, yield loss can be very large with up to 75% loss in severe infestations.

Control of adults is based on the ability to prevent egg laying. The present system of control is to apply insecticides as soon as midge adults can be found within the leaves of the growing point. This entails, detailed and regular crop inspection of all vining peas as they reach the susceptible growth stage (enclosed bud - G.S. 201). Earlier work showed that the best time to inspect crops was in the late afternoon, as females migrated from the emergence sites from late morning onwards. However, it is important to apply the sprays before oviposition has occurred and often detection of adults may be too late for effective control to be achieved.

Attempts at predicting the time of emergence have been made for some years. The current practice involves the extraction, by water, of overwintering midge cocoons, from soil sampled at regular intervals from a number of known infested fields. The cocoons are monitored up to the time of pupation. This, however, is time-consuming and limited by the number of sites that can be monitored in this way. The system cannot predict the time of emergence, nor can it take into account local variations of incidence of attacks, as this can vary according to soil type, geographical area, local climatic conditions, soil moisture levels and the type of crop growing in the overwintering field.

This results is inaccurately timed and unnecessary or prophylactic spraying of crops in areas known to contain midge populations. In practice, sprays are applied to vining peas as soon as the first midge are found in the locality. There is a need therefore of a method which will provide rapid, reliable predictions of midge infestation.

Earlier work by Wall *et al* (1985), showed that the female pea midge attracts males by means of a sex-pheromone and preliminary work using captive female midge over water traps showed the potential of such a method as a means of detecting newly emerged adult males in an overwintering site (Wall *et al*, 1994)

Work began in 1990, funded by HDC, PGRO, MAFF and the major pea processing companies, to identify the pheromone of the pea midge and utilise this in a monitoring system to predict the infestation period of pea midge into susceptible pea crops.

The work was undertaken jointly by PGRO and the Swedish University of Agricultural Sciences, then in Lund, Sweden. Several tonnes of soil were sampled from known infested fields in the UK and cocoons extracted by water. These were reared in growth rooms and preparations of newly

emerged adults were examined by electron microscopy. The females were found to produce pheromones from a gland situated at the base of the ovipositor. Preparations of dissected ovipositors were found to be attractive to male midges when flown in wind tunnels. Hexane extracts of excised ovipositors and effluvia collected from glass pipettes containing female midges were analysed. Gas chromatograms of extracts and effluvia consistently showed two female specific peaks which elicited clear responses in male antennae when extracts of ovipositors were analysed by coupled gas chromatographic-electroantennographic detection. However, tests in the field failed to show a response to males. The funded work concluded in 1995 (HDC Report FV59)

Since that time, further work continued at the Swedish Agricultural University, using cocoons supplied over four years by PGRO and from cocoons collected from France. Recently, a third component of the sex pheromone has been detected and a blend of these compounds proved to be highly attractive to male midges in wind tunnels. The components have been identified as 2-acetoxytridecane, (2*S*,11*S*)-diacetoxytridecane, and (2*S*,12*S*)-diacetoxytridecane (Hillbur *et al*. 2000).

This discovery is the first time that all the active components of a Cecidomyid midge have been identified and synthesised. The use of the compound in a pea midge monitoring system is proposed.

Work completed in previous years (1999-2000)

Summary of results in 1999

Lures containing synthetic forms of the single, double and triple components of the female pea midge sex-attractant , and a racemic form of the three, were placed in Oecos delta traps in two fields known to contain overwintering populations of the pea midge (*Contarinia pisi*). Male midges were caught on the sticky inserts of all traps containing the triple component. Recordings of catches showed a peak time of emergence from both a low and a high population overwintering site. This formed the basis of a monitoring and prediction system for pea midge in vining peas in the UK.

Summary of results 2000

The three-component pheromone as 2-acetoxytridecane, (2*S*,11*S*)-diacetoxytridecane, and (2*S*,12*S*)-diacetoxytridecane was dispensed onto lures at 0µg, 1µg, 10µg and 100µg doses and placed in Oecos delta traps. The traps were placed at 10m intervals along tramlines in 3 winter wheat crops known to contain populations of pea midge from the previous years pea crop. Male midges were caught in the traps from 11th June with maximum numbers being recorded around 26th June. Recordings showed that the 10 µg dose rate consistently caught the highest numbers of male midge at all sites.

Specific targets for 2001

In order to validate the results of the lures containing the 10 µg dose rate, and to verify the activity period of the pheromones in the field, a further series of trials were undertaken to monitor midge catches in previously infested fields. If successful, a commercial version of the trapping system would be available for the 2002 season.

SCIENCE SECTION

Introduction

Work on the identification of the pea midge sex pheromone began in 1990 and was jointly funded by HDC, MAFF and PGRO. However since 1996, the work has continued by PGRO and the Swedish University of Agricultural Sciences.

In 1998, the major active components were identified and synthesised and laboratory trials have shown them to be active in attracting male midges to lures in a wind tunnel. (Hillbur *et al* 1999, Hillbur *et al* 2000).

The synthesised actives were used in singly and in combinations in field trials during 1999 and 2000 when the 3 component compound was found to be most active (Hillbur *et al* 2000). Work in 2001, with the three-component compound was carried out with a view of testing the activity and persistency of the 10 μg dose rate, and in addition, a further investigation was made using the racemic versions.

MATERIALS AND METHODS

Identification of monitoring sites 1999 - 2001

1. 1999 monitoring sites

Four fields where peas were grown in 1998 and reported to have been attacked by pea midge, were sampled in the spring of 1999.

Soil samples were taken using a 15cm diameter core sampler to a depth of 8cm, at 10 randomly selected locations in various parts of the fields. Soil was wet sieved and midge cocoons extracted after floating the organic matter retained on the finest sieve, in a saturated solution of magnesium sulphate. Cocoons were counted and the two fields showing the highest and lowest population were chosen for the experiments. The site details are shown in table 1.

Table 1. Monitoring sites

Site 1:	Low Hunsley Farm, Walkington, Yorkshire
Field name:	Yard field
Previous crop:	Waverex vining peas
Site 2:	Hessleskew Farm, Market Weighton, Yorkshire
Field name:	Arras Hill
Previous crop:	Bikini vining peas

2. 2000 monitoring sites

Three fields where vining peas had been grown in 1999 and reported to have been attacked by pea midge, were sampled in the spring of 2000. The soils were checked for midge populations and chosen for monitoring as before. The site details are shown in Table 2.

Table 2 Trapping Sites 2000

Site 1. Warter Priory Estates
Warter
Driffield
Yorks
Field reference: Wood field
Previous crop: Waverex vining peas

Site 2. Hessleskew Farm
Market Weighton
Yorkshire

Field name: Arras Hill (north)
Previous crop: Puget vining peas

Site 3. Middledale Farm
Kilham
Yorkshire

Field name: Midledale South
Previous crop: Sigra vining peas

3. 2001 Monitoring sites

Three fields where vining peas had been grown in 2000 and reported to have been attacked by pea midge, were sampled and assessed for midge populations the spring of 2001, as before.

The site details are shown in Table 3.

Table 3. Monitoring sites

Site 1. M. Marginson
Lion's Den
Walkington
Yorkshire

Field reference: Little Hunsley
Previous crop: Waverex vining peas

Site 2. J. Jackson
Arras Hill Farm
Market Weighton
Yorks

Field name: Arras (north)
Previous crop: Waverex vining peas

Site 3. JSR Farms
Haywold Farm
Tibthorpe

Yorkshire

Field name: Haywold
Previous crop: Bikini vining peas

Field monitoring of pea midge 1999

i. *Pheromone components*

The pea midge pheromone compounds 2-acetoxytridecane, (2*S*,11*S*)-diacetoxytridecane and (2*S*, 12*S*)-diacetoxytridecane were used singly or in mixtures in the 1999 field trials. In addition, corresponding isomers of the compounds were also used in the trials (triple R). The compounds were synthesised at the Institute of Organic Chemistry, Hamburg University and lures prepared at the Swedish Agricultural University. The compounds were dosed on to dental cotton rolls (Celluron no. 2), cut into thirds and placed within the body of an Oecos pea moth trap, with a sticky insert placed inside the base of the trap.

The lures and doses were as follows:

1. Blank (control)
2. Single component 2-acetoxytridecane (10µg)
3. Double component 2*S*,11*S* - diacetoxytridecane (10µg) and 2*S*, 12*S* diacetoxytridecane (10µg)
4. Three component (2 and 3)
5. Racemic versions of the three components 2-acetoxytridecane (10µg), (2*S*,11*S*)-diacetoxytridecane (40µg) and (2*S*,12*S*)-diacetoxytridecane (40µg) (3R)

ii. *Trapping*

Traps containing one of each lure were placed at 10m intervals along tramlines of each field, both of which were currently in winter wheat. The treatments were replicated five times in a Latin square design and the traps were placed on the soil within the wheat crop. The traps were examined twice weekly and the sticky inserts were replaced each time. The lures were replaced after the second visit.

The sticky inserts were returned to the PGRO laboratory and midge numbers recorded for each trap. The identity and sex of the midge were confirmed.

Trapping commenced on 11th June following soil samples made on 8th June when more than 25% of the cocoons were beginning to pupate at both the emergence sites. Recordings were made on 14th, 17th, 22nd and 26th June, by which time the midge numbers had fallen to a low level and it was assumed that the main emergence period had ended.

Field monitoring of pea midge 2000

Lures were prepared as in 1999 but only the synthesised 3 - component compound was used at a range of doses. The traps were set up as before.

Then doses of the lures were as follows:

1. blank (control)
2. 1 µg each of the components 2-acetoxytridecane (2*S*,11*S*)- diacetoxytridecane (10µg) and (2*S*,12*S*)-diacetoxytridecane
3. 10 µg of each of the above components
4. 100 µg of each of the above components

Traps containing one of each lure were placed at 10m intervals along tramlines (24m centres) of each winter wheat field. Each dose was replicated 4 times in a randomised block design and the traps were placed on the soil within the wheat crop. The traps were examined regularly throughout the season and sticky inserts replaced each time. The lures were replaced on the fourth visit.

Traps were sited on 9th June. After each visit, the inserts were returned to the PGRO laboratory and midge numbers were recorded for each trap.

The first midge were recorded on 11th June and subsequently on 14th, 19th, 22nd, 26th, 30th, 4th July and 7th July by which time numbers had fallen and it was assumed that the main emergence period had ended.

Field monitoring 2001

As in the previous year, the synthesised 3-component compound of the pea midge sex pheromone (2*S*, 11*S*)-diacetoxytridecane plus (2*S*, 12*S*)-diacetoxytridecane and 2-acetoxytridecane were dosed and placed in traps as before. In addition, the racemic versions of the compounds were also included in the trial.

Then doses of the lures were as follows:

1. 1 µg of each of the components 2-acetoxytridecane, (2*S*,11*S*)- diacetoxytridecane and (2*S*,12*S*)- diacetoxytridecane
2. 10 µg of each of the above components
3. 1 µg 2-acetoxytridecane + 1µg (2*S*,11*S*)-diacetoxytridecane + 3µg (2,12)-diacetoxytridecane (racemic)
4. 0.5µg 2*S*-acetoxytridecane + 1µg (2*S*,11*S*)-diacetoxytridecane + 1µg (2*S*,12*S*)-diacetoxytridecane
5. 0.5µg 2*R*-acetoxytridecane (racemic) + 1µg (2*S*,11S)-diacetoxytridecane + 1µg (2*S*,12*S*)-diacetoxytridecane
6. Blank (control)

Traps containing one of each lure were placed at 10m intervals along tramlines (24m centres) of each winter wheat field. Each dose was replicated 3 times in a randomised block design and the traps were placed on the soil within the wheat crop. The traps were examined regularly throughout the season and sticky inserts replaced each time.

Traps were sited on 2nd June. After each visit, the inserts were returned to the PGRO laboratory and midge numbers were recorded for each trap.

The first midge were recorded on 6th June and subsequently on 14th, 18th, 21st, 25th, 28th, June, 2nd ,5th, 9th, 12th and 16th July by which time numbers had fallen and peak emergence periods had been noted.

Results

Monitoring 1999

Midge were first caught in the traps between the 11th and 14th June. The highest numbers were recorded on 17th at both sites. Numbers declined at both sites by the 22nd June although at the Market Weighton site, numbers began to increase slightly by 25th June although all traps were removed from the sites after that time. The catches over the period are shown in figures 1 and 2.

Figure 1. Midge trap catches Walkington 1999

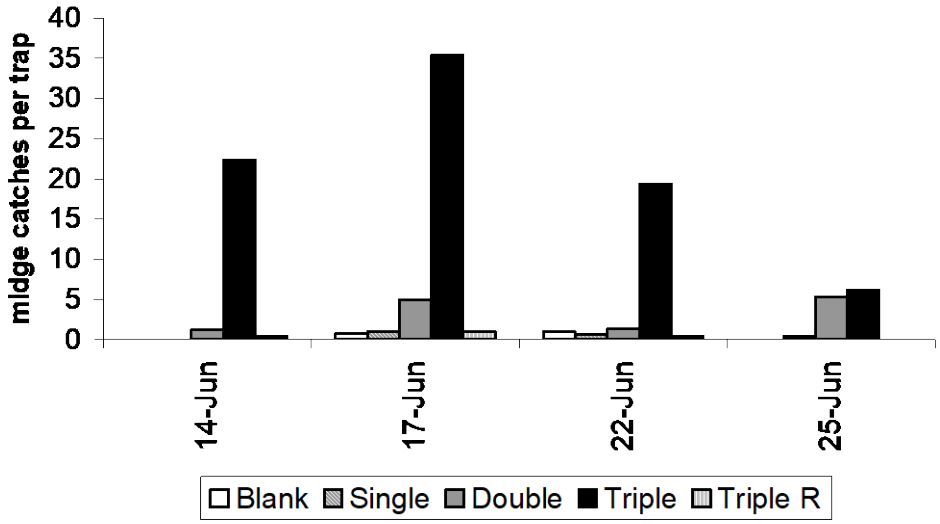
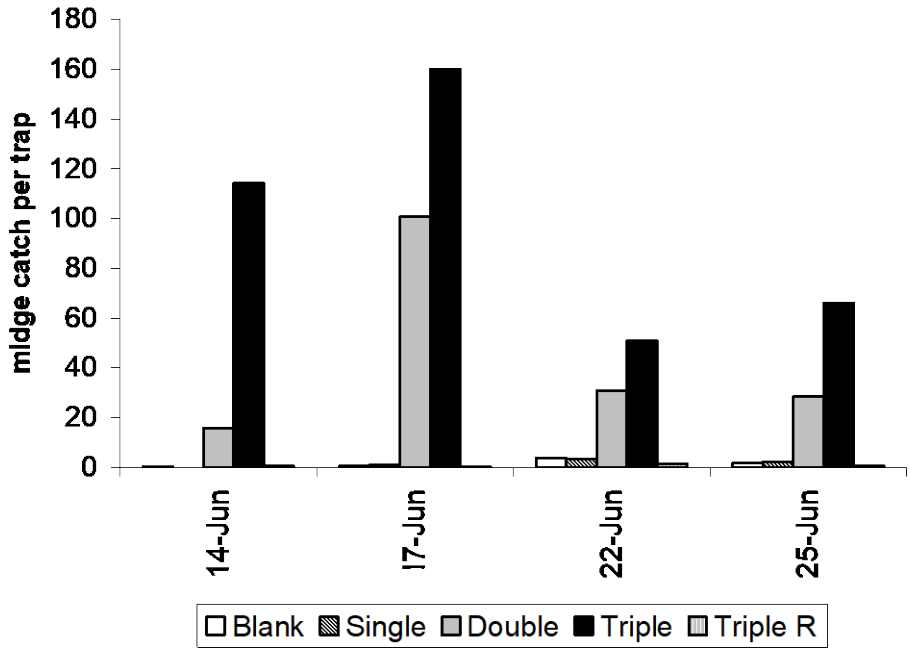


Figure 2. Midge trap catches Market Weighton 1999



All midges caught were male *Contarinia pisi.*

The data showed highly significant differences between catches from the triple component compound compared with the single, double and racemic compound at the Walkington site. However, at the Market Weighton site, the catches form the triple component compounds were higher than the double component compounds although not statistically significantly different.

The trapping data clearly showed that at least one compound was highly effective in attracting male pea midge to Oecos delta traps. Midge were exclusively caught, with very few other genera present on the traps. A wet spell of weather, however, allowed some predation of midge caught on the sticky insert, by the grey slug (*Derocerus reticulatum*). Although this did not affect the count, as the remains of the midge were still discernible, (legs and wings). It is a factor which will need to be addressed in future field trials.

The most consistent results were achieved by the triple component compound at both sites. It is not known why the double component compound performed well at the Market Weighton site and there could be slight population differences of pea midge causing an alteration in response to the pheromone.

The trap catches reflected the high and low population overwintering sites of the pea midge, but emergence patterns were similar at both sites. The Oecos traps performed well and will be used for the rest of the project.

Monitoring 2000

Midge were recorded in traps at the three site from 11th June with the highest numbers being recorded on 26th June. There was an initial peak of catches at all sites but this was possibly due to attraction of earlier emerged midge. The catches over the period are shown in figures 3, 4 and 5.

Figure 3. Mean trap catches Arras Hill 2000

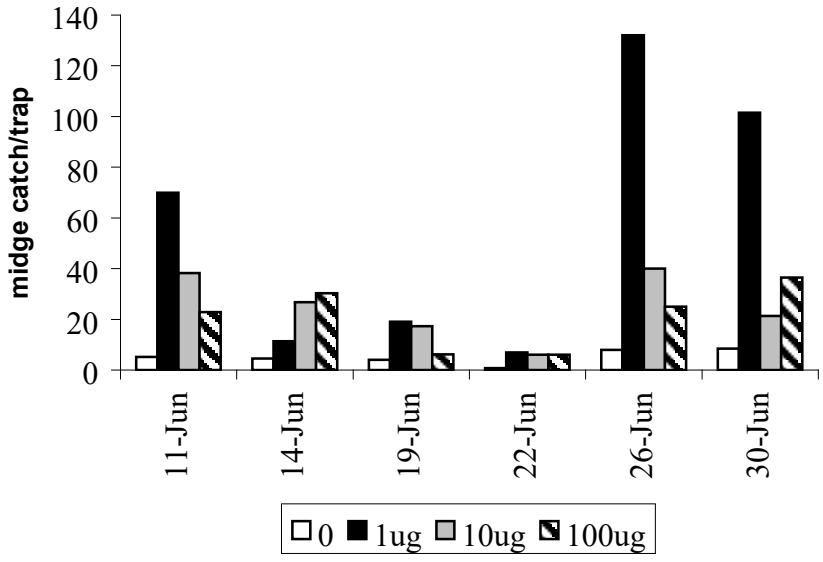


Figure 4. Mean trap catches Kilham 2000

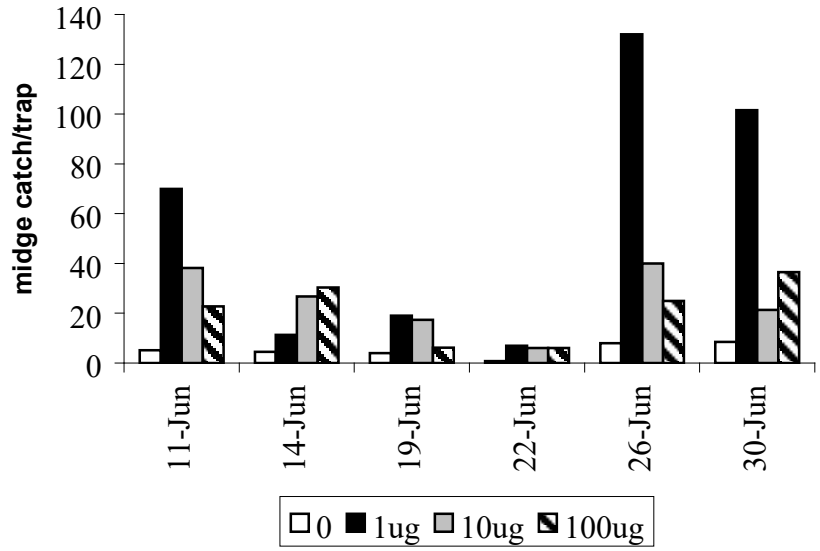
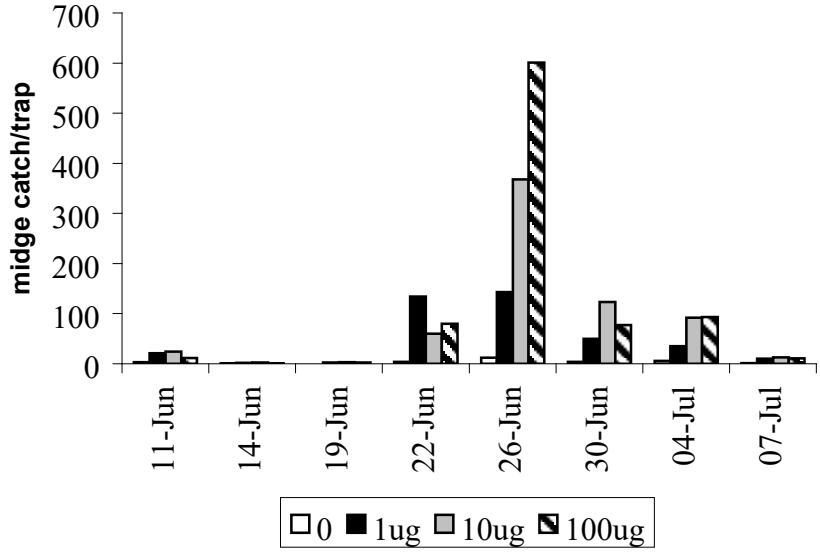


Figure 5. Mean trap catches Warter Estates 2000



The full data sets are shown in Appendices III-V

At all sites, there were clear indications that the 3 - component compound was effective in attracting male pea midge and that Oecos traps were successful in trapping. The work confirmed the results found in 1999. The dose response was a little variable over the 2000 season. Weather conditions were not favourable for midge activity on several days over the trapping season, but it appeared overall that doses between 1 and 10 μg gave consistently satisfactory catch numbers.

Further work is necessary to confirm a single dose rate that satisfies a range of conditions and also work is necessary to field test different dispenser types.

Monitoring 2001

Pea midge were first recorded on 6th June at all sites, although there were large differences in numbers between the three sites. The trapping period was extended in order to ascertain any differences in emergence over time and also to test the persistency and release rate of the lures.

The results are shown in figures 6, 7 and 8 and the full data sets are presented in Appendices V-VII

Figure 6. Mean trap catches Walkington 2001

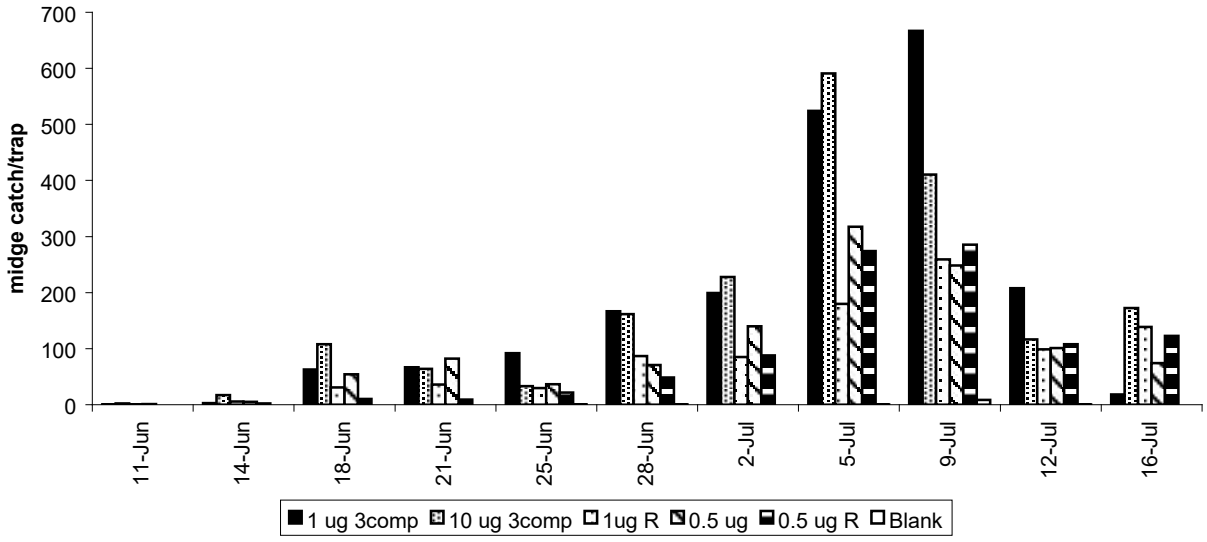


Figure 7. Mean trap catches Market Weighton 2001

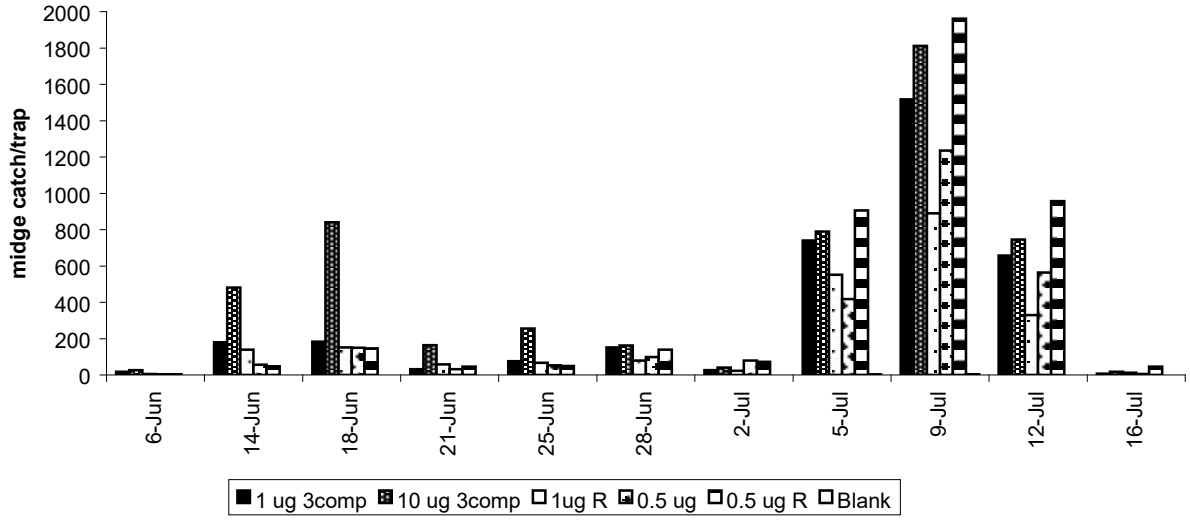
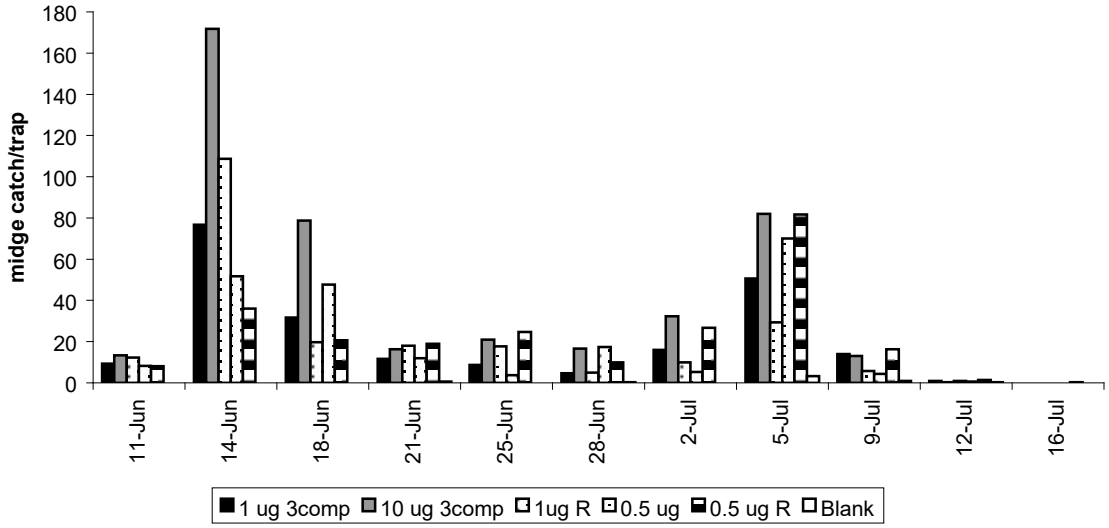


Figure 8. Mean trap catches Tibthorpe 2001



The three monitoring sites showed that the 10µg dose of the 3-component synthesised pheromone gave the most consistent results relating to pea midge catches. The racemic forms gave variable results and overall the numbers of midges caught was significantly lower.

CONCLUSIONS

The results of three years work in a number of monitoring sites clearly showed the effectiveness of the 3-component pheromone in attracting male pea midge to sticky traps. The trap positioning and design was satisfactory and the results form the basis of a commercially available system. The traps should be placed in the emergence site by the third week of May and monitoring undertaken on a twice weekly basis at the minimum. The midge numbers can be very high, in excess of 500 midges per trap and therefore an assessment key should be devised to aid users in assessing the likely numbers of midge. Because the traps are almost exclusive in pea midge catches, identification is of little importance**.**

A trapping system should comprise at least four traps placed at 10m intervals along a suitable tramline or row on the overwintering site. By assessing the peak in numbers over a two or three week period, sufficient time between midge flight from the overwintering area to infesting a nearby pea crop, will be given to organise pea crop inspection and subsequent spray action if necessary**.**

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APPENDICES

I. Midge trap catches Walkington 1999

Lure	Date			
	14/6	17/6	22/6	25/6
1. Blank	0	0.8	1.0	0
2. Single	0	1.0	0.6	0.4
3. Double	1.2	5.0	1.4	5.4
4. Triple	22.4	35.4	19.4	6.2
5. Triple R	0.4	1.0	0.4	0
LSD	10.18	8.75	7.04	4.01
probability	0.001	0.001	0.001	0.001
CV %	158.1	75. 1	115.2	124.5

II. Midge trap catches Market Weighton 1999

Lure	Date			
	14/6	17/6	22/6	25/6
1. Blank	0.4	0.8	4.0	2.0
2. Single	0	1.0	3.6	2.2
3. Double	15.8	101.0	31.0	28.4
4. Triple	114.2	160.2	51.0	66.2
5. Triple R	0.6	0.4	1.4	0.6
LSD	72.0	91.0	27.5	32.0
probability				
CV %	205.0	128.9	112.5	120.2

III. Midge trap catches Arras Hill 2000

Lure	date							
	11/6	14/6	19/6	22/6	26/6	30/6	4/7	7/7
1. Blank	0	0	0.8	1.3	2.	7	4	5
2. 1 µg	14.0	0.5	13.0	39.5	117.	231	138	61
3. 10 µg	8.3	3.0	7.0	37.7	365	273	99	126
4. 100 µg	3.2	2.75	3.2	6.5	125	38	18	18
Transformed $\log_{10}$ (n + 1)								
1. Blank	0	0	0.20	0.30	0.46	0.68	0.66	0.71
2. 1 µg	0.95	0.12	1.05	1.42	1.68	1.87	1.84	1.58
3. 10 µg	0.86	0.51	0.88	1.38	2.46	2.36	1.98	2.01
4. 100 µg	0.60	0.40	0.56	0.85	1.92	1.54	1.19	1.27
LSD	0.47	0.56	0.52	0.68	1.03	0.89	0.72	0.67
probability	0.005	0.21	0.02	0.01	0.01	0.01	0.01	0.01
CV%	48.7	135.2	48.8	42.7	39.5	34.5	31.7	30.2

IV. Midge trap catches Kilham 2000

Lure	date							
	11/6	14/6	19/6	22/6	26/6	30/6	4.7.00	8.7.00
1. Blank	3.0	0.75	0.25	4.	12	4	6	1.0
2. 1 µg	21.0	2.0	2.5	134	143	50	35	10.5
3. 10 µg	24.0	2.5	3.25	60	368	123	92	12.5
4. 100 µg	11.7	0.42	2.33	80	601	77	93	10.8
Transformed $\log_{10}(n + 1)$								
1. Blank	0.51	0.23	0.08	0.69	1.08	0.63	0.74	0.23
2. 1 µg	1.33	0.39	0.51	2.03	2.09	1.70	1.46	0.93
3. 10 µg	1.33	0.45	0.62	1.77	2.54	1.98	1.82	0.99
4. 100 µg	1.06	0.16	0.41	1.66	2.79	1.68	1.91	1.10
LSD	0.37	0.48	0.37	0.50	0.33	0.47	0.60	0.66
probability	0.01	0.20	0.05	0.002	<.001	0.001	0.01	0.06
CV%	21.3	94.1	55.4	19.5	9.2	18.8	24.5	48.2

V. Midge trap catches Warter Estates 2000

Lure	date					
	11/6	14/6	19/6	22/6	26/6	30/6
1. Blank	5.5	4.5	4.0	0.8	8	8.5
2. 1 µg	70.0	11.3	19.0	7.0	132	101.5
3. 10 µg	38.2	26.8	17.3	6.0	40	21.3
4. 100 µg	22.8	30.8	6.2	6.0	25	36.5
Transformed $\log_{10}(n + 1)$						
1. Blank	0.63	0.66	0.67	0.19	0.89	1.94
2. 1 µg	1.81	1.0	1.29	0.87	2.01	1.27
3. 10 µg	1.44	1.11	1.10	0.66	1.46	1.31
4. 100 µg	1.19	1.36	0.82	0.67	0.95	
LSD	0.44	0.74	0.44	0.64	0.71	0.62
probability	0.001	0.26	0.04	0.18	0.02	0.02
CV%	21.5	44.7	28.1	66.8	33.3	29.1

VI. Midge trap catches Tibthorpe 2001

Lure	date										
	6/6	14/6	18/6	21/6	25/6	28/6	2/7	5/7	9/7	12/7	16/7
1. (1 µg)	9.3	77	31.7	11.7	8.7	4.7	16.0	50.7	14.0	1.0	0
2 (10µg)	10.3	172	70.7	16.3	21.0	16.7	32.3	82.0	13.0	0.3	0
3 (1µg R)	12.3	109	19.7	18.0	17.7	5.0	10.0	29.3	5.7	1.0	0
4 (0.5µg)	8.3	52	47.7	12.0	3.7	17.3	5.3	70.3	4.3	0.7	0
5 (0.5 µg R)	8.0	36	20.7	19.0	24.7	10.0	26.7	81.7	16.3	1.3	0.3
6 (blank)	0	0	0	0.7	0		0	3.3	1.0	0.3	0
Transformed $\log_{10}(n + 1)$											
1. (1 µg)	0.99	1.84	1.37	0.96	0.89	0.59	1.23	1.65	0.95	0.25	0
2 (10µg)	1.01	2.14	1.88	1.21	1.13	1.24	1.30	1.89	1.13	0.10	0
3 (1µg R)	0.89	1.75	1.23	0.96	1.03	0.57	0.93	1.31	0.75	0.20	0
4 (0.5µg)	0.81	1.61	1.48	0.98	0.45	0.89	0.78	1.81	0.68	0.16	0
5 (0.5 µg R)	0.80	1.5	1.30	1.87	1.16	0.98	1.02	1.90	1.03	0.30	0.1
6 (blank)	0	0	0	0.20	0	0	0	0.59	0.30	0.10	0
LSD	0.68	0.60	0.54	0.60	0.89	0.88	0.76	0.57	0.65	0.50	0.13
probability	0.06	<.001	<.001	0.04	0.09	0.11	0.03	0.003	0.15	0.92	0.46
CV%	49.7	22.3	24.6	36.0	63.0	67.7	47.6	20.5	44.5	148.3	424.3

VII. Midge trap catches Market Weighton 2001

Lure	date										
	6/6	14/6	18/6	21/6	25/6	28/6	2/7	5/7	9/7	12/7	16/7
1. (1 µg)	18	180	183	32	76	152	27	739	1517	658	7.3
2 (10µg)	26.3	482	841	164	255	163	40	789	1811	746	18
3 (1µg R)	4.7	140	151	59	66	79	23	552	889	329	11.7
4 (0.5µg)	3.3	56	149	31	53	99	79.7	418	1235	564	5.3
5 (0.5 µg R)	3.3	48	164	45	49	139	72.7	905	1961	956	43.3
6 (blank)	0.3	0	0	0	0	0	0.7	1	3	1.0	0.3
Transformed $\log_{10}(n + 1)$											
1. (1 µg)	1.02	2.24	2.18	1.51	1.76	2.05	1.31	2.81	3.10	2.79	0.85
2 (10µg)	1.44	2.63	2.87	2.13	2.56	2.19	1.56	2.89	3.26	2.85	1.20
3 (1µg R)	0.75	2.15	2.14	1.68	1.67	1.87	1.27	2.73	2.94	2.51	0.94
4 (0.5µg)	0.63	1.74	2.06	1.36	1.73	1.90	1.66	2.60	2.96	2.56	0.75
5 (0.5 µg R)	0.63	1.57	2.14	1.65	1.69	2.12	1.85	2.96	3.27	2.93	1.51
6 (blank)	0.10	0	0.10	0	0	0.10	0.20	0.26	0.46	0.20	0.10
LSD	0.53	0.41	0.51	0.54	0.55	0.58	0.82	0.36	0.58	0.57	0.65
probability	0.004	<.001	<.001	<.001	<.001	<.001	0.01	<.001	<.001	<.001	0.01
CV%	38.1	13.0	14.6	21.4	19.9	18.7	34.4	8.4	12.1	13.7	40.1

VIII. Midge trap catches Lions Den, Walkington 2001

Lure	date										
	6/6	14/6	18/6	21/6	25/6	28/6	2/7	5/7	9/7	12/7	16/7
1. (1 µg)	0.67	3.0	63	67	91.7	167	199	524	667	208	181
2 (10µg)	2.0	17.0	108	64	37.0	162	228	591	411	117	173
3 (1µg R)	6.3	5.7	31	36	29.7	87	85	180	259	99	139
4 (0.5µg)	1.3	5.3	54.3	82	36.3	71	140	317	248	101	74
5 (0.5 µg R)	0	2.3	10.3	9	21.7	49	88	274	285	108	123
6 (blank)		0	0	0	0.3	0	0	1.0	8	0	0
Transformed $\log_{10}(n + 1)$											
1. (1 µg)	0.20	0.59	1.76	1.56	1.90	2.22	2.23	2.67	2.79	2.30	2.11
2 (10µg)	0.46	1.04	1.95	1.66	1.52	2.11	2.31	2.68	2.57	2.02	2.18
3 (1µg R)	0.10	0.81	1.37	1.54	1.35	1.92	1.92	2.22	2.41	1.99	2.12
4 (0.5µg)	0.30	0.50	1.64	1.65	1.49	1.75	2.14	2.49	2.39	2.01	1.87
5 (0.5 µg R)	0	0.49	1.03	1.01	1.33	1.69	1.93	2.36	2.40	1.98	1.87
6 (blank)	0	0	0	0	0.10	0	0	0.20	0.92	0.10	0
LSD	0.33	0.58	0.36	0.75	0.41	0.37	0.37	0.43	0.43	0.34	0.69
probability	0.07	0.04	<.001	0.01	<.001	<.001	<.001	<.001	<.001	<.001	<.001
CV%	104.2	55.6	15.3	33.2	17.7	12.4	11.7	11.2	10.7	10.7	22.5