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THE POTENTIAL OF PARASITES OF *TIPULA* SPP. AS BIOLOGICAL CONTROL AGENTS AND FIELD TRIALS WITH *TIPULA* IRIDESCENT VIRUS

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Summary A field survey has shown that tipulid larvae may be infected by viruses, bacteria, protozoa, nematodes, insects and possibly fungi. *Tipula* iridescent virus, *Tipula* nuclear polyhedrosis virus, mermithid nematodes and tachinid insects usually kill infected host larvae and are therefore potential biological control agents. The bacterial and microsporidian parasites probably damage the host and deserve further investigation.

Field trials with *Tipula* iridescent virus on $0.25m^2$ and $1.0m^2$ plots have been carried out among a tipulid population in hill pasture. The virus was introduced into the plots by releasing live infected *Tipula oleracea* larvae, by placing dead infected larvae and by spraying an aqueous suspension of virus. A few wild larvae became infected with *Tipula* iridescent virus but insufficient to achieve adequate control of pest populations. Possible reasons for this are discussed.

Sommaire Un examen des larves tipulides dans les champs a démontré que des virus, bactéries, protozoaires, nématodes, insectes et peut-être champignons peuvent elles infectées. Le virus iridescent de *Tipula*, le virus des polyèdroses nucléaires de *Tipula*, nématodes mermithides et insectes tachinids d'ordinaire font mortes les larves de l'hôte, et donc ils sont des agents virtuels de lutte biologique. Le bacterium et le microsporidie probablement font tort à l'hôte, et méritent autre recherche.

L'on a fait des essais avec le virus iridescent de *Tipula* sur pièces de terre de $0.25m^2$ et $1.0m^2$ parmi une population de tipulides dans une pâture des hautes terres. Pour introduire le virus dans les pièces de terre on y a mis des infectées larves de *Tipula oleracea*, vivantes et mortes, et on a vaporisé une suspension aqueux du virus. Quelques larves ont acquis une infection du virus iridescent de *Tipula*, mais insuffisant pour contrôler populations des pestes. On discute des raisons possibles pour ces résultats.

INTRODUCTION

Larvae of some *Tipula* spp. (leatherjackets) are agricultural pests, damaging grassland and cereals. In order to assess the feasibility of controlling these insects by a biological method a field survey of their parasites was carried out. The objectives of the survey were to determine what kinds of parasites are present in populations of tipulid larvae in pasture, and what effect, if any, the parasites have on their host populations. The survey followed a similar one

carried out by Sherlock (1973).

Attempts have been made to introduce one of the viral parasites, *Tipula* iridescent virus, into wild tipulid populations in field plots. These attempts have met with only limited success to date.

FIELD SURVEY

Tipulid larvae were sampled from a number of locations in north-east England by applying a 0.0013% emulsion of the irritant orthodichlorobenzene (Dawson, 1932) to the soil. This brings to the surface most larvae, but is less effective for those in the late fourth instar. Sample turves were dug, and dissected in concentrated NaCl solution to detect any larvae remaining after the orthodichlorobenzene treatment.

The majority of larvae were infected with gregarine and coccidian protozoa. These parasites were in the cells of the gut epithelium and between the gut epithelium and the peritrophic membrane. Some larvae carried a huge biomass of these protozoa, but nevertheless appeared normal and healthy, at least superficially.

Another protozoan, a microsporidian, was found infecting the nerve tissue of a few larvae. Some of the nerve ganglia of the infected insects were much enlarged. It is probable that this protozoan is harmful, if not lethal, to its host.

A few larvae were found infected with a bacterium, the characteristics of which suggest that it was a *Bacillus* sp. The affected larvae were pale in colour, and their haemolymph contained large numbers of bacterial cells. It is probable that this parasite is also harmful to its host.

Fungi developed on the cuticle of some larvae after they had been kept for a period in the laboratory. This may have been a laboratory phenomenon resulting from the conditions in which the larvae were maintained, but nevertheless demonstrates that the larvae are susceptible to infection by fungi.

Three types of insect parasite were found. The most significant of these were tachinids, the larvae of which normally killed the host when they emerged from it to pupate. Phorids were found infecting a few larvae, but they seemed to cause little or no damage to their hosts, and a single figitid adult was found in a dish containing tipulid larvae from the field.

Two types of nematode were found. One type was fairly common in the lumen of the hind-gut of later instar larvae. It was identified as an oxyuroid, and appeared to be a commensal. The other type of nematode was a mermithid, which infects the haemocoel of the host larva, and generally causes its death when it ruptures the cuticle to emerge.

At least two viruses of *Tipula* are known and both were found in the survey. *Tipula* iridescent virus (TIV) infection results in the infected host becoming blue or purple in colour due to the reflection of light by crystals of virus particles formed in the insect's tissues. *Tipula* nuclear polyhedrosis virus infects the insect's haemocytes and the virus particles are occluded in polyhedral structures visible by light microscopy, which cause the insect to become chalky white in colour. Both the viruses are normally lethal to their hosts.

In the early stages of investigating the possibility of biological control of a pest, resources should be concentrated upon those agents which cause the host's death. In the case of *Tipula* these agents include the two viruses, mermithid nematodes, tachinid insects, probably the *Bacillus* and the microsporidian and possibly fungi.

In this survey these parasites which were harmful to the host were generally rare, whereas those which the host could tolerate were common. However, significant numbers of tipulids may on occasion be infected by harmful parasites. Epizootics of TIV have been reported, e.g. Ricou (1975). Microbial control systems attempt to create epizootics of pathogens which occur enzootically. Attempts to achieve this end are in progress with TIV.

FIELD TRIALS WITH TIV

Two trials have been carried out on a population comprised mainly of *T. paludosa, T. oleracea* and *T. czizeki* in hill pasture at Redesdale Experimental Husbandry Farm in Northumberland. The pasture has been seeded with clover and seems to provide a suitable environment for these three tipulid species, so much so that in one year areas were completely stripped of their vegetation and the leatherjackets had to be killed with insecticide pellets.

It has been shown (Carter, 1974) that the first two larval instars are much more susceptible to infection after ingesting TIV than the last two instars. Therefore attempts were made to introduce the virus into the populations in the autumn shortly after *T. paludosa* and *T. oleracea* had hatched. *T. czizeki* does not hatch until the spring.

The first trial was commenced in October, 1973 on plots $0.25m^2$ laid out in a Latin square with 2m between each plot. It has been shown in laboratory experiments that TIV may be transmitted by cannabalism, and that some TIV-infected fourth-instar larvae can survive for long enough to infect the next generation of first instars (Carter, 1973 a and b). It was therefore hoped that if a proportion of the early instar larvae could be infected with TIV, then the later instars might feed on them and acquire the infection. Populations of mites can be infected with a virus by releasing virus-infected mites into them (Gilmore and Tashiro, 1966).

Live TIV-infected *T. oleracea* larvae were released into four plots (five per plot), dead TIV-infected *T. oleracea* larvae were placed on four plots (five per plot), four plots were sprayed with an aqueous suspension of purified TIV (approx. 5×10^9 median infective doses [measured by injection into fourth-instar *T. oleracea* larvae] per plot), and four plots were left untreated as controls.

The tipulid larvae in the plots were sampled in the following December, February, April and June, and some areas between and around the plots were sampled at bi-monthly intervals from November to July. All larvae were incubated individually at $20^{\circ}C$ to see whether any developed iridescence. Some larvae died in the laboratory possibly due to damage caused by the sampling fluid; each of these was tested for TIV by preparing an extract of its tissues and injecting it into 10 *T. oleracea* larvae. Dead larvae putrefied rapidly, and in most cases it was not possible to remove their guts intact, therefore this technique might also detect ingested virus in the gut lumen and a positive result is not conclusive evidence of infection in the insect's tissues.

The results of the sampling from the plots are shown in Table 1. All four larvae in which TIV was detected were third-instar *T. paludosa*. All four isolates

were identified as TIV when they gave identical titres in the latex agglutination test (Carter, 1973 c) with the virus isolate which was introduced into the field. No TIV infection was detected in 66 larvae sampled from between and around the plots.

Each of the four larvae in which TIV was detected was from a different plot, one treated with live infected larvae, one treated with dead infected larvae, one sprayed with virus and one control plot. There are several possible explanations for the finding of TIV in an insect in a control plot. Considerable lateral movement of tipulid larvae may occur (Barnes, 1941), so that either a released infected larva or a wild larva could have moved into a control plot, or there could have been some movement of virus and/or larvae by another agent, e.g. wild animal, bird, sheep. The finding of the virus in a control plot means that it is not known which of the three methods of virus application introduced the infection into the field population. However, this is not too important at present, as none of the methods had a very high efficiency. That the virus was introduced into the field population does seem fairly certain, as no TIV has been detected in intensive sampling of larvae in the region of the plots both before and during the period of the trial.

Table 1

Results of 1973-4 field trial

Sampling date	No. of larvae sampled	No. of larvae iridescent	No. of larval extracts in which TIV detected	Percentage larvae in which TIV detected
14.12.73	5	0	1	20.0
21.2.73	18	1	2	16.7
25.4.74	5	0	0	0.0
20.6.74	23	0	0	0.0

In order to test whether earlier treatments would give a greater efficiency of introduction of virus into the field population, a second trial was commenced in September, 1974. This was 31 days earlier than the trial of the previous year. The trial was set out in a similar fashion to before, except that the plots were each $1m^2$ with 4m between plots. The plots treated with live and dead infected larvae each received 25 larvae, and the plots sprayed with virus suspension received approx. 1.2×10^9 median infective doses (measured by injection into fourth-instar *T. oleracea* larvae).

Both these plots and the site of the previous trial were sampled at approximately two-monthly intervals. The results are shown in Table 2. The larval population densities were higher than in the previous year, so larger numbers of larvae were recovered during sampling. Too many larvae died in the laboratory for their extracts to be tested for TIV, so that extracts were tested by the latex agglutination test, which is less time-consuming, but less sensitive than tests for infectivity (Carter, 1973 c). TIV was not detected in any of the extracts.

Three iridescent *T. paludosa* larvae were recovered from the field, one on each of the first three sampling occasions. Their larval instars were II, III and IV, respectively, and the plots from which they were taken were control, dead infected and live infected, respectively. Even allowing for the fact that a few infections may not have been detected in the latex test, the results show that a September application of virus is no more favourable than an October one. TIV was not detected in any larvae sampled from the site of the previous trial, indicating that there was no carry-over of the infection to the next generation.

Table 2

Results of 1974-5 field trial

Sampling date	No. of larvae sampled from plots	No of larvae iridescent	Percentage larvae in which TIV detected	No. of larvae sampled from site of 1973-4 trial
5.12.74	22	1	4.5	11
11.2.75	128	1	0.8	38
29.4.75	108	1	0.9	17
13.6.75	24	0	0.0	not done

The reason why few larvae became infected with TIV in these trials may be the same reason why TIV has not been found at this location, other than in the trial plots, whereas TIV-infected larvae were regularly found at some other locations in the field survey. Perhaps there is some factor, e.g. a plant species which enhances the uptake of virus from the gut, absent from this location, or alternatively, perhaps there is a factor present which inhibits the transmission of the virus. In order to test this hypothesis the next field trial with TIV will be carried out at a location where TIV is known to be enzootic.

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THE USE OF JUVENILE HORMONE ANALOGUES FOR THE CONTROL OF SOME DOMESTIC INSECT PESTS

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Summary The juvenile hormone analogue Altosid was evaluated as a potential control agent for the domestic pests Monomorium pharaonis and Blatella germanica. In two small-scale field trials, baits containing 0.5% w/w Altosid were tested against heavy infestations of M.pharaonis. The baits, placed throughout the infested areas were renewed twice weekly for a period of 10 weeks. This technique resulted in the complete eradication of the infestations between 6 and 9 weeks after treatment ended. Preliminary laboratory studies have shown that feeding first, second and third stage nymphs of B.germanica food containing 0.1% w/w Altosid completely prevented the production of F_1 nymphs by the subsequent adult stages. Similar exposure of older nymphs to Altosid reduced the numbers of F_1 nymphs they produced. Virgin adult B.germanica were apparently unaffected by food containing 0.1% Altosid. The potential use of juvenile hormone analogues for the control of these and other domestic pests is discussed.

INTRODUCTION

The main effect of insect juvenile hormones and their analogues is to disrupt the development of insects at the end of the larval stage (Staal, 1972). In some insects such compounds also sterilize adults or prevent eggs hatching (Riddiford, 1972). When the only effect is the disruption of development, the compounds may be particularly suitable for the control of pests which do little or no damage during the larval stage. A pest with harmless immature stages is Pharaoh's ant Monomorium pharaonis. Previous studies have shown that laboratory colonies of this ant die out when given only food containing the juvenile hormone analogue Altosid (Edwards, 1975).

This paper presents the results of small-scale field trials of Altosid (isopropyl-11-methoxy-3,7,11-trimethyl-dodeca-2,4-dienoate) against Monomorium pharaonis. Some preliminary laboratory tests of Altosid on the German cockroach Blattella germanica are also reported and the potential use of insect juvenile hormone analogues against other domestic pests is discussed.

METHOD AND MATERIALS

Field trials of Altosid against Monomorium pharaonis

Two premises heavily infested with M.pharaonis were used. The first site was a chapel and hall at a hospital. These were connected to each other and to other buildings by underground ducts containing heating pipes (Fig. 1). The whole hospital was infested so the trial area was isolated by bands of fenitrothion (w.d.p.) sprayed at approx. 100 mg/0.092 m^2 (Fig. 1). At the second site, a commercial aquarium, the whole building was treated and no insecticide banding was necessary (Fig. 2). The air temperature at both sites reached a maximum of 32°C while the average temperature at the hospital was 23°C and that at the aquarium 26°C. The humidity was not measured but the aquarium was noticeably more humid than the hospital. The initial extend of the infestations at both premises was determined by baiting with raw liver throughout the trial areas. Subsequently small plastic tubes, 40 x 25 mm, each containing approximately 1 g of bait were placed at appropriate points throughout the trial areas as shown in Figs. 1 and 2.

At the hospital 85 baits were used in a floor area of 660 m^2. At the aquarium, where the infestation was heavier, 90 baits were used in 230 m^2. The bait was a mixture of liver powder, honey and sponge cake (2:1:1 w/w) containing 0.5% w/w Altosid as described by Edwards (1975). Baits were replaced twice weekly for ten weeks. The number of worker ants present in the bait tubes was recorded at weekly intervals. After 10 weeks treatment, baits without Altosid were used to monitor the number of ants present each week. Queen ants attracted to the baits were removed and their ovaries examined. At the hospital site a reinfestation from an untreated part of the hospital occurred in the chapel and this necessitated a 4-week re-treatment of the affected area with Altosid baits together with a re-spraying of fenitrothion in the adjoining ducts. The retreated area is shown in Fig. 1.

Laboratory studies with Altosid on Blatella germanica

Nymphs of each nymphal stage and virgin adults of the German cockroach were given only food containing 0.1% w/w Altosid. Treated food was made by dissolving Altosid in diethyl ether, mixing this thoroughly with wheatfeed, rolled oats, fish meal and yeast powder (5:5:2:1 w/w) and allowing the ether to evaporate at room temperature. Control insects were given food treated with diethyl ether only. Food was stored at 5°C to minimise decomposition. Nymphs from standard Laboratory cultures of Blatella germanica were anaesthetized with CO_2 and weighed so that their exact stage of development could be determined by reference to the data of Woodruff (1938). Batches of 20 nymphs at each of the six nymphal stages were transferred to glass troughs (30 x 20 x 35 cm) where they were kept on a continuous diet of food containing 0.1% Altosid. Further batches of 20 nymphs were kept on a diet of untreated food. Mortality was recorded at weekly intervals until 15 weeks after adult emergence. As each group of nymphs reached the adult stage, those that were deformed were counted and sexed. Ten weeks after each group of nymphs had first developed into adults, the total numbers of egg-cases and F_1 nymphs produced were recorded.

Virgin adult cockroaches were obtained by isolating insects of the two sexes during the sixth nymphal stage. Ten virgin male and 10 virgin female adult cockroaches were placed in a glass trough and given only food containing 0.1% w/w Altosid for a period of two weeks. Subsequently the insects were given untreated food for a further eight weeks. A similar group of control insects were fed untreated food for the full 10 weeks. The mortality and the production of F_1 nymphs and egg cases was recorded at weekly intervals. All insects were kept at 27° C and 40% r.h. and given eight hours light per day.

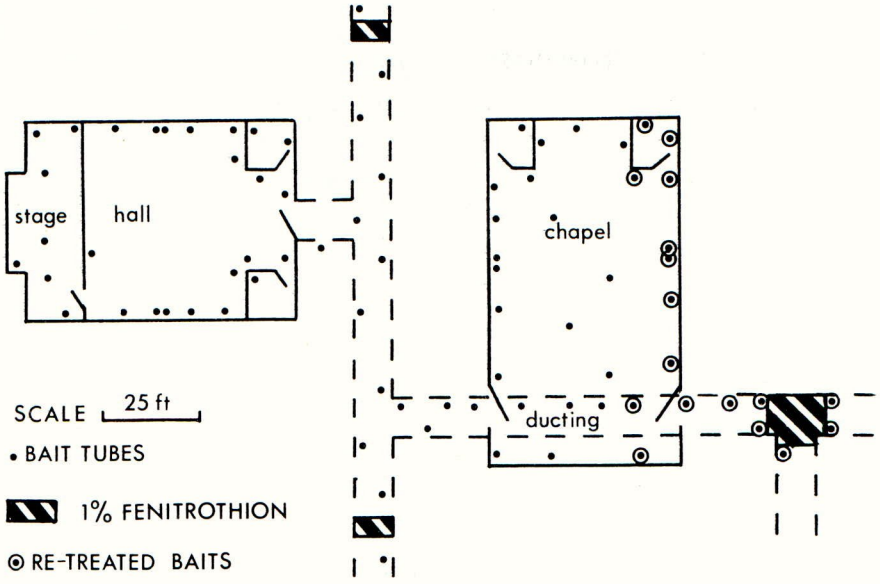

Fig 1. Hospital site for field trials of Altosid against Monomorium

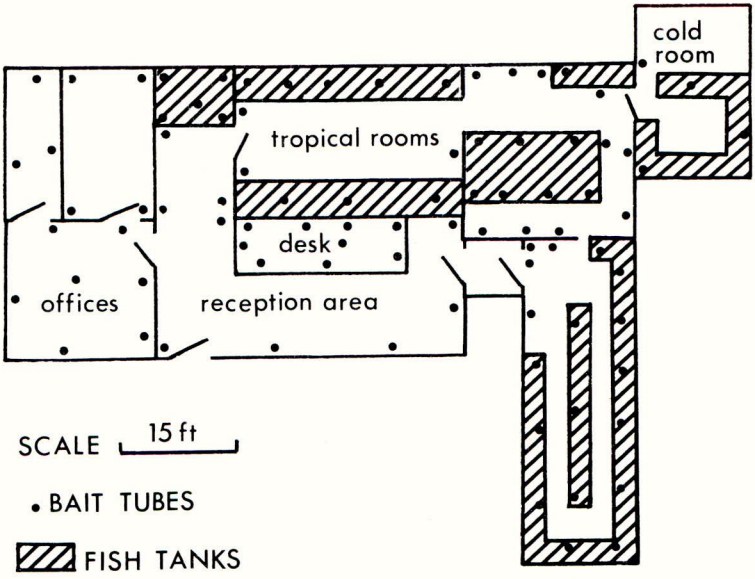

Fig 2. Aquarium site for field trials of Altosid against Monomorium.

RESULTS

Field trials of Altosid against Monomorium pharaonis

Table 1 shows the number of worker and queen ants attracted to bait tubes at both sites over the 10-week treatment and the following 10-week post-treatment periods. After about 10 weeks the number of workers declined and none was found after 17 weeks at the hospital site and after 15 weeks at the aquarium. At both sites, queen ants began to appear in the bait tubes towards the end of the treatment period and continued to be found up to seven weeks after treatment at the hospital and five weeks after treatment at the aquarium. All queens collected after the treatment period had degenerate ovaries which contained no mature oocytes. The complete eradication of ants at both sites was confirmed by liver baiting 11 weeks after treatment.

Table 1

Numbers of ants found in bait tubes during field trials with Altosid against Monomorium pharaonis

		Hospital site			Aquarium site		
	Week	% tubes with worker ants[a]	Total workers	Queens	% tubes with worker ants[b]	Total workers	Queens
Treatment period	1	51	646	0	56	1303	0
	2	70	598	0	55	724	0
	3	76	515	0	48	397	0
	4	82	642	0	45	275	0
	5	75	533	0	56	774	0
	6	81	625	0	41	592	0
	7	67	329	0	48	637	0
	8	63	175	0	54	397	0
	9	54	98	1	46	258	1
	10	36	91	1	37	230	1
Post-treatment period	1	27	187	2	33	163	0
	2	34	170	4	27	111	4
	3	21	113	3	23	77	4
	4	7	56	3	15	40	4
	5	16	22	9	3	5	0
	6	4	10	2	0	0	0
	7	3	7	16	0	0	0
	8	0	0	1	0	0	0
	9	0	0	0	0	0	0
	10	0	0	0	0	0	0

[a] % based on 85 tubes

[b] " " " 90 "

Laboratory studies of Altosid on Blatella germanica

Table 2 shows the mortality and number of deformed adults produced when nymphs of B. germanica were continuously exposed to food containing 0.1% w/w Altosid. Mortality was high in both treated and control insects during the first week of each experiment and may have resulted from the use of CO_2 during anaesthetisation. All nymphs exposed to treated food produced some deformed adults. However this deformity did not appear to affect the longevity of the insects. All deformed insects had poorly developed elytra and were similar to those described by Das and Gupta (1974) except, that in the present experiments, the juvenile hormone analogue did not produce darker pigmentation. All but one of the deformed insects were females. The numbers of egg cases and F_1 nymphs produced after 10 weeks by adults that developed from treated nymphs are given in Table 3. All adults produced egg cases although fewer were produced by adults that developed from treated nymphs. However, when treatment commenced during the first three nymphal stages, the egg cases did not produce nymphs. Adults that developed from nymphs treated during the last three nymphal stages produced fewer F_1 nymphs than corresponding control insects (Table 3). Exposure of virgin adults to food containing 0.1% Altosid for two weeks had no apparent effect on mortality, egg case and nymph production either during or for eight weeks after the treatment.

Table 2

Mortality and deformity in Blattella germanica nymphs exposed to food containing 0.1% Altosid

Nymphal stage at start of treatment	No. dead/20		Deformed males		Deformed females	
	treated	control	treated	control	treated	control
I	7	4	0	0	2	1
II	10	8	0	0	3	0
III	12	9	1	0	2	0
IV	5	2	0	0	2	0
V	5	8	0	0	3	0
VI	1	0	0	0	4	0

Table 3

Number of egg-cases and F_1 nymphs produced during 10 weeks by adult Blattella germanica after exposed to Altosid during the nymphal stage

Nymphal stage at start of treatment	No. of egg cases/female		No. of F_1 nymphs/female	
	treated	control	treated	control
I	1.9	4.0	0	88
II	1.3	3.3	0	90
III	1.8	3.8	0	104
IV	2.2	3.5	26	78
V	2.5	3.0	9	61
VI	2.8	3.1	37	72

DISCUSSION

Previous laboratory studies indicated that Altosid has potential for the control of Monomorium pharaonis. The present field trials have shown that baits containing Altosid are effective in eradicating infestations of this species.

At present, the technique involves a long treatment period which in commercial practice would lead to high labour costs. However, laboratory studies have shown that food containing Altosid is effective in destroying colonies of Pharaoh's ant when fed to the ants for only one week (Edwards, 1975) and further trials are planned in which shorter treatment periods will be used. Although Altosid baits are effective in controlling infestations, the time taken for complete eradication is long compared with conventional insecticides. This is because the hormone analogue has no lethal effect on worker ants which therefore remain alive for their normal life span.

In the United Kingdom Monomorium pharaonis is a serious domestic pest in hospitals, canteens and other heated premises. Infestations are often difficult to control and are a potential threat to public health (Beatson, 1972). The present field trials have demonstrated that Altosid has potential as a control agent for this pest particularly in situations like intensive care units, mental hospitals and tropical aquaria as a less toxic replacement for the organochlorine insecticides currently used against this pest.

The laboratory studies with Altosid and Blattella germanica although preliminary, have indicated that this compound can prevent reproduction and so has potential as a control agent for this species. Although the production of F_1 nymphs was completely prevented only when treatment commenced before the fourth nymphal stage, further preliminary experiments have indicated that higher doses of Altosid can completely prevent the production of F_1 nymphs when fed to all but final stage nymphs (J. P. Edwards unpublished). Furthermore, Riddiford et al., (1975) have shown that

some juvenile hormone analogues are more effective than Altosid against Blatella germanica.

In many domestic insects it is the adult which, by its unwanted presence or ability to transmit disease, is responsible for the pest status of the species. The larval stages are often neither a nuisance nor a threat to public health.

Table 4

The type of activity of juvenile hormones on domestic pests

Species		Activity: morphogenic	sterilizing	ovicidal	References
Firebrat	(Thermobia)	+	+	+	Rohdendorf & Senhal (1975)
Earwig	(Labidura)	+		+	Srihari et al. (1975)
Flies	(Musca)	+			
	(Stomoxys)	+			Harris et al. (1973)
	(Haematobia)	+			
Mosquitoes	(Culex) (Aedes)	+			Jakob & Schoof (1971)
Beetles	(Dermestes)	+			Slama (1974)
	(Trogoderma)	+	+		Metwally & Landa (1972)
	(Lasioderma)			+	Walker & Bowers (1970)
Clothes moth	(Tineola)	+		+	Mauchamp (1974)
Cockroaches	(Blattella)	+	+		Riddiford et al. (1975)
House ants	(Monomorium)	+	+		Edwards (1975)
	(Solenopsis)				Troisi & Riddiford (1974)
Body lice	(Pediculus)	+	+	+	Vinson & Williams (1967)

Pests of this type, like Monomorium pharaonis may be particularly suitable for control by juvenile hormone analogues. However, when juvenile hormones affect reproduction, as in B. germanica they may also be effective against insects in which the larval stages are pests. Studies at other laboratories have shown that compounds with juvenile hormone activity disrupt development and in some cases interfere with reproduction in a number of other domestic pests (Table 4). Such compounds, therefore, have potential as control agents for these species. However, the practical effectiveness of such control measures will depend upon the relationship between the insects biology and the particular effects produced by juvenile hormones in each species.

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THE USE OF PHEROMONES IN TRAPPING MOTH PESTS IN U.K. TOP FRUIT ORCHARDS

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Summary Trials were carried out between 1973-75 with traps, baited with female sex attractants (pheromones), placed in top fruit orchards. These pheromones have proved to be a reliable means of determining population levels and periods of emergence of such important Lepidopterous pests as codling moth, fruit tree tortrix, summer fruit tortrix, fruitlet mining tortrix and plum fruit moth. The pheromones are shown to be equal or superior to mercury vapour light traps in relation to codling moth trapping and superior in relation to the trapping of the fruit tree tortrix and the summer fruit tortrix.

An attempt has been made to relate accumulated heat sums with moth catches to provide a means of determining the optimum time of insecticide spray applications.

Résumé Des essais furent réalisés entre 1973-75 avec des pièges garnis avec des agents attirants sexuelles féminins (phéremones) placés dans des vergers. Ces phéremones se sont révélées comme une méthode sûre de savoir les niveaux de population et les périodes d'émergence des pestes Lepidoptères importantes telles que Laspeyresia pomonella, Archips podana, Adoxophyes orana, Pammene rhediella et Laspeyresia funebrana. Ces phéromones se montrent égales ou supérieures aux pièges de vapeur de mercure en ce qui concerne la prise au piège de Laspeyresia pomonella et supérieures en ce qui concerne la prise au piège de Archips podana et Adoxophyes orana.

On a essayé d'établir un rapport entre les quantités de chaleur accumulée avec les prises des Lepidoptères afin de donner un moyen d'établir l'optimum temps d'application des insecticides.

INTRODUCTION

Pest control in U.K. top fruit orchards is currently costing the growers in excess of one million pounds sterling. (Anon.a 1974). Some of the most important Lepidopterous pests include the codling moth (Laspeyresia pomonella), the fruit tree tortrix (Archips podana), the summer fruit tortrix (Adoxophyes orana), the fruitlet mining tortrix (Pammene rhediella) and the plum fruit moth (Laspeyresia funebrana).

The overwintering caterpillars are controlled by winter wash and spring spray treatments but there is often a build up of caterpillars in July and August following moths immigration during June. The control of these caterpillars depends

upon well-timed summer spray applications. In the U.K. the codling moth tends to lay eggs later than in former years and a current commercial recommendation for codling moth and tortrix control (Anon.b 1974) suggests that spraying should normally commence by 20 June or one week later where tortrix is the main problem, and be repeated twice at three-week intervals. One or even two of these sprays are frequently omitted by growers who consider that they do not have a codling moth problem.

This calendar spraying programme can be regarded only as a possible insurance as it makes no allowance for the early emergence, for the presence of non-economic numbers or even for the absence of the pests.

Help in deciding the optimum date for the commencement of spraying can be made by monitoring the catches of codling moths in light traps or by a calculation of accumulated heat sums (J.E.Cranham personal communication). The disadvantages of using light traps are (a) they are usually situated in an orchard near to a source of electricity and not necessarily near to an orchard which may experience codling attacks, (b) moths flying during daylight hours are not trapped and (c) the non-specificity of catches with the consequent problems of moth identification. The pheromone traps appear to offer advantages over other systems in that they are reliable, cheap, convenient and easy to service.

Sex-attractant traps have been used to monitor codling moth populations and to determine the need for insecticide sprays in several countries including: the U.S.A. (Batiste et al.1973), France (Milaire, 1973), British Columbia (Madsen and Vakenti, 1973), S. Africa (Madsen et al. 1974; Myburgh et al.1974). This report concerns work carried out in the U.K. between 1973-75 with sex-attractant traps, in some instances in comparison with light traps, to monitor codling and tortricid moths in individual orchards and in 1975 to establish control thresholds, particularly with the codling moth.

In 1974 and 1975 joint programmes were carried out between Murphy Chemical Ltd., the Agricultural Development and Advisory Service and East Malling Research Station, some of the 1974 trial results from A.D.A.S. and E.M.R.S. are included in this report.

METHODS AND MATERIALS

The sex-attractant (pheromone) traps used were Pherocon 1 C traps which are wing-type paperboard construction with a sticky trapping adhesive on the upper surface of the lower section. The two sections are joined by a wire frame which also serves as a hanger. The attractant is absorbed on to a cap which is placed in the middle of the adhesive lower section. The caps were replaced after six weeks use in a trap.

The attractant baits used contained synthetic female sex hormones (pheromones) which attract male moths only. They were as follows :

1. Codlemone or Pherocon CM baits consisted of a small synthetic rubber septum containing 0.1% (1mg/septum) of pure trans-8,trans-10 dodecadien-1-ol. Codlemone attracts males of the codling moth and also the fruitlet mining tortrix moth.

2. Adoxomone or Pherocon TM baits consisted of a small inert polythene cap containing 9mg of cis-9 and 1mg of cis-11-tetradecenylacetate. Adoxomone attracts males of the summer fruit tortrix moth.

3. Archemone baits consisted of a small inert polythene cap containing 1mg of cis-11 and 1mg of trans-11-tetradecenylacetate. Archemone attracts males of the fruit tree tortrix moth.

4. Funemone baits consisted of a small inert polythene cap containing 5mg of cis-8-dodecenylacetate. Funemone attracts males of the plum fruit moth.

Siting The traps were placed, at a density of one/2ha, approximately 100m apart in a line through the centre of the orchard and across the direction of the prevailing wind. Perimeter traps were sometimes used, these were placed on the perimeter row of trees adjacent to suspected sources of infestation, e.g. packhouses, bulk bin stacks, apple dumps, unsprayed orchards. The traps were hung on the outside of the tree canopy at a height of 2m from the ground. Where mercury vapour lamp (MVL) traps were used these were sited approximately 100m from the pheromone traps.

Where codling and tortrix traps were tested in the same orchard they were placed in adjacent trees.

Timing The traps were placed in the orchards in mid-June 1973, early June 1974 and early to mid-May 1975.

Assessment Catches of moths were recorded weekly and all insects were removed after recording. Fruit was examined during August and at harvest for signs of damage where untreated plots were compared with treated plots timed from trap catches.

Spraying The aim in 1975 was to apply the first codling spray (chlorpyrifos 1 kg a.i./ha) 10 to 14 days following the first week in which more than three to five moths were caught per trap and the minimum dusk temperature, on one or more days in that week was 14°C, followed by a second application of chlorpyrifos two-three weeks later.

The areas of orchard covered by trap 2 at Faversham, Rochester and Robertsbridge were each sprayed twice with chlorpyrifos at 1.0 kg a.i./ha, the dates being 25 June and 11 July, 4 July and 24 July, 30 June and 21 July respectively. The area of orchard covered by trap 1 at the three sites was left unsprayed.

RESULTS

Codling Moth

1973 A limited number of trials for codling moth and summer fruit tortrix were carried out mainly in Kent. The codling traps were set up on 18 June. The mean number of codling caught per trap, for the nine traps at four sites in Kent, was over seven moths for the weeks ending 25 June, 2 and 16 July and over 4 moths for the week ending 9 July. After the 16 July few codling were trapped.

1974 The weekly catches of codling moth are given in Table 1. At the Kent sites codling was recorded in small numbers, in seven out of ten pheromone traps, during the week ending 27 May, which was two and one weeks respectively before any recorded catch in the two MVL traps. At the Petherton, Somerset, trial the pheromone trap also recorded codling two weeks before the MVL trap. The pheromone traps recorded higher total catches at Herne Bay (a) and Petherton (c) such that the low catches recorded in the MVL traps would probably not have

warranted subsequent spraying, a result not borne out by the pheromone catches. At Maidstone (b) both traps recorded high numbers of codling although the MVL recorded the higher number.

Generally all the sites produced a reasonable number of catches but the Preston and possibly the Herne Bay sites may not have warranted spraying. From the mean figures for the Kent sites peak emergence was between 8 and 22 July and a mean of almost four moths/trap was recorded for the week ending 5 August which was much later than in 1973 when a mean of one or less was recorded after 23 July.

1975 The weekly catches of codling moth are given in Table 2 and are appreciably lower than those recorded in 1974. Peak emergence appeared to be 14-21st August which was much later than in 1974. Total catches at the Robertsbridge, Faversham and probably the Canterbury sites were so low not to warrant spraying for codling moth. The Rochester site and portions of the Littlebourne site probably warranted spraying.

A mid-August codling damage assessment of the sprayed and unsprayed apple orchards at the Faversham, Rochester and Robertsbridge sites (Table 2), showed that there was little difference between the sprayed and unsprayed orchards as regards the number of codling strikes. The sprayed orchards, however, all recorded nil successful entries with active codling caterpillar, whereas the unsprayed orchards recorded 0.2-0.9% successful entries. Surprisingly, the 0.9% entries recorded on the unsprayed orchard at Robertsbridge, where very few codling moth were trapped, were equal to the percentage entries at Rochester where a much higher number of moths was trapped.

Fruit tree tortrix

1974 Unfortunately at two of the three sites, the traps were set late in the season. Peak emergence for the sites was a mean of 38/trap and appeared to be during the week ending 15 July (Table 3). The single moth recorded in the MVL trap at Ash and the highest catch of eight in the Canterbury MVL trap, were also during the same week. At the Canterbury site there was a second peak recorded by the pheromone trap, during the week ending 12 August.

1975 The traps were set about one month earlier than in 1974. The first significant catches by the pheromone traps were recorded in the week ending 23 June which was two-three weeks earlier than the MVL traps which recorded much lower total catches as in 1974. The period of peak emergence varied from week ending 23 June for Rochester and Canterbury (b) to week ending 14 July for Faversham, with a mean peak week ending 7 July, which was probably a week earlier than in 1974. However, at the Robertsbridge site fairly large numbers of fruit tree tortrix were caught between 30 June and 18 August.

Summer fruit tortrix

1974 The three pheromone traps at both sites gave very consistent results (Table 5). Two distinct flights were recorded, the first and largest around mid-June and the second extending from the week ending 12 August to 23 September. The MVL trap at Ash recorded total catches of summer fruit tortrix moth far lower than those recorded by the pheromone traps. The peak catch for the second flight was recorded two weeks later than that recorded by the pheromone traps.

1975 The numbers of first generation summer fruit tortrix moth caught in the pheromone traps (Table 6) were only a small percentage of those caught in 1974. None were caught in the MVL trap at Ash in comparison with 45 caught at the same site in 1974. The peak catch for the first flight was during the week ending 23 June which was a similar date to the recorded peak in 1974.

Fruitlet mining tortrix

1975 One trial at Maidstone was carried out with two pheromone traps containing the Codlemone sex-attractant baits. Relatively small total catches (Table 7) were made with a distinct peak during the week ending 24 May.

Plum fruit moth

1975 Of the three trials carried out only the site at Staplehurst gave significant catches (Table 8). The distinct peak catch was recorded during the week ending 30 June.

TABLE 1

Weekly catches of codling moth/trap in Kent, Sussex, Cambs., and Somerset in 1974

	Faversham, Kent		Rochester, Kent		Herne Bay, Kent		W.Malling, Kent	Preston, Kent	Herne Bay, Kent(a)		Maidstone, Kent(b)		Kent Trap Mean	Chichester, Sussex	Wisbech, Cambs.		Petherton, Somerset (c)	
Trap	1	2	1	2	1	2	1	1	1	MVL	1	MVL		1	1	2	1	MVL
Week ending																		
20.5.	1	2	0	2	0	0	-	3	0	0	0	0	0.9	0	-	-	-	-
27.5.	2	1	0	2	2	0	0	2	11	0	10	0	3.0	0	-	-	17	0
3.6.	1	0	1	0	1	1	2	2	3	0	3	1	1.4	3	-	-	21	0
10.6.	3	0	0	2	1	6	9	3	7	3	5	0	3.6	6	0	0	32	1
17.6.	6	0	0	5	0	5	13	3	11	3	21	11	6.4	10	20	14	103	3
24.6.	2	9	0	9	0	5	1	5	6	0	14	8	5.2	8	5	6	42	3
1.7.	2	1	1	2	1	3	0	5	19	6	22	13	5.6	3	0	0	20	3
8.7.	2	10	21	23	1	14	15	5	7	2	12	34	11.0	4	9	6	70	4
15.7.	29	9	5	25	11	28	6	2	1	5	19	27	13.5	0	3	19	10	3
22.7.	7	4	12	10	3	15	2	5	29	4	35	59	12.2	1	0	0	45	0
29.7.	20	1	3	10	3	7	0	0	6	0	13	60	6.3	1	2	11	24	3
5.8.	0	4	1	7	1	5	0	0	7	16	14	24	3.9	0	0	0	24	4
12.8.	0	2	2	0	3	2	0	0	0	3	0	19	0.9	0	4	3	13	1
19.8.	0.	0	2	2	0	3	0	0	0	0	6	12	1.3	0	0	0	2	0
27.8.	0	0	0	0	1	0	0	0	0	0	2	6	0.3	0	0	0	5	0
Total	75	43	48	99	28	94	48	35	107	42	176	274		36	43	59	428	25

(a) ADAS Wye trial

(b) EMRS trial

(c) ADAS Bristol trial

TABLE 2

Weekly catches of codling moth/trap in Kent and E.Sussex and fruit damage counts (mid-August) in 1975

	Faversham, Kent		Rochester, Kent		Robertsbridge, E.Sussex		Canterbury, Kent						Littlebourne, Kent						Trap Mean
Trap	1	2	1	2	1	2	1	2	3	4	5	6	1	2	3	4	5	6	
Week ending																			
19.5.	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	0.0
26.5.	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	0.0
2.6.	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	0.0
9.6.	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	0	2	1	0.4
16.6.	4	3	3	3	0	0	0	2	2	5	0	0	15	1	5	7	2	1	2.9
23.6.	1	1	5	4	2	1	0	0	1	4	0	0	2	0	9	3	5	0	2.1
30.6.	0	spray 1	5	7	0	0	spray 1	0	2	4	0	0	0	0	4	1	6	1	1.8
7.7.	0	0	8	spray 8	0	1	0	1	0	3	0	0	1	1	7	1	5	0	2.0
14.7.	9	spray 4	17	11	0	0	0	2	0	10	0	2	3	0	1	0	5	0	3.6
21.7.	7	7	7	7	1	1	spray 0	1	0	1	0	2	5	2	5	5	30	1	4.6
28.7.	0	0	6	spray 4	1	2	0	3	1	2	1	1	3	0	3	2	0	0	1.6
4.8.	4	1	3	3	1	0	0	6	0	3	1	4	1	2	1	3	10	0	2.4
11.8.	0	0	2	1	2	0	0	1	0	0	0	1	0	2	0	0	0	0	0.5
18.8.	1	0	1	2	1	0	0	0	0	4	1	0	0	0	0	0	0	0	0.6
Total	26	17	54	50	8	5	1	16	6	36	3	10	31	10	37	22	65	4	
150 day °C heat sum reached:	12.6		29.6		21.6		2.7						2.7						
Catches at above date:	1	0	12	13	0	0	1	2	5	13	0	0	18	3	20	11	15	3	
% strike:	0.5	0.7	0.5	0.4	0.2	0.1													
% entries:	0.2	0.0	0.9	0.0	0.9	0.0													

TABLE 3

Weekly catches of fruit tree tortrix moth in Kent in 1974

Trap	Rochester 1	2	3	Ash 1	2	3	MVL	Canterbury 1	MVL	Mean/ trap	MVL
Week ending											
17.6.	-	-	-	-	-	-	-	16	0		
24.6.	-	-	-	-	-	-	-	40	0		
1.7.	-	-	-	-	-	-	-	6	3		
8.7.	26	23	34	13	12	4	0	16	4	18.3	2.0
15.7.	72	68	72	26	12	9	1	10	8	38.4	4.5
22.7.	33	36	33	22	3	5	0	8	2	20.0	1.0
29.7.	8	14	11	4	4	2	0	0	0	6.1	0.0
5.8.	3	9	2	4	5	3	0	0	0	3.7	0.0
12.8.	8	6	6	7	2	1	0	31	0	8.7	0.0
19.8.	2	2	5	4	2	3	0	15	0	4.7	0.0
26.8.	1	0	1	5	0	5	0	9	0	3.0	0.0
2.9.	3	0	1	2	0	0	0	4	0	1.4	0.0
9.9.	7	3	4	0	0	0	0	0	0	2.0	0.0
16.9.	2	5	2	1	1	3	0	4	0	2.6	0.0
23.9.	0	1	1	1	2	2	0	4	0	1.6	0.0
30.9.	0	0	0	0	0	0	0	1	0	0.1	0.0
Total	165	167	172	89	45	37	1	154	17		

TABLE 4

Weekly catches of fruit tree tortrix moth in Kent and E.Sussex in 1975

	Faversham, Kent		Rochester, Kent		Roberts-bridge, E.Sussex		Canterbury, Kent (a) (Mean of 6 traps)	Littlebourne, Kent (Mean of 6 traps)	Ash, Kent		Canterbury, Kent (b)				Mean/ trap	Mean/ MVL
Trap	1	2	1	2	1	2			1	MVL	1	MVL	2	MVL		
Week ending																
2.6.	0	0	0	0	0	0	-	-	-	-	-	-	-	-	0.0	-
9.6.	0	0	0	0	0	0	0	0	-	-	0	0	0	0	0.1	0.0
16.6.	0	0	11	4	0	0	0	0	0	1	2	0	0	0	0.9	0.3
23.6.	0	0 spray	46	54	10	5	5	3	11	0	73	0	6	0	12.1	0.0
30.6.	7	3	10	26 spray	32	14	spray 9	14	32	0	30	0	11	0	14.9	0.0
7.7.	9	6 spray	2	8	16	47	18	45	25	0	10	4	63	1	28.2	1.7
14.7.	37	9	9	6	4	11	25	11	5	1	2	11	3	1	15.2	4.3
21.7.	8	7	5	9 spray	52	71	spray 19	19	8	0	22	4	30	2	22.7	2.0
28.7.	13	13	7	2	6	24	19	3	1	0	10	4	10	1	9.8	1.6
4.8.	12	13	5	0	14	10	6	3	0	0	1	5	2	0	6.0	1.6
11.8.	0	0	0	1	21	19	6	5	0	0	6	2	6	0	5.8	0.6
18.8.	6	3	2	0	14	12	4	4	1	0	5	0	3	0	4.9	0.0
25.8.	1	0	2	3	3	2	5	3	0	0	6	0	4	0	2.6	0.0
1.9.	0	0	3	2	0	0	0	1	0	0	2	0	0	0	0.7	0.0
8.9.	0	0	1	3	0	0	-	-	5	0	4	0	1	0	1.5	0.0
Total	93	54	103	118	172	215	116	111	88	2	173	30	139	5		

TABLE 5

Weekly catches of summer fruit tortrix moth in Kent in 1974

Trap	Rochester 1	Rochester 2	Rochester 3	Ash 1	Ash 2	Ash 3	MVL	Mean/ trap
Week ending								
17.6.	-	-	-	97	144	89	7	110.0
24.6.	68	53	85	29	24	10	5	44.8
1.7.	4	2	3	0	0	0	0	1.5
8.7.	2	0	0	0	0	0	0	0.3
15.7.	1	0	0	2	0	0	0	0.5
22.7.	0	0	0	0	0	0	0	0.0
29.7.	0	0	0	0	0	0	1	0.1
5.8.	1	0	0	0	0	0	0	0.1
12.8.	14	9	10	2	0	1	2	6.0
19.8.	41	49	30	17	13	5	0	25.8
26.8.	35	36	37	29	25	7	6	28.2
2.9.	19	19	23	21	22	11	24	19.2
9.9.	12	23	15	3	1	6	0	10.0
16.9.	42	30	27	3	7	8	0	19.5
23.9.	10	6	7	21	23	18	0	14.2
30.9.	0	0	0	-	-	-	-	
Total	249	227	237	224	259	155	45	

TABLE 6

Weekly catches of summer fruit tortrix moth in Kent and E.Sussex in 1975

Trap	Faversham, Kent 1	Faversham, Kent 2	Rochester, Kent 1	Rochester, Kent 2	Robertsbridge, E.Sussex 1	Robertsbridge, E.Sussex 2	Canterbury, Kent (Mean of 6 traps)	Littlebourne, Kent (Mean of 6 traps)	Ash, Kent 1	Ash, Kent MVL	Mean/trap
Week ending											
9.6.	0	0	0	0	0	0	0	0	-	-	0.0
16.6.	0	0	2	1	1	1	0	3	0	0	1.3
23.6.	2	2	3	1	2	0	1	6	12	0	3.1
30.6.	0	spray 1	1	0	0	0 spray	1	1	4	0	0.7
7.7.	0	0	0	spray 0	0	0	1	0	0	0	0.4
14.7.	0	spray 0	0	0	0	0	0	0	1	0	0.1
21.7.	0	0	2	0	3	0 spray	0	0	0	0	0.4
28.7.	0	0	0	spray 1	3	0	0	0	0	0	0.2
4.8.	0	0	0	0	0	0	1	0	0	0	0.2
11.8.	0	0	0	2	0	0	0	1	0	0	0.3
18.8.	0	2	5	2	0	0	0	9	3	0	2.3
25.8.	2	0	3	3	0	0	0	18	0	0	2.8
1.9.	3	0	4	3	0	0	0	15	18	0	4.7
8.9.	2	3	1	0	0	0	-	-	7	0	1.8
Total	9	8	21	13	9	1	4	53	45	0	

TABLE 7

Catches of fruitlet mining tortrix moth in Kent in 1975

Trap	Maidstone 1	Maidstone 2
Date of inspection		
12.5.	2	1
16.5.	9	4
24.5.	21	22
27.5.	0	2
30.5.	1	0
4.6.	1	1
6.6.	0	0
9.6.	0	0
13.6.	0	0
Total	34	30

TABLE 8

Weekly catches of plum fruit moth in Kent in 1975

Trap	Canterbury 1	Canterbury 2	Canterbury 3	Canterbury 1	Canterbury 2	Staplehurst 1	Staplehurst 2
Week ending							
9.6.	0	0	0	0	0	0	0
16.6.	0	0	0	1	0	1	1
23.6.	0	0	0	0	0	3	6
30.6.	0	0	0	0	1	57	14
7.7.	2	0	0	5	0	10	4
14.7.	9	0	0	0	0	10	6
21.7.	0	0	0	0	0	2	0
28.7.	0	0	0	0	0	0	0
4.8.	3	1	0	0	0	0	0
11.8.	0	0	0	0	0	0	0
18.8.	0	0	0	0	0	0	0
Total	14	1	0	6	1	83	31

DISCUSSION

Codling Moth

The difficulty in obtaining good control of codling moth using "the preventative" or "calendar" spray programme is demonstrated by the codling emergence figures for 1973-75. The pheromone traps showed that codling emergence was later in 1975 than in 1974 which in turn was later than in 1973. Spraying in 1975 by the customary date of 20 June would probably have been a week too early except perhaps at the Littlebourne site.

Total moth catches by the pheromone traps were usually much higher than the catches in the MVL traps which generally started to attract codling moths when the pheromone catches were at their first peak. The early pheromone catches in May and early June were probably made during the two hours before and after sunset when temperatures were favourable for flight. By the time the moths were attracted to the MVL traps the temperature had probably dropped below flight threshold and consequently no moths were caught. These early catches, however, can be misleading and the current product label recommends spraying 10-14 days following the week of maximum catch.

It would appear that the codling sex-attractant is extremely sensitive, and the relationship between numbers trapped and actual densities is probably linear, in the density ranges commonly found in commercial apple orchards used in the trials. This supports work in S. Africa where it was found that the monitoring efficiency of the traps became progressively greater as codling moth activity levels became lower (Myburgh, 1974).

Correct interpretation of the trap catches is essential, particularly when orchard perimeter traps, used to pinpoint sources of infestation, show higher catches than traps placed in the orchard centre. The need to spray will depend upon the distance between the perimeter trap and the source of the moths as it has been observed (Wildbolz and Baggiolini, 1959) that whereas males may fly considerable distances, females remain close to the source of infestation.

It is difficult to draw definite conclusions from the three sites in 1975 where spraying a portion of each orchard followed pheromone trap monitoring (Table 2). Spraying did not prevent "strikes" by the codling caterpillar but at all three sites the sprayed apples showed no active codling entries. The unsprayed apples all showed entries although less than 1% which in terms of economic return may be borderline. More data is required to correlate the number of male moths captured with the potential damage to the crop in unsprayed orchards, and thus to establish a control threshold which, if exceeded indicates the need for spraying.

However, a provisional threshold of three to five moths/trap/week is suggested by the authors. Results with codling trapping over three years (Ludlam, 1975) show that the rate of emergence and hence of trapping of male moths relates closely to the accumulated heat sum over a threshold of 10°C i.e. $(\frac{\max + \min}{2}) - 10°C$. The suggested threshold (F.A.B.Ludlam, personal communication) is based on the number of moths caught per trap up to the date when the accumulated heat sum reaches 150 day°C (determined for each district or even each farm). Suggested provisional thresholds for numbers of codling per trap by this system for 1975 were :

0	-	20	no spray required
20	-	40	one spray required, timed from trap data
40	-		two sprays required at an interval of three weeks.

From the 1975 trials only one portion of one orchard (Littlebourne) reached 20 moths trapped by the time 150 day°C was reached. Yet two out of the three trials with sprayed and unsprayed trees showed a positive response to spraying. Until the results of the 1975 ADAS and EMRS trials are known it is not possible to draw firm conclusions but it may prove that the accumulated heat sum should be raised to 180 or 200 day°C.

Fruit tree and summer fruit tortrix moths

There is not yet sufficient data to apply the accumulated heat sum method for spray timing to the fruit tree and the summer fruit tortrix moths. Both these species, unlike codling, are predominantly day fliers which might explain the low numbers caught in the MVL traps, compared with the high numbers caught in the pheromone traps.

The fruit tree and the summer fruit tortrix moths probably do not cause economic damage, to apples or pears, at such low population densities as does the codling moth. However, as shown in the results, both species and particularly the fruit tree tortrix are often present in much higher numbers; in fact the numbers caught in one week were often higher than the codling catch for the season. The fruit tree tortrix is considered to be the most serious caterpillar pest of apples and pears, whilst the summer fruit tortrix is a more localised pest occuring mainly in N. and E. Kent although it has been recorded in a few Adoxomone traps in other fruit growing districts.

It is suggested that a provisional threshold, for the fruit tree and the summer fruit tortrix moth, might be 20 moths/week/trap.

Fruit tree tortrix moth

In 1974, using the 20 moth threshold for fruit tree tortrix, all three traps at Rochester, one at Ash and the trap at Canterbury caught moths at levels which would require a spray treatment during the second week of July. This date is backed up for the Rochester site where the codling traps catch indicated a codling spray at the end of June, followed by a second codling spray two weeks later which would probably have controlled the tortrix. At the Canterbury site a second tortrix spray, during the third week in August, would probably have been required.

In 1975 (Table 4) the sprays were timed for codling not tortrix control and as it happened the second codling spray at Rochester was also correctly timed as the first tortrix spray. The first codling spray at Robertsbridge was slightly early and the second codling spray slightly late for the first flush of fruit tree tortrix. At Faversham the first codling spray was unnecessary for tortrix and the second codling spray was too early. These trials emphasise that more accurate timing of spraying for tortrix control could be achieved by the use of Archemone traps, rather than a "calender" spray based on codling spray timing.

Damage counts will be made on these trials at time of harvest.

Summer fruit tortrix

In 1974 there was indication that at Rochester the first codling spray, timed according to the codling moth catch, was also correct for the first summer fruit tortrix spray. Whilst it is not known whether the second generation of summer fruit tortrix causes economic damage, from the numbers caught, at both sites in August, it would appear that there was a necessity for a spray to control tortrix in late August early September.

For some unknown reason, in 1975, there was virtually no first generation of summer fruit tortrix at the trial sites, with consequently no necessity for a spray treatment.

Plum fruit moth

Only one of the three trials carried out in Kent recorded significant numbers. However the ability of the Funemone to attract the plum fruit moth has been previously demonstrated at several sites (D.V.Alford, personal communication).

Where the pheromone traps containing Codlemone, Adoxomone and Archemone were placed in adjacent trees in the same orchard, each trap showed complete specificity from the other two. However the Codlemone also attracted the fruitlet mining tortrix which is in flight before codling and is sufficiently distinctive to be easily recognised; the Adoxomone also attracted small numbers of other moth species such as broom moth and middle bar minor moth, which again could be easily separated; the Funemone also attracted Laspeyresia tenebrosana; the Archemone was found to be completely specific.

The data presented indicate that, traps baited with synthetic female sex pheromones can be used to determine population levels of several important top fruit moth pests, and thus to determine the necessity for an insecticide spray. With careful attention to numbers caught, and date of capture, and using knowledge of moth life-history the sprays can be timed for maximum effectiveness. Although the data in this report does not indicate this, it is possible that by determining the necessity of spraying and by increasing the effectiveness of the sprays used, the number of applications needed may be reduced. This could have beneficial effects on fruit tree red spider mite predator populations, thus perhaps reducing the need for late-season acaricide sprays.

The pheromone trap would appear to be a useful tool for pest control management in top fruit orchards and its use should help the grower to produce quality fruit at the same time as possibly preserving beneficial insects and reducing his costs of pest control.

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INITIAL AND CHRONIC EFFECTS OF THE INSECT GROWTH REGULATOR, PH 6040, ON THE AMERICAN BOLLWORM, *Heliothis armigera*

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Summary Topical and oral application of an insect growth regulator (IGR) (PH 6040), 1-(4-chlorophenyl)-3-(2,6-difluorobenzoyl)-Urea to 4th and 6th instar larvae of *Heliothis armigera* demonstrated initial and chronic insecticidal activity as well as a unique mode of action. A lower mortality occurred in the larval stages than in the post-treatment pre-pupal and pupal stages. A chronic effect was also apparent at adult eclosion; ED 50's from topical applications were 2.50 and 2.75 ug/larva and from oral application 4.70 and 13.5 ug/larva for 4th and 6th instar larvae, respectively.

INTRODUCTION

The use of growth hormones or chemicals capable of mimicking the action of insecticides or chemosterilants has been suggested as a modern approach to the biological control of insects (Williams, 1967). Several investigators have subsequently studied the effects of chemical compounds classified as insect growth regulators (IGR) against some economic insects notably; *Heliothis* spp (Guerra, 1970) spruce budworm *Choristoneura fumiferana* (Outram, 1972), Mexican bean beetle *Epilachna varivestis* (Walker, 1973); the pink bollworm *Pectinophora gossypiella* (Agripino *et al*, 1974).

Mulder and Gijewijt (1973) reported that one of these chemicals, PH - 6040, (1 - (4 - chlorophenyl 1) - 3 - (2,6 - difluorobenzoyl-urea), possessed insecticidal properties against larvae of *Leptinotarsa decemlineata*, *Pieris brassicae*, *Aphis fabae*, *Tetranychus cinnabarinus*, and *Musca domestica*. In addition TH 6040 performed satisfactorily against the Egyptian cotton leafworm *Spodoptera littoralis* (Rizk and Radwan, 1974; Rizk and Shoukry, 1974 and the Pink boll worm *Pectinophora gossypiella* (Rizk and Radwan, 1974).

The present study was made to determine the initial and chronic effects of TH 6040 from topical and oral applications on *H. armigara* larvae.

METHODS AND MATERIALS

Heliothis armigera larvae were reared in the laboratory on the Adkisson and Vanderzant artificial diet (Supplied by the International Chemical Corp. Ohio, U.S.A.) at 25± 2°C and 60± 5% R.H. with a normal day-night photoperiod.

Fourth and 6th instar larvae from the culture were treated individually and then maintained under standard rearing conditions until adult eclosion.

Solutions of technical grade PH 6040 were prepared using analytical grade acetone. 1-ul of the solution was applied either to the dorsum of the thorax or in to the buccal cavity of larva using an Agla Microapplicator. Control larvae were treated with acetone. Each dose was applied to 50 larvae (see Table 1).

Observations were made on the larvae of pupal and adult stages to assess the effect of each treatment.

RESULTS AND DISCUSSION

Larvae mortality in both instars was similar for each method of application (Table 1 & 2) but the fourth instars were much more susceptible than the sixth instar larvae.

Table 1

Initial and subsequent effects of topical and oral application of PH 6040 on 4th instar larvae of H. armigera

Application method	Dosage a.i. ug/larva	Initial effect: Larvae No. larvae treated	Initial effect: Larvae Mortality (%)	Retarding effect: Prepupae No. Pre-Pupae	Retarding effect: Prepupae Mortality (%)	Retarding effect: Pupae No. Pupae	Retarding effect: Pupae Mortality (%)	Total* Mortality (%)
Topical	5	50	2	49	22.4	38	52.6	64
	10	50	0	50	36	32	65.6	78
	25	50	2	49	42.8	28	82.1	90
	50	50	22	39	56.4	17	100	100
	75	50	38	31	70.9	9	100	100
	100	50	44	28	82.1	5	100	100
	125	50	52	24	100.0	0	100	100
Check	-	50	0	50	2.0	49	2.4	4
Oral	5	50	0	50	6	47	53.1	56
	10	50	0	50	18	40	51.2	60
	25	50	2	49	24.4	37	54.0	66
	50	50	16	42	30.9	29	62.0	78
	75	50	22	39	38.4	24	62.5	82
	100	50	42	29	65.5	10	100	100
	125	50	46	27	81.4	5	80	100
Check	-	50	2	49	4.0	47	2.1	6

* Based on mean adult emergence (Table 3)

Table 2

Initial and subsequent effects of topical and oral application of PH 6040 on 6th instar larvae of H. armigera

Application method	Dosage a.i. ug/larva	Initial effect: Larvae No. larvae treated	Initial effect: Larvae Mortality (%)	Retarding effect: Prepupae No. Pre-Pupae	Retarding effect: Prepupae Mortality (%)	Retarding effect: Pupae No. Pupae	Retarding effect: Pupae Mortality (%)	Total* Mortality (%)
Topical	5	50	0	50	16.0	42	50	58
	10	50	2.0	49	16.3	41	56.0	64
	25	50	0	50	20.0	40	72.5	78
	50	50	2.0	49	24.4	37	78.3	84
	75	50	4.0	48	39.5	29	100	100
	100	50	2.0	49	42.8	28	100	100
	125	50	4.0	48	66.6	16	100	100
Check	-	50	-	50	0	50	2	2

Table 2 (Continued)

Initial and subsequent effects of topical and oral application of PH 6040 on 6th instar larvae of H. armigera

Application method	Dosage a.i. ug/larva	Initial effect Larvae No. larvae treated	Initial effect Larvae Mortality (%)	Retarding effect Prepupae No. Pre-Pupae	Retarding effect Prepupae Mortality (%)	Retarding effect Pupae No. Pupae	Retarding effect Pupae Mortality (%)	Total* Mortality (%)
Oral	5	50	2.0	49	0	49	36.7	38
	10	50	0	50	4.0	48	43.7	46
	25	50	0	50	16.0	42	47.5	56
	50	50	4.0	48	18.7	39	51.2	62
	75	50	2.0	49	22.4	38	71.0	78
	100	50	0	50	24.0	38	76.3	82
	125	50	4.0	48	43.7	27	100	100
Check	-	50	2	49	2.0	48	2.0	4

* Based on mean adult emergence (Table 3)

Observations on the prepupal, pupal and adult stages showed that delayed mortalities occurred in the pupal stage (Tables 1 & 2). Mulla et al (1974) revealed that most mortality occurred in the pupal stage in spite of some larvae mortalities at the higher dosages.

Over 45% mortality was obtained amongst 4th instar treated larvae which increased to 100% in the pupal stage. The same level of accumulated mortality was also obtained with sixth instar larvae in spite of a negligible mortality in the larval stage. Accordingly, it can be concluded that mortality from both methods of application was distributed amongst all stages tested.

In a previous study with Spodoptera littoralis, PH 6040 behaved in a similar way i.e. it induced delayed mortality in the larval and pupal stages (Rizk and Shoukry 1974).

Mulla et al (1974) reported that PH 6040 was very active against mosquito pupae and induced mortality in this stage as well as amongst the adults. The proportion of pupae developing adult pigmentation was considered to be a reliable criterion for IGR activity and was found to be more readily observed than other morphogenic effects (Bradleight et al 1974).

Table 3

Percentage adult emergence following topical and oral application of H.armigera larvae

Dosage a.i. ug/larva	% Adult emergence 4th Instar Topical	4th Instar Oral	6th Instar Topical	6th Instar Oral
5	36	44	42	62
10	22	40	36	54
25	10	34	22	44
50	0	22	16	38
75	0	18	0	22
100	0	0	0	18
125	0	0	0	0
Check	96	94	98	96
ED_{50}* ug/larvae	2.5	4.70	2.75	13.5

*ED_{50} value represent the dosage required for 50% inhibition of adult emergence.

Data shown in Table 3 indicate that PH 6040 reduced adult emergence by 50% from treating 4th instar larvae with either topical or oral applications. The effect was pronounced at 125 ug/larvae (100% inhibition). The increased effect from topical application was also demonstrated against house flies by Cerf and Georghiou (1974). On the other hand, it is worth mentioning that this finding contradicts the recognised performance of PH 6040 in that it tends to be active mostly against larval stages and apparently only if ingested (Wright 1974).

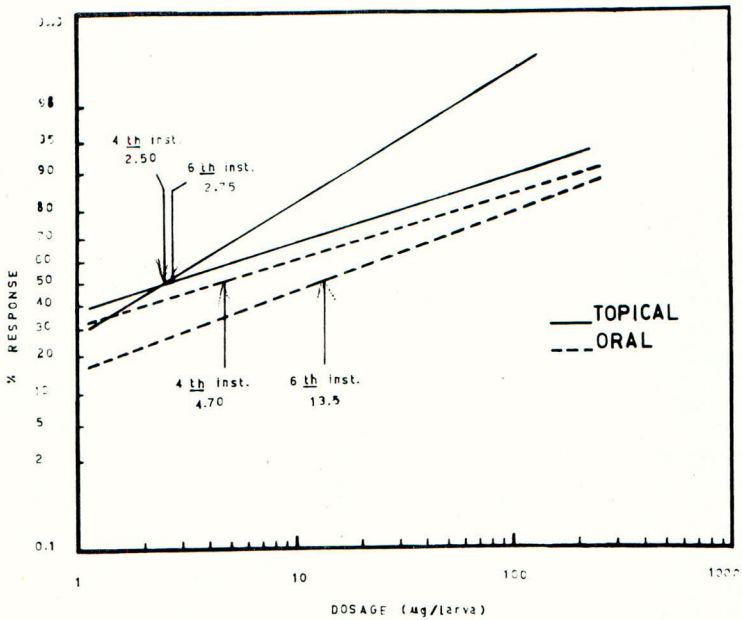

FIG. 1 Dosage-response for topical and oral applications of IGR (PH 6040) on the H. armigera larvae. Arrows indicate the dosage required to inhibit 50% of adult eclosion (ED_{50}).

Fig 1 represents the inhibition rate of adult emergence from both application methods used for PH 6040. The calculated ED 50 for topical application are 2.50 and 2.75 ug/larva for 4th and 6th instar respectively, and for oral application 4.70 and 13.5 an/lava.

These findings show that PH 6040 killed larvae directly or by inducing mortalities in the pupal and adult stages. Inhibition of adult emergence was also pronounced from both topical and oral application. Topical application satisfied the requirements for a reliable bioassay for screening such highly active compounds. A similar bioassay would nevertheless be required to elucidate chronic effects on non-target economic insects before this compound could be used in the field.

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RESPONSE OF PINK BOLLWORM TO SOIL APPLICATION OF TWO UNIQUE GROWTH DISRUPTORS

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Summary Two insect growth regulators, PH 6038(1-(4-chloropheyl) -3-(2,6-dichlorobezoyl) - Urea and PH 6040 (1-(4-chlorophenyl) -3- (2,6-difluorobezoyl) - Urea were compared in the laboratory as soil surface treatments applied at 0.25 - 1.0 kg. a.i./feddan. The higher rates of both compounds inflicted larval mortality and residual control of the later stages of Pectinophora gossypiella. In spite of a lower larval mortality compared with the OP Leptophos 10% G the IGR compounds were more effective against pupal formation and moths' eclosion.

INTRODUCTION

The pink bollworm, Pectinophora gossypiella (Saunders) is the key pest of cotton in Egypt and various cultural and chemical control programmes are used throughout the world to combat this pest.

Previous investigations in Egypt have demonstrated the capability of suppressing the first generation of this pest in spring with granular insecticides applied to the soil surface (Abo-Elghar, et al, 1974; 1975). The problems of resistance to insecticides have enforced the need to search for alternative chemicals. Over the past several years, many new compounds have been shown to exert similar activity to naturally occurring insect hormones (IGR) and to have a potential as insect control agents (Menn and Beroza, 1972).

A number of these growth regulators have been evaluated against some economic lepidopterous larvae and have been found to be effective in inhibiting growth and adult emergence of Heliothis spp. (Guerra, 1970), Pieris brassicae and Barratra brassicae (Mulder and Swennen, 1973), Pectinophora gossypiella (Agripino, et al, 1974), Spodoptera littoralis (Rizk and Shokrey, 1974), S.littoralis and Pectinophora gossypiella (Rizk and Radwan, 1974).

The present study tested the feasibility of using certain IGRs for controlling P.gossypiella compared with the granular O.P. insecticide Leptophos used as a standard soil surface application.

METHOD AND MATERIALS

Two anti-moulting compounds, PH 6038 W.P.25% (1-(2,6-dichloro benzoyl)-3-(4-chlorophenyl) urea) and PH 6040 W.P.25% (1-(2,6-difluorobenzoyl)-3-(4-chlorophenyl) urea) and the standard, Leptophos G 10% (O-(4-bromo-2,5-dichlorophenyl) O-methyl phenyl phosphonothicate) were tested. They were applied at four rates equivalent to 0.25, 0.50, 0.75 and 1.0 kg a.i./feddan as a broadcast treatment.

Fifth instar P.gossypiella larvae, 17-19 days-old, were obtained from the field from infested cotton bolls. Fresh untreated blooms were used for feeding larvae.

Clay pots, 20 cm in diameter, were filled with 0.8 kg air-dry clay soil. The compounds under test were broadcast over the soil surface at predetermined rates and infested blooms containing five larvae added to each pot. The soil in the pots was watered to field capacity. Twenty pots were used for each treatment. Four pots were used for determining the initial effect and 16 pots for residual activity, which was assessed after 7, 14, 21 and 28 days. Larval mortality was recorded 3 - days after treatment. At the end of the test the surface trash together

with the upper five centimetres of soil in each pot was examined for dead larvae and pupae. Inhibition of adult emergence was used as the main criterion for estimating efficacy of the treatments.

RESULTS AND DISCUSSION

Although there was a considerable variability in % mortality amongst the various stages from the different treatments, similar initial and residual activity was obtained from PH 6038 and PH 6040. The standard, Leptophos, was slightly better initially as shown in Tables 1 & 2. Performance of the IGR compounds improved in the later observations with the highest effect at 14 days after application. Exposure to 1.0 kg a.i./feddan of both IGE compounds (Table 1) affected about 40% of the larvae, PH 6040 being slightly less effective than PH 6038. In addition over 50% of the larvae survived the metamorphic moult in all treatments but all survivors did not eclose normally. Abo-Elghar and Radwan (1975) showed that larval mortality as a parameter of soil insecticide potentiality against P.gossypiella was an erratic measurement. However, soil pesticides usually give a good control of pupae, suggesting that inhibition of adult emergence should be the final measurement in the assessment of a soil pesticide's effectiveness.

Although there were some treatment effects after 28 days, the major effect was obtained after 14 days. The accumulated effect during larval and pupal stages (Table 2) show a remarkable increase in percentage mortality even at the lowest rate for both IGR compounds compared with Leptophos. although higher doses gave a better performance. These findings agree with the results of Radwan and Rizk(1975) who found that mortality from topical and oral applications to H.armigera larvae was mostly distributed in all developmental stages and also produced inhibition of adult emergence.

Considering the persistence and biological activity of the tested compounds it is evident that PH 6040 and PH 6038 were better than the standard Leptophos specially after 21 and 28 days (Table 2). In spite of the maximum effect which was reached 14 days after application PH 6040 at 0.75 and 1.0 kg a.i./feddan had a slightly better residual activity. Presumably the differences between PH 6040 and PH 6038 could be simply attributed to differences in penetration, metabolism or receptor sites.

To ascertain the long-term efficacy of the tested compounds, the two IGRs and Leptophos residues were assessed on the adult emergence (Table 3). Results obtained indicate that inhibition of adult eclosion arose from prolonged contact with the IGRs. PH 6040 at 0.75 and 1.0 kg a.i./feddan could provide an effective candidate material for pink P.gossypiella larvae control, the higher rate inhibiting adult emergence.

In conclusion, it is evident that insect growth regulators are potential candidate materials for the control of P.gossypiella and may be effective if applied in early May. This application would reduce survival of the first generation and have a subsequent effect on the pest population during the growing season. This would be achieved as a direct effect of the IGR compound on both larvae and pupae in dried blooms when they drop on to the treated soil.

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Table 1

% larval mortality after exposure of 5th larval instar of P.gossypiella to treated soil

Treatment	Rate kg a.i./feddan	% larvae mortality after treatment (days)				
		0	7	14	21	28
Leptophos	2.25	5	5	0	0	0
	0.50	10	15	10	10	5
	0.75	40	35	40	10	10
	1.0	45	50	60	30	20
PH 6038	0.25	10	5	0	0	0
	0.50	35	30	10	0	0
	0.75	35	40	50	0	0
	1.0	45	40	50	0	0
PH 6040	0.25	10	5	0	0	0
	0.50	10	5	0	0	0
	0.75	30	25	20	20	15
	1.0	35	35	40	30	30

Table 2

Accumulated % mortality in the larval and pupal stages of P.gossypiella after exposure of the 5th larval instar of treated soil

Treatment	Rate kg a.i./feddan	% accumulated mortality after treatment (days)				
Lepthophos	0.25	80	90	70	50	25
	0.50	85	90	80	80	35
	0.75	90	95	90	90	50
	1.0	100	100	100	90	60
PH 6038	0.25	90	95	30	70	50
	0.50	90	100	50	70	60
	0.75	95	100	60	90	70
	1.0	100	100	90	100	90
PH 6040	0.25	90	95	50	80	75
	0.50	95	95	60	80	80
	0.75	100	95	80	90	90
	1.0	100	100	100	100	100

Table 3

% adult eclosion exposure of 5th larval instar of P. gossypiella to treated soil

Treatment	Rate kg a.i./feddan	% adult emergence after treatment (days)				
		0	7	14	21	28
Leptophos	0.25	20	10	30	50	70
	0.50	15	10	20	20	50
	0.75	10	5	10	10	40
	1.0	0	0	0	10	30
PH 6038	0.25	10	5	70	30	50
	0.50	10	0	50	30	40
	0.75	5	0	40	10	30
	1.0	0	0	10	0	10
PH 6040	0.25	10	5	50	20	25
	0.50	5	5	40	20	20
	0.75	0	5	20	10	10
	1.0	0	0	0	0	0