THE WINSTON CHURCHILL MEMORIAL TRUST OF AUSTRALIA

Report by
Rudolf Urech
1997 Churchill Fellow

PROJECT: NON-INSECTICIDAL CONTROL OF INSECT PESTS USING BEHAVIOUR-MODIFYING CHEMICALS

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1.

EXECUTIVE SUMMARY

1997 Churchill Fellowship

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Project description: Non-insecticidal control of insect pests using behaviour-modifying chemicals

Highlights: Dr Urech worked at Lund University in Sweden as part of a team leading the world on insect chemical communication. The Pheromone Group explores the chemical communication of insects and then applies this knowledge to modify the behaviour of pest species. Such behavioural modifications can be used to control pest insects with minimal pesticide application. There is great interest around the world in replacing insecticidal pest control methods with alternative technology. The practical benefits of the new technologies are agricultural produce free from chemical residues and an avoidance of insecticide resistance build up in the pest insect.

The Pheromone Group under the leadership of Professor Löfstedt carries out a variety of research projects in the area of insect communication including pheromone-based management systems for insect pests. Dr Urech was involved in two projects which gave him the opportunity to learn and practise new techniques and methods in analytical chemistry and in insect physiology and behaviour. The first project explored the chemical profiles of pheromones released by a stored product pest moth and by artificial pheromone dispensers. The second area of work was on the chemical signatures of a parasitic bee and its host and the effect of these chemicals on the bees' behaviour.

Visits were made to the Department of Biological Sciences, University of Bristol, (Dr Richard Wall), AgriSense BCS, Pontypridd, (Mr Enzo Casagrande) and the National Resources Institute, University of Greenwich, Chatham, (Professor David Hall) in the UK. Discussion were held with these researchers on attractants and traps for flies.

Major lessons: The use of behaviour-modifying chemicals for the control of pest insects is a growing and viable alternative to the currently widespread use of insecticides. The successful Pheromone Group at Lund University is a multidisciplinary team carrying out basic and applied research in the laboratory and in the field. A similar approach in Australia would assist in keeping our agricultural industries competitive in world markets.

New ideas, techniques and procedures in the area of insect chemical communication were acquired by Dr Urech. They will be disseminated through this report, oral presentations to Departmental staff, scientific publications and through scientific discussions with colleagues, and incorporated into ongoing research in Australia.

2. INTRODUCTION

Economic losses due to insect damage are one of the major problems encountered by Australian food and fibre producers. Currently, pest insects are largely controlled by the application of insecticides. Because of problems with residues in produce and the development of resistance to insecticides in pest insects, alternative methods for their control are urgently required. The availability of a sustainable food and fibre production with minimum insecticide usage is critical for Australia to maintain its competitive edge and to avoid non-tariff import restrictions by our major trading partners.

Dr Urech is part of an Animal Research Institute (ARI), Queensland Department of Primary Industries, based interdisciplinary team working on non-insecticidal control of sheep blowfly, buffalo fly and screwworm fly using behaviour-modifying chemicals. The team has developed a trapping system, comprising a synthetic attractant and a novel trap for the Australian sheep blowfly which is now commercially available. Work on buffalo fly with similar objectives is currently in progress. A cornerstone of the research is the elucidation of chemicals which are involved in the natural behaviour of the pest insects, eg host finding, mating. These chemicals can be utilised to deter, attract or confuse the insect, thus interrupting its life cycle.

A few laboratories around the world are involved in work of this type. A very successful and experienced group is led by Professor Christer Löfstedt at the University of Lund. The main thrust of their work is on chemical communication between insects of the same species (pheromones) and between insects and their hosts (kairomones). The laboratory is equipped with special apparatus for the collection and analysis of these chemicals and for the assessment of behavioural responses of insects when exposed to them. Through necessity, the European laboratories initiated their work on these new technologies ahead of their Australian counterparts giving them a more comprehensive understanding of these systems.

The Churchill Fellowship gave Dr Urech the opportunity to access the knowledge and expertise in the Lund laboratory and to bring back to Australia advanced concepts and the research processes and up-to-date information on these novel techniques.

The objectives of the overseas study project were:

1. To enhance the applicant's knowledge and understanding of novel sustainable pest control technology and to facilitate Australia's access to non-insecticidal control of pest insects by visiting an institution recognised as a leader in research, development and deployment of such technology.
2. To exchange ideas and advances, and to actively participate in research programs on the use of behaviour-modifying chemicals in insect control and to bring back to Australia the latest knowledge.

These objectives were met through an extended visit to Professor Löfstedt's Pheromone Group at the University of Lund, Sweden, and short visits to the Department of Biological Sciences, University of Bristol, (Dr Richard Wall), AgriSense BCS, Pontypridd, (Mr Enzo Casagrande) and the National Resources Institute, University of Greenwich, Chatham, (Professor David Hall) in the UK. A detailed account of activities and outcomes at these centres is provided in the main body of this report.

3. PROGRAMME

14 April to 28 June 1997	Pheromone Group Department of Animal Ecology Lund University S-223 62 Lund Sweden *Professor Christer Löfstedt* *Dr Zhu Junwei* *Mr Jan Tengo (and many more)* Participate in laboratory work and discussions related to insect chemical communication, including the collection and analysis of chemicals and gas chromatography/electroantennography
30 June to 4 July 1997	Department of Biological Sciences University of Bristol Bristol BS18 7DU UK *Dr Richard Wall* AgriSense BCS Pontypridd, Mid Glamorgan CF37 5SU UK *Mr Enzo Casagrande* National Resource Institute University of Greenwich Chatham Maritime Kent ME4 4TB UK *Professor David Hall* *Dr Stephen Torr* Discussions with researchers on fly attractants and targets

4.

PHEROMONE GROUP, UNIVERSITY OF LUND

4.1 Introduction

The Pheromone Group in the Department of Ecology at Lund University in southern Sweden is led by Professor Löfstedt and comprises approximately 25 people. Their research programs are cross-disciplinary, and include ecology, insect physiology and morphology, analytical chemistry, biochemistry, and genetics. Their work deals with insect chemical communication, eg chemical signals between individual insects of the same species which are called pheromones. The current research areas include evolutionary biology and the ecology of insect communication systems, neurobiological processes involved in insect olfaction and odour production, and development of pheromone-based management systems for insect pests including both monitoring and direct population control. My main project was part of the pheromone-based management for insect pests program and my principal collaborator was Dr Zhu Junwei who is leading this program. More information on the Pheromone Group and on their research and output can be obtained via their Internet homepage (http://pheromone.ekol.lu.se/index.html).

I spent 11 weeks in the laboratories of the pheromone group. During this time I worked on two projects designed to meet the objectives of my visit: The first project involved the matching of chemical profiles of pheromones released by a stored product pest moth with the volatiles released from rubber septa or filter paper loaded with pheromones which were used for monitoring pest populations and wind tunnel assays respectively. The second project aimed at resolving the question of why parasitic bees were able to enter the nests of the host bee without being attacked. The hypothesis was that the chemical signature of the parasite bee was similar to the hosts signature. Details of these two projects including the progress achieved are provided in the following sections.

I presented a 45 minute seminar entitled "Development and application of a novel trapping system for the Australian sheep blowfly" to the group and other researchers from the Ecology Department and from the Agricultural University at Alnarp. I attended all the weekly pheromone group seminars and participated in discussions on chemical ecology of insects.

A Pheromone Day was held at the Agricultural University at Alnarp at which most members of the Lund Pheromone Group and the Alnarp Chemical Ecology Group attended. I presented a paper on "Cuticular hydrocarbons from the buffalo fly, *Haematobia irritans exigua*" reporting on some recent work in our project aimed at the development of non-insecticidal control of buffalo fly.

My stay at Lund University gave me the opportunity to look at and work in a modern purpose-built laboratory and office complex. The ecology building at the University of Lund which houses all ecologists is only two years old. It is the result of cooperation between ecologists and architects and has scientifically and aesthetically pleasing features. The laboratories are well designed and equipped and a successful system combining heating/air conditioning with removal and extraction of contaminated air is in place. The offices are practical and attractive with raw timber furniture, computer compatible desks and ergonomic chairs. The only drawback was a lack of space available to the pheromone group which led to crowded conditions in laboratories and offices.

4.2 Chemical profiles of pheromones released by the Indian meal moth (*Plodia interpunctella)* and from pheromone-loaded rubber septa and filter paper

The Indian meal moth (*Plodia interpunctella*) is considered one of the most serious pests of stored products, including grain, nuts, dried fruit and legumes. The use of insecticides in the control of this and other insect pests in the storage facilities is restricted for environmental and human health reasons. Alternative control methods using biorational chemicals such as pheromones are being developed to overcome these constraints.

The major pheromone components of the Indian meal moth have been known for some time. The Pheromone group in Lund has recently identified secondary pheromone components in the glands of female *P. interpunctella* and demonstrated that incorporation of these secondary components improved the attractivity of synthetic pheromone blends for male *P. interpunctella*.

The aim of my work at Lund was to formulate synthetic pheromone blends which when applied to filter paper or to rubber septa would release pheromone components at the same concentration as the female Indian meal moth. It is assumed that a pheromone plume of this composition would provide optimal attraction for male moths. Filter paper loaded with pheromone blends are used in behavioural assays in the wind tunnel whereas rubber septa, which release pheromones over longer time periods, are used for population monitoring or suppression in storage facilities.

The strategy was to collect pheromones in the air near calling female moths. Such a measurement would provide the actual composition of the pheromone blend released by the insect to attract a partner for mating. The quantitation of pheromone components had previously been carried out on pheromone gland contents. Synthetic pheromone blends will then be applied to filter paper and to rubber septa, and the composition of the mixtures released from these systems determined. It was known from other work that the dispensing systems will influence the release rates of the individual components, eg the same mixture applied to filter paper and to rubber septa will result in releases of different compositions.

Collection of airborne chemicals is traditionally done by passing a constant stream of air or inert gas over the source and then through a device which adsorbs the chemicals from the passing stream. This is then followed by elution of the trapped chemicals with an appropriate organic solvent, evaporation of the solvent and analysis by gas chromatography (GC) combined with a suitable detection system, eg mass spectrometry (MS) or flame ionisation detection (FID). An alternative to solvent elution is thermal desorption of the trapped chemicals with an inert gas directly into the GC. The commonly used trapping materials for pheromone components are glass wool and activated charcoal.

Recently a new system providing effective and convenient adsorption of chemicals became commercially available. The solid phase micro extraction system (SPME) adsorbs organic compounds directly from the sample onto a fused-silica fibre which is coated with an appropriate inert, polymeric adsorbent. The fibre is then inserted into the injector port of a GC where it is heated and the analytes are thermally desorbed onto a capillary GC column for analysis. Although SPME was originally developed for the collection of organic compounds from aqueous matrices, it has been equally successfully used for the adsorption of airborne compounds. The Pheromone Group had purchased a SPME unit just before my arrival and my first task was to evaluate the capacity of this new device for the collection of pheromones and to compare its performance with the traditional systems.

A rubber septa loaded with a four component pheromone mix was used as a source for these experiments. A nitrogen flow was sequentially passed over the septa and one of the collecting materials, eg glass wool, a charcoal filter and the SPME fibre. The adsorbed pheromones were eluted from glass wool and charcoal filter with hexane and dichloromethane respectively, and analysed by GC/FID. Glass wool was the most effective adsorption material, followed by charcoal filter and SPME. One reason why smaller amounts of pheromones were adsorbed on SPME, could be that part of the nitrogen flow by-passed the SPME fibre which was inserted into a narrow glass tube carrying the nitrogen flow, whereas the glass wool and the charcoal covered the entire width of the flow tube. The ratio of components collected with the three different systems was constant, indicating that no preferential adsorption of some compounds took place. This meant that SPME could be used for the collection of airborne pheromone components and the determination of their relative concentrations. However, it was noted that the nitrogen flow rate effected the ratio of components collected on glass wool.

The determination of the composition of the pheromone plume released by a calling female moth proved more difficult. This was mainly due to the small amounts of pheromone released by the moth which made it necessary to increase the collection time. However, this also led to increased collection of other chemicals present in the system, eg in the nitrogen stream or in the collection environment, thus leading to interference in the measurement of pheromone components. When a single moth was placed in the flow through system, no pheromone components were detected above background noise with SPME, even after several hours. The same result was obtained using several moths in a larger container and/or different trapping materials. An attempt to collect the pheromones by placing an SPME fibre near the gland of a calling female resulted in disaster when the moth by fanning its wings layered the fibre with scales, rendering it unusable. Eventually, successful collections were made by placing the SPME fibre only a few millimetres from the abdominal gland of a moth with clipped wings. This provided us with the ratios of the four pheromone components emitted by a calling moth.

A mixture containing the pheromone components in the determined ratio was applied to filter paper and to rubber septa. The emission from these two artificial sources was determined using a nitrogen stream in the apparatus described above. Pheromone emission from filter paper was measured for 10 minutes (after 1 minute standing to evaporate the hexane solvent), the same time the filter paper was used in the wind tunnel assay. Six filter papers loaded with the pheromone mix were collected subsequently onto one SPME fibre, to give a reasonable signal in the GC/FID. The longer lasting rubber septa was placed in the collection system for one hour, after it had been left in the open for at least one week.

The filter paper released a mixture which was enriched by about a factor of two with the most volatile, and deficient by about 50% of the least volatile component, when compared to the composition of the solution which was applied to the filter paper. The rubber septa on the other hand released a relatively increased amount of the least volatile component probably due to its advanced age at this stage (3 weeks). The amount of the most volatile component released from the rubber septa could not be determined, due to the presence of an interfering component released by the septa.

The ratios of components obtained by this investigation for the different release systems can now be used to prepare pheromone mixtures which when applied to filter paper and rubber septa should release a pheromone plume with a composition which is identical to the plume from the moth.

The pheromone loaded filter paper lost its attractancy for the male moths in the wind tunnel assay after approximately 10 minutes. This placed a severe restriction on the running of behavioural assays in the wind tunnel, as a freshly loaded filter paper had to be introduced every ten minutes. I investigated the use of a solution of the pheromone mixture in paraffin instead of the hexane. The idea was that the non-volatile paraffin oil would, unlike the hexane solvent, remain on the filter paper and act as a matrix releasing the pheromones at a constant rate over an extended time span. This was indeed found to be the case under the proviso that the pheromone mixture concentration in paraffin oil was increased by about a factor of 1000 compared to the hexane solution, and the ratio of the pheromone components was adjusted to compensate for the different release characteristics of the paraffin soaked filter paper. The pheromone mixture in paraffin oil loaded filter paper released pheromones even after 24 hours at a rate of approx. 70% of the initial rate.

The response of the male moths to the pheromones released either by a female moth or from an artificial device such as filter paper or rubber septa loaded with synthetic pheromone was assessed in a wind tunnel. The wind tunnel used for this work at Lund University was 0.7 meters high and wide and 2 metres long, with a laminar airflow along the long axis of 0.5 metres per second. The source releasing the pheromone was placed at the upwind end, and single male moths were released at the downwind end of the tunnel. An operator recorded which stages of the "usual" behaviour of the male moth in response to stimuli by female pheromones were observed. These stages included activation, taking flight, orientation in the plume, upwind flight half distance to the source, flight full distance, landing on source with copulation posture observed. The different pheromone mixtures and release systems could thus be assigned a score for each of these stages (mean of 10 replicates) which was used to compare them with each other. I did not carry out much flight tunnel work, as these experiments with the manual data recording of visual observations were time consuming and did not offer new technology.

4.3 Chemical composition of and electroantennogram responses to cuticular extracts from host (*Andrena scotica)* and parasitic (*Nomada marshamella*) bees

My objective in this project was to acquire knowledge and experience in electroantennogram recording, particularly when combined with gas chromatography (GC). This is a useful technique for the detection of behaviourally active components in a mixture which elicits a desired behaviour in the target insect. The chemical mixture is applied to a GC column which separates the mixture into the individual components. The gas stream emerging from the column and carrying the analytes is split, with one half going to a flame ionisation detector (FID) which produces a response for every organic (carbon containing) compound. The other half of the gas stream is passed over an antenna of the target insect. If the antenna possesses receptors responding to the compounds passed over it, a small electric potential difference is induced in the antenna, the signal from the receptor to the insect's central nervous system that this has happened. By the use of micro electrodes attached to the opposite ends of the antenna, an amplifier and an appropriate data recording system (PC with special hard- and software) this electric potential difference can be captured. A comparison of the response signals from the FID and electroantennogram detectors (EAD), enables the operator to pinpoint the components in the original mixture which are recognised by the insect's antenna. The structure of these components can subsequently be obtained by GC/ mass spectrometry. This technique does not reveal what type of behaviour (if any) the active components induce, and this must subsequently be established in behaviour assays.

Jan Tengo, who is based at the Ecological Research Station of Uppsala University on Öland (an island off the eastern coast of southern Sweden), has been investigating the ecology of bees on this island for many years. The behaviour of the nest parasite *Nomada marshamella* was of particular interest. *N. marshamella* bees enter the established nests of *Andrena scotica* bees and lay their eggs. The emerging *A. scotica* larvae kill the host larvae and consume their food supplies. In spite of a large differences in appearance and pubescence, an encounter between the females of the two species in or just outside the nest causes no aggressiveness. The hypothesis to explain this unusual observation was that the parasitic bee imitates the chemical signature, that is the chemical composition of gland contents and/or the cuticular hydrocarbons, of the host bee. There was also a speculation that the most abundant chemical component present in an abdominal gland of *A. scotica*, farnesyl hexanoate (F6), which was also present in male *N. marshamella,* was transmitted from male to female *N. marshamella* during mating. It had been shown that F6 was not present in unmated females, but was found in the cephalic (mandibular) gland of male *N. marshamella*. The work undertaken was to test these hypotheses and to identify the chemical components present in glands or on the cuticle which were detected by either of the two bee species.

The first experimental step was to learn and practise the technique of preparing the antenna. Capillary glass tubes with very fine tips were prepared with a commercial pipette puller. The antenna was removed from the insect by cutting the flagellum just above the pedicel with micro scissors under a microscope. The capillary glass tube which had been filled with Ringer solution (an aqueous solution with salts and sugars at physiological concentrations) was cut, so that the end of the freshly cut antenna could just be pushed into the opening. The part of the flagellum inserted into the capillary was kept to a minimum to provide maximum exposure of the antenna to airstream, while still holding onto the glass capillary. The capillary connected to the antenna was mounted on silver wire which was connected to the amplifier. The second capillary glass tube was mounted on another silver wire mounted on a micro manipulator. The tip of the flagellum was then cut off and the second capillary tube brought into a position where the exposed tip was in contact with the ringer solution. Thus a conducting circuit had been made which was connected to an amplifier. The antenna mounted as described above was placed at the outlet of a glass tube delivering the air stream containing the compounds being eluted from the chromatographic column of a GC. This setup makes it possible to measure and record potential differences induced by molecules passing over and triggering the receptors on the antenna.

GC/EAD trial runs were carried out with moth antenna because they are easy to work with and provide strong EAD responses. It became evident that there was a problem with the GC system which was supposed to deliver the pheromone as sharp and clearly separated components. However, there was considerable peak broadening, a low signal to noise ratio and signal drift during temperature programmed runs, indicating that the system had a major fault. A major problem in the flow splitter was rectified and some other improvements were made to the gas flow system. The GC/FID/EAD system subsequently provided good quality responses and had an improved sensitivity.

Bees for the GC/EAD experiments were provided by Jan Tengo. The procedure to obtain the antenna was as described above, with the female bees being anaesthetised with carbon dioxide just before antenna removal. The antenna had be mounted on the silver wire with the shiny side of the flagellum tip oriented away from the air stream, in order to maximise the response.

Solvent extracts of head, thorax and abdomen of *A. scotica* and *N. marshamella* bees were investigated with the GC/FID/EAD system by running these extracts on the antenna of female and male bees of both species.

Responses were observed for many but not all of the saturated and unsaturated hydrocarbons present in the cuticular wax layer and glands of the two bee species. It was noted that EAD responses from bee antennae to such compounds were much lower than those of moth antennae to moth pheromones (a different class of compounds) had been observed at lower concentrations. This is probably due to the smaller number of sensilla present on the bees' antennae. Antennae from male bees of both species gave a higher EAD response than female bees. This can be expected, since the male bees have to locate and then fly to the females for mating to occur.

There were also responses to farnesyl hexanoate (F6) by female and male antenna of both species. F6 is a sesquiterpene which is present in the abdominal gland of female *A. scotica* and the mandibular gland of male *N. marshamella*. This is the, or one of the, substance(s) which was believed to play a role in the unchallenged entry of the parasitic bee into the host nest. However, in the course of this work F6 could not be detected in any of the extracts from mated female *N. marshamella.* It is thus unlikely that F6 plays a major role in the parasite host interaction. Both species have an extensive range of hydrocarbons in their cuticular layer with some but not complete structural overlap. It is possible that the females of both species have receptors for a common subgroup of these hydrocarbons and that this matching pattern enables the parasite to enter the nest of *A. scotica*. Further investigations on these interesting phenomena are in progress.

5. VISITS TO UK LABORATORIES

5.1 Introduction

In the United Kingdom short visits were made to laboratories working on chemical ecology of flies and related insects. Institutions visited included the Department of Biological Sciences at the University of Bristol, AgriSense BCS, and the National Resource Institute at the University of Greenwich in Chatham. They were selected because their work is closely related to the current projects of our Brisbane based group.

The purpose of these visits was to present our latest research findings, to learn about these laboratories' recent research, to discuss the results and implications of the research and to exchange ideas for future developments. I was made feel welcome at all laboratories and frank discussions took place, although there were some barriers to complete disclosure due to agreements with commercial companies such as AgriSense. Overall, the objectives were achieved and these exchanges of results, techniques, problems and ideas for future work are an important part of a research scientist's activities. The major issues raised during the visits are summarised in the following paragraphs.

5.2 Department of Biological Sciences, University of Bristol

I visited the group led by Dr Richard Wall which carries out research on attractants and targets for the sheep blowfly (*Lucilia sericata*) in England. This work is closely related to our work on the Australian sheep blowfly (*Lucilia cuprina*) which led to the development and commercialisation of Lucitrap. The objective of their work is also to produce a system which is able to reduce sheep blowfly populations and thus aid in control of fly strike without the use of chemicals on sheep.

Dr Wall's group concentrated its work more on the colour of the target, the behaviour of the fly and the modelling of fly emergence and population build up. Current work included laboratory assays to differentiate the effects of hues, intensity and reflectance of various colours on the response of the sheep blowfly. Field trials with coloured targets and various attractants, including Lucilure developed by our group, are also in progress.

During my visit to the University of Bristol, I presented a seminar on the "Development and application of a novel trapping system for the Australian sheep blowfly". I also inspected their experimental facility and fly breeding rooms.

5.3 AgriSense BCS

AgriSense BCS develops and commercialises biological and chemical products for insect pest detection, monitoring and control for use in agriculture, food commodities, forestry, industrial and domestic insect pest control. I met their Senior Product Development Manager, Mr Enzo Casagrande. Mr Casagrande had previously indicated that he was interested in non-chemical control of buffalo flies, an area our group is investigating. Our discussion revolved around the various possibilities to achieve non-insecticidal control of buffalo flies. The use of attractants combined with a system for killing the attracted flies emerged as a likely candidate. He stated that AgriSense would be interested in commercialising such a system if it was developed. It became evident that AgriSense prefers to enter into such ventures only when the research team has developed a prototype system and demonstrated its effectiveness. However, he left the door open for AgriSense to provide some support to earlier stages of such a project, albeit at a limited level. Our group will assess and possibly further investigate the potential involvement of AgriSense BCS in our buffalo fly project.

5.4 National Resources Institute, University of Greenwich, Chatham

The National Resources Institute of the University of Greenwich is a centre of expertise in research and consultancy in the environment and natural resources sector. The Institute carries out research and development on behalf of international donor agencies. My visit was to the Chemical Ecology Group which is part of the Pest Management Department. The leader of the Chemical Ecology Group is Dr David Hall and their main areas of expertise are analytical chemistry including GC/MS, natural product chemistry, electrophysiological recording from insect antenna (including GC/EAD), laboratory bioassays for attractants and repellents, slow-release formulations of volatile chemicals and field trials of new pest control agents (for more details see their internet page http://www.nri.org/capstats/chemico9.htm).

One of the group's major achievements was the identification of attractants for tsetse flies. This was of particular interest to me because the tsetse fly's host, cattle, is the same as for buffalo fly. This group had also developed new attractants for the New World screwworm fly and we were interested in this work, as it may be applicable to our work on the Old World screwworm fly.

At the start of my visit I presented our work on the development of the novel sheep blowfly trap. Dr Hall showed me their facilities and we discussed the tsetse fly, screwworm fly and blowfly work. There is still work ongoing on attractants and traps in Africa, but no fresh data on attractant composition has been obtained since the most recent publications. The work on screwworm fly attractants has been terminated. Information on the effectiveness of the newly developed attractants for catching New World screwworm fly is in the process of being written up and should in principle be available from Alan Cork (who was absent during my visit). This would provide us the opportunity to test these new attractants in the surveillance trapping program for Old World screwworm fly in northern Australia. The group has also been involved in the search for attractants for the sheep blowfly (with Dr R Wall), in particular by running GC/EAD.

Further discussion were held with Dr Stephen Torr, a specialist in tsetse fly behaviour and control. Various aspects of attractants, their formulation, the shape and colour of targets and traps and their effectiveness in killing the attracted flies were the main topics. Dr Torr also briefly talked about their recent work on mosquito attractants.

6. CONCLUSIONS

The 1997 Churchill Fellowship on non-insecticidal control of insect pests with behaviour-modifying chemicals gave Dr Urech the opportunity to work at Lund University in Sweden as part of a team leading the world on insect chemical communication. The group explores the chemical communication of insects and then applies this knowledge to modify the behaviour of pest insects. Such behavioural modifications can be used to control pest insects with minimal pesticide application. There is great interest around the world in replacing insecticidal pest control methods with alternative technology. The practical benefits of the new technologies are agricultural produce free from chemical residues and an avoidance of insecticide resistance build up in the pest insect.

The Pheromone Group under the leadership of Professor Löfstedt carries out a variety of research projects in the area of insect communications including pheromone-based management systems for insect pests. Dr Urech was involved in two projects which gave him the opportunity to learn and practise new techniques and methods in analytical chemistry and in insect physiology and behaviour. The first project explored the chemical profiles of pheromones released by a stored product pest and by artificial pheromone dispensers. The second area of work was on the chemical signatures of a parasitic bee and its host and the effect of these chemicals on the bees' behaviour.

Progress was made in both projects. Recommendations were made for the preparation of pheromone dispensers for wind tunnel (short release time) and for population monitoring and suppression (long term) work. Solvent extracts of the cuticle of host and parasite bees were analysed by gas chromatography with flame ionisation and electroantennogram detection.

The interaction with approximately 25 lecturers, post doctoral fellows, post graduate students and visitors in the Pheromone Group was very stimulating. Dr Urech presented a seminar on the development and application of a sheep blowfly trapping system and took part in all group presentation and discussion. He also attended the Pheromone Day at Alnarp Agricultural University.

Visits were made to the Department of Biological Sciences, University of Bristol, (Dr Richard Wall), AgriSense BCS, Pontypridd, (Mr Enzo Casagrande) and the National Resources Institute, University of Greenwich, Chatham, (Professor David Hall) in the UK. Discussion were held with these researchers on attractants and traps for flies.

The extended stay at Lund University and the short visits to the UK institutions enabled Dr Urech to achieve the objectives of this study tour. He acquired new knowledge in insect chemical communication and he learnt and applied new chemical and entomological techniques. This gain will now be incorporated into the ongoing research in Australia and disseminated to a wider audience through this report, oral presentations to Departmental staff, scientific publications and through scientific discussions with colleagues.

The use of behaviour-modifying chemicals for the control of pest insects is a growing and viable alternative to the currently widespread use of insecticides. The successful Pheromone Group at Lund University is a multidisciplinary team carrying out basic and applied research in the laboratory and in the field. A similar approach in Australia would assist in keeping our agricultural industries competitive in world markets.

7. ACKNOWLEDGMENTS

I am grateful to The Winston Churchill Memorial Trust of Australia for granting me the Fellowship which enabled me to undertake the study tour and to the Queensland Department of Primary Industries for salary support during that time.

I thank Professor Christer Löfstedt for allowing me to work in his group at Lund University, Dr Zhu Junwei for his tuition in the laboratory, Dr Jan Tengo and Florian Schiesstl for their input to the bee project, and all members of the group for their scientific and social support and interaction. I also acknowledge the time and information provided by various people during my stay in the UK.

I thank the members of our Brisbane based group for their support and for carrying the candle during my absence, particularly Peter Green, Geoff Brown and Evan Harris, and the many other colleagues (Bob Dalgliesh, Stephen Sexton, Chris Moore, Jim Walkley) who contributed in some way to the success of this Fellowship.