WAGENINGEN UNIVERSITY
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ANNUAL REPORT 2004

LABORATORY OF ENTOMOLOGY

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FOREWORD

When I visited the Museum of Modern Art in Lissabon the other week, I experienced a nice surprise of being able to enjoy an exhibition on the Portugese artist Manuel Botelho who depicted moths, wasps and dragonflies in many of his most recent work (2001-present). Insects are indeed present in our daily lives. For instance, when reading the newspaper, insects appear on the pages regularly: in advertisements, in the general news items or in the scientific news items.

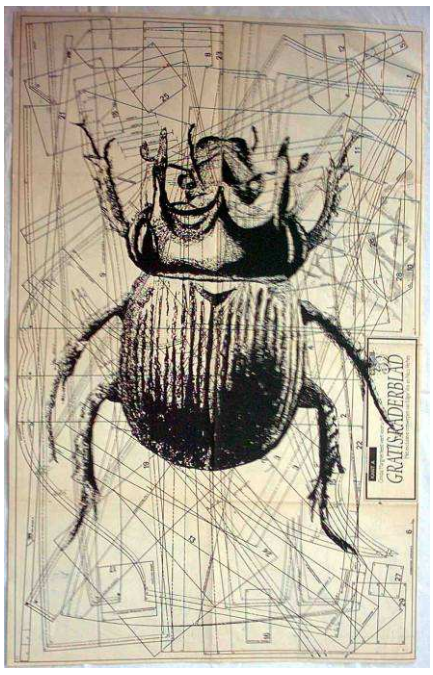
The research of the Laboratory of Entomology on insects initially concerns fundamental research with subsequent spin-off in applied projects that benefit from the fundamental research. Our research concentrates on the ecology of multitrophic interactions and involves e.g. behavioural ecology, molecular ecology, functional ecology and is related to basic aspects of human society, such as human health, agriculture, biodiversity and global change. The research programme is mainly based on natural sciences but in addition important links to the social sciences are being made.

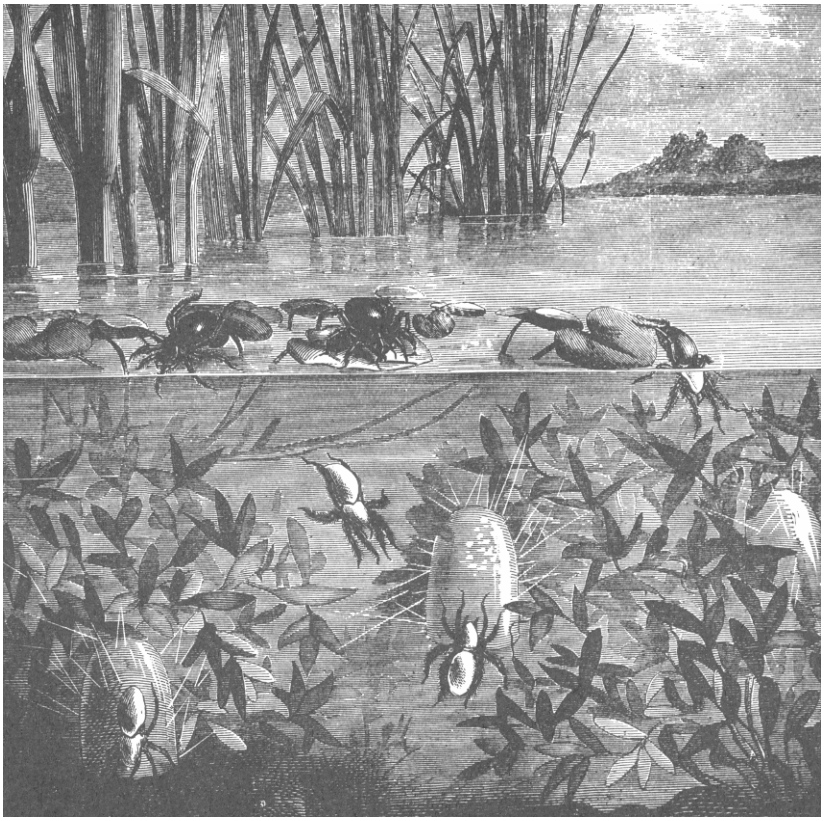
Our aim at the Laboratory of Entomology is to carry out a research and teaching programme of excellent quality that is continuously updated so as to be internationally at the forefront.
The research of the laboratory of Entomology is centred on three themes: (1) chemical and molecular ecology, (2) population and behavioural ecology and (3) functional biodiversity and agroecology. Our research programmes are curiosity-driven and we exploit the knowledge obtained in developing applied programmes, especially related to the health of man, animals and the environment. Applied research includes projects on e.g. malaria mosquitoes, integrated crop, soil, and pest management through a participatory approach and development of functional biodiversity studies to develop novel, durable, pest control strategies.
In our teaching programme we develop courses for BSc, MSc and PhD students, most of them in English, as well as a course for laymen so as to raise the interest of the general public for insects.

This annual report informs you about the major activities and achievements in our group in 2004. There were many memorable events.
More information about our activities, on our teaching and research programmes, on recent PhD theses, on our social activities and much more can be found on our website The URL of our website is: http://www.dpw.wur.nl/ento/english/index.htm.

Marcel Dicke
Head of the Laboratory of Entomology

May 2005





Laboratory of Entomology

Entomology is the life science that addresses the biology of insects. The laboratory of Entomology integrates fundamental and applied aspects related to the biology of insects. Studies within the new area of environmental genomics have been initiated, combining studies of subcellular mechanisms with population- and community ecology. The fundamental research concentrates on multitrophic interactions using on the one hand molecular, sensory physiological, neurobiological and behavioural biological approaches, and on the other hand ecological, population genetic and modelling approaches. Our strategic research focuses on finding sustainable and environmentally safe solutions to problems caused by insects in the agricultural and medical-veterinary sector in temperate and tropical zones, in collaboration with social scientists.

Position within Wageningen University and Research centre (Wageningen UR)

The Laboratory of Entomology is part of the Plant Sciences Group of Wageningen University and Research centre. All research in our group is part of the two graduate schools 'Experimental Plant Sciences (EPS)' and 'Production Ecology & Resource Conservation (PE&RC)'. The research within the graduate school EPS deals with chemical and molecular ecology as well as host plant resistance. The research within the graduate school PE&RC focuses on the ecology of bio-interactions involving plants and insects, humans and disease-transmitting-vectors, hosts and parasitoids, prey and predators, and also focuses on behavioural and population ecology, functional biodiversity and agro-ecology. The research themes in the group are closely connected and the staff members collaborate in different research themes. As a result, the research of the laboratory of Entomology is coherent and well-coordinated.

Mission and strategy

The mission of the laboratory of Entomology is to carry out excellent research and teaching in a continuously updated research programme that is nationally and internationally at the forefront and well-linked to the research of international collaborators, while working in a group in Wageningen with a very good and stimulating atmosphere and excellent internal collaboration. The group has an outstanding reputation in multitrophic interactions, biological control and malaria vector research. Multitrophic interactions will receive more attention by incorporating molecular approaches on the one hand and by engaging in research projects dealing with functional biodiversity and ecological approaches in agriculture on the other. Malaria vector research is also increasingly adopting molecular approaches. Molecular ecology will continue to receive major emphasis with more attention to mechanisms at the molecular level and by using molecular techniques in the study of ecological processes. In our tropical research programme, cooperation with social sciences ensures that societal stakeholders are included in the research process, and that research is centred around the needs and opportunities of farmers.

Activities in 2004

The year 2004 has been a productive and rewarding year in terms of science. The Executive Board of Wageningen University ranked us among the best groups in the university, which was accompanied by extra funds. In addition, an international peer review committee that evaluated our contribution to the Graduate School *Production Ecology and Resource Conservation,* qualified us as an excellent group by international comparison.

Many honorable elections have been made in 2004. Willem Takken has been elected as visiting professor at the University of Durham (UK), Joop van Loon received a visiting professorship at the Chinese Academy of Sciences, Beijing (China) and Arnold van Huis has been awarded a personal chair at the Laboratory of Entomology to further develop the interaction between the natural and social sciences in crop protection.

Louise Vet was elected as member of the Royal Netherlands Society of Arts and Sciences (KNAW) and Bart Knols was elected as member of the newly formed Young Academy of the Royal Netherlands Society of Arts and Sciences (KNAW). Joop van Lenteren was elected president of the International Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC). We highly value these important signs of recognition of the work that our members do at the local, national and international levels.

Several new grants were obtained, such as a strategic-funds-grant from the Graduate School *Experimental Plant Sciences* on 'linking variation in plant defence to higher level biodiversity'. Three sandwich PhD programmes were awarded that will further strengthen our collaboration with IITA in Uganda, ICIPE in Kenya, The Research Institute for Crop Protection in Kazachstan and the Social Sciences Group of Wageningen University. In addition, a Marie Curie Research and Training Network on 'ecological and physiological functions of biogenic isoprenoids and their impact on the environment' has started. Furthermore, an EU-Alβan project was awarded on host-plant resistance in potato to aphids, and an ALW project (in collaboration with the Mathematical and Statistical Methods Group of Wageningen University) on 'spatio-temporal modelling of infochemicals in a food web context'. Finally, Martijn Bezemer obtained a strategic-funds-grant from the Graduate School *Production Ecology and Resource Conservation* on 'unraveling interactions between soil biota, plants, and aboveground herbivores and antagonists' that he will carry out at the Laboratories of Nematology and Entomology.

The research of the laboratory of Entomology has been well-received. We have published 114 papers, of which 50 were in ISI journals, such as Science, Proceedings of the Royal Society Biology London, the Lancet, Oikos, Heredity, Insect Biochemistry and Molecular Biology, and the Plant Cell. There was an increase of ca 15% both in number of ISI publications as well as the average impact factor of the journals in which the papers were published compared to 2003.
Science has interviewed Arnold van Huis on locust control strategies.

A total of 7 PhD students have successfully defended their theses in 2004. On average there were 7.2 PhD defences over the last 5 years, which is well above the average for Wageningen University as a whole being 2 PhD defences per group per year.
The PhD defences in themselves are rather formal events that are open to the public. They are usually followed by a party that is enlivened by special songs and a sketch that are created for this special occasion.

Two members of the Laboratory of Entomology celebrated an anniversary: Leo Koopman has worked for 40 years with us, while Frans van Aggelen worked for 25 years at Wageningen University, most of which was in the Laboratory of Entomology. Their work for the insect rearing of the Laboratory of Entomology is very important as it provides the basis for our teaching and research programmes. The insect rearing group cultures more than 30 insect species, with many lines (up to 200!) for some species. In addition to their use for teaching and research these insect cultures are also important for public relations and are even regularly used to demonstrate that insects can be good and tasty food for human consumption.
In November 2004 Wouter Tigges has left the Laboratory of Entomology, after having worked at Wageningen University for 36 years. The last years he devoted to the research on tritrophic interactions in plant-caterpillar-parasitoid and plant-spider-mite-predatory mite interactions.

In the spring of 2004 we had an exhibition of work by José van Loon and Josien Godding. These artists had worked in the Laboratory of Entomology by using the historic insect collection (see our website) as a source of inspiration. The exhibition was open to the public and these activities will have a follow-up in 2005.

TEACHING

GENERAL

The laboratory of Entomology is involved in teaching to BSc, MSc, and PhD students. The BSc and MSc teaching relates mainly to the programmes of Biology and Plant Sciences, but also involves students in Animal Sciences, Biological Production Sciences, Molecular Sciences, Organic Agriculture and Environmental Sciences. The staff of the laboratory of Entomology teaches the following courses:

- Analysis and Prevention of Health Risks in Tropical Countries
- Bee Science
- Biology and Management of Plant Pathogens, Pests and Weeds I
- Biology and Management of Plant Pathogens, Pests and Weeds II
- Biosystematics and Biodiversity
- Ecological Aspects of Bio-interactions
- Ecology
- Ecophysiology of plants
- Evolutionary Biology
- Fundamental and Applied Aspects of the Biology of Insects
- Insect-Plant Interactions
- Insects and Society
- Molecular and Evolutionary Ecology
- Molecular Aspects of Bio-interactions
- Plant- and Crop Sciences I
- Plant- and Crop Sciences II
- Population Ecology

Teaching to PhD students is done through the teaching programmes of the Graduate Schools Experimental Plant Sciences (EPS:http://www.graduateschool-eps.info) and Production Ecology and Resource Conservation (PE&RC:http://www.dpw.wageningen-ur.nl/PEenRC).

In the academic year 2003/2004 a total of 20 students finished their MSc-thesis under the supervision of the staff of the Laboratory of Entomology.

STUDENT THESES 2004

- Boerwinkel, Floor, Optimal foraging behaviour in a discrete and in a continuous environment.(04.16)
- Bossinga, Tim, The effect of soil organisms on plant/herbivore and herbivore/parasitoid interactions. (04.08)
- Caballé, Jordi Just, Response of two apple pests (*Dysaphis plantaginea* and *Anthonomus pomorum*) to pheromone and host plant odours. (04.05)
- Cardinel, Nelly, Effect of induced plant defences on populations of herbivore and parasitoid *Diadegma semiclausum* in Brussels sprout fields. (04.12)
- Fuld, Verinne, Foraging costs and harvestability as determinats of giving up densities in Bewick's swans. (03.16)

- Garcia Lor, Andres, Cloning of a putative nerolidol synthase after spider mite infestion in cucumber (cucumis sativus). (04.10)
- Groot de, Maarten, Testing white mustard *Sinapis alba* (L.) and sweet alyssum *Lobularia maritima* as a trapcrop for the diamondback moth *Plutella xylostella* (L.). (04.09)
- Guajard Homs, Maria o, Response of the predatory mite *Phytoseiulus persimilis* towards volatiles of Lima beam stems from plants infested by *Tetranychus urticae* and uninfested plants. (04.04)
- Huijben, Silvie, Avian Malaria in Rotterdam Zoo – study on the natural history of avian malaria parasite in the Netherlands. (04.01)
- Joosten, Lotte, Learning in blood feeding mosquitoes. (04.06)
- Kalkers, Lucas, Does the generalist parasitoid *Trichogramma* brassicae use an oviposition-induced synomone of *Brassica oleracea* to locate its host *Pieris brassicae*? (04.15)
- Munneke, Marion, Repellent and toxic effects of essential oils on the potato aphid, *Macrosiphum euphorbiae*. (04.07)
- Noort van, Tom, On the interactions between the parasitoid wasp *Trichogramma kaykai*, its sex ratio distorders and its hosts. (04.03)
- Noort van, Tom, Plant defence tackled by the flea beetle *Phyllotreta nemorum* (Coleoptera: Chrysomelidae: Alticinae): a mechanistic perspective. (04.14)
- Raaijmakers, Elma, Development of a short-range flight test for the quality control of *Encarsia formosa*. (04.13)
- Wijsman, Daan, Avian malaria in Rotterdam Zoo. (04.02)

PHD THESES 2004

A total of 7 PhD theses were completed and successfully defended:

- Almeida, R.P. de, Trichogramma and its relationship with Wolbachia: Identification of Trichogramma species, phylogeny, transfer and costs of Wolbachia symbionts, 2004, Promotor: Prof.Dr. J.C. van Lenteren, Co-promotor: Dr.Ir. R. Stouthamer.
- Boer, J.G. de, Bugs in odour space. How predatory mites respond to variation in herbivore-induced plant volatiles, 2004, Promotors: Prof.Dr. M. Dicke, Prof.Dr. M.W. Sabelis.
- Bukovinszky, T., Tailoring complexity: Multitrophic interactions in simple and diversified habitats, 2004, Promotors: Prof.Dr. J.C. van Lenteren, Prof.Dr. L.E.M. Vet.
- Charleston, D., Integrating biological control and botanical pesticides for management of Plutella xylostella, 2004, Promotors: Prof.Dr. L.E.M. Vet, Prof.Dr. M. Dicke
- Jeong, G.S., Evoloutionary interactions between sex ratio distorters and their hosts, 2004, Promotor: Prof.Dr. J.C. van Lenteren, Co-promotor: Dr.Ir. R. Stouthamer.
- Kindt, F., Probing behaviour of thrips. Behavioural study on the feeding of Western flower thrips related to Tomato spotted wilt virus transmission and host plant susceptibility, 2004, Promotors: Prof.Dr. M. Dicke, Prof.Dr. R. Goldbach. Co-promotor: Dr. W.F. Tjallingii.
- Scholte, E.J., The entomopathogenic fungus *Metarhizium anisopliae* for mosquitoe control. 2004, Promotor: Prof.Dr. J.C. van Lenteren, Co-promotors: Dr.Ir. W. Takken, Dr.Ir. B.G.J. Knols

RESEARCH PROGRAMME

The laboratory of Entomology investigates interactions between arthropods on the one hand and plants, animals and humans on the other. Our research aims at improving the understanding of multitrophic interactions in natural and agro-ecosystems and at (i) developing environmentally benign crop protection, (ii) improving health of animals and humans and (iii) conserving natural resources. The research relates both to temperate and tropical systems. The main focal points of our research are:

- chemical and molecular ecology
- behavioural and population ecology and
- functional biodiversity and agroecology.

Through both experimental and model approaches we address (a) the mechanisms that insects use to locate and evaluate their food sources and that plants and animals use to defend themselves against insects; (b) the causes of population fluctuations and differences in genetic composition among populations; (c) molecular aspects that underlie processes, interactions and evolutionary changes; (d) functional aspects of the characteristics of particular insect species and (e) the role of biodiversity in durable agriculture.

Our fundamental research concentrates on multitrophic interactions. On the one hand we investigate mechanisms of interactions, e.g. through molecular, sensory physiological and behavioural approaches. On the other hand ecological aspects of multitrophic interactions are investigated, through e.g. population genetical, population ecological and model approaches.

The applied research especially aims at finding durable and environmentally benign solutions to problems that are caused by insects. This relates to research on insects in common agricultural practices and in organic agriculture as well as in medical-veterinary problems.

All research of the laboratory of Entomology participates in the graduate schools Production Ecology and Resource Conservation (PE&RC - http://www.dpw.wageningen-ur.nl/PEenRC/index/index.htm) and Experimental Plant Sciences (EPS - http://www.graduateschool-eps.info/).

Progress in the research programmes is presented below:

Chemical and sensory ecology

Joop J.A. van Loon; Hans M. Smid; Renate C.S. Smallegange, Maaike Bruinsma, Erik H. Poelman, Limei Yang, Yu Tong Qiu, Maartje A.K. Bleeker, Nina E. Fatouros, Wilant van Giessen, and Suzanne Blatt

When under attack by herbivores, plants may compensate for the feeding damage in order to reduce or prevent potential fitness loss. In the interactions between black mustard *Brassica nigra (L)* Koch and the large cabbage white butterfly *Pieris brassicae* L. we examined the impact of *Pieris brassicae* herbivory on *B. nigra* grown from wild seed collected locally. Greenhouse studies utilised 4 herbivore densities and two vegetative developmental stages of the plant and quantified leaf damage, overall plant height, days to flowering, silique and seed production. Results showed that although *P. brassicae* would readily feed on *B. nigra*, with enough time the plant would regrow and produce equivalent amounts of seed as non-attacked controls. These results demonstrate that at the herbivore densities and timing of damage studied, *B. nigra* tolerates folivory from *Pieris brassicae* through compensation. An important parameter in this type of experiment is the growth stage of the plant. A surprising finding in subsequent experiments was that as soon as flower buds appeared, *P. brassicae* in their third and later instar moved into the racemes of black mustard plants and started feeding on buds, flowers and siliques. This flower-feeding behaviour has not been documented before for these well-studied insects. Direct attack of the reproductive organs might

have a much more serious impact on plant fitness than leaf feeding. We tested this and extended the study of this insect-plant interaction to the third trophic level, involving the gregarious braconid parasitoid *Cotesia glomerata,* in both greenhouse and field studies. The benefit that plants may gain by attracting parasitoids has only been examined from the perspective of reduced leaf herbivory. We studied whether parasitism would influence feeding site selection. Parasitized *P. brassicae* were observed to feed less on flowers than non-parasitized caterpillars, resulting in greater silique production for plants experiencing herbivory from parasitized caterpillars. We will expand these studies and will examine the effect of recruitment of parasitoids under field conditions and involve several genotypes of *Brassica nigra* which we found to differ in their flowering time.

Ecology, evolution and genetics of interactions between phytophagous insects, their host plants and their enemies.

Peter W. de Jong, Patrick Verbaarschot, Manabu Kamimura and Susanne Lommen

The interactions between phytophagous insects, their host plants, and their enemies provide ideal opportunities to study the ecology, evolution and genetics of adaptations in the field. In the past year, the line of research to study such interactions, which was started in the beginning of 2002, was further developed. The work is carried out in close collaboration with Dr. Jens Kvist Nielsen in Copenhagen, and with Prof. Paul Brakefield, Prof. Eddy van der Meijden, Dr. Klaas Vrieling, Dr. Casper Breuker and Dr. Kathleen Victoir at the University of Leiden. Manabu Kamimura joined the team in May 2004, to work in this programme for one year. The research programme is closely tied to the three major foci of interest of the Laboratory of Entomology, especially the first two: a) chemical- and molecular ecology; b) behavioural- and population ecology, and c) functional biodiversity and agroecology. The project focuses on the interaction between a flea beetle, its (natural) host plants, and its enemies. The chrysomelid flea beetle *Phyllotreta nemorum* lives on a limited number of Crucifers. The larvae are leaf miners, implying an intimate relation with the host plants, including (chemical) host plant defences. *Barbarea vulgaris* is an atypical host plant of this beetle: one chemically distinguishable form of this plant is unsuitable as host plant for the majority of *P. nemorum*. The adults do not eat from this plant, and the larvae die within three days when put on leaves of the plant. However, populations have been discovered that use this plant as their natural host. These beetles are apparently 'resistant' to the defences of *Barbarea*. We have found that this resistance is genetic, and involves genes with a major phenotypic effect. Some of these genes appear to be located on the sex chromosomes, whereas others seem to be autosomally inherited. The beetles are polymorphic for the presence of these genes; when collected on *Barbarea* in the field, all beetles have resistance genes, but on other host plants a major proportion of the beetles do not contain resistance genes. These observations raise a number of fundamental questions: 1) why are not all beetles resistant to *Barbarea* defence?; 2) what ecological and/or genetic factors limit the spread of resistance genes?; 3) how many loci are involved in the resistance, what is their inheritance, and if there is more than one locus involved, did they originate as independent mutations? Exciting progress in addressing these questions has been made in the past year, with the start of the implementation of a 'population genomics' approach. The aim is to link variation at the population level at neutral (microsatellite) loci with that at the resistance loci. This will enable the assessment of the relative contributions of selection and migration to the present day distribution of resistance genes. To this aim, primers have been developed for a number of microsatellite loci. Furthermore, Dr. Kamimura has applied a candidate gene approach to characterise the resistance genes at the molecular level. It is thought that beta-glucosidases are responsible

for the different resistance-genotypes. Sampling the flea beetle populations in Denmark that had been earlier sampled (1997) has shown that the frequencies of resistant flea beetles on other plants than *Barbarea* are decreasing. This monitoring will be continued. Analysis of population structure of the flea beetles with allozymes has shown that different resistance-phenotypes are genetically differentiated.

Next to the work on the flea beetles, a new line of research has started on the two spot ladybird beetle. This work is done in collaboration with the Intitute of Biology in Leiden (group of Prof. P.M. Brakefield), and involves the use of wingless two-spot ladybird beetles in biocontrol of aphid-pests. Simultaneously, we are monitoring natural ladybird populations to detect changes in gene-frequencies involved in colour polymorphism in ladybirds, possibly associated with climatic change. Finally, we have started monitoring the invasion of The Netherlands by the Asian ladybird beetle, *Harmonia axyridis*.

Infochemicals in multitrophic interactions

Marcel Dicke, Rieta Gols, Wouter Tigges, Adriana E. Alvarez, Jetske G. de Boer, Colette Broekgaarden, Maaike Bruinsma, Tibor Bukovinszky, Deidre S. Charleston, Nina E. Fatouros, M.(Ties) E. Huigens, Iris F. Kappers, Marjolein Lof, Ludo L.P. Luckerhoff, Evarist Magara, Oscar Magenya, Roland Mumm, Vivian R. van Oosten, Remco M.P. van Poecke, Erik H. Poelman, Conny Schütte, Isabel M.M.S. Silva, Tjeerd A.L. Snoeren, William Tinzaara, Limei Yang, and Si-Jun Zheng

Most of the work in this group is related to the themes *Chemical and molecular ecology* and *Behavioural and population ecology*. Through two new grants, i.e. a VICI grant from NWO and a strategic funding grant from the research school EPS (together with NIOO and PRI), there will now be a link with the third research theme of the Laboratory of Entomology, i.e. *Functional biodiversity and agroecology*.

Chemical communication among organisms is a widespread phenomenon that involves plants, insects, humans and many other organisms. We investigate infochemically-mediated biointeractions through different approaches addressing: (1) the mechanisms of induction of plant volatiles at the molecular and biochemical level, (2) the signal transduction and involvement of phytohormones such as oxylipins, salicylate and ethylene, (3) how herbivorous arthropods as well as their carnivorous enemies respond to the induced plant volatiles, (4) variation in induction between plant species and plant genotypes and (5) the ecology of infochemically-mediated bio-interactions. Our research addresses three main systems: (1) crucifer-*Pieris*-parasitoid interactions with an emphasis on the plants *Arabidopsis thaliana* and *Brassica* spp., (2) plant-spider mite-predatory mite interactions with an emphasis on interactions between Lima bean plants, the herbivorous mite *Tetranychus urticae* and the predatory mite *Phytoseiulus persimilis* and (3) *Drosophila*-parasitoid interactions.

At the transcriptomic level Remco van Poecke has compared the changes in gene expression pattern in Arabidopsis thaliana in response to feeding damage by a specialist herbivore, *Pieris rapae* caterpillars, and a generalist herbivore, *Spodoptera exigua*. Using an 8K microarray more than 100 insect-responsive genes potentially involved in defence were identified, including genes involved in pathogenesis, indole glucosinolate metabolism, detoxification and cell survival. Surprisingly, both herbivore species induced almost identical transcript profiles. The role of some of the induced genes is being further investigated in plant-herbivore-parasitoid interactions.

In cucumber Iris Kappers and Ludo Luckerhoff, in collaboration with Harro Bouwmeester at PRI, have used an approach that combines metabolomics and transcriptomics to identify genes involved in spider-mite induced plant volatiles. Through a subtractive library approach a cDNA microarray was developed. By analysing transcriptome and metabolite patterns in response to different treatments and time periods clusters of genes that had similar expression patterns as plant volatiles were identified. In this way the cucumber (E,E)-α-farnesene and (E)-β-caryophyllene synthases were cloned.

The role of the spider-mite-induced Lima bean volatile methyl salicylate in the attraction of the predatory mite was investigated by Jetske de Boer by manipulating plant headspace with the phytohormone jasmonic

acid (JA). JA induces most Lima bean odours in the same way as spider mite herbivory does. However, JA does not induce methyl salicylate (MeSA) in Lima bean plants. By supplementing the headspace of JA-treated Lima bean plants with MeSA we demonstrated that although JA treatment does induce predator attraction, addition of MeSA was essential to obtain attraction that was comparable to attraction to herbivore-induced plants.
Deidre Charleston demonstrated that an extract of the syringa tree (Meliaceae) induces the emission of parasitoid-attracting volatiles in cabbage plants. This was done in a project investigating the potential of syringa extract for integration in an IPM approach to control diamondback moth in South Africa.

Evolutionary Ecology
Louise E.M. Vet, Hans M. Smid, Tibor Bukovinszky, Maartje A.K. Bleeker, Deidre S. Charleston, Joanneke Talsma, Roxina Soler, Hanneke van Leur. At NIOO in close collaboration with Wim van der Putten, Jeff Harvey, Felix Wäckers, Martijn Bezemer and Nicole van Dam.

The research focuses on the ecology and evolution of multitrophic systems of plants, herbivorous insects and their natural enemies. Using a multitude of approaches we study the functioning of natural enemies in a spatially diverse multitrophic context. The behavioural ecological work investigates evolutionary aspects of phenotypic variation in foraging and life history traits. The chemical ecological approach focuses on the mechanism and function of chemical information conveyance between plants, herbivores and natural enemies and the influence of plant defence on the functioning of higher trophic levels. In addition we study sensory physiological and neurobiological aspects, specifically the perception and information processing (learning and memory) of herbivore-induced plant volatiles by insect parasitoids.
The research ranges from fundamental to strategic. The fundamental questions relate to understanding the evolution of species traits and species interactions within communities. Understanding the functioning of herbivores and their natural enemies in natural and agro-ecosystems is crucial for the strategic development of sustainable agroecosystems that are primarily based on the prevention of pests and diseases (life-support function of biodiversity).
In 2004, Deidre Charleston and Tibor Bukovinszky successfully finished their PhD project.
Selection of results: Deidre Charleston studied whether biological control and botanical pesticides are compatible pest management strategies. Her results indicated that biological control and the use of botanical pesticides derived from the neem and syringe trees can indeed be integrated for management of *Plutella xylostella*. Several papers are being published on this subject.
Tibor Bukovinszky studied multitrophic interactions in simple and diversified habitats as part of a larger programme on functional biodiversity. His research aim was to understand how vegetation diversity leads to pest suppression in agro-ecosystems. His studies included behavioural, laboratory and field studies. The results point to the great importance of foraging behaviour in explaining variable responses of herbivores and parasitoids to plant-species mixtures. Several papers have been or are being published.
Together with Hans Smid, Maartje Bleeker and Joop van Loon research on the behaviour and neurobiology of two closely related parasitic wasps that differ in olfactory learning of plant odours was continued. A comparative SEM and TEM study of the antennal sensillae of *C. glomerata a*nd *C. rubecula* was published. The memory dynamics of both wasp species were determined after a single conditioning trial with oviposition as reward stimulus. The memory trace was followed using a windtunnel bioassay at different time intervals varying from 1 minute to 5 days after conditioning. Furthermore, the morphology of octopaminergic, candidate reward-sensitive neurons was studied by immunolabeling and dye injection and visualized using confocal laserscanning microscopy. Several isoforms of a candidate memory suppressor gene in these wasps, (cAMP responsive element binding protein, CREB) were cloned and sequenced.
At the NIOO, department of Mutitrophic Interactions, several PhD projects are running and new ones started on the role of plant defence on multitrophic interactions. Joanneke Talsma (with Biere and Harvey) studies direct and indirect defence in *Plantago* to see if these defence strategies are compatible or conflicting.

Roxina Soler (with Bezemer and Harvey) is trying to link interactions between above- and below-ground herbivores and investigates how these affect the performance of parasitoids and hyperparasitoids. Hanneke van Leur (with van Dam) looks at molecular, phytochemical, and ecological aspects of glucosinolate polymorphism in *Barbarea vulgaris*. Ron Galiart (with van Dam) started his PhD on metabolic profiling of aboveground and belowground induced responses in wild crucifers. In collaboration with Dicke and van Loon (Entomology) and Vosman (PRI), we managed to obtain strategic competitive funds from the research school EPS to expand the research line of Ron Galiart/van Dam to a triplet PhD project to assess intra- and interspecific variation in defence strategies in wild and cultivated crucifer species, study the effect of (experimental) defence induction on gene expression and metabolome profiles and make field assessments of the effect of defence variation on higher trophic level biodiversity, the latter aspect started by Erik Poelman.

Tropical entomology
Arnold van Huis, Jeroen Spitzen, Godwin Ayenor, Emmanuel Dormon, Evarist Magara, Oscar Magenya, Suzanne Nederlof, Antonio Sinzogan, William Tinzaara, Gebremedhin Woldewahid

Effect of host quality of Callosobruchus maculates *on performance of the egg parasitoid* Uscana lariophaga *(Jeroen Spitzen and Arnold van Huis)*
Fitness of the solitary egg parasitoid *Uscana lariophaga* Steffan was studied after development on eggs of the bruchid storage pest *Callosobruchus maculatus* Fab. reared at either low or high densities on cowpea seeds and laid at day one and four of maternal life. Both bruchid larval competition and maternal age negatively affected egg size, but the latter more than the first. *U. lariophaga* reared in small hosts developed slower, were smaller and produced fewer eggs compared to wasps reared in large hosts. Particularly fecundity of the parasitoid was influenced by host egg size. This was reflected in the values for the intrinsic rate of increase of the wasp, which differed for wasps that developed in host eggs laid by bruchid females of different age. Mothers did allocate more females to larger hosts, but not significantly.
Semiochemical cues used by Uscana lariophaga Steffan (Hymenoptera: Trichogrammatidae) to locate its host, Callosobruchus maculatus Fab. (Coleoptera: Bruchidae) (Pablo Jacome and Arnold van Huis)
Uscana lariophaga parasitizes the eggs of the cowpea storage pest *Callosobruchus maculates*. In order to test how the female wasp locates the host egg, different bio-essays were compared. Three types of olfactometers baited with *C. maculatus* eggs were tested: one based on diffusion (glass tube), and two based on airflows: the Y-tube represented the choice situation and a linear airflow in a glass tube representing the no-choice situation. The disadvantage of the diffusion olfactometer was the high number of non-responding wasps and the uncertainty about the type of odour gradient building up in the tube. The Y-tube olfactometer in which the wasp was able to make a choice failed to give clear results, maybe due to the minute size of the wasps. The linear airflow olfactometer showed a significant arrestment response of the wasp. All the bio-essays indicated that egg odours are a cue for the wasp to find its host. However, the airflow olfactometer seemed to give best results. In this olfactometer it was sure that any change in behavioural response had to be due to the perception of the odour. Adding honey increased considerably the percentage of wasps that responded.

Vector biology and control
Willem Takken, Bart G.J. Knols, Krijn Paaijmans, Yu Tong Qiu, Ernst-Jan Scholte, Renate C. Smallegange, Jeroen Spitzen, and Wycliffe Wanzala

Mosquito-host interactions - Research on malaria mosquitoes and ticks continued, albeit somewhat less intensive than previous years due to change-over of programme funding. The investigations on human volatiles as kairomones for malaria vectors made significant progress on the odour coding of *Anopheles gambiae*. Single sensillum recordings were routinely measured from exposure to a range of candidate

compounds derived from human skin. Sub-groups of antennal sensilla appeared to express different sensitivity to chemical compounds, allowing for a first-time classification of olfactory sensilla according to chemical response pattern. In addition, the GC-MS work on human volatiles, in collaboration with the Laboratory of Organic Chemistry, revealed a number of compounds that appeared to be present more in highly attractive compared to least attractive individuals. Work on the behavioural significance of these compounds is in progress. In the 3D image analysing work it was found that combinations of heat and odours produced a more directed response of host-seeking mosquitoes compared to heat or odours alone.
Biological control - Work on the role of the entomopathogenic fungus *Metarhizium anisopliae* was completed with the field studies reported in the 2003 annual report. Incorporation of the fungal effects on malaria epidemiology and risk demonstrated a highly significant reduction of new malaria infections in houses treated with the fungus compared to untreated houses. These important findings were further highlighted by complementary findings at the University of Edinburgh, which showed a significantly reduced *Plasmodium* development in fungus-infected mosquitoes. As a result, the fungus appears to cause a dual effect on malaria transmission: a) significant mortality and reproductive fitness of infected mosquitoes and b) a negative effect on within-mosquito parasite development. It is currently being studies how these different traits can be exploited as an alternative, and effective, method for malaria control.
Risk of Lyme disease in The Netherlands – Borrelia identifications in field-collected *Ixodes ricinus* nymphs revealed significant differences in tick infections rates between the Hoge Veluwe and the Dune area. Mean infections in the latter were approx. 10%, whilst in ticks from the former area up to 5% infections were found.

From behavioural and population ecology to functional biodiversity and agro-ecology
Joop van Lenteren, Raul Almeida, Mohammed Ardeh, Tibor Bukovinszky, Rieta Gols, Gilsang Jeong, Hajnalka Trefas, Wouter Tigges, Louise Vet, Karin Winkler, Yde Jongema

Until recent most of our work involved understanding of parasitoid behaviour and development of biological and integrated pest management programmes (Behavioural and population ecology; first paragraphs of this report), currently our main activities are in the field of Functional Biodiversity and Agroecology (the third research theme of the Laboratory; second paragraph of this report).
Behavioural and population ecology
Several PhD projects concerning development of biological control methods have been finished during this report period (Almeida, Jeong and Scholte); see the theses summaries on our website for more information.
For years, we have studied the biology of *Encarsia formosa* in greenhouses. To be able to answer several questions about the foraging behaviour of this parasitoid, we realised we should study its behaviour in its natural setting: Central America. The results of these fundamental studies on *Encarsia* and *Trialeurodes* are now appearing in international journals (see publication list).
In an ongoing whitefly biological control project, Mohammed Ardeh studied arrhenotokous and thelytokous strains of *Eretmocerus* species, and the benefits and costs of the use of thelytokous parasitoids in control of whiteflies (see publication list). Ardeh also studied the reaction of various *Eretmocerus* strains/species to pheromones and analysed intra- and interspecific host discrimination.
Work on risk assessment of importing and releasing of exotic natural enemies was continued and resulted in several papers.
Functional Biodiversity and Agroecology:
The general objective of the project on Functional Biodiversity and Agroecology is to determine how increased biodiversity leads to reduced pest development. The specific objectives are: (a) to study how functional groups of pests and their natural enemies survive and disperse in simple and diverse agro-ecosystems, (b) to specify the ecological conditions for conservation and augmentation of natural enemies by diversification, (c) to design agroecosystems of higher biodiversity within a landscape ecological framework that have a lower pest pressure, and (d) to provide strategies for sustainable use of biodiversity

within the production function of biodiversity. Together with other Wageningen University and Research Centre groups, work is also done on prevention of diseases and weeds.
Karin Winkler studied the effect of the provision of nectar and pollen in field edges on the development of natural enemy populations. A spectacular finding of this year was that provision of nectar providing plants in the field led to dramatically increased life span and reproduction of parasitoids (see publication list).
Hajnalka Trefas determined the effect of mixed cropping on the predation by and reproduction of polyphagous predatory beetles. She found that vegetation characteristics by themselves may influence egg laying site preference, in addition to availability of prey for adults and larvae in the different plant systems. Abiotic factors (e.g. light, humidity and structure) appeared to affect the selection of oviposition sites and egg survival of carabid beetles.
Tibor Bukovinszky found that our results from field and laboratory studies do not yet allow generalizations about the behaviour of specific or generalist herbivores and their natural enemies in monocultures or mixed cropping systems. Still, knowledge of the searching behaviour of pests and their natural enemies is essential to predict the effect that mixed cropping will have on pest reduction and natural enemy increase. Individual based simulation modelling (Bukovinszky and Potting) helped us to identify those characteristics that determine behaviour of herbivores and natural enemies in diversified agr-ecosystems (see publication list). Information on Bukovinszky's thesis can be found on our website.

Spatio-temporal dynamics of herbivores and their antagonists in diversified agro-ecosystems.
Roel P.J. Potting

The development of the individual-based simulation framework continued. The framework was adapated to investigate the adaptive value of different host searching strategies of parasitoids in different heterogeneous environments. In collaboration with Tibor Bukovinszky the framework was tailored for the behaviour of the cabbage aphid (*Brevicoryne brassicae*), diamondback moth (*Plutella xylostella*) and cabbage butterfly (*Pieris rapae*), to explain differences in their responses to small-scale fragmentation of their habitat. Simulated spatial dynamics of these herbivores were similar to those observed in patch size experiments in the field.

Aphid-plant interactions and host plant resistance.
W.F. Tjallingii, Elisa Garzo and Adriana Alvarez.

Plant penetration activity by mouthparts of aphids has been studied by the use of the electrical penetration graph (EPG) technique. Fundamental (international) research projects are running on aphid activities during stylet penetration of phloem sieve elements. Plant responses and the insect's reactions on these have shown a number of interesting results. Aphids always start to inject saliva into the sieve elements when they puncture these cells. Presumably this is essential to suppress the normal phloem wound responses at wounding. This avoids phloem protein clogging that would block the plant's mass transport as well as the food canal in the aphid's stylets.
This clogging is presumably the main factor in the resistance in the TGR accession of melon (*Cucumis melo*) to the cotton aphid (*Aphis gossypii*). Once the aphid has inserted its stylets into a sieve element, it continues salivating without switching to phloem feeding. Garzo has continued a post-doc project this year to study this hypothesis, using EPGs and transmission electron microscopy. We presume to find a difference between resistant and susceptible melons with respect to phloem proteins coagulation. This study will also investigate the impact of the melon resistance on the transmission of circulative viruses by the aphid.
Another type of host plant resistance has been studied in a short MSc study. In tomato the introduced wild *Mi*-gene, causing resistance nematodes appears to confer resistance in tomato to the potato aphid, *Macorsiphum euphorbiae* as well. Earlier work suggested that the *Mi*-resistance might also be related to problems in suppression of phloem wound responses. This new study, however, seems not to confirm this

but the results do support the earlier idea that the susceptible tomato (cv. Moneymaker) appears to confer also some resistance to the potato aphid, the Mi-resistances is additional to the Moneymaker resistance.
In another project (Alvarez, PhD) resistance to the aphid Myzus persicae in (wild) Solanaceae is studied as a potential source to cross into potato (Solanum tuberosum). So far, some resistance has been traced that shows a great similarity to the melon resistance, i.e. sustained phloem salivation without subsequent phloem ingestion, as detected in EPGs.
Last year, the results of Kindt's EPG and video study (PhD) on probing behaviour of thrips (Frankliniella occidentalis) on peppers (Capsicum annuum) were reported in his thesis. It could be concluded that 1) a single probe by the thrips can transmit tomato spotted wilt virus (TSWV) , 2) TSWV inoculation needs only stylet insertion and salivation activity during a probe, 3) inoculation success ratio is very low (<1%) and seems to be reduced by subsequent sap ingestion activity, which is responsible for TSWV acquisition, 4) the thrips resistance in pepper hardly affects the probing activities involved in TSWV transmission. The strongly reduced TSWV infection on thrips resistant peppers is mainly due to the plant's antixenotic effects, greatly reducing the numbers of vectors.

Projects within graduate school Experimental Plant Sciences:

- EPS2-2b28. Insect-plant interactions during stylet penetration by aphids. W.F. Tjallingii.
- EPS2-2b75. Antagonistic and synergistic effects of resistances in sweet pepper on transmission of Tomato Spotted Wilt Virus and population development of Western Flower Thrips. 1999-2004. F. Kindt & W.F. Tjallingii.
- EPS2-b128. Molecular characterisation of mechanisms of *Solanum* resistance to *Myzus persicae*. Impact on PLRV transmission. 2003-2007. A.E. Alvarez, W.F. Tjallingii, B. Vosman & M. Dicke
- EPS2-2d06. Induction of plant volatiles by herbivory: signal transduction and behavioural modification in a multitrophic context. M. Dicke, W. Tigges, R. Gols.
- EPS2-2d04. Variation in foraging behaviour of the predatory mite *Phytoseiulus persimilis*. 1992-2005. C. Schütte, M. Dicke and J.C. van Lenteren.
- EPS2-2d05. Sensory, behavioural and nutritional effects of plant substances on host plant and host insect evaluation and utilization by insects. J.J.A.van Loon, H.M. Smid.
- EPS2-2d19. Quantitative and qualitative variation in odour blend composition: effect on behavioural responses of predatory mites 1999-2004. J.G. de Boer & M. Dicke, in collaboration with M.W. Sabelis (UvA).
- EPS2-2d20. A new disease in the predatory mite *Phytoseiulus persimilis*: Pathogen identification, development of a detection method and prevention and cure in mass rearing. 1998-2005. C. Schütte, I.M.M.S. Silva, O. Poitevin, and M. Dicke
- EPS2-2d24. Chemical ecology and management of the banana weevil *Cosmopolites sordidus*. W. Tinzaara, C. Gold, A. van Huis and M. Dicke. 2000-2005.
- EPS2-2d21. The compatibility between biological control of the diamondback moth, *Plutella xylostella*, host plant resistance and chemical control using novel botanical pesticides: Evaluation in a tritrophic context. 2000-2004. D.S. Charleston, R. Kfir, L.E.M. Vet and M. Dicke.
- EPS2-2d22. Induced indirect plant defence and plant fitness: testing the "evolutionary enlistment" hypothesis. 2001-2005. R.C. Smallegange, J.J.A. van Loon, J.A. Harvey & M. Dicke
- EPS2-2d23. Cross-talk between signal-transduction pathways in induced defence of Arabidopsis against microbial pathogens and herbivorous insects. 2001-2005. V.R. van Oosten, C.M.J. Pieterse, L.C. van Loon & M. Dicke.
- EPS2-2c27. Induced defence of Arabidopsis against herbivorous insects: cross-talk with induced defences against microbial pathogens. 2002-2004. R.M.P. van Poecke & M. Dicke.
- EPS2-2d27 Genomics approach to integration of host plant insect resistance and biological control. 2001-2005. L. Yang, J.J.A. van Loon, M.A. Jongsma & M. Dicke.
- EPS2-2d28. Development of a method for breeding of cucumber for improved attraction of biological control agents. 2002-2006. I.F. Kappers, L. Luckerhoff, H.J. Bouwmeester & M. Dicke.
- EPS2-4a22. Mode of action of sex-modifying supernumerary chromosomes, 2000-2004. J. van Vugt, H. de Jong (Genetics, WU), J.C. van Lenteren, R. Stouthamer and L. Beukeboom (RUG).
- EPS-2c036. Phenotypic manipulation of induced plant defense in Brassica, 2004-2008. M. Bruinsma, M. Dicke, J.J.A. van Loon.
- EPS-2c037. Manipulation of plant genotype and effects on interactions with community members. 2004-2008. T.A.L. Snoeren, M. Dicke, P.W. de Jong.
- EPS-3c062. Metabolomics of indirect defence in cultivated Brassica oleracea varieties and its effects on insect biodiversity, 2004-2008. E.H. Poelman, J.J.A. van Loon, M. Dicke
- EPS-new. Identification and expression of genes related to herbivory, 2004-2008. C. Broekgaarden, M. Dicke, B. Vosman.

- EPS-new. Molecular ecology of terpenoids in plant-insect interactions. 2004-2007. R. Mumm and M. Dicke

Projects within graduate school Production Ecology and Resource Conservation:

- PE33-00b. Control of *Callosobruchus maculatus* and *Bruchidius atrolineatus* (Col.: Bruchidae), insects in storage or cowpea (*Vigna unguiculata*) by the egg parasitoid *Uscana* sp. (Hym.: Trichogrammatidae). A. van Huis, C. Stolk and G.J.K. Pesch.
- PE&RC32-00aj. Factors that affect host searching by anopheline mosquitoes. W. Takken, J. Spitzen.
- PE32-94a. Understanding biological control of whiteflies by natural enemies. J.C. van Lenteren
- PE&RC-ipr096. Genetics and physiology of *Wolbachia*-host interactions in *Telenomus nawai* populations: their implications on the reproduction and behavior of *Telenomus nawai*. 2000-2004. Gilsang Jeong & R. Stouthamer.
- PE&RC39-99d Enhanced biodiversity of arthropod natural enemies for sustainable control of herbivores. 2000 – 2004. T. Bukovinszky, J.C. van Lenteren & L.E.M. Vet.
- PE&RC-33-01a. Functional biodiversity: strategic use of nectar and pollen sources to boost biological control. 2000 – 2005. K. Winkler, J.C. van Lenteren, F. Wäckers.
- PE&RC31-00u. Learning-related differences at the neural level in two closely related parasitic wasps: a comparison between a generalist and a specialist. 2000-2005. M.A.K. Bleeker, H.M. Smid, J.J.A. van Loon & L.E.M. Vet.
- PE&RC. Enhancing the biocontrol of the Western Flower Thrips (*Frankliniella occidentalis*) with the predatory bug (*Orius laevigatus*) on greenhouse cucumber. 1998-2005. J. Hulshof, A.J.M. Loomans, J.C. van Lenteren.
- PE&RC prep29. Evaluation of the biological control capacity of *Eretmocerus* spp for the control of whiteflies on Gerbera. 2001-2005. M. Ardeh & J.C. van Lenteren.
- PE&RC ipr103. Factors important for the biological control performance of *Trichogramma*. 1999-2004. R. Porfiro de Almeida, R. Stouthamer & J.C. van Lenteren.
- PE&RC 32 00ag. Entomopathogenic fungi for biological control of malaria and filariasis vectors on Mfangano Island, Lake Victoria, Kenya. 2000-2004. E.J. Scholte, J.C. van Lenteren, W. Takken & B.G.J. Knols.
- PE&RC.new. Temperature distribution in shallow water bodies: Influence of abiotic factors on the population dynamics of immature stages of African malaria vectors. 2003-2007. K. Paaijmans, A.F.G. Jacobs, W. Takken, A.A.M. Holtslag & M. Dicke.
- PE&RC new. Environment and *Beauveria bassiana* performance against banana weevil: The effects of agroecological conditions and banana crop management on Entomopathogenic persistence and infectivity. 2004-2008. E. Magara, M. Dicke, A. van Huis, C. Gold.
- PE&RC new. Interactions among leafhopper vector populations, maize streak virus disease, agro-environments and soil fertility. 2004-2008. O. Magenya, M. Dicke, A. van Huis.
- PE&RC-3204a. Spatio-temporal modelling of infochemicals in a food-web context. 2004-2008. M. Lof, L. Hemerik, M. Dicke & J. Grasman.

REPRESENTATION IN EXTERNAL COMMITTEES

International:

- Consortium developing the SeaWaterGreenhouse, advisor crop protection (van Lenteren)
- European Branch Society of Vector Ecology 2002-2006 (Takken, president)
- European Academies' Science Advisory Council, Environment Strategy Group (Vet)
- European Meeting of the Society for Vector Ecology 2006 (Takken, scientific board)
- European Science Foundation (ESF), Steering committee programme Volatile Organic Compounds in the Biosphere-Atmosphere System (VOC-BAS) (Dicke)
- Expert Advisory Committee Canadian Network of Biocontrol Research (van Lenteren)
- FAO Technical Group of the Desert Locust Control Committee (Van Huis)
- Honorary Professor Beijing Normal University, China (van Lenteren)
- Honorary Professor University of Perugia, Italy (van Lenteren)
- International EPG Workshop (Tjallingii, co-organizer/main scientific supervisor)
- International Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC-IUBS) (2000-2004) (van Lenteren, Vice President)
- International Congress of Entomology, Council (1998-2008) (Takken, secretary-treasurer)
- International Congress of Entomology, Brisbane August 2004, Organisation of several symposia (Dicke, van Loon, Vet).
- International Organization for Biological and Integrated Control of Noxious Animals and Plants, West Palearctic Regional Section (IOBC-WPRS), council member (van Lenteren)
- International Organization for Biological Control, IOBC, Steering Committee Working Group 'Induced Resistance' (Dicke)
- International Project *Convergence of Sciences* for better integrated soil and crop management, executed in Benin and Ghana (Van Huis, coordinator)
- International Symposium TERPNET 2005, Wageningen, April 2005, Local Organisation Committee (Dicke)
- International Working Group on Mediators of Bloodfeeding Arthropods (Takken, secretary)
- Measuring Behaviour 2005 -5th International Conference on Methods and Techniques in Behavioural Research- Scientific Program Committee (Vet, chair; Dicke member)
- OECD working group Regulation of Import and Release of Exotic Natural Enemies (van Lenteren)
- Panel of Experts on Environmental Management of Vectors (PEEM), WHO, Geneva (Takken)
- PhD examination committees at international university (van Lenteren, Vet)
- 'Professeure associée' at Laval University, Quebec, Canada (Vet)
- Visiting Professor, Institute of Zoology, Chinese Academy of Sciences, Beijing, China (van Loon)

National:

- Biological advisory board, Biologische Raad, KNAW (Vet)
- Board for the Authorisation of Pesticides "CTB" (van Lenteren).
- Board of 'Landbouwexport fonds 1918', Wageningen (Dicke)
- Board Uyttenboogaart-Eliasen foundation (van Lenteren).
- Board Van Groenendael-Krijger fund (van Lenteren).
- Board National Science Museum (NEMO) (Vet)
- Boterbloemhuis, Productschap Sierteelt, Advisory Committee (Tjallingii)
- Committee on Functional Agrobiodiversity of LTO (van Lenteren)
- Committee on Genetic Modification (COGEM), Ministry of Environment (Dicke)

- Committee 'Studium Generale' of Wageningen University, involved in extracurricular teaching (Dicke)
- Department of Plant Sciences, Wageningen University, advisory committees and working groups (Dicke)
- Dutch Entomological Society (van Lenteren, vice-president).
- Dutch Entomological Society, Section Experimental and Applied Entomology (SETE-NEV) (van Huis, secretary).
- Earth and Life Sciences council of the Netherlands Organization for Scientific Research (Gebiedsbestuur ALW-NWO) (Vet)
- Graduate School Production Ecology & Resource Conservation, Scientific Advisory Board, (Vet).
- Graduate School of Production Ecology & Resource Conservation, Educational Committee (Takken, chairman).
- Graduate School of Production Ecology & Resource Conservation, Scientific Committee (van Huis).
- Hollandsche Maatschappij der Wetenschappen (Vet)
- Institute of Biology Leiden University, Advisory Council (Vet)
- IUCN Netherlands, advisory committee (Vet)
- Jury Prins Bernhard Cultuurfonds, Prize for Nature Conservation (Vet)
- Library committee, Centre for Crop Protection, Wageningen University (de Jong)
- Policy Advice Committee of National Science Foundation ALW (Beleids Advies Commissie ALW) (Dicke)
- Member several PhD Examination committees (Dicke, van Loon, van Huis, van Lenteren, Takken, Vet)
- Ministry OCW on restructuring higher education (OCW-Profielcommissie N&T/N&G), advisory committee (Vet)
- National Graduate School Experimental Plant Sciences, Scientific Advisory Board (Dicke).
- National Graduate School Experimental Plant Sciences. Education committee (Dicke, chairman).
- National Graduate School Experimental Plant Sciences. Scientific Committee (Dicke).
- National Committee on the Prevention of Head Lice Infections, Ministry of Public Health (Takken)
- Natural History Museum Naturalis, Supervisory Board (Raad van Toezicht) (Vet)
- Netherlands Science Foundation (NWO), Selection committees personal research grants (Vet)
- Netherlands Science Foundation (NWO), Selection committee VENI grants (Dicke)
- Noorderlicht VPRO (popular scientific radio programme), Scientific Advisory Board (Vet)
- Organising Committee of workshops of NWO Stimulation Program Biodiversity (Potting)
- Project Enhanced Biodiversity, Alterra, Laboratory of Entomology, Laboratory of Phytopathology, Laboratory of Plant Ecology and Weed Science (van Lenteren, coordinator)
- ROC Biology, Wageningen University (Dicke).
- Royal Netherlands Academy of Arts and Sciences. (van Lenteren, Vet)
- Royal Netherlands Academy of Arts and Sciences, The Young Academy (Knols)
- Teylers Tweede Genootschap, Teylers Museum, Haarlem (Vet)
- Wageningen Plant Sciences Group-Wageningen UR-Expertise-unit Biointeractions and Health (Dicke, coordinator)
- Wageningen University, Biointeractions Laboratories within Department of Plant Sciences (Dicke, coordinator)

Journals:
- Annual Review of Entomology (Vet, editorial board)
- Biochemical Systematics and Ecology (Dicke, editorial board).
- Biological Control: Theory and Application in Pest Management (van Lenteren, editorial board).
- Bionieuws, column (Vet)

- British Ecological Society's Symposium Series (Vet, advisory editorial board)
- Chemoecology (Vet, associate editor)
- Ecological Entomology (Dicke, editorial board)
- Entomologia Experimentalis et Applicata (co-editor, van Loon).
- European Journal of Entomology (de Jong, editorial board)
- Bulletin of Insectology (van Lenteren, editorial board)
- Insect Science (Dicke, editorial board)
- International Journal of Pest Management (van Lenteren, editorial board).
- International Journal of Tropical Insect Science (van Huis, editorial board)
- IOBC bulletins (van Lenteren, editor).
- IPM practitioner (van Lenteren, editorial board).
- Journal of Chemical Ecology (Dicke, editorial board).
- Journal of Ethology (Dicke, advisory board).
- Journal of Insect Behaviour (van Lenteren, Vet, editorial board).
- Neotropical Entomology (van Lenteren, editorial board)

PROJECTS FUNDED EXTERNALLY

- **1998-2004** A new disease in the predatory mite *P. persimilis*: Pathogen identification, development of detection method and prevention and cure in mass rearing. Funded by Technology Foundation (STW).
- **2000–2004** Enhanced biodiversity for sustainable crop protection Funded by NWO/ALW.
- **2000–2004** Functional biodiversity: strategic use of nectar and pollen sources to boost biological control. Funded by Robert Bosch Foundation.
- **2000–2004** The role of natural enemies in reducing whitefly populations in Panama. Funded by Senacyt, Panama.
- **2000-2004** Mode of action of sex modifying supernumerary chromosomes. Funded by NWO-ALW.
- **2000-2004** Identification of human volatiles as attractants for *Anopheles gambiae sensu stricto*. In collaboration with the Laboratory of Organic Chemistry, Wageningen University. Funded by Technology Foundation (STW).
- **2000-2004** Entomopathogenic fungi for biological control of malaria and filariasis vectors on Mfangano island, Lake Victoria, Kenya. Funded by WOTRO.
- **2000-2004** Chemical ecology and management of the banana weevil *Cosmopolites sordidus* (Germar) (Coleoptera: Curculionidae) Funded by IITA.
- **2000-2004** Host-plant selection in *Helicoverpa* moths. Collaborative project with Institute of Zoology, Chinese Academy of Sciences, Beijing, China. Funded by Koninklijke Nederlandse Akademie van Wetenschappen, KNAW)
- **2002-2004** Induced defence of *Arabidopsis* against herbivorous insects: cross-talk with induced defences against microbial pathogens. Funded by Graduate school Experimental Plant Sciences.
- **2000–2005** Learning-related differences in olfactory information processing in two closely related parasitic wasps: phenotypic plasticity analysed from behaviour to neuron. Funded by NWO/ALW.
- **2001-2005** Genomics approach to integration of host plant insect resistance and biological control. (Funded by Dutch and Chinese government.**)**
- **2001-2005** Evaluation of the biological control capacity of Eretmocerus spp for the control of whiteflies on Gerbera. Funded by the Ministry of Agriculture of the Islamic Republic of Iran.
- **2001-2005** Induced indirect plant defence and plant fitness: testing the "evolutionary enlistment" hypothesis. Funded by NWO/ALW.
- **2001-2005** Cross-talk between signal-transduction pathways in induced defence of Arabidopsis against microbial pathogens and herbivorous insects. Funded by NWO/ALW.
- **2001-2005** Convergence of sciences: inclusive technology innovation processes for better integrated crop and soil management. Funded by International Research and Education Fund (INREF) and Directorate General of International Cooperation (DGIS) of the Netherlands' Ministry of Foreign Affairs.
- **2002-2004** Learning-related differences in olfactory information processing in two closely related parasitic wasps; phenotypic plasticity analysed from behaviour to neuron. (Funded by NWO/ALW)
- **2003-2005** Evolution and epidemiology of human malaria – mosquito interacations. Funded by EU.
- **2003-2005** Phloem located resistance to the aphid *Aphis gossypii* in accession "TGR-1551". Funded by Director General de Universidades (Spanish Government).
- **2001-2006** Development of a method for breeding of cucumber for improved attraction of biological control agents. Funded by Technology Foundation (STW).
- **2000-2006** Convergence of Science: inclusive innovation technology processes for better integrated soil and crop management. (Funded by INREF and DGIS)

- **2003-2006** EU-FIPSE Transatlantic Exchange Program in Higher education on Sustainable Crop Protection (SUSPROT) Funded by EU.
- **2003-2007** Temperature distribution in shallow water bodies: Influence of abiotic factors on the population dynamics of immature stages of African malaria vectors. Funded by WOTRO.
- **2004-2007** Molecular characterisation of mechanisms of *Solanum* resistance to *Myzus persicae* - Impact on PLRV transmission. Funded by Alβan-EU.
- **2004-2008** Linking variation in plant defence to higher level biodiversity. Experimental Plant Sciences, Strategic Funds. (collaboration between Entomology, NIOO and Plant Research International).
- **2004-2009** A molecular genetic approach to chemical ecology and community ecology. Funded by NWO-VICI.
- **2004-2009** Behavioural and ecological determinants of gene flow in African malaria vectors. Funded by NWO-VIDI.
- **2004-2009** Ecological and physiological functions of biogenic isoprenoids and their impact on the environment (ISONET). Funded by EU.
- **2004-2008** Spatio-temporal modelling of infochemicals in a food-web context. Funded by NWO-ALW (collaboration with Mathematical and Statistical Methods Group)
- **2004-2008** Ethnobotanicals for the control of *Ripicephalus appendiculatus*, the vector of East Coast Fever in East Africa. Funded by Wageningen University, IFS and ICIPE.
- **2004-2008** Effect of agro-ecological conditions and banana crop management of efficacy and persistance of Beauveria bassiana for control of the banana weevil in Uganda. Funded by Wageningen University, Rockefeller foundation and IITA.
- **2004-2008** Assessing the contribution of Farmer Field School approach to the management of cassava, soil and family health and its role in food security in Malawi. Funded by JICA.
- **2004-2008** Crop protection perspectives in Kazakhstan: shifting interfaces between farmer practice and agricultural research. Funded by WUR and Govt. of Kazakhstan.
- **2004-2008** Interactions among leafhopper vector populations, maize streak virus disease, agro-environments and soil fertility. Funded by WOTRO.

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