WAGENINGEN UNIVERSITY
WAGENINGEN UR

ANNUAL REPORT 2006

LABORATORY OF ENTOMOLOGY

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ANNUAL REPORT LABORATORY OF ENTOMOLOGY 2006

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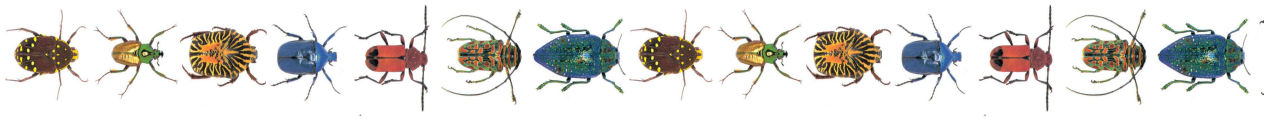

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FOREWORD

On 15 April 1907 Niko Tinbergen was born in The Hague, The Netherlands. Tinbergen studied Biology in Leiden and was one of the founders of modern Behavioural Biology through an experimental approach. In 1973 he received the the Nobel Prize in Physiology or Medicine together with Konrad Lorenz and Karl von Frisch. His best known works are *The study of instinct* (1951) and *On aims and methods of ethology* (1963). In the latter publication he presents the four 'why' questions related to the study of behaviour, i.e. questions related to the mechanism, the ecological function, the ontogeny and the evolution of behaviour. Tinbergen's ideas on behavioural biology are still well alive today and stimulate many behavioural biologists.
Behavioural biology has been one of the foci of the Laboratory of Entomology for several decades. We concentrate on the behaviour of herbivorous, carnivorous and haematophagous insects and the integration of different aspects ranging from mechanisms to evolutionary ecology characterize much of our research. For instance, we aim at understanding how mosquitoes exploit odours to localise their food source, i.e. us, and why some parasitic wasps learn rapidly while others do not. An important novel component is the neurobiological component that includes an electrophysiological analysis of the perception of volatiles as well as the molecular analysis of learning. One of the studies on insect behaviour from the Laboratory of Entomology, i.e. the discovery that malaria mosquitoes are attracted to Limburger cheese by Bart Knols and Ruurd de Jong, has received the Ig Nobel Prize for Biology 2006 (www.ignobel.com/ig/ig-pastwinners.html#ig2006), a prize for research that makes people laugh and then think.

In 2006 we celebrated the 80th anniversary of the Laboratory of Entomology. The aim of our group 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 around 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 humans, 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 for laymen so as to raise the interest of the general public for insects. For instance, in September 2006 we organised the week-long science festival *Wageningen – City of Insects* (www.cityofinsects.nl) that attracted more than 20,000 visitors.

This annual report informs you about the major activities and achievements in our group in 2006. There were many memorable events.
More information about our activities, on our teaching and research programmes, on recent PhD theses, and much more can be found on our website. The URL of our website is: www.ent.wur.nl/uk.

Marcel Dicke
Head of the Laboratory of Entomology

April 2007

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, and population genetic 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.

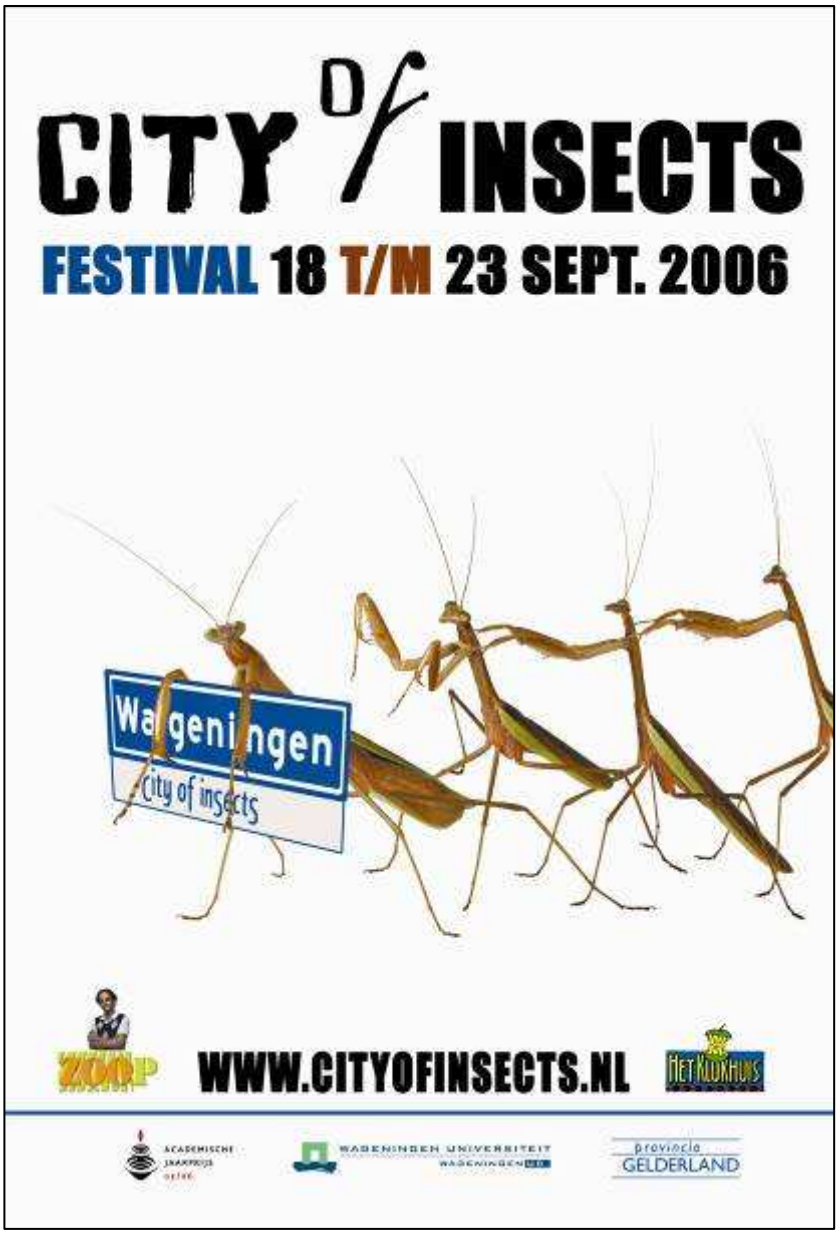
Mission and strategy
The mission of the laboratory of Entomology is to carry out excellent research and teaching in a continuously updated research programme that is nationally and internationally at the forefront and well-linked to the research of international collaborators, while working in a group 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. The vector research programme 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.

In the year 2006 we celebrated the 80th anniversary of the Laboratory of Entomology. Prof. W.K.J. Roepke was appointed the first professor of Entomology in Wageningen on 28 January 1926. With this professorship the independent Laboratory of Entomology was founded in Wageningen. The Laboratory of Entomology had evolved from the Institute for Phytopathology, that included an entomological section and was founded in 1906. Prof. J. Ritzema Bos was the director of the Institute for Phytopathology. Prof. Roepke headed the Laboratory of Entomology from 1926-1953. He was succeeded by Prof. Jan de Wilde who led the group from 1954-1983. He was succeeded by Prof. Joop van Lenteren (1983-2003) and Prof.

Louis Schoonhoven (1985-1991), while Prof. René Cobben (1970-1987) and Prof. Rory Post (1991-1997) headed the Taxonomy section.
In June 2006 the Entomology team won the Academic Year Prize (100,000 €), awarded by the naional newspaper NRC Handelsblad in cooperation with the Netherlands Organisation for Scientific Research (NWO) and the Royal Netherlands Academy of Arts and Sciences (KNAW). This prize is awarded in a national contest to the team that combines excellent research with the best plan to transfer scientific knowledge to a wide audience. With the award we have produced a popular scientific book, *Mierenneukers en Muggenzifters – insecten onder de loep genomen* (www.ent.wur.nl/NL/Webshop/), and organised the science festival *Wageningen – City of Insects* from 18-24 September 2006 (www.cityofinsects.nl). In the festival many external partners participated such as artists, shop keepers, cooks, movie theaters etc. In total more than 20,000 visitors came to the activities. There were more than 50 activities throughout the week. These included e.g. exhibitions on insects in art, Children University, street performances, an insect march through town, science demonstrations and an open day at the Laboratory of Entomology. These were completed with a collective insect consumption happening where at the same time at the same place (Salverda square in downtown Wageningen) 1747 people ate a portion of mealworms that had been prepared by professional cooks. The festival enjoyed ample coverage in the media with extensive newspaper coverage within the Netherlands and abroad, with tens of radio interviews and many TV programs paying attention to the festival. News about TV coverage reached us from China (prime time news), Brazil, Mexico, Germany, Italy, Great Britain, Ukraine etc.
In February 2006 Joop van Lenteren, Louise Vet and Marcel Dicke received the Rank Prize for Nutrition 2006 in London, for their collective work on fundamental studies of the interactions between plants, their arthropod pests and the natural enemies of these pests, and the development of strategies for practical biological methods of pest control.
In October 2006 the Ig Nobel Prize 2006 Biololy was awarded to Bart Knols and Ruurd de Jong at Harvard for their 1996 publication in Parasitology Today (now Trends in Parasitology) entitled: "Limburger cheese as an attractant for the malaria mosquito *Anopheles gambiae*".

A total of 7 PhD students have successfully defended their theses in 2006. On average there were 7 PhD defences per year 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 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 and highlight additional memorable moments from the PhD student's period in the Laboratory of Entomology. Four of these PhD defences were part of a group of 9 PhD defences of students that worked within the programme *Convergence of Sciences,* run by a consortium of chair groups from natural and social sciences of Wageningen University and groups from Universities in Benin and Ghana.These 9 PhD defences were held in Benin and Ghana through a collaborative ceremony.

In the summer of 2006 the Netherlands, Belgium, Germany and France were startled by a sudden appearance of the bluetongue virus that is transmitted by midges. The Dutch Ministry of Agriculture asked the Laboratory of Entomology for advice on the entomological aspects of the outbreak and commissioned Willem Takken and colleagues to carry out research on midges and the transmission of bluetongue virus.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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 the Tropics
- Bee Keeping
- Biology and Management of Plant Pathogens, Pests and Weeds I
- Biology and Management of Plant Pathogens, Pests and Weeds II
- Biosystematics and Biodiversity
- Cutting Edge Ecology
- Ecological Aspects of Bio-interactions
- Ecology I & II
- Ecophysiology of plants
- Evolutionary Biology
- Frontiers of Medical and Veterinary 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 2005/2006 a total of 24 students finished their MSc-thesis under the supervision of the staff of the Laboratory of Entomology.

MSC THESES 2006

- Agtmaal van, Maaike - Masking the attractiveness of human odours to mosquitoes: A dual-port olfactometer study which investigated the putative allomonal effects of several selected human volatiles on *anopheles gambiae* s.s. host seeking behaviour - 06.15
- Allema, Bas - Thrips resistance in cabbage: a study on host plant resistance - 06.18
- Beeuwkes, Jacob - 3D Flight behaviour of the malaria mosquito, *Anopheles gambiae* s.s. in a wind tunnel in response to kairomones - 06.05
- Duindam, Jelle; Exploring the use of neem formulations in Cocoa pest and disease management in Ghana; 06.02

- Glas, Joris - Can *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) be controlled by using Vetiver grass (*Vetiveria zizanioides* (L.) Nash) as a trap plant - 06-08
- Glas, Joris- Resistance against crop rotation in the western corn rootworm -- 06.24
- Govaert, Marcel - Genetic variability in thelytokous populations of the parasitoid fairyfly, *Anagrus delicates* - 06.11
- Huijben, Silvie - Interspecific competition between larvae of *Anopheles gambiae* s.s. and *An. arabiensis* in a semi-field situation in western Kenya - 06.13
- IJdema, Harm - The effect of jamonic acid treatment of *Brassica nigra* on the attraction of pollinators - 06.17
- Kerstes, Niels - The role of enemy-free space in the host range expansion of the flea beetle *Phyllotreta nemorum* - 06.23
- Kessel van, Monique - The behaviour of *Oecophylla longinoda*. How to manipulate or use *Oecophylla* ants in cocoa agro-ecosystems in order to suppress capsids - 06.04
- Kos, Gijs - Melanism and population structure of *Adalia bipunctata* in the Netherlands - 06.07
- Ngu, Vu Quoc - The parasitoid *Uscana lariophaga* and the location of its host *Callosobruchus maculates* - 06.06
- Ngu, Vu Quoc - Interactions between the predatory mites *Amblyseius cucunerus* (Oudermans) and minute pirate bug *Orius sauteri* (Poppius) in prey patches of thrips *Thrip palmi* (Karny) - 06.16
- Nijland, Bart - Inductie van geurstofvorming door Spintmijt (*Tetranychus urticae*) in *Arabidopsis thaliana* - 06.20
- Oduor, Ayub - Host searching of parasitoid: does infochemically - complex habitat affect host searching efficiency of cotesia wasps and could this affect indirect defense of plants? - 06.19
- Postma, Wiebe - Characterization of an enzyme that converts (3S)-(E)-nerolidol to 4.8-dimethyl-1,3(E),7-nonatriene (DMNT) in cucumber (*Cucumis sativus* L.) upon spider mite (*Tetranychus urticae Koch*) infestation - 06.09
- Ros, Carola - Rupsenvraat induceert meerdere geurstoffen bij *Arabidposis*: welke rol speelt de gerustopf Methyl Salicylaat op aantrekking van de sluipwesp - 06.12
- Schellekens, Judith - Ecological genetics of the polymorphic ladybeetle *Harmonia axyridis* in The Netherlands - 06.14
- Simpson, Laura - *Trichogramma* wasps of Kauai: A survey of *Trichogramma* species and the presence of *Wolbachia* - 06-22
- Sombroek, Heleen - Ecology of *Anopheles gambiae* s.l. in wetlands of the River Gambia - 06.10
- Vermeer, Kim - Role of coadapted gene complexes in the use of *Barbarea vulgaris* as a host plant by *Phyllotreta nemorum* - 06.21
- Wandaga, Mozes; Direct effects of rainfall on larvae of *Anopheles gambiae* Giles sensu stricto (Diptera: Culicidae): Case study, Western Kenya; 06.01
- Wijngaarden van, Machiel - The behaviour of *Oecophylla longinoda*. How to manipulate or use *Oecophylla* ants in cocoa agro-ecosystems in order to suppress capsids - 06.03

PHD THESES 2006

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

- Ayenor, G.K.(2006) 'Capsid control for organic cacoa in Ghana: results of participatory learning and action research.' Promotors: Prof. dr. N. G. Röling, Prof. dr. ir. A. van Huis, Prof. dr. D. Obeng-Ofori, Dr. P.B. Atengdem
- Dormon, E.N.A. (2006) 'From a technology focus to innovation development; the management of cocoa pests and diseases in Ghana. Promotors: Prof. dr. ir. C. Leeuwis, Prof. dr. ir. A. van Huis, Prof. dr. D. Obeng-Ofori, Dr. O. Sakyi-Dawson
- Fatouros, N.E. (2006) Infochemicals in host location by *Trichogramma* egg parasitoids. Promotors: Prof. dr. M. Hilker and Prof. dr. M. Dicke
- Nederlof, E.S. (2006) 'Research on agricultural research; towards a pathway for client-oriented research in West Africa.' Promotors: Prof. dr. ir. N.G. Röling, Prof. dr. ir. A. van Huis, Prof. dr. D.K. Kossou, Dr. O. Sakyi-Dawson
- Schuette, C. (2006) 'A novel bacterial disease of the predatory mite *Phytoseiulus persimillis*; disease syndrome, disease transmission and pathogen isolation.' Promotors: Prof. dr. M. Dicke, Prof. dr. J. van Lenteren.
- Sinzogan, A.A.C. (2006) Facilitating learning toward sustainable cotton pest management in Benin: the interactive design for development.' Promotors: Prof. dr. ir. A. van Huis, Prof. dr. ir. D.K. Kossou, Prof. dr. J. Jiggins, Prof. dr. V. Agbo
- Vos de, M. (2006) Signal signature, transcriptomics, and effectiveness of induced pathogen and insect resistance in Arabidopsis Promotors; Prof. dr. C.M.J.Pieterse, Prof. Dr. L.C. van Loon, Prof. dr. M. Dicke

(Hier overzicht met PhD-students)

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; Yu Tong Qiu, Maaike Bruinsma, Erik H. Poelman, Wilant van Giessen, Dongsheng Zhou, Suzanne Blatt, Limei Yang, Honglei Wang, Qingbo Tang, Jinying Peng, Baoping Pang, Guohong Wang.

Electrophysiological studies of contact-chemosensory neurons in insects generally employ single compounds. Such studies have been useful to reveal specificity and sensitivity characteristics of gustatory neurons, e.g. sugar-best neurons, amino acid-best neurons or deterrent neurons. We studied electrophysiological activity of two types of gustatory sensilla styloconica on the maxillary galea of the caterpillars of the related species *Helicoverpa armigera* and *H. assulta* (Lepidoptera: Noctuidae) in response to saps of cotton (*Gossypium hirsutum* L.) and pepper (*Capsicum frutescens* L.). In dual-choice bioassays, *H. armigera,* although a polyphagous species, exhibits a strong preference for cotton over pepper, whereas *H. assulta* is oligophagous on Solanaceae and strongly prefers pepper. We used this behavioural contrast to assess whether the behavioural preference could be correlated with the response profiles in response to each sap. Multineural responses were obtained that were subjected to template analysis in an attempt to quantify the response intensity of each neuron separately and response profiles were constructed and statistically compared. Analyses were based on assumptions rather than firm proof on assignment of spike classes to identified neurons. To overcome this problem we developed an activity-dependent labeling technique that allows the histological identification of neurons from which electrophysiological activity was recorded. We stimulated maxillary taste sensilla of *P. brassicae*, innervated by four taste neurons, with sucrose mixed with agmatine (1-amino-4-guanidobutane) and then visualized the agmatine label in receptor neurons by immunocytochemistry and confocal laser scanning microscopy. The agmatine label was highly localized in a single receptor neuron in the lateral taste sensillum. This technique holds promise to overcome problems of assignment of spike class to an identified neuron in multineural gustatory activity in response to complex stimuli.

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

Peter W. de Jong, Patrick Verbaarschot, David Calvo-Hernandez.

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. Exciting progress has been made in the past year, with 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 dozen of microsatellite loci (Verbaarschot, Calvo-Hernandez). 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. In 2006 one new aspect of this phytophagous insect-host plant interaction was added, namely the possible presence of "enemy free space" on *Barbarea*. Field work carried out in 2006 has demonstrated that the overall chance of flea beetles to be parasitized by two common larval parasitoids is reduced when they live on *Barbarea*,

compared to when they live on other host plants. Paradoxically, the momentanous fractions of parasitized larvae are almost always higher on *Barbarea*. This line of work will be continued in 2007. Also, new methods have been developed to study host plant acceptance/-preference of the flea beetles, and pilots have been carried out. Furthermore, we have started monitoring the invasion of The Netherlands by the asian ladybird beetle, *Harmonia axyridis*. All of these lines of research are continued in 2007, through the employment of 2 PhD students (1 on *Harmonia*, one on flea beetles), and 1 Japanese post doc (working on flea beetles).

Infochemicals in multitrophic interactions

Marcel Dicke, Rieta Gols, Adriana E. Alvarez, Michaël van den Berg, Colette Broekgaarden, Maaike Bruinsma, Tibor Bukovinszky, Nina E. Fatouros, M.(Ties) E. Huigens, Iris F. Kappers, Marjolein Lof, Ludo L.P. Luckerhoff, Roland Mumm, Denis Ochieno, Vivian R. van Oosten, Ying-Jing Peng, Erik H. Poelman, Conny Schütte, Renate Smallegange, Tjeerd A.L. Snoeren, William Tinzaara, Martin de Vos, Limei Yang, and Si-Jun Zheng.

Herbivore-induced plant volatiles that affect plant-insect interactions are addressed through a combination of (1) transcriptomic, (2) metabolomic, and (3) ecological approaches.

Global changes in gene expression have been recorded in *Arabidopsis thaliana* and *Brassica oleracea* in response to feeding damage by herbivorous insects such as caterpillars and aphids. Clear differences in gene expression were recorded when these herbivores with very different feeding modes damage the plants. Moreover, gene expression changes also differ among plant genotypes that differ in defence characteristics.

A *B. oleracea* 13-LIPOXYGENASE gene has been cloned and quantitative effects in gene expression have been investigated through q-PCR. The gene is highly responsive to jasmonic acid (JA) and to feeding by *Pieris* caterpillars. *Pieris* feeding induces JA and JA-treatment results in avoidance of oviposition by *Pieris* butterflies. Furthermore, herbivory by *Pieris* caterpillars primes the defence against turnip crinkle virus in *Arabidopsis* which seems to be mediated by ethylene-induced sensitization of SA-dependent gene expression.

In *Arabidopsis* crosstalk between defences induced by phytopathogens and herbivorous insects were investigated. *Pieris* feeding primes the defence of the plant against Turnip Crinkle Virus. The increased production of ET upon herbivore feeding sensitizes the tissue to respond faster to SA, thereby contributing to an enhanced defensive capacity toward pathogens, such asTCV, that trigger SA-dependent defenses upon infection.

Adult female *Phytoseiulus persimilis* predatory mites of one of our laboratory populations (=NR-population) shrink several days after mating, cease egg production and die several days after shrinking; furthermore they show a lower degree of attraction to herbivore-induced plant volatiles. We have shown that the NR-syndrome is a contagious phenomenon and that the factor inducing the syndrome is the novel bacterium *Acaricomes phytoseiuli* that is transmitted horizontally among and between generations via feces and debris deposited by symptomatic females.

The application of leaf extracts of the syringa tree (*Melia azedarach*) induce changes in volatile emission in *B. oleracea* and in increased attraction of parasitic wasps that parasitize *Plutella xylostella* caterpillars. The application of the extract results in reduced development of the caterpillars and may be exploited in environmentally benign control of pests in cabbage.

Evolutionary Ecology

Louise E.M. Vet, Hans M. Smid, Joanneke Talsma, Roxina Soler, Hanneke van Leur, Erik Poelman, Michael van den Berg. At NIOO in close collaboration with Wim van der Putten, Jeff Harvey, and Nicole van Dam.

The research focuses on the ecology and evolution of multitrophic systems of plants, herbivorous insects and their natural enemies. We use a multitude of approaches to study the functioning of natural enemies in a spatially and (fyto)chemically diverse world. 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 diversity, behaviour and performance of higher trophic levels (Soler, Poelman, van Leur, Talsma). In addition we study neurobiological aspects, specifically information processing (learning and memory) of herbivore-induced plant volatiles by insect parasitoids (Smid, van den Berg). We study learning and subsequent memory formation in two *Cotesia* parasitoid wasp species that differ in associative learning of the odours of plants on which they have encountered a host caterpillar. This difference in learning between these two closely related wasp species provides an attractive model to study physiological, neurological and ecological factors that could influence learning. Both wasps display associative learning of plant odours after an oviposition reward conditioning, but they differ in their long-term memory (LTM) acquisition and consolidation. This species-specific difference is likely an adaptation to the very different spatial distributions of the wasps' caterpillar hosts in nature (clustered vs spread out). We are presently studying the genes that are involved in these learning processes.

Tropical entomology

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

Parasitoids use semiochemicals emitted by their host to locate their victims. The behaviour of the egg parasitoid *Uscana lariophaga* was studied in the location of their host *Callosobruchus maculates*. Instead of using beetle eggs we studied whether semiochemicals emitted by the adult beetle had an effect on the wasp. This in order to see whether phoresy occurs. Did the sex or the mating conditions of the beetle have an effect on the response of the wasp? Female wasps stayed longer in Petri dish quadrants with mated female and male beetles than in those with virgin ones. After mating male and female beetles attracted wasps more often than before mating. It seems that during mating, a substance is released by the male beetle acting as a semiochemical for the wasp. It is not clear whether phoresy plays a role in host location.

Vector biology and control

Willem Takken, Bart G.J. Knols, Jeroen Spitzen, Hans Beijleveld, Heather Ferguson, Fedor Gassner, Michelle Helinski, Helène Hiwat (Suriname), Susan Imbahale (Kenya), Frans Jacobs, Victor Mwingira (Tanzania), Kija R. Ng'habi (Tanzania), Krijn P. Paaijmans, YuTong Qiu, Renate C. Smallegange, Remco A. Suer, Niels Verhulst, Wycliffe Wanzala (Kenya).

Our research focuses on the chemical ecology of mosquitoes, the ecology of aquatic stages of malaria vectors, the development of entomopathogenic fungi for malaria vector control and the population biology and vector-host interactions of disease vectors in natural areas. In a broader perspective the work contributes to development of sustainable solutions for vector-borne disease control in temperate and tropical regions. Electrophysiological studies on the malaria mosquito *Anopheles gambiae* showed that

electroantennogram signals in mosquitoes can be made significantly more sensitive by serial connection of 3 antennae. Furthermore, a single sensillum in-depth study on *An. gambiae* testing 44 odorants, naturally present in humans, revealed that significantly different sensitivities for many of these odorants were present in antennal sensilla. The sensitivity to odorants changed significantly following a blood meal. In a behavioural study, testing 27 human volunteers, significant differences in attractiveness to human odour was found in *An. gambiae*. These differences were constant over several months. Work is in progress to identify the key components that are responsible for the differences in attractiveness. In a collaborative study with the Ifakara Health Research and Development Centre, Tanzania, a new age grading method for anopheline mosquitoes was developed, which enables evaluation of demographic patterns and mortality in male mosquitoes. This provides new avenues for studies considering GM or sterile male programmes for malaria control. In field studies in Kenya we investigated the impact of size of mosquito breeding sites on water temperature range and fluctuations under field conditions. Daily water temperatures varied most in the smallest (hoof print size) site, while in larger sites the temperature variations were still considerable, varying from 25 to 34^{o}C, being 5-7^{o}C higher than ambient temperatures. Corresponding studies on anopheline mosquito development and survival are in progress. A country-wide study on the distribution and population dynamics of candidate vectors of infectious disease in the Netherlands was completed in October 2006. We found that biting midges (*Culicoides* spp.), blood-feeding mosquitoes and ticks represented the largest groups of arthropod species present. Livestock farms had the highest biodiversity of blood-feeding species, and highest densities were found in nature reserves rich in peatland. River floodplains had a relatively poor species number of blood-feeding arthropods, and ticks were absent of such habitats. It was concluded that several candidate vectors of infectious disease are present in the Netherlands, and that a combination of suitable climate, presence of an infectious reservoir and high density of vectors could cause outbreaks of infectious disease. (This scenario occurred in August 2006, when an outbreak of bluetongue virus was reported from Limburg province, see elsewhere in this report). In the continuing work on entomopathogenic fungi, it was established that *Metarhizium anisopliae* has a high virulence for the dengue vectors *Aedes aegypti* and *Aedes albopictus*. This provides new opportunities for the design of strategies for the control of these important disease vectors.

Genetic and biological control of African malaria mosquitoes

Bart Knols, Heather Ferguson, Kija Ng'habi, Bernadette Huho, Willem Takken.

Ecological and population biology issues remain challenges to the application of genetic control strategies for combatting African malaria mosquitoes. Similarly, molecular geneticists need to resolve pertinent issues related to gene driving systems and develop means to ensure complete linkage of the refractoriness genes to the drive system, failure of which may seriously undermine the potential of this technology. Moreover, until such time that the probability of potential public health benefits can be maximised, it will be unlikely that approval for release of transgenic mosquitoes will be granted. The use of contained field-based research is currently advocated to face the shortfalls in understanding of the behaviour and ecology of genetically- engineered vectors, prior to their release in the wild. A central goal of this project is to investigate ecological factors that determine gene flow in African malaria vectors under semi-field conditions. This research is conducted within a 700m^2 semi-field system, that uniquely allows experimental study of mosquito gene flow in field realistic conditions for the purpose of assessing prospects for reducing malaria transmission by using genetic control strategies and other innovative vector control methods.
In 2006, the greenhouse facility reached completion and is currently routinely used for experimental purposes. In 2007, efforts to establish a self-perpetuating population of *Anopheles arabiensis* will continue. In 2006, both MSc students working in the project submitted their theses to the University of Dar es Salaam. Kija Ng'habi has enrolled as a PhD student and will continue to work within the project. He also visited the laboratory of Prof. Greg Lanzaro (UC Davis, USA) through a fellowship awarded by the International

Atomic Energy Agency (IAEA) and will strengthen this collaboration in 2007 with another visit. Dr. Ferguson, who served on the project for 2.5 years, finished her contract and left Ifakara in October 2006, but will continue to collaborate with those in the project and visit Tanzania frequently.

Since 1 July, a large multi-partner project on furthering the methodology of *Metarhizium*-based mosquito control started in Wageningen, in close collaboration with the Ifakara Health Research and Development Centre in Tanzania. Within Wageningen, a collaboration with the Food and Bioprocess engineering group (Arjen Rinzema and Frank van Breukelen) was initiated. The project is embedded within a large international consortium that meets annually to discuss progress and options for further expansion of the work. Studies on entomopathogens are now undertaken in Kenya, Tanzania, South Africa, and discussions are underway to initiate a project in Ghana, where insecticide resistance is rampant.

From behavioural and population ecology to functional biodiversity and agro-ecology
Joop van Lenteren, Bas Allema, Giovanni Burgio, Carmen Isabel Castillo Carrillo, Valentina Lo Verde, Sara Ruschioni.

Much of our work involves (1) parasitoid behaviour and development of biological and integrated pest management programmes (Behavioural and population ecology; first paragraphs of this report), and (2) functional biodiversity and agroecology (the third research theme of the Laboratory and the second paragraph of this report).
Behavioural and population ecology:
Valentina Lo Verde (University of Palermo) is doing a post doc project on elemination of supernumerary parasitoid larvae in *Eretmocerus mundus*. Until now it was unclear whether elimination occurs when the parasitoid larvae are still outside the host (*Eretmocerus* lays its eggs between the host and the host plant), or that elimination occurs within the host after the parasitoid larvae have penetrated the host. Valentina found several cases of parasitoid larvae attacking each other outside the host. In an experiment where superparasitism was created, parasitoid mortality was higher than in once parasitized hosts, also showing elimination during the phase that the parasitoid larvae are still outstide the host. Valentina is now working with Carmen Isabel Castillo Carrillo (MSc student, Ecuador) on the transfer of *Wolbachia* from one strain of *Eretmocerus* to another strain.
Work on risk assessment of importing and releasing of exotic natural enemies was continued in collaboration with Antoon Loomans (Plant Protection Service) and has resulted in several papers and book chapters (see publication list).

Sara Ruschioni, in a collaborative PhD project with the universities of Ancona and Perugia, studied the reaction of parasitoid ovipositors to different solutions related to host discrimination. She succeeded for the first time in history to make recordings of sensilla on the ovipositor of a parasitoid.
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. Several projects within this topic have been finished during the past years (see publications by Tibor Bukovinszky and Karin Winkler. Some of our findings are (1) that it is still too early to generalize on processes related to natural biological control in diversified agro-ecosystems, and (2) that research spanning several scales – from individual to ecosystem – is needed to

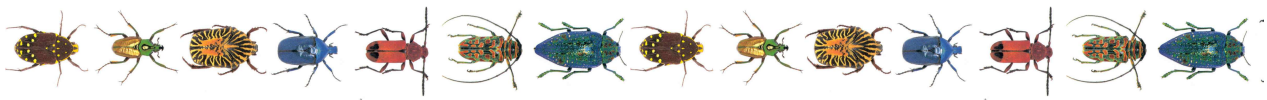
evaluate the effect of diversified ecosystems on herbivore and carnivore population dynamics. Concerning point 2, we hope to come up with a new classification of herbivores and carnivores on basis of their searching behaviour. This new classification may help in formulating generalizations on pest regulation processus in diversified ecosystems.
Giovanni Burgio (University of Bologna; PhD student at Entomology Wageningen) has finished a study on the effect of the degree of biodiversity in field edges and other landscape elements on natural biological control in several crops. His research, which is a combination of observations and determination of biodiversity indexes, will result in a thesis that will be defended at Wageningen University in 2007.
PhD projects on the role of polyphagous predators in herbivore reduction and on risks of releasing exotic polyphagous predators have been started recently.

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

Plant-aphid interactions are studied with respect to mouthpart activities and host selection behaviour of aphids as well as by plant properties before and after aphid attack. Moreover, the transmission of plant viruses – the main economic impact of aphid pests – is studied. The electrical penetration graph (EPG) technique plays a dominant role since this reflects mouthparts activities, salivary secretions into and sap ingestion from plant tissues and individual cells. Host plant resistance to the aphid *Myzus persicae* in wild *Solanum* species (potato like tuber bearing plants) has been analysed and resistance factors appeared located at different levels of tissue in different species (Alvarez, PhD). Some resistance is plant age dependent, changes after aphid infestation or virus infection. The impact of additional induced resistance has been studied with respect to plant penetration and acceptance behaviour of aphids as well as regarding transcriptional changes in induced plants (micro-array analysis at PRI, Wageningen). Resistance to *M. persicae* is not effective to *Macrosiphum euphorbiae* in some wild *Solanum* species and transcriptional changes in the same species differ between infestations by the two aphids.
Correlation of EPG signals, waveform and patterns with biological aphid or plant properties provides a source of very useful information. Nevertheless, some signal components could not be related to any aphid and plant feature so far. Internal movements of mouthparts and foregut are now recorded by micro-video in combination with EPG recording in order to establish more complete signal correlations. Also, simultaneous EPG recording with two different electronic signal processing methods (newly developed) and the use of plant viruses as markers of crucial behavioural events in virus transmission (acquisition and inoculation) is started.

Projects within graduate school Experimental Plant Sciences:

- EPS2-2b28. Insect-plant interactions during stylet penetration by aphids. 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, R. Gols.
- EPS2-2d04. Variation in foraging behaviour of the predatory mite *Phytoseiulus persimilis*. 1992-2006. 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.
- EPS2-2d23. Cross-talk between signal-transduction pathways in induced defence of Arabidopsis against microbial pathogens and herbivorous insects. 2001-2007. V.R. van Oosten, C.M.J. Pieterse, L.C. van Loon & M. Dicke.
- EPS2-2d27 Genomics approach to integration of host plant insect resistance and biological control. 2001-2006. 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. 2002-2007. I.F. Kappers, L. Luckerhoff, H.J. Bouwmeester & M. Dicke.
- 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-32c060. 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
- EPS- Molecular, phytochemical and ecological aspects of glucosinolate polymorphism. H. van Leur, W.H. van der Putten & L.E.M. Vet.



Projects within graduate school Production Ecology and Resource Conservation:

- 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 32 03b. 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-3204a. Spatio-temporal modelling of infochemicals in a food-web context. 2004-2008. M. Lof, L. Hemerik, M. Dicke & M. de Gouw.
- PE&RC 31 05d. Neural basis of associative learning in two closely related Cotesia parasitoid wasp species. 2005-2009. M. van den Berg, H.M. Smid, J.J.A. van Loon and M. Dicke.
- PE&RC The contribution of landscape elements to natural pest control. G. Burgio, J. van Lenteren
- PE&RC new: Behaviour and elimination of supernumerary parasitoid larvae in *Eretmocerus mundus*. 2005-2009. V. Lo Verde, J. van Lenteren
- PE&RC new: Behaviour, anatomy and sensory physiology of chemosensillae in parasitoids. 2005-2009. S. Ruschioni, J. van Lenteren
- PE&RC new: Evaluation of natural enemies in augmentative biological control. 2005-2009. K. Bolckmans & W. Ravensberg, J. van Lenteren
- PE&RC 06068. Ethnobotanicals used for ectoparasites control in traditional livestock holdings 2004-2008. W. Wanzala, W. Takken
- PE&RC 06072. The effects of water management systems in traditional agriculture on Malaria Mosquitoes in Western Kenya. 2005-2009 . S. Imbahale, W. Takken, M. Dicke
- Development and evaluation of entomopathogenic fungi for controlling malaria – a study to assess the efficacy of an entomopathogenic fungus for malaria intervention in rural villages of Tanzania. 2006-2010. M. Jumbe, W. Takken, B. Knols
- PE&RC 06077. Behavioural characteristics of the main malaria vector *Anopheles darlingi* in Suriname, and implications for vector control. 2006-2009. H. Hiwat, W. Takken & M. Dicke.
- PE&RC 31 05c. Linking direct and indirect plant defences in cultivated Brassicaceae to wild relatives. R. Gols & M. Dicke.
- PE&RC 31 05e. Reproductive biology and induced sterility as determinants for genetic control of mosquitoes with the sterile insect technique. M. Helinski, B.J.G. Knols & M. Dicke
- PE&RC 06034. Effect of crop management on performance of endophytic *Fusarium* spp. in tissue culture banana against the banana weevil *Cosmopolites sordidus* (Germar) and nematodes in Uganda. D. Ochieno, A. vanHuis & M. Dicke.
- PE&RC 32 03d. Linking interactions between above- and below-ground herbivores and the performance of parasitoids and hyperparasitoids. R. Soler, T.M. Bezemer, J.A. Harvey & L.E.M. Vet.
- PE&RC 07018. Disruption of malaria transmission by chemical manipulation of Anopheline olfactory responses. N. Verhulst, W. Takken & M. Dicke.
- PE&RC 06085. Cassava cropping and HIV/AIDS: assessing the contribution of experimental learning approach to crop protection, food security and family health in Domasi, Malawi. M. Yajima, A. van Huis & J. Jiggins.

International:

- Consortium developing the SeaWaterGreenhouse, advisor crop protection (van Lenteren)
- ERA-MORE, European Network of Mobility Centres, Advisory Committee (Vet)
- European Branch Society of Vector Ecology 2004-2006 (Takken, president)
- 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)
- European Food Safety Authority, Full member of Panel of Experts on Plant Health, (EFSA), Parma, Italy (van Lenteren)
- 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 Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC-IUBS) (2004-2008) (van Lenteren, President)
- International Congress of Entomology, Council (1998-2008) (Takken, secretary-treasurer)
- International Congress of Entomology, July 2008,Durban, South Africa, organisation of two symposia: (1) 'Insects and Society' (Dicke, van Huis), (2) 'Omics and Ecology and Evolution of Multitrophic Interactions' (Dicke, Vet)
- International Joint Workshop on PR Proteins and Induced Resistance Against Pathogens and Insects, Doorn, the Netherlands, May 2007 (Dicke, co-organiser)
- 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 'Biogenic Volatile Organic Compounds: Sources and Fates in a Changing World', October 2007, Montpellier, France (Dicke, co-organiser)
- International Symposium 'Vegetative volatiles: molecular ecology and metabolomics' at Gordon Research Conference 'Floral & Vegetative volatiles', October 2007 (Dicke, co-organiser)
- International Working Group on Mediators of Bloodfeeding Arthropods (Takken, secretary)
- Member Governing Council Interantional Centre for Insect Physiology and Ecology (ICIPE)(van Huis)
- 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)
- 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 NWO Darwin Centre for Biogeology (Vet)
- Board 'Landbouwexport fonds 1918', Wageningen (Dicke)
- Board Uyttenboogaart-Eliasen foundation (Dicke)
- Board Van Groenendael-Krijger fund (Dicke)
- Board National Science Museum (NEMO) (Vet)
- 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 until April 2006, Dicke, vice-president from April 2006)
- Dutch Entomological Society, Section Experimental and Applied Entomology (SETE-NEV) (de Jong, secretary).
- Earth and Life Sciences council of the Netherlands Organization for Scientific Research(ALW-NWO) (Dicke)
- Evaluation committee 'Bio- and Geosphere' of NWO (Knols)
- International Conference on Agricultural Development (ICAD) of the Royal Netherlands Society for Agriculture (KLV) (van Huis, member)
- 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, van Lenteren)
- 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)
- 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).
- Natural History Museum Naturalis, Supervisory Board (Raad van Toezicht) (Vet)
- Netherlands Ecological Research Network (NERN) (Dicke, representative of Department of Plant Sciences)
- Noorderlicht VPRO (popular scientific radio programme), Scientific Advisory Board (Vet)
- Organising Committee Brassica 2006 – 15th Crucifer Genetics Workshop, September 30 – October 4, Wageningen (van Loon)
- 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)

- User committee Resistance of white cabbage to the onion thrips, Thrips tabaci. Plant Research International, Louis Bolcke Institute (van Loon)
- 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:

- Animal Biology, special issue on learning in insects (Vet, Smid, guest editor)
- Annual Review of Entomology (Vet, editorial board)
- Biochemical Systematics and Ecology (Dicke, editorial board)
- 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)
- Entomological Bulletin Guido Grandi, University of Bologna (van Lenteren, editorial board)
- Evolutionary Ecology (de Jong, editorial board)
- European Journal of Entomology (de Jong, 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)
- Malaria Journal (Knols, editorial board)
- Neotropical Entomology (van Lenteren, editorial board)
- Open Parasitology Journal (Knols, editorial board)
- Open Tropical Medicine Journal (Knols, editorial board)
- Plant Signaling and Behaviour (Dicke, editorial board)

PROJECTS FUNDED EXTERNALLY

- **2004-2006** 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)
- **2001-2006** Capsid Control for Organic Cocoa in Ghana. Results of participatory learning and action research, Godwin Kojo Ayenor. Funded by Interdisciplenary Research and Education Fund (INREF) and Directorate General of International Cooperation (DGIS), Ministry of Foreign Affairs of the Netherlands.
- **2001-2006** From a technology focus to innovation development. The management of cocoa pests and diseases in Ghana, Emmanuel N.A. Dormon. Funded by Interdisciplenary Research and Education Fund (INREF) and Directorate General of International Cooperation (DGIS), Ministry of Foreign Affairs of the Netherlands.
- **2001-2006** Facilitating learning toward sustainable cotton pest management in Benin. The interactive design of research for development, Antonio A.C. Sinzogan. Funded by Interdisciplenary Research and Education Fund (INREF) and Directorate General of International Cooperation (DGIS), Ministry of Foreign Affairs of the Netherlands.
- **2001-2006** Research on Agricultural Research. Towards a pathway for client-oriented research in West Africa, E. Suzanne Nederlof. Funded by Interdisciplenary Research and Education Fund (INREF) and Directorate General of International Cooperation (DGIS), Ministry of Foreign Affairs of the Netherlands.
- **2001-2006** Genomics approach to integration of host plant insect resistance and biological control. Funded by Dutch and Chinese government.
- **2001-2006** Cross-talk between signal-transduction pathways in induced defence of Arabidopsis against microbial pathogens and herbivorous insects. Funded by NWO/ALW.
- **2001-2007** Development of a method for breeding of cucumber for improved attraction of biological control agents. Funded by Technology Foundation (STW).
- **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.
- **2004-2007** Evolutionary transition from solitary to gregarious development in parasitoid wasps. Funded by NSF. (collaboration between Wageningen University, University of Minnesota, Norht Dakota State University and University of Illinois).
- **2004-2008** Linking variation in plant defence to higher level biodiversity. Experimental Plant Sciences, Strategic Funds. (collaboration between Entomology, NIOO and Plant Research International).
- **2004-2008** 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.
- **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.
- **2005-2006** Behaviour, anatomy and sensory physiology of chemosensillae in parasitoids. (Financed by Univ Ancona)
- **2005-2007** Evaluation of natural enemies in augmentative biological control. (Financed by Koppert BV)
- **2005-2008** Behaviour and elimination of supernumerary parasitoid larvae in *Eretmocerus mundus*. (Financed by Univ Palermo)
- **2005-2009** Phenotypic plasticity of taste in insects. Funded by the Royal Dutch Academy of Arts and Sciences (KNAW), in collaboration with the Chinese Academy of Sciences, Institute of Zoology, Beijing, China.
- **2005-2009** Effect of crop management on performance of endophytic *Fusarium* spp. in tissue culture banana against the banana weevil *Cosmopolites sordidus* (Germar) and nematodes in Uganda (sandwich scholarship).
- **2005-2009** 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)
- **2005-2009** Crop Protection Perspectives in Kazakhstan: Shifting Interfaces between Farmer Practice and Agricultural Research (funded by WUR and Kazakhstan)
- **2006-2007** Naturally healthy from day to day: a national interactive website for monitoring, forecasting, managing and communicating health risks from nature in space and time. (funded by RGI, the Netherlands – Space for Geoinformation)
- **2006-2008** Innovative biological control of malaria mosquitoes using fungi.
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- **2006-2009** Harmonization of regulation regarding risk assessment of exotic organisms. (Financed by EU)

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