WAGENINGEN UNIVERSITY
WAGENINGEN UR

ANNUAL REPORT 2003

LABORATORY OF ENTOMOLOGY

PERSONNEL PER 1 JANUARY 2003

Professors:
Prof. Dr. Marcel Dicke
Prof. Dr. Joop C. van Lenteren
Prof. Dr. Louis M. Schoonhoven (emeritus)
Prof. Dr. Louise E.M. Vet

Personnel:
Aggelen, Frans K.M. van
Almeida MSc, Raoul P. de (EMBRAPA)
Alvarez, Ir. Adriana E. (EU-Alβan))
Ardeh MSc, Mohammed J. (Min. Iran)
Berg, Dr. Ir. Henk van den (FAO)
Bleeker, Ir. Maartje A.K. (NWO)
Boer, Ir. Jetske G. de (NWO)
Boëte, Dr. Christophe, (EU)
Bruinsma, Drs. Maaike (NWO)
Bukovinszky MSc, Tibor (NWO)
Boot, Dr. Ir. Willem J. (Inbuzz)
Burgio MSc, G.
Boudewijn, Marthy
Calis, Dr. Johan (Inbuzz)
Charleston MSc, Deidre S. (IFS)
Dicke, Prof. Dr. Marcel
Docters van Leeuwen, Ir. Buul
Dormon, Ir. Emmanuel (INREF)
Fatouros, MSc, Nina
Gidding, André
Gebremedhin, MSc,Woldewahid (FAO/DGIS)
Gols, Ing. Rieta
Huigens, Dr. Ir. Ties M.E.
Huis, Dr.Ir. Arnold van
IJkhout, Bart
Jeong MSc, Gil Sang
Jong, Dr. Peter W. de
Jongema, Yde
Kappers, Dr.Ir. Iris F. (STW)
Kindt, Drs. Frodo (STW)
Knols, Dr. Ir. Bart G.J.
Koopman, Leo
Koyo Ayenor Giga, Godwin (INREF)
Lenteren, Prof. Dr. Joop C. van
Loon, Dr.Ir. Joop J.A. van
Luckerhoff, Ing. Ludo L.P. (STW)
Meijerink, Sabine M.
Nederlof, Ir. Suzanne (INREF)
Oosten, Drs. Vivian van (NWO)
Paaijmans, Ir. Krijn (WOTRO)
Pesch, Gerard J.K.
Poecke van, Dr. Ir. Remco M.P.
Potting, Dr. Ir. Roel P.J.
Qiu, MSc., Yu Tong (STW)
Roseboom, Dick J.
Scholte, Ir. Ernst Jan (WOTRO)
Schoonhoven, Prof. Dr. Louis M.
Schütte, Ir. Conny
Silva, Dr. Isabel M.M.S. (STW)
Sinzogan, MSc, Antonio (INREF)
Smallegange, Dr. Ir. Renate (NWO)
Smid, Dr. Hans M.
Snoeren, Ir. Tjeerd (NWO)
Spitzen, Ing. Jeroen
Takken, Dr.Ir. Willem
Tigges, Wouter
Tinzaara, MSc, W. (IITA)
Tjallingii, Dr. W. Freddy
Trefas MSc, Hajnalka
Tricault, Dr. Yann (EU)
Twigt, Wilma
Verbaarschot, Ing. Patrick
Vet, Prof. Dr. Louise E.M.
Vugt, Ir. Joke van (NWO)
Winkler, Ir. Karin (Bosch Foundation)
Yang, MSc, Limei (CAAS)

ANNUAL REPORT LABORATORY OF ENTOMOLOGY 2003

CONTENTS

Laboratory of Entomology
Wageningen University
Binnenhaven 7, 6709 PD Wageningen
P.O.Box 8031, 6700 EH Wageningen
Telephone: +31-(0)317-484075
Fax: +31-(0)317-484821
E-mail: office.ento@wur.nl
Website: http://www.dpw.wau.nl/ento/english/index.htm

Compilation: Marcel Dicke
Cover: the cover design is based on the cover of the PhD thesis by Dr. Isabel Silva

FOREWORD

Whether we like it or not, insects dominate your and my life. Most people do not realise to what extent their life is influenced by insects. Biodiversity on earth is predominantly a biodiversity of insects: of all animal species ca 80% walk on six legs. Insects are in our garden, in our house, in our clothes, and on our bodies. Insects are a wonderful group of organisms to investigate from a fundamental perspective, which is the first research interest of the Laboratory of Entomology of Wageningen University. In addition, insects are excellently suited for a teaching programme in Biology or Plant Sciences. Moreover, insects can be appropriate models for understanding the biology of other organisms. For instance, basic brain functions can very well be investigated in insects and extensive knowledge on the functioning of our own brain can be gained from hexapods. In medical sciences, the use of maggot therapy experiences a revival now that a worrysome number of bacteria develop resistance to antibiotics. Furthermore, robot developers use basic information about brain functioning in insects.

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. Last month we have received news that the Laboratory of Entomology has been ranked among the best research groups of Wageningen University, a position that we are very proud of.
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 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 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 2003. 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.wau.nl/ento/english/index.htm.

Marcel Dicke
Head of the Laboratory of Entomology

June 2004

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 2003
The laboratory of Entomology has experienced an intensive and productive year. Despite the financial constraints that are present in science world-wide, as well as in the Netherlands and in Wageningen, we have been able to continue our performance at a high level. Yet, this asks for more and more efforts to supplement the first money stream from the university to be able to finance our research programme.

The Dutch science foundation NWO has launched a new personal grant system called VENI-VIDI-VICI ("I came, I saw and I conquered"), after the famous quote from Julius Cesar. In 2003 Bart Knols was successful in the VIDI line of the programme with a research proposal entitled "Behavioural and ecological determinants of gene flow in African malaria mosquitoes" that was granted with 600.000 euro. After the

success in the VICI line (1.250.000 euro) by Marcel Dicke in 2002 this means that we have been able to acquire 2 major grants from this prestigious granting programme that was only started in 2002. In addition, staff members have obtained highly competitive grants from NWO and the EU for initiating 7 other research projects. These successes were made despite the ever increasing competitiveness during the selection process. Getting 'very good' or 'excellent' qualifications from reviewers no longer guarantees that a project will be funded and within the EU getting a 90% rating is not necessarily sufficient for being elected for funding.

In 2003 two books were edited: "Quality control and production of biological control agents – Theory and application", edited by Joop van Lenteren and "Ecological aspects for application of genetically modified mosquitoes" by Willem Takken and T.W. Scott. Furthermore, a special journal issue was edited: "Induced plant responses towards herbivory" in Basic and Applied Ecology by Monika Hilker and Marcel Dicke. In total, 118 papers have been published on our research, including papers in Nature Biotechnology, Behavioral Ecology and Sociobiology, Genome, Journal of Animal Ecology, Cell and Tissue Research, Oikos, Oecologia, Trends in Plant Science, Malaria Journal and Behavioral Ecology.

A total of 10 PhD students have successfully defended their theses in 2003, including the thesis by Ties Huigens that received a *cum laude* qualification, that is only given to the best 2% of the theses of Wageningen University. 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.

The courses that we teach have received enthusiastic responses from students. A total of 22 MSc theses have been completed in 2003 under the supervision of the Entomology staff. In the course *Insects and Society* the Dutch biologist Midas Dekkers explained that human children are very similar to insect larvae and other topics of the course included e.g. insects as food for humans, insects in culture, forensic entomology and maggot therapy. This course in Dutch is taught for students and laymen once every 2 years. Information on the contents (in Dutch) can be found on our website (http://www.dpw.wau.nl/ento/)

In the past year we have had retreats to discuss the research in the group (YELREM - Yearly Entomology Laboratory Research Exchange Meeting - topics in 2003: (a) Expression Profiling and (b) Biodiversity and Conservation Ecology) or to set the strategic goals of the group in general.

Cotesia glomerata parasitizing *Pieris brassicae* caterpillars Photo: Hans Smid

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 Control of Pests and Diseases I
- Biology and Control of Pests and Diseases II
- Biosystematics and Biodiversity
- Ecological Aspects of Bio-interactions
- Ecology
- Ecophysiology
- 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 2002/2003 a total of 24 students finished their MSc-thesis under the supervision of the staff of the Laboratory of Entomology. In addition, 3 students completed an internship at a national or international institution.

STUDENT THESES 2003

- Ayala, D., 03.23, Population structure of the malaria vector *Anopheles funestus* (Diptera) in Madagascar an in Comoros.
- Bakker, G., 03.14, Molecular analysis of species composition and kinship in breeding sites of the malaria vectors *Anopheles gambiae* sensu stricto and *Anopheles arabiensis*.
- Boons, P.A.H., 03.17, Natural horizontal transmission of *Wolbachia* in *Trichogramma* species.
- Boons, P.A.H., 03.02, Temporal patterns of parasitization levels of *Gnophodes chelys* by parasitoids and the life history of *Gnophodes chelys* studied.
- Helinski, M., 03.13, Fieldwork (bednets) Muheza, Tanzania
- Hendriksma, H., 03.20, Onderzoekstage in de bijenteelt
- Holtkamp, R., 03.10, Risicoschatting voor de kans op Lyme and populatiedynamiek in herfst and winter van *Ixodes ricinis* teken.

- Hulskes, A. & Kloth, K., 03.18, Host plant preference of the stemborers, *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) and *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) in relation to the push-pull system in South Africa.
- Kruidbos, F., 03.07, Contextueel foerageergedrag door de kasspintmijt *Tetranychus urticae*: de invloed van voedselkwaliteit op de tolerantie van predatierisico.
- Kruidbos, F. 03.08, De schapenteek *Ixodes ricinus*: tussen gastheer en vegetatie. Een exploratief onderzoek naar de fenologie en populatiedynamica van *I. ricinus* in twee studie gebieden in Nederland.
- Kruidhof, M. 03.04, Associative learning in *Cotesia glomerata* and *Cotesia rubecula*; an intra- and interspecific comparison of memory structure.
- Lengoiboni, M., 03.06, Geo-information for malaria risk assessment in Western Kenya.
- Lommen, S., 03.11, Caste biology of the termite *Bulbitermes sarawakensis* in Malaysia.
- Majambere, S., 03.15, The effects of old instars, food and space on survival and development of larval stages of the *Anopheles gambiae* Giles complex.
- Pinto, D. 03.21, Use floral nectar sources by the herbivore *Plutella xylostella* in diversified agroecosystems: attractivity and nutritional benefits.
- Pisa, L., 03.22, *Borrelia burgdorferi* infection in *Ixodes ricinus* nymphs collected in oak and pine dominated woodland in the Hoge Veluwe and the Amsterdam Water Supply Dunes.
- Rozema, M., 03.19, Wood-boring caterpillars in White cedar (*Tababuia heterophylla*) and Blady tree (*Pisonia subcordata*) on Saba (NL Antilles)
- Soler, R., 03.01, Performance of *Eretmocerus eremicus* (Hymentoptera: Aphelinidae) on *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae). Reproductions, development and searching behaviour.
- Termaat, T., 03.03, Effects of lepidopteran host egg size on larval mortality of *Wolbachia*-infested *Trichogramma kaykai*.
- Velema. H., 03.09, The influence of brochosomes on parasitisation efficiency of *Gonatocernus ashmeadi* (Girault) (Hymenoptera: Mymaridae), parasitising *Homalodisca coagulata* (Say) (Hemiptera: Cicadellidae) egg masses.
- Verhulst, N., 03.05, Blood meal identification of *Anopheles maculipennis* s.l. by enzyme-linked immunosorbent assay (ELISA).

PHD THESES 2003

A total of 10 PhD theses were completed and successfully defended:

- Boom van der, C.E.M., Plant defence in a tritrophic context : chemical and behavioural analysis of the interactions between spider mites, predatory mites and various plant species. Promotors: Prof. Dr. A. de Groot, Prof. Dr. M. Dicke; Co-promotor: Dr. T.A. van Beek;
- Gohole, L., Enhancing foraging behaviour of stemborer of stemborer parasitoids: role of a non-host plan *Melinus minutiflora.* Promotor: Prof. dr. L.E.M. Vet, Co-promotors: Dr. W.A. Overholt, Dr. Z. Khan;
- Huigens, M.E., On the evolution of Wolbachia-induced parthenogenesis in *Trichogramma* wasps Promotor: Prof. Dr. J.C. van Lenteren; Co-promotor: Dr. Ir. R. Stouthamer;
- Koenraadt, S., Mosquitoes, men and malaria in Kenya: a study on ecological factors affecting malaria risk. Promotor: Prof. Dr. J.C. van Lenteren; Co-promotor: Dr. Ir. W. Takken;
- Loomans, A., Parasitoids as biological control agents of thrips pests. Prof. Dr. J.C. van Lenteren;
- Masanza, M., Effect of crop sanitation on banana weevil *Cosmopolites sordidus* (Germar) populations and associated damage. Promotor: Prof. Dr. J.C. van Lenteren; Co-promotors: Dr.Ir. A. van Huis; Dr. C.S. Gold;

- Niyibigira, E., Genetic variability in *Cotesia flavipes* and its importance in biological control of lepidopteran stemborers. Promotor: Prof. Dr. J.C. van Lenteren; Co-promotor: Dr. Ir. R. Stouthamer;
- Nomikou, M., Combating whiteflies: Predatory mites as a novel weapon. Promotors: Prof.dr. M.W. Sabelis and Prof. dr. J.C. van Lenteren; Co-promotor: Dr. A. Janssen
- Tommassini, M., Evaluation of *Orius* species for biological control of *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). Promotor: Prof. Dr. J.C. van Lenteren;
- Woldewahid, G., Habitats and spatial pattern of solitarious desert locusts (*Schistocerca gregaria* Forsk.) on the coastal plain of Sudan. Promotor: Prof. Dr. J.C. van Lenteren; Co-promotors: Dr. Ir. A. van Huis; Dr. Ir. W. van der Werf.

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; Sara Boeke, Linde Hess, Limei Yang, Yu Tong Qiu, Maartje A.K. Bleeker, Wilant van Giessen and Sylvia Anton

Over the last year significant advances were made in our projects on neurobiology, olfactory electrophysiology and odour-mediated behaviour of malaria mosquitoes. Their olfactory receptor neurons are located in cuticular sensilla, that are present on the antenna and on the maxillary palps. Their axons project into spherical neuropil, the glomeruli, which are characteristic structures in the antennal lobe, the primary olfactory centre of insects. Olfactory receptor neurons in insects often respond to a limited set of volatile compounds (see below). The projection pattern of these neurons within the antennal lobe is largely unknown. We developed a method to stain central projections of receptor neurons responding to host odour compounds in the malaria mosquito, *Anopheles gambiae*. Axons from olfactory receptor neurons

innervating antennal sensilla arborized in only one glomerulus each and had few branches within it. The up to five neurons originating from the same sensillum, presumably responding to different host odour compounds, always branched into different glomeruli. Olfactory receptor neurons originating from maxillary palp sensilla all projected into one posterior-medial glomerulus in both the ipsi- and contralateral antennal lobe, a glomerulus which received in no case axon terminals of antennal receptor neurons. Staining of maxillary palp receptor neurons in a second mosquito species (*Aedes aegypti*) revealed unilateral arborizations in a glomerulus at a similar position as for *An. gambiae*. Our results indicate that olfactory receptor neurons with presumably different odour specificity project to different glomeruli within the antennal lobe of mosquitoes. Whether each host odour is represented in a distinct anatomical unit will have to be shown in the future by developing more sophisticated 3-dimensional data analysis methods.
Concomitant to the analysis of projection patterns of olfactory neurons in *An. gambiae* mosquitoes as outlined above, over the last year we have made considerable progress in the analysis of specificity profiles of olfactory neurons of antennal trichoid and basiconic sensilla or grooved pegs. In the morphological E- and C-subtypes of sensilla trichodea, 3 and 4 olfactory neuron types respectively have been identified. Discriminatory ligands that have been used are indole, geranylacetone, phenols and ammonia. Behavioural assays in our laboratory have demonstrated that these compounds have kairomonal effects on *An. gambiae*. In the grooved pegs three neuron types have been identified, characterised by their differential responses to lactic acid, oxocarboxylic acids and ammonia. These electrophysiological results can be linked to the tripartite synergism between lactic acid, ammonia and carboxylic acids demonstrated at the behavioural level in our windtunnel studies and shed light on olfactory coding mechanisms operating in this important vector insect.

Ecology, evolution and genetics of interactions between phytophagous insects, their host plants, and their enemies.
Peter W. de Jong, Patrick Verbaarschot

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 built up. 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. 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 does 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. In collaboration with Dr. Nielsen, we investigated the role of parasitoids in host plant use of the flea beetles, and we found that the beetles appear to suffer less from parasitism when they use *Barbarea* as host plant. In collaboration with the group in Leiden, we have begun to map the resistance genes with AFLP mapping. This has already led to an AFLP marker for a resistance gene found in one Danish population. At the same time, we have also started the development of microsatellite markers of flea beetles. This is ongoing work, and the aim is to link variation at the population level at the 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. Furthermore, we studied the effect of a resistance gene on the fitness of the flea beetles to directly assess the selection acting on the resistance in the flea beetles. We also studied the mechanism involved in the (un)suitability of *Barbarea* for the different genotypes of flea beetles by performing bioassays. Finally, we sampled the flea beetle populations in Denmark that were earlier sampled (1997) to assess the distribution of resistance in Danish flea beetle populations. By resampling, we aim to monitor the frequencies of resistant phenotypes (and eventually genotypes) and link that to our ecological and population genetic data. In the past year, Dr. Nielsen has established permanent field plots in Denmark, that are now available for field experimentation.

Infochemicals in multitrophic interactions

Marcel Dicke, Rieta Gols, Wouter Tigges, Adriana E. Alvarez, Jetske G. de Boer, Cindy E.M. van den Boom, Deidre S. Charleston, Nina Fatouros, Linde Hess, M.(Ties) E. Huigens, Iris F. Kappers, Ludo L.P. Luckerhoff, Vivian R. van Oosten, Remco M.P. van Poecke, Olivier Poitevin, Conny Schütte, Isabel M.M.S. Silva, William Tinzaara, and Limei Yang

Chemical communication among organisms is a widespread phenomenon that involves plants, insects, humans and many other organisms. The volatiles that plants emit in response to being damaged by herbivorous arthropods affect herbivorous and carnivorous arthropods as well as neighbouring plants. To allow careful manipulation of the emission of the volatiles we investigate the induction mechanism. Rieta Gols has demonstrated that the phytohormone jasmonic acid can induce volatile emission in a dose-dependent manner. Also, herbivore induction is dose dependent: it was amazing to find that predatory mites are even attracted to bean plants infested by only 1-4 spider mites for 3 days, albeit that an infestation of 50 spider mites was more attractive. Deidre Charleston demonstrated that an extract of leaves from the syringa tree induces parasitoid-attracting volatiles in cabbage plants. The active component remains to be identified. Research in collaboration with the group of Prof. Junji Takabayashi (Kyoto University) demonstrated that exposure of undamaged bean plants to volatiles from infested neighbouring bean plants primes the undamaged plants which results in a stronger response to subsequent herbivory, leading to a stronger attraction of carnivores.

Genes that code for enzymes involved in the biosynthesis of plant volatiles, particularly terpene biosynthesis genes, are being cloned in collaboration with the group of Dr. Harro Bouwmeester (Plant Research International). When such genes are inserted in plants such as potato or Arabidopsis the plants can be made to emit certain terpene volatiles constitutively. Iris Kappers and Ludo Luckerhoff have shown that as a result of this, carnivorous arthropods such as predatory mites are attracted to these undamaged transgenic potato or Arabidopsis plants.

Carnivorous arthropods are exposed to complex volatile blends emitted by herbivore-infested plants. However, they do not respond to all the volatiles but use a subset of volatiles instead. This response is subject to previous experience as has been shown by Jetske de Boer. The predatory mite *Phytoseiulus persimilis* can learn to discriminate between very similar blends of volatiles from prey-infested and non-prey infested bean plants. Individual compounds from the blend have been identified that mediate this learned response. Rewarding experiences, i.e. exposure to prey-infested plants, have a much stronger influence on

subsequent responses that non-rewarding experiences, i.e. exposure to non-prey-infested plants. In nature carnivorous arthropods forage in an environment that consists of many odour sources and the odour plumes mix. Yet, predatory mites were not found to be hindered by mixing odour blends, neither in an olfactometer nor in a semi-field setup.
The focus of our research concerns the influence of herbivore-induced plant volatiles on species interactions in food webs. This is addressed through an integration of molecular, analytical chemical, and behavioural approaches. Our research falls within the themes 'chemical and molecular ecology' and 'behavioural ecology'.
Infochemicals are interesting because they cannot be directly used in body building. Yet, the responses they elicit have important consequences for fitness, and thus for interactions in a community. Through manipulative studies we investigate the effects of the infochemicals on food-web interactions.
Our research addresses two main systems: (1) crucifer-*Pieris-Cotesia* interactions with an emphasis on the plant *Arabidopsis thaliana* and (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*. In addition we have initiated research on molecular ecology of aggregation pheromone in *Drosophila* (Ties Huigens).
The funding of a VICI project entitled *A molecular genetic approach to chemical ecology and community ecology* that will address a system of crucifers, lepidopteran herbivores and their parasitoids will intensify this research programme in the years to come.

Evolutionary Ecology
Louise E.M. Vet, Hans M. Smid, Tibor Bukovinszky, Maartje A.K. Bleeker, Roos Buitenhuis, Deidre S. Charleston, Linnet Gohole, 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 2003 Linnet Gohole and Roos Buitenhuis successfully finished their PhD projects. Linnet Gohole investigated why intercropping maize with molasses grass reduced damage by stem borer pests. It was shown that (especially host infested) plant odours play an important role in the searching behaviour of the two major parasitoids. Molasses grass was attractive to one of the parasitoid species but it was repellent to the other. However, behavioural studies showed that the host searching of the parasitoids was not really influenced by the presence of molasses grass, which was conclusive with field studies that did show a reduction in pest pressure when the grass was present but that did not show any effects of the grass on levels of parasitism.
Roos Buitenhuis compared the life history traits and host searching behaviour of four aphid hyperparasitoid species that differ in development mode (koinobiont or idiobiont), host stage attacked and host range. The

results revealed a large variation in life history traits between species, which could not be explained simply by dichotomy in development mode, as proposed for primary parasitoids. In many aspects, the life history parameters and behaviour of aphid hyperparastoids differ from those reported for primary aphid parasitoids. Olfactometer tests and behavioural observations indicated, for example, that searching hyperparasitoid females were not attracted by olfactory cues.
Hans Smid and Louise Vet spent a 4-month sabbatical at the Department of Biology, University of Toronto to add a genomics research line to our existing behavioural ecological and neurobiological studies on plant odour learning in parasitoids (see Maartje Bleeker, project entitled: "Learning-related differences at the neural level in two closely related parasitic wasps"). In close collaboration with Dr. Marla Sokolowski we aimed to compare gene expression of naïve wasps with experienced wasps in two parasitoid wasp species, which are different in associative learning, using the candidate gene- and the microarray approach. The methodologies were tested and the collaboration will be continued to find genes in our wasps that are known to be involved in learning (e.g. CREB, PKA, PKC) and spatial mobility (*for,* PKG).

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

*Habitats and spatial pattern of solitarious desert locusts (*Schistocerca gregaria *Forsk.) on the coastal plain of Sudan (Gebremedhin Woldewahid, Wopke van der Werf and Arnold van Huis)*
The spatial distribution of solitarious desert locusts on the Red Sea coastal plain of Sudan, and its relationship to plant communities, have been described and analysed. Multivariate data analysis resulted in the separation of four main plant communities in the study area: the *Suaeda monoica*, the *Acacia tortilis*, the *Panicum turgidum*, and the *Heliotropium*/millet plant community. The spatial extent of these plant communities was delineated, mapped and correlated with site descriptors such as soil particle size and moisture. Locust density maps were constructed using geostatistical methods, estimation errors were quantified and the relationship between sampling intensity and estimation error was established. The results show a strong relationship between solitarious desert locusts and the *Heliotropium*/millet plant community. Egg laying and hoppers were only found in this plant community. The *Heliotropium*/millet plant community occurs at the transition between the *P. turgidum* grasslands and the *S. monoica* scrub, at places where spreading wadies provide for supplemental water. This habitat is therefore characterised by better moisture status and has a higher nitrogen content in host plants than in surrounding habitats. Observations on other parts of the coastal plain confirmed the association between solitarious desert locusts and millet croplands. These croplands cover a restricted portion of the coastal plain (only 5% of the area). The collected information might be used in planning locust survey operations.
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.

Vector biology and control

Willem Takken, Sander C.J.M. Koenraadt, Bart G.J. Knols, Krijn Paaijmans, Yu Tong Qiu, Ernst-Jan Scholte, Renate C. Smallegange, and Jeroen Spitzen

Within the vector biology and control group, research continued to be focussed on mosquitoes and ticks. The major research themes are a) mosquito-host interactions, b) population ecology and control of malaria vectors and c) the risk of Lyme disease in The Netherlands.

Mosquito-host interactions: as the force of transmission of vector-borne parasites and pathogens is much determined by the biting rate of the vectors, our research is focussed on the processes that regulate vector-host contacts. In this, we study mosquito physiology and behaviour. In the past year, it was found that multiple feeding of malaria mosquitoes *Anopheles gambiae* is importantly determined by metabolic reserves at emergence. Multiple feeding can overcome these effects, and leads to increased mosquito fitness. Single-cell electrophysiology revealed odour-specific olfactory receptors on the mosquito antennae, suggesting functional differentiation at odour receptor level. Field studies in The Gambia, West Africa, confirmed the activity of odour blends consisting of NH_3, lactic acid and carboxylic acids. The results also confirmed the essential role of CO_2 in the behaviour of *An. gambiae* and other mosquitoes. A candidate synthetic odour blend appeared to be as attractive as the natural odours of a human host.

Population ecology and control of malaria vectors: Field and laboratory studies on the use of the entomopathogenic fungus *Metarhizium anisopliae* revealed that this fungus has a potentially large impact on adult *Anopheles gambiae*. Laboratory studies showed a strong dose-dependent relationship, causing high mortality within a few days following inoculation. Blood-feeding behaviour and reproduction were also affected. In a field trial in Tanzania, the fungus was tested as a contact biological agent from cotton screens attached to walls and ceilings of rural homes. It was found that mosquitoes became rapidly infected and that up to 18.5% of mosquitoes collected in such houses died because of fungal infection. The combined studies show the great potential of a novel method of anopheline vector control using a biological control agent.

In another study in western Kenya, the genetic composition of larvae of *Anopheles arabiensis* was investigated using microsatellites. The purpose of the study was to obtain information in oviposition behaviour of adult female mosquitoes. Using 9 microsatellites, we found a high degree of kinship between larvae collected in the same breeding site and that few females used several (but adjacent) larval sites for oviposition.

Risk of Lyme disease in The Netherlands: Last year, we reported on the initiation of a pilot study to investigate the seasonal phenology and association between *Ix. ricinus* and its vertebrate hosts and habitat. The study is conducted in a dune area south of Haarlem and within the National Park Hoge Veluwe, in the centre of the country. The first results of the study indicated significant differences in tick density and population activity between the two study sites: in the dune area ticks were active already in February, while in the centre of the country ticks became active several weeks later. Questing activity continued until late in October, with nymphs remaining active throughout the winter on days with temperatures >5^{o}C. *Borrelia* infections in nymphal ticks varied from 5 – 10%, with 4 genospecies present.

From behavioural and population ecology to functional biodiversity and agro-ecology

Joop C. van Lenteren, Mohammed Ardeh, Tibor Bukovinszky, Rieta Gols, Gladys Gonzalez, Antoon J.L. Loomans, Hajnalka Trefas, Wouter Tigges, Yann Tricault, Louise E.M. Vet, Raf de Vis, Felix L. Waeckers, 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), currently our main activities are in the field of Functional Biodiversity and Agroecology (the third research theme of the Laboratory).

Behavioural and population ecology: 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. In a combination of field work in Costa Rica, laboratory and modelling work in Wageningen, Joep Burger showed that at very low host densities, which often occur in the natural habitat of whitefly, killing hosts by host feeding is maladaptive; the hosts should primarily be used for parasitisation for production of offspring. At the high host densities normally found in greenhouses, parasitoids that host feed produce more eggs per unit of time than those that were not allowed to host feed. The results of these very important fundamental studies on *Encarsia* and *Trialeurodes* are now appearing in international journals (see publication list).

In order to better understand parasitoid foraging behaviour and to evaluate the biocontrol capabilities of natural enemies we have earlier developed individual-based simulation models for the relationship between *Encarsia* parasitoids, whitefly herbivores and host plants. Currently, Yann Tricault has adapted the models (1) to include the relationship between parasitoids and entomopathogens, and (2) to include behaviour of different *Encarsia formosa* strains. We are now studying the potential interference of parasitoids and pathogens in biocontrol of whitefly, as well as the difference in control capacity of *Encarsia* strains.

In an ongoing whitefly biological control project, Mohammed Ardeh studies arrhenotokous and thelytokous strains of *Eretmocerus* species, and the benefits and costs of the use of thelytokous parasitoids in control of whiteflies. Many results of our earlier studies on various other natural enemies of *Trialeurodes* and *Bemisia* have been summarised and published this year (K. Hudak et al., M. Manzano et al., Y.T. Qiu et al., R. de Vis et al.; see publication list).

During this year, the book on *Quality Control and Production of Biological Control Agents: Theory and Testing Procedures* appeared, which is meant for all persons involved in rearing of insects. We also produced one of the first papers on risk assessment of exotic natural enemies (van Lenteren et al., see publication list) and finalised a guidance document for regulation of import and release of natural enemies with an OECD working group.

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 and Felix Wäckers studied the effect of the provision of nectar and pollen in field edges on the development of natural enemy populations. Although there is growing interest for the use of flowering field margins to boost natural enemies, it is often forgotten that pest species may as well profit from additional nectar sources, so these potential negative effects were studied as well. We aimed at identifying flowering plant species which selectively fulfil the needs of predators and parasitoids, without supporting pest organisms, and found several plants that fulfil this aim.

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 oviposition 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 available information and our own field results do not yet allow generalisations 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 agro-ecosystems.

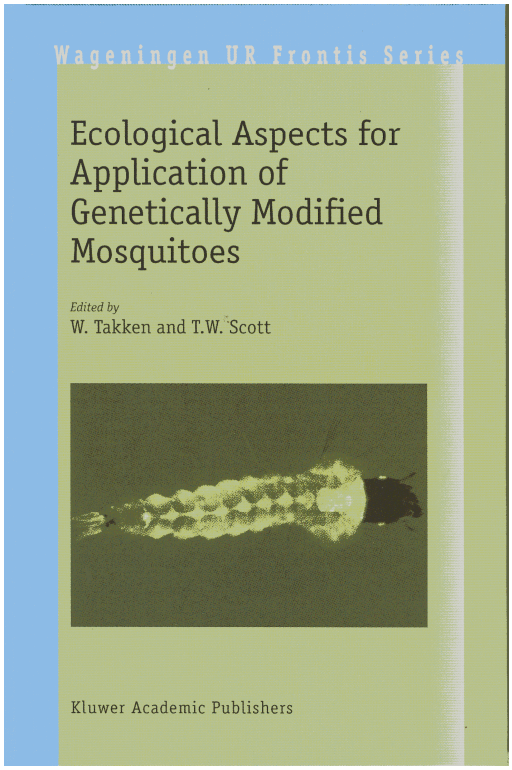
Spatio-temporal dynamics of herbivores and their antagonists in diversified agro-ecosystems.
Roel P.J. Potting

There is a rapidly increasing interest in using agro-ecosystem diversification as a pest management strategy. Using this strategy pest-disturbing and/or natural enemy-enhancing plants are embedded in agro-ecosystems, with the aim of decreasing the pest density. However, increasing the vegetational diversity of agroecosystems can have variable results depending on the species of herbivore, natural enemy and vegetation involved. The main objective of this project is to develop a mechanistic framework to understand and predict the response of herbivores and natural enemies in relation to composition and spatial arrangements of vegetation in agricultural systems. An object-oriented individual-based simulation framework was developed that includes behavioural-based stochasticity and spatial structures based on vegetation composition and structure. With the model we determine optimal diversification strategy sets. We thereby generate guidelines for practitioners trying to establish an environmental benign control strategy in the field. In addition, the model indicates which aspects of the ecology of the plants and insects are determining factors. The research in this project is strongly embedded in the theme 'Functional biodiversity and Agroecology'. It provides a conceptual framework to understand insect response to diversified ecosystems and enables an extrapolation of our knowledge of individual behaviour to the spatial and temporal population dynamics at a field scale level. Within the theme 'Functional biodiversity and Agroecology', the aim of this project is to integrate experimentation and simulation. As a first step, the simulation framework was adapted to the specific ecology of crucifer pests (*Plutella xylostella* and *Pieris rapae*) to understand field-experimental data of insect response to specific intercrop strategies.
The development and implementation of the individual-based simulation framework continued. In collaboration with T. 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. To upscale the virtual environment of the simulation framework it is now possible to load landscape maps (generated by RULE software) with or without specified herbivore densities. This will form the template to simulate the searching behaviour of the parasitoid *Diadegma semiclausum* and investigate the evolution of learning strategies of parasitoids.

Aphid-plant interactions and host plant resistance.
W.Freddy Tjallingii, Frodo Kindt, Elisa Garzo and Adriana E. Alvarez

Plant penetration activity by insect mouthparts, of aphids and thrips in particular has been studied by the use of the electrical penetration graph (EPG) technique. Fundamental research (in international co-operation) on aphid activities during stylet penetration of phloem sieve elements and reactions on plant responses has revealed a number of interesting results. First, the role of the saliva injected into the sieve elements at the start of a sieve element puncture has shown to play a role in the suppression phloem wound responses, especially in the avoidance of 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. Elisa Garzo has started 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 circulative viruses by the aphid.
In another new project (Adriana 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.
Frodo Kindt's EPG and video study (PhD) on probing behaviour of thrips (*Frankliniella occidentalis*) on peppers (*Capsicum annuum*) was finished in 2003 by showing evidence that 1) a single probe can transmit tomato spotted wilt virus (TSWV), 2) that TSWV inoculation needs only stylet insertion and salivation, 3) that inoculation success is very low (<1%) and reduced by subsequent sap ingestion, which is responsible for TSWV acquisition, 4) that 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. 1999-2003. 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*. 1992-2004. 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- 2d15. Indirect defense of plants: variation among plant species and determination of the bioactivity and chemical nature of the plant volatiles involved. 1997-2003. C.E.M. van den Boom, T.A. van Beek, M. Dicke & A.E. de Groot.
- EPS2-2d19. Quantitative and qualitative variation in odour blend composition: effect on behavioural responses of predatory mites 1999-2003. 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. 1998-2004. C. Schütte, I.M.M.S. Silva, O. Poitevin, and M. Dicke
- EPS2-2d24 new. 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. L. Hess, 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), R. Stouthamer and L. Beukeboom (RUG).

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. Extrafloral nectar in a tri-trophic context. 2000-2003. F.L. Wäckers.

- PE31-98a. Effects of molasses grass (*Melinis minutiflora)* on the foraging behaviour and searching efficiency of cereal stemborer parasitoids in cereal based cropping systems. 1997-2003. L.S. Gohole, L.E.M. Vet, Z.R. Khan and W.A. Overholt.
- PE&RC32-00aj. Factors that affect host searching by anopheline mosquitoes. W. Takken.
- PE32-94a. Understanding biological control of whiteflies by natural enemies. J.C. van Lenteren, Y. Tricault.
- PE&RC31-00f. Genomic conflicts over sex ratios in Trichogramma wasps 1999-2003. M. E. Huigens & R. Stouthamer.
- PE&RC Wolbachia genome project 2000-2003. F.Vavre and R. Stouthamer.
- 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 – 2004. K. Winkler, J.C. van Lenteren, F. Wäckers.
- PE&RC32-01e. The role of the natural enemies in reducing whitefly populations in Panama. G.I. Gonzalez, J.C. van Lenteren. 1999 – 2003.
- PE&RC31-00u. Learning-related differences at the neural level in two closely related parasitic wasps: a comparison between a generalist and a specialist. 2000-2004. M.A.K. Bleeker, H.M. Smid, J.J.A. van Loon & L.E.M. Vet.
- PE32-94h. Biological control of thrips pests: Evaluation of hymenopterous parasitoids as potential biological control agents of Western Flower Thrips (*Frankliniella occidentalis*). 1991-2003. A.J.M. Loomans, J.C. van Lenteren.
- PE&RC. Enhancing the biocontrol of the Western Flower Thrips (*Frankliniella occidentalis*) with the predatory bug (*Orius laevigatus*) on greenhouse cucumber. 1998-2004. J. Hulshof, A.J.M. Loomans, J.C. van Lenteren.
- PE&RC32-01b. Integrating Geographical Information Systems and Cellular Automata for the Assessment of Malaria Risk and Control. 1998-2003. C.J.M. Koenraadt, and W. Takken. In cooperation with Maastricht University.
- PE&RC23-00i. Genetic variability in *Cotesia flavipes* Cameron and its significance for population establishment in the biological control of lepidopteran stemborers, 1998-2003 E.I. Niyibigira, R. Stouthamer & W.A. Overholt.
- PE39-97a. Designing improved Desert Locust survey operations and control strategies using scenario studies. 1998-2003. W.T. Gebremedhin & A. van Huis.
- PE&RC. Social parasitism in the Cape honeybee *Apis mellifera capensis*. 2001-2003. W.J. Boot, J. Calis & L.E.M. Vet.
- 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*. 1999-2003. 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

REPRESENTATION IN EXTERNAL COMMITTEES

International:

- Advisor crop protection to consortium developing the SeaWaterGreenhouse (van Lenteren)
- British Ecological Society, Symposium Series, Advisory Editorial Board (Vet)
- Contractor EU project Environmental Risks of Importing Exotic Natural Enemies for Biological Control (ERBIC) (van Lenteren)
- European Branch Society of Vector Ecology 2002-2006 (Takken, president)
- European Academies' Science Advisory Council, Environment Strategy Group (Vet)
- 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 (van Lenteren)
- Honorary Professor University of Perugia, Italy (van Lenteren)
- International Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC-IUBS) (2000-2004) (van Lenteren, Vice President)
- International Organization for Biological and Integrated Control of Noxious Animals and Plants, West Palearctic Regional Section (IOBC-WPRS), Council (van Lenteren)
- International Congress of Entomology, Council (1998-2004) (Takken)
- International Congress of Entomology, Brisbane August 2004, Organisation of several symposia (Dicke, van Loon, Vet).
- International Congress of Vector Ecology, Scientific board, (Takken)
- 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 Working Group on Mediators of Bloodfeeding Arthropods (Takken, secretary)
- Local Organisation Committee International Symposium TERPNET 2005, Wageningen, April 2005 (Dicke)
- 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)
- Selection committee Professor of Entomology, Giessen University, Giessen, Germany (Dicke)

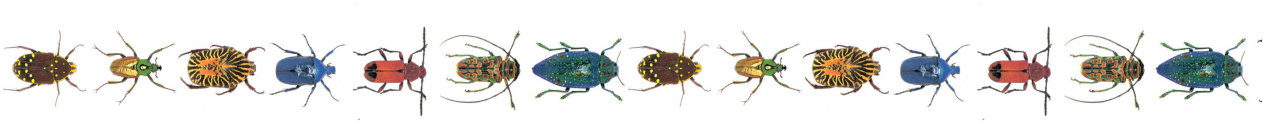
National:

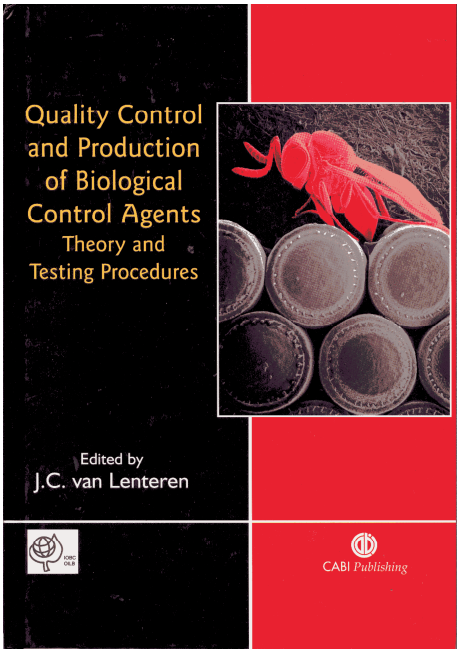
- Biological advisory board, Biologische Raad, KNAW (Vet)
- Board for the Authorisation of Pesticides "CTB" (van Lenteren).
- Board IAC course on crop protection (van Lenteren).
- Board of 'Landbouwexport fonds 1918', Wageningen (Dicke)
- Board Uyttenboogaart-Eliasen fund (van Lenteren).
- Board Van Groenendael-Krijger fund (van Lenteren).
- 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)
- Department of Plant Sciences, Wageningen University, Committee International Affairs (van Huis)
- 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)
- Library Committee, Centre for Crop Protection, Wageningen University (De Jong).
- Management Advice Committee of National Science Foundation ALW (Beleids Advies Commissie ALW) (Dicke)
- 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)
- Organising Committee of workshops of NWO Stimulation Program Biodiversity (Potting)
- PhD Examination committees at different national universities (Dicke, van Loon, van Huis, van Lenteren, Takken, Vet).
- Programme Committee Plant Sciences, Wageningen University (Takken).
- Project Enhanced Biodiversity, Alterra, Laboratory of Entomology, Laboratory of Phytopathology, Laboratory of Plant Ecology and Weed Science (van Lenteren, coordinator; Vet)
- Representative Department for ROC Biology (Dicke).
- Selection committee Professor of Evolutionary Phytopathology, Wageningen University (Dicke)
- Selection committee Professor of Functional Biodiversity with special attention to multitrophic interactions of above-below ground interactions, Wageningen University (Dicke)
- 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)
- Basic and Applied Ecology. Guest Editor for special issue on 'Induced responses of plants towards herbivory' (Dicke).
- Biochemical Systematics and Ecology (Dicke, editorial board).
- Biological Control: Theory and Application in Pest Management (van Lenteren, editorial board).
- Bionieuws, column (Vet)
- Chemoecology (Vet, editorial board).
- Ecological Entomology, editorial board (Dicke, editorial board)

- Entomologia Experimentalis et Applicata (co-editor, van Loon).
- Entomologische Berichten – bimonthly column (Dicke)
- Insect Science and its Application (van Huis, Editorial Advisory Board).
- Bulletin of Insectology (van Lenteren, editorial board)
- International Journal of Pest Management (van Lenteren, editorial board).
- IOBC bulletins (van Lenteren, editor).
- IPM practitioner (van Lenteren, editorial board).
- Journal of Insect Behavior (van Lenteren, Vet, editorial board).
- Journal of Chemical Ecology (Dicke, editorial board).
- Journal of Ethology (Dicke, advisory board)
- Neotropical Entomology (van Lenteren, editorial board)





PROJECTS FUNDED EXTERNALLY

- **1998-2003** Genetic variability in Cotesia flavipes Cameron and its significance for population establishment in the biological control of lepidopteran stemborers. Funded by WOTRO.
- **1998-2003** Improvement of Desert Locust Survey and control strategies. Funded by DGIS.
- **1999-2003** Quantitative and qualitative variation in odour blend composition: effect on behavioural responses of predatory mites. Funded by ALW-NWO.
- **1999-2003** Antagonistic and synergistic effects of resistances in sweet pepper on transmission of Tomato Spotted Wilt Virus and population development of Western Flower Thrips. Funded by Technology Foundation (STW).
- **1999-2003** Genomic conflicts over sex ratios in *Trichogramma* Wasps. Funded by NWO/ALW
- **1999-2003** Factors important for the biological control performance of *Trichogramma*. Funded by EMBRAPA.
- **2000-2003** Evaluating environmental risks of biological control introductions into Europe (ERBIC) Funded by EU.
- **2000-2003** Extrafloral nectar in a tri-trophic context. Funded by KNAW.
- **2000-2003** *Wolbachia* genome project (EUWOL). Funded by EU.
- **2000-2003** Effect of crop sanitation on timing of attack, distribution and survivorship of the banana weevil *Cosmopolitan sordidus* (Germar) (Coleoptera: Curculionidae) in banana fields in Uganda. Funded by WOTRO
- **2001-2003** Social parasitism in the Cape honeybee *Apis mellifera capensis*. Funded by WOTRO.
- **2001-2003** Assessment of malaria risk in areas with different transmission characteristics as determined by environmental factors and mosquito bionomics. Funded by WOTRO.
- **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 the 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.
- **2002-2004** Induced defence of *Arabidopsis* against herbivorous insects: cross-talk with induced defences against microbial pathogens. Funded by Graduate school Experimental Plant Sciences.
- **2000-2004** Chemical ecology and management of the banana weevil *Cosmopolites sordidus* (Germar) (Coleoptera: Curculionidae) Funded by IITA.
- **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.
- **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).
- **2003-2006** EU-FIPSE Transatlantic Exchange Program in Higher education on Sustainable Crop Protection (SUSPROT) Funded by EU.
- **2003-2007** Molecular characterisation of mechanisms of *Solanum* resistance to *Myzus persicae* - Impact on PLRV transmission. Funded by Alβan-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.
- **2003-2008** Linking variation in plant defence to higher level biodiversity. Experimental Plant Sciences, Strategic Funds. (collaboration between Entomology, NIOO and Plant Research International).
- **2003-2008** A molecular genetic approach to chemical ecology and community ecology. Funded by NWO-VICI.
- **2003-2008** Behavioural and ecological determinants of gene flow in African malaria vectors. Funded by NWO-VIDI.
- **2003-2008** Ecological and physiological functions of biogenic isoprenoids and their impact on the environment (ISONET). Funded by EU.

Beninese farmer explaining weed control measures to scientists - Photo: Arnold van Huis

PUBLICATIONS

- Allsopp, M.H., Boot, W.J., Calis, J.N.M 2003. Differential feeding of worker larvae affects caste characters in the Cape honeybee, *Apis mellifera capensis*. Behavioral Ecology and Sociobiology 54: 555-561
- Almeida, R.P. de, Stouthamer, R. 2003. Molecular identification of *Trichogramma cacoeciae* Marchal (Hymenoptera: Trichogrammatidae): A new record for Peru. Neotropical Entomology 32: 269-272
- Anonymous (Lenteren, J.C. van, et al.) Guidance for regulation of invertebrates as biological control agents (IBCAs). Organization for Economic Cooperation and Development (OECD), Paris: 19 pp.
- Anton, S., Loon, J.J.A. van, Meijerink, J., Smid, H.M., Takken, W., Rospars, J-P 2003. Central projections of olfactory receptor neurons from single antennal and palpal sensilla in mosquitoes Arthropod Structure & Development 32: 319-327
- Ardeh, M.J., Lenteren, J.C. van, Loomans, A.J.M. 2003. Putative sex pheromone and mating behaviour in the whitefly parasitoid *Eretmocerus eremicus* Rose & Zolnerowich. Proceedings of the Section Experimental and Applied Entomology of the Netherlands Entomological Society 14: 75-80
- Berg, H. van den, Senrath, H., Amarasinghe, L 2003. Farmer field schools in Sri Lanka: assessing the impact. Pesticides News. Journal of the Pesticides Trust 61: 14-16
- Bjornson, S., Schuette, C 2003. Pathogens of mass-produced natural enemies and pollinators In: Quality control and production of biological control agents: theory and testing procedures / J.C. van Lenteren. - CABI Publishing, pp. 133-165
- Boeke, S.J., Kossou, D.K., Huis, A. van, Loon, J.J.A. van, Dicke, M. 2003. Field trials with plant products to protect stored cowpea against insect damage. International Journal of Pest Management 50: 1-9
- Boeke, S.J., Sinzogan, A.A.C., Almeida, R.P. de, Boer, P.W.M. de, Jeong, G.S., Kossou, D.K., Loon, J.J.A. van 2003. Side-effects of cowpea treatment with botanical insecticides on two parasitoids of Callosobruchus maculatus Entomologia Experimentalis et Applicata 108: 43-51
- Boom, C.E.M. van den 2003. Plant defence in a tritrophic context: chemical and behavioural analyses of the interactions between spider mites, predatory mites and various plant species. Wageningen Universiteit. Promotoren: Prof.dr. Æ. de Groot, Prof.dr. M. Dicke, co-promotor: Dr. T.A. van Beek. - Wageningen : C.E.M. van den Boom, 2003.- 148 pp.
- Boom, C.E.M. van den 2003. Verdedigingsmechanismen van planten in een tritroof systeem Gewasbescherming 34: 194-196
- Boom, C.E.M. van den, Beek, T.A. van, Dicke, M. 2003. Differences in host plant acceptance of the two-spotted spider mite *Tetranychus urticae*. Journal of Applied Entomology 127: 177- 183.
- Bouwmeester, H.J., Verstappen, F.W.A., Aharoni, A., Lücker, J., Jongsma, M.A., Kappers, I.F., Luckerhoff, L.L.P., Dicke, M. 2003. Exploring multi-trophic plant-herbivore interactions for new crop protection methods. In: Proceedings of the British Crop Protection Council International Congress Crop Science & Technology 2: 1123-1134
- Bueno, V.H.P., Lenteren, J.C. van 2003. The popularity of augmentative biological control in Latin America: history and state of affairs. In: 1st International Symposium on Biological Control of Arthropods : Symposium, Honolulu, Hawaii , pp. 180-184
- Bueno, V.H.P., Lenteren, J. C. van, Silveira, L. C. P., Rodrigues, S. M. M. 2003. An overview of biological control in greenhouse chrysanthemums in Brazil. Bulletin IOBC/WPRS 26(10): 1-5.

- Bukovinszky, T., Brewer, M.J., Winkler, K., Trefas, H., Vet, L.E.M., Lenteren, J.C. van 2003. Effects of flowering field margins on flight activity of the diamondback moth (*Plutella xylostella* L.) and its parasitoids *Diadegma* spp., and observations on distance from field edge, and vertical position of traps In: Proceedings Integrated Protection in Field Vegetable Crops : Meetings at Gödöllö (Hungary) and Krakow (Poland) IOBC/WPRS Bulletin 26 (3): 307-314
- Bukovinszky, T., Potting, R.P.J., Clough, Y., Lenteren, J.C. van, Vet, L.E.M 2003. Responses of insect herbivores to habitat texture: the role of foraging strategy. In: Landscape Management for Functional Biodiversity. IOBC WPRS Bulletin 26(4): 25-29
- Bukovinszky, T., Rasztik, V., Lenteren, J.C. van, Vet, L.E.M., Bujaki, G. 2003. The effects of undersowing (Brussels sprouts - black mustard) on population density of *Brevicoryne brassicae* and natural enemies of aphids IOBC-WPRS Bulletin 26 (3): 167-176
- Choi, Y.H., Bohan, D.A., Semenov, M.A., Potting, R.P.J., Glen, D.M. 2003. Slugs and nematodes in a fighting arena - individual based models of parasitism. In: 2003. British Crop Protection Council Symposium proceedings 80 , 2003. - p. 177-182
- Dam, N.M. van, Harvey, J.A., Waeckers, F.L., Bezemer, T.M., Putten, W.H. van der, Vet, L.E.M 2003. Interactions between aboveground and belowground induced responses against phytophages. Basic and Applied Ecology 4: 63-77
- Dicke, M. 2003. Slapende vliegen wakker maken. Entomologische Berichten Amsterdam 63: 1
- Dicke, M. 2003. Insecten en oorlog. Entomologische Berichten Amsterdam 63: 25
- Dicke, M. 2003. Bruin. Entomologische Berichten Amsterdam 63: 49
- Dicke, M. 2003. Angst. Entomologische Berichten Amsterdam 63: 81
- Dicke, M. 2003. Boekenwurm op vakantie. Entomologische Berichten Amsterdam 63: 109
- Dicke, M. 2003. Dood en bezieling. Entomologische Berichten Amsterdam 63: 137
- Dicke, M. 2003. Hoe planten insecten herkennen: van 'spitting image' tot voetstapherkenning. www.kennislink.nl 2003.: 1-6
- Dicke, M. 2003. Geïnduceerde geurstoffen van planten: van gen tot levensgemeenschap. In: NWO/ALW Jaarverslag 2002 Den Haag : Nederlandse Organisatie voor Wetenschappelijk Onderzoek , 2003.
- Dicke, M. 2003. Mijten mijden mijten. Kennislink (2003.) - p. 1-4 In: Kennislink http://kennislink.weten.nl. - Stichting Weten, 2003. - 4 pp.
- Dicke, M., Agrawal, A.A., Bruin, J., 2003. Plants talk, but are they deaf? Trends in Plant Science 8: 403-405
- Dicke, M., Boer, J. de, Höfte, M., Rocha-Granados, C. 2003. Mixed blends of herbivore-induced plant volatiles and foraging success of carnivorous arthropods. Oikos 101: 38-48
- Dicke, M., Hilker, M. 2003. Induced plant defences: from molecular biology to evolutionary ecology. Basic and Applied Ecology 4: 3-14
- Dicke, M., Poecke, R.M.P. van, Boer, J.G. de 2003. Inducible indirect defence of plants: from mechanisms to ecological functions. Basic and Applied Ecology 4: 27-42
- Drijfhout, F.P., Groot, A.T., Beek, T.A. van, Visser, J.H. 2003. Mate location in the green capsid bug, *Lygocoris pabulinus* Entomologia Experimentalis et Applicata 106: 73-77
- Gnanvossou, D., Hanna, R., Dicke, M., 2003. Infochemical-mediated intraguild interactions among three predatory mites on cassava plants. Oecologia 135: 84-90
- Gnanvossou, D., Hanna, R., Dicke, M. 2003. Infochemical-mediated niche use by the predatory mites *Typhlodromalus manihoti* and *T. aripo* (Acari: Phytoseiidae). Journal of Insect Behavior 16: 523-535
- Gnanvossou, D., Yaninek, J.S., Hanna, R., Dicke, M., 2003. Effects of prey mite species on life history of the phytoseiid predators *Typhlodromalus manihoti* and *Typhlodromalus aripo* Experimental and Applied Acarology 30: 265-278

- Gohole, L.S. 2003. Enhancing foraging behaviour of stemborer parasitoids: role of a non-host plant *Melinis minutiflora*. Dissertation. Promotor: Prof. Dr. L.E.M. Vet. - Wageningen : [s.n.], 2003. - 140 pp.
- Gohole, L.S., Overholt, W.A., Khan, Z.R., Vet, L.E.M 2003. Role of volatiles emitted by host and non-host plants in the foraging behaviour of *Dentichasmias busseolae*, a pupal parasitoid of the spotted stemborer *Chilo partellus*. Entomologia Experimentalis et Applicata 107: 1-9
- Gohole, L.S., Overholt, W.A., Khan, Z.R., Pickett, J.A., Vet, L.E.M. 2003. Effects of molasses grass, *Melinis minutiflora* volatiles on the foraging behavior of the cereal stemborer parasitoid, Cotesia sesamiae. Journal of Chemical Ecology 29: 731-745
- Gols, G.J.Z., Roosjen, M., Dijkman, H., Dicke, M. 2003. Induction of direct and indirect plant responses by jasmonic acid, low spider mite densities, or a combination of jasmonic acid treatment and spider mite infestation Journal of Chemical Ecology 29: 2651-2666
- Groot, A.T., Heijboer, A., Visser, J.H., Dicke, M. 2003. Oviposition preference *of Lygocoris pabulinus* (Het., Miridae) in relation to plants and conspecifics. Journal of Applied Entomology 127: 65-71
- Hajnalka, T., Bukovinszky, T., Lenteren, J.C. van, Bujaki, G. 2003. Activity and dispersal of a generalist predator (*Pterostichus melanarius*, Col.: Carabidae) in intercrops and monocrops of Brussels sprouts and brewer's barley - preliminary results. In: Landscape Management for Functional Biodiversity. - IOBC WPRS Bulletin 26(4): 173-178
- Harvey, J.A., Dam, N.M. van, Gols, G.J.Z., 2003. Interactions over four trophic levels: foodplant quality affects development of a hyperparasitoid as mediated through a herbivore and its primary parasitoid. Journal of Animal Ecology 72: 520-531
- Hilker, M., Dicke, M. 2003. Induced plant responses towards herbivory. Basic and Applied Ecology 4: 1-2
- Hokkanen, H.M.T., Bigler, F., Burgio, G., Lenteren, J.C. van, Thomas, M.B. 2003. Ecological risk assessment framework for biological control agents. In: Environmental Impacts of Microbial Insecticides / Hokkanen, H.M.T., Hajek, A.E. - Dordrecht: Kluwer Academic Publishers, 2003. (Progress in biological control; Vol. 1). - p. 1-14
- Horiuchi, J.I., Arimura, G.I., Ozawa, R., Shimoda, T., Dicke, M., Takabayashi, J., Nishioka, T. 2003. Lima bean leaves exposed to herbivore-induced conspecific plant volatiles attract herbivores in addition to carnivores. Applied Entomology and Zoology 38: 365-368
- Huibers, F.P., Takken, W., Klinkenberg, E., Touré, Y.T. 2003. The phenology of malaria mosquitoes in irrigated rice fields in Mali. Acta Tropica 85: 71-82
- Huigens, M.E. 2003. On the evolution of *Wolbachia*-induced parthenogenesis in *Trichogramma* wasps. Wageningen. Promotor: Prof. J.C. van Lenteren, co-promotor: Dr. Ir. R. Stouthamer. - Wageningen: 2003. - 183 pp.
- Huigens, M.E., Stouthamer, R. 2003. Parthenogenesis associated with *Wolbachia*. In: Insect Symbiosis / Bourtzis, K. Miller, T.A. (eds) - CRC Press, Boca Raton FL. - pp. 247-265
- Huis, A. van, 2003. Insects as food in Sub-Saharan Africa. Insect Science and its Application 23: 163-185
- Huis, A. van, Bruin, J. de 2003. Sectie Experimentele en Toegepaste Entomologie van de NEV. Entomologische Berichten Amsterdam 63: 43-45
- Huis, A. van, Meerman, F. 2003. Innovation through integrated pest management requires new roles and attitudes from scientists. In: Integrated Pest and Vector management in the tropics: Perspectives and Future strategies: 15th Biennial congress of the African Association of insect scientists and silver jubilee celebrations jointly organised with the Entomological society of Kenya, Nairobi, 1-13 June 2003. / Bahana, Bal, Dakouo, Omwega. - 2003.

- Hulshof, J., Ketoja, E., Vänninen, I., 2003. Life history characteristics of *Frankliniella occidentalis* on cucumber leaves with and without supplemental food Entomologia Experimentalis et Applicata 108: 19-32
- Kindt, F., Joosten, N.N., Peters, D., Tjallingii, W.F. 2003. Characterisation of the feeding behaviour of western flower thrips in terms of electrical penetration graph (EPG) waveforms Journal of Insect Physiology 49: 183-191
- Knols, B.G.J., Dicke, M. 2003. Bt crop risk assessment in the Netherlands. Nature Biotechnology 21: 973-974
- Knols, B.G.J., Dicke, M. 2003. Multitrofe interacties in genetisch gemodificeerde gewassen. 2003. - 43pp.
- Koenraadt, C.J.M. 2003. Mosquitoes, men and malaria in Kenya. A study on ecological factors affecting malaria risk. Wageningen Universiteit. Promotor: Prof. J.C. van Lenteren, co-promotor: Dr. W. Takken, 2003. - 224 pp.
- Koenraadt, C.J.M., Paaijmans, K.P., Githeko, A.K., Knols, B.G.J., Takken, W. 2003. Egg hatching, larval movement and larval survival of the malaria vector *Anopheles gambiae* in desiccating habitats. Malaria Journal 2: 1-9
- Koenraadt, C.J.M., Takken, W. 2003. Cannibalism and predation among larvae of the *Anopheles gambiae* complex. Medical and Veterinary Entomology 17: 61-66
- Lenteren, J.C. van (ed.) 2003. Quality Control and Production of Biological Control Agents - Theory and Testing Procedures Wallingford, Oxon, U.K.: CABI Publishing, 2003. - 327 pp.
- Lenteren, J.C. van 2003. Commercial availability of biological control agents. In: Quality control and production of biological control agents / Lenteren, Prof. Dr. J.C. van - Oxon: CABI Publishing, 2003. - pp. 167-179
- Lenteren, J.C. van 2003. Greenhouses without pesticides: a vision for the future IOBC/WPRS Bulletin 26 (9): 3
- Lenteren, J.C. van 2003. How to determine the risks of release of exotic natural enemies used in biological control? 8th Symposium of Biological Control, 22-26 June 2003, Siconbiol, San Pedro, Brazil: 60.
- Lenteren, J.C. van 2003. Need for quality control of mass-produced biological control agents. In: Quality control and production of biological control agents / Lenteren, Prof. Dr. J.C. van - Oxon: CABI Publishing, 2003. pp. 1-18
- Lenteren, J.C. van 2003. Quality control and mass production of natural enemies: where do we go? Bulletin IOBC Global 2: 47-48.
- Lenteren, J.C. van, 2003. Regulation of release of natural enemies: need or non-sense? Bulletin IOBC Global 2: 49.
- Lenteren, J.C. van 2003. Quality control of natural enemies: where are we and where do we go? IOBC/WPRS Bulletin 26 (10): 171-175.
- Lenteren, J.C. van 2003. Risks of releasing exotic natural enemies: is there a need to regulate biocontrol agents? IOBC/WPRS Bulletin 26 (10): 177-180
- Lenteren, J.C. van 2003. World-wide situation of biological control in protected cultivation. 8th Symposium of Biological Control, 22-26 June 2003, Siconbiol, San Pedro, Brazil: 60.
- Lenteren, J.C. van, Bueno, V.H.P. 2003. Augmentative biological control of arthropods in Latin America. BioControl 48: 123-139
- Lenteren, J.C. van, Schettino, M. 2003. Kinky sex and suicidal mating behaviour in Aphidoletes aphidimyza Entomologische Berichten Amsterdam 63: 143-146
- Lenteren, J.C. van, Tommassini, M.G. 2003. Mass production, storage, shipment and release of natural enemies In: Quality control and production of biological control agents: theory and testing procedures / Lenteren, Prof. Dr. J.C. van - Oxon: CABI Publishing, 2003. - p. 181-190

- Lenteren, J.C. van, Babendreier, D., Bigler, F., Burgio, G., Hokkanen, H.M.T., Kuske, S., Loomans, A.J.M., Menzler-Hokkanen, I., Rijn, P.C.J. van, Thomas, M.B., Tommassini, M.G., Zeng, Q.Q. 2003. Environmental risk assessment of exotic natural enemies used in inundative biological control. BioControl 48: 3-38
- Lenteren, J.C. van, Babendreier, D., Bigler, F., Burgio, G., Hokkanen, H.M.T., Kuske, S., Loomans, A.J.M. 2003. Regulation of import and release of mass-produced natural enemies: a risk-assessment approach. In: Quality control and production of biological control agents / J.C. van Lenteren. - 2003. - pp 191-204
- Lenteren, J.C. van, Hale, A., Klapwijk, J.N., Schelt, J. van, Steinberg, S. 2003. Guidelines for quality control of commercially produced natural enemies. In: Quality Control and Production of Biological Control Agents / ed. J.C. van Lenteren. - Wallingford: CABI Publishing, 2003. - p. 265-303
- Lewis, W.J., Vet, L.E.M., Tumlinson, J.H., Lenteren, J.C. van, Papaj, D.R. 2003. Variations in Natural-enemy foraging behaviour: essential element of a sound biological control theory. In: Quality control and production of biological control agents / J.C. van Lenteren. - 2003. - pp. 41-58
- Loomans, A.J.M. 2003. Parasitoids as Biological Control Agents of Thrip Pests. Wageningen. Promotor: Prof. J.C. van Lenteren. - Wageningen : [s.n.], 2003. - 200 pp.
- Manzano, M.R., Lenteren, J. C. van, Cardona, C. 2003. Comportamiento de busqueda de *Amitus fuscipennis* (Hymenoptera: Platygasteridae): Tiempo de permanencia en la planta hospedera y actividad de búsqueda. Revista Colombiana de Entomologia 29(2): 221-226.
- Manzano, M.R., Lenteren, J.C. van, Cardona, C.2003. Influence of pesticide treatments on the dynamics of whiteflies and associated parasitoids in snap bean fields. BioControl 48: 685-693
- Masanza, M. 2003. Effect of crop sanitation on banana weevil *Cosmopolites sordidus* (Germar) populations and associated damage. Wageningen. Promotor: Prof. J.C. van Lenteren, co-promotoren: Dr. ir. A. van Huis & Dr. C. Gold. - 2003. - 163 pp.
- Nielsen, J.K., Kjær, C., Schoonhoven, L.M. 2003. (eds.) Proceedings of the Eleventh International Symposium on Insect-Plant Relationships; August 4-10, 2001, in Helsingør, Denmark Dordrecht: Kluwer Academic Publishers, 2003. - 260 pp.
- Niyibigira,E.I. 2003. Genetic variability in Cotesia flavipes and its importance in biological control of lepidopteran stemborers. Wageningen. Promotor: Prof. Dr. J.C. van Lenteren. Co-promotor: Dr. Ir. R. Stouthamer- Wageningen : s.n., 2003. - 162 pp.
- Paaijmans, K.P., Koenraadt, C.J.M., Dallas, J.F., Billingsley, P.F., Takken, W. 2003. Use of microsatellites for kinship analysis of sympatric populations of the malaria mosquito larvae of *Anopheles gambiae* Giles s.s. and *An. arabiensis* Patton. Proceedings of the Section Experimental and Applied Entomology of the Netherlands Entomological Society 14: 17-23
- Perfecto, I, Vet, L.E.M. 2003. Effect of a nonhost plant on the location behavior of two parasitoids: The tritrophic system of *Cotesia* spp. (Hymenoptera: Braconidae), *Pieris rapae* (Lepidoptera: Pieridae), and *Brassica oleracea*. Environ. Entomol. 32: 163-174
- Poecke, R.M.P. van, Dicke, M. 2003. Signal transduction downstream of salicylic and jasmonic acid in herbivory-induced parasitoid attraction by Arabidopsis is independent of JAR1 and NPR1. Plant Cell and Environment 26: 1541-1548
- Poecke, R.M.P. van, Roosjen, M., Pumarino, L., Dicke, M. 2003. Attraction of the specialist parasitoid *Cotesia rubecula* to *Arabidopsis thaliana* infested by host or non-host herbivore species. Entomologia Experimentalis et Applicata 107: 229-236
- Romeis, J., Babendreier, D., Wäckers, F.L. 2003. Consumption of snowdrop lectin (*Galanthus nivalis* agglutinin) causes direct effects on adult parasitic wasps. Oecologia 134: 528-536
- Scholte, E-J., Takken, W., Knols, B.G.J. 2003. Pathogenicity of five East African entomopathogenic fungi against adult *Anopheles gambiae* s.s. mosquitoes (Diptera: Culicidae). Proc. Exper. Appl. Entomol., NEV, Amsterdam 14: 25-29.

- Scholte, E.J., Njiru, B.N., Smallegange, R.C., Takken, W., Knols, B.G.J. 2003. Infection of malaria (*Anopheles gambiae* s.s.) and filariasis (*Culex quinquefasciatus*) vectors with the entomopathogenic fungus *Metarhizium anisopliae*. Malaria Journal 2: 1-8
- Schuler, T.H., Potting, R.P.J., Denholm, I., Clark, S.J., Clark, A.J., Stewart, C.N., Poppy, G.M. 2003. Tritrophic choice experiments with Bt plants, the diamondback moth (*Plutella xylostella*) and the parasitoid *Cotesia plutellae*. Transgenic Research 12: 351-361
- Smallegange, R.C., Qiu, Y.T., Galimard, A.M.S., Posthumus, M.A., Beek, T.A. van, Loon, J.A. van, Takken, W. 2003. Why humans are attractive to malaria mosquitoes. Entomologia Experimentalis et Applicata 63: 50-53
- Smid, H.M., Bleeker, M.A.K., Loon, J.J.A. van, Vet, L.E.M. 2003. Three-dimensional organization of the glomeruli in the antennal lobe of the parasitoid wasps *Cotesia glomerata* and *C. rubecula*. Cell and Tissue Research 312: 237-248
- Smit, R., Dijk, F., Kruidbos, F., Schouls, L.M., Pol, I. van de, Docters van Leeuwen, W.M., Helinski, M., Takken, W. 2003. Populatiedynamiek en fenologie van teken in Nederland. Infectieziekten bulletin 14 (5): 167-170
- Steidle, J.L.M., Loon, J.J.A. van 2003. Dietary specialization and infochemical use in carnivorous arthropods: testing a concept. Entomologia Experimentalis et Applicata 108: 133-148
- Stouthamer, R. 2003. The use of unisexual wasps in biological control. In: Quality control and production of biological control agents / J.C. van Lenteren. - CABI Publishing, 2003. pp. 93-113.
- Takken, W. 2003. Letter to editor. European Mosquito Bulletin 15: 27-28
- Takken, W., Boëte, C. 2003. An introduction to ecological challenges concerning the use of genetically-modified mosquitoes for disease control. In: Ecological aspects for application of genetically modified mosquitoes / Takken, W., Scott, T.W. - Dordrecht: Kluwer Academic Publishers, 2003. - p. 9-12
- Takken, W., Lindsay, S.W. 2003. Factors affecting the vectorial competence of *Anopheles gambiae*: a question of scale. In: Ecological aspects for application of genetically modified mosquitoes / Takken, W., Scott, T.W. - Dordrecht: Kluwer Academic Publishers, 2003. (Wageningen UR Frontis series Vol. 2). - p. 75-90
- Takken, W., Scott, T.W. 2003. Ecological Aspects for Application of Genetically Modified Mosquitoes. Wageningen UR Frontis Series. Vol. 2. Kluwer Academic Publishers, 2003, Dordrecht, The Netherlands. 243 pp.
- Takken, W., Huijben, S., Wijsman, A., Paaijmans, K.P., Schmidt, H., Schaftenaar, W. 2003. Avian malaria in Rotterdam Dutch Wildlife Health Centre Newsletter 2003.-2: 3-4
- Tinzaara, W., Dicke, M., Huis, A. van, Loon, J.A. van, Gold, C.S. 2003. Different bioassays for investigating orientation responses of the banana weevil, *Cosmopolites sordidus*, show additive effects of host plant volatiles and a synthetic male-produced aggregation pheromone. Entomologia Experimentalis et Applicata 106: 169-175
- Tinzaara, W., Gold, C.S., Dicke, M., Huis, A. van, Nankinga, C. 2003. Use of infochemicals for the management of the banana weevil in Uganda. In: Integrated Pest Management Conference Proceedings: African Crop Science Society Uganda, 2003. - p. 244-255
- Tjallingii, W.F. 2003. Stiletpenetratie door bladluizen. Entomologische Berichten Amsterdam 63: 110-116
- Tol, J. van, Loon, J.J.A. van 2003. Jonge vliegen vinden amylacetaat bijzonder aantrekkelijk Entomologische Berichten Amsterdam 63: 75-76
- Tommasini, M.G. 2003. Evaluation of Orius species for biological control of *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). Wageningen. Promotor: Prof. dr. J.C. van Lenteren. - Wageningen : [s.n.], 2003. - 215 pp.

- Tommasini, M.G., Lenteren, J.C. van 2003. Occurrence of diapause in *Orius laevigatus*. Bulletin of Insectology 56: 225-251.
- Vet, L.E.M., Lewis, W.J., Papaj, D.R., Lenteren, J.C. van 2003. A variable-response model for parasitoid foraging behaviour. In: Quality control and production of biological control agents / Prof. dr. J.C. van Lenteren. - CABI Publishing, 2003. - pp. 24-40
- Vis, R.F.M. de, Lenteren, J.C. van 2003. Longevity, fecundity, oviposition frequency and intrinsic rate of increase of the greenhouse whitefly, *Trialeurodes vaporariorum* on greenhouse tomato in Colombia. Bulletin of Insectology 55: 3-8.
- Vis, R.M.J. de, Mendez, H., Lenteren, J.C. van 2003. Comparison of foraging behavior, interspecific host discrimination, and competition of *Encarsia formosa* and *Amitus fuscipennis*. Journal of Insect Behavior 16: 117-152
- Vos, M., Hemerik, L. 2003. Linking foraging behavior to lifetime reproductive success for an insect parasitoid: adaptation to host distributions. Behavioral Ecology 14: 236-245
- Vugt, J.F.A. van, Salverda, M., Jong, J.H. de, Stouthamer, R. 2003. The paternal sex ratio chromosome in the parasitic wasp *Trichogramma kaykai* condenses the paternal chromosomes into a dense chromatin mass. Genome 46: 580-587
- Wäckers, F.L. 2003. The parasitoids'need for sweets: sugars in mass rearing and bioligocal control In: Quality control and production of biological control agents / Prof. dr. J.C. van Lenteren. - CABI Publishing, 2003. - pp. 59-72
- Wäckers, F.L., Bezemer, T.M. 2003. Root herbivory induces an above-ground indirect defence. Ecology Letters 6: 9-12
- Wertheim, B., Vet, L.E.M., Dicke, M. 2003. Increased risk of parasitism as ecological costs of using aggregation pheromones: laboratory and field study of *Drosophila-Leptopilina* interaction Oikos 100: 269-282
- Westerman, P.R., Hofman, A, .Vet, L.E.M., Werf, W. van der 2003. Relative importance of vertebrates and invertebrates in epigeaic weed seed predation in organic cereal fields. Agriculture Ecosystems and Environment 95: 417-425
- Winkler, K., Waeckers, F., Valdivia, L., Larraz, V., Lenteren, J.C. van 2003. Strategic use of nectar sources to boost biological control. In: Landscape Management for Functional Biodiversity. - s.1. : s.n., 2003. (IOBC WPRS Bulletin 26(4): 209-214
- Woldewahid Teklu, G. 2003. Habitats and spatial pattern of solitarious desert locusts (*Schistocerca gregaria* Forsk.) on the coastal plain of Sudan Wageningen Universiteit. Promotor: Prof. Dr. J.C. van Lenteren; co-promotoren: Dr.ir. A. Van Huis, Dr.ir. W. van der Werf, 2003. - 162 pp.

Frankliniella occidentalis lined up for EPG recording - Photo: Frodo Kindt