WAGENINGEN UNIVERSITY
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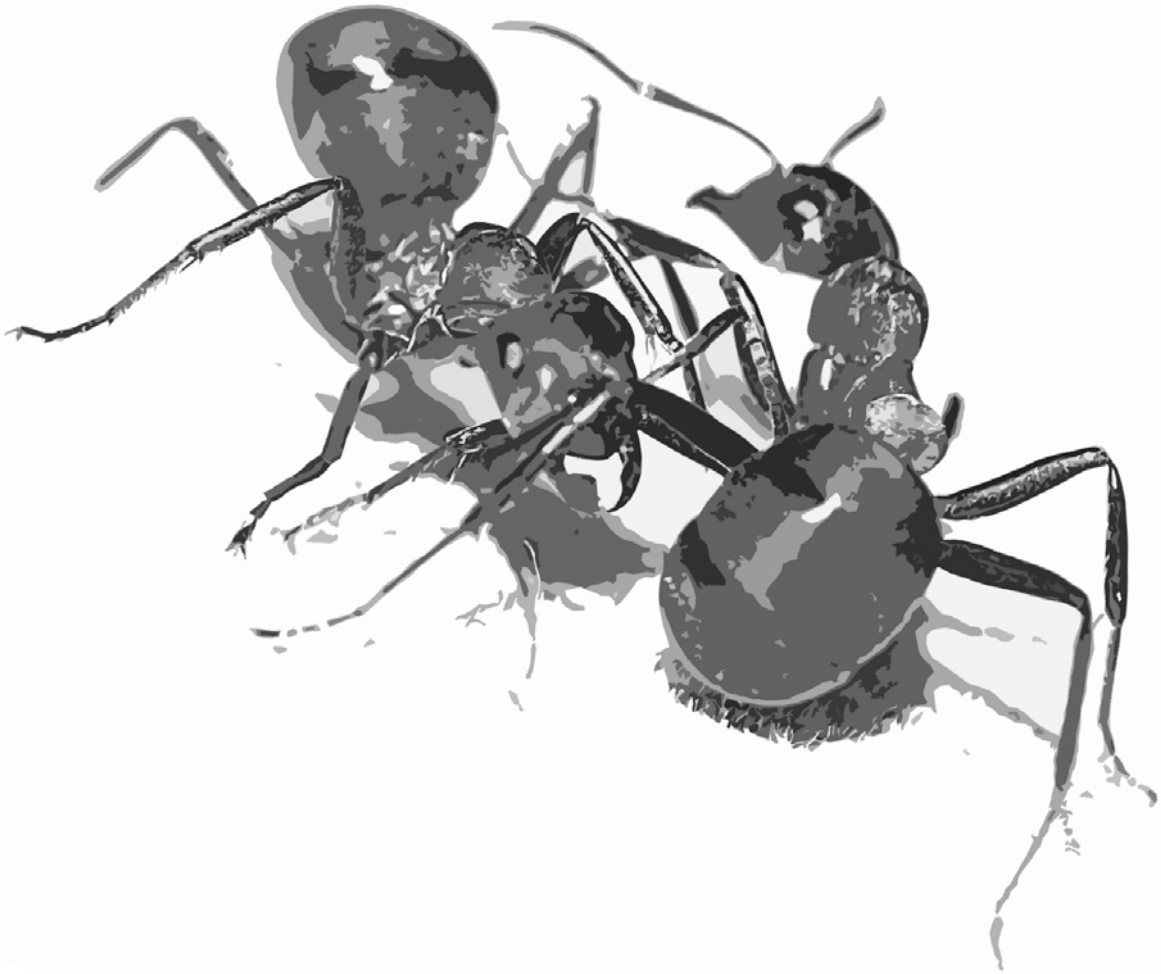
Annual report 2008-2009
Laboratory of entomology



Head:
Prof.Dr. Marcel Dicke

Aggelen, Frans K.M. van
Allema, Ir. Bas (PE&RC)
Berg van den, Ir. C. Lidwien
Boer, Ir. Jetske G. de (NWO/RUG)
Boot, Dr. Willem J. (Inbuzz)
Bosch, Angélique D.
Broeke, Cindy M.J. ten (TTI-GG)
Bukhari, MSc Tullu (Nuffic)
Bukovinszkine, Gabriella (GCGH)
Calis, Dr. Johan N.M. (Inbuzz)
Dannon, MSc Elie (Nuffic)
Dicke, Prof.Dr. Marcel
Duijvendijk, Ir. L.A. Gilian van (LNV-PPE)
Elsen, Ir. Floor H.W. van den (TTI-GG)
Ennik, E. Liesbeth
Farenhorst, Ir. Marit (Adessium)
Fatouros, Dr. Nina (DFG)
Ferrater, MSc Jedeliza D. (IRRI)
Gassner, Ir. Fedor
Gidding, André
Gols, Dr.Ing. Rieta
Hiwatt, MSc Helene (Surinam Medical Mission)
Hoedjes, Ir. Katja M. (NWO)
Howard, MSc Annabel F.V.
Huigens, Dr.Ir. Ties M.E. (NWO)
Huis, Prof.Dr.Ir. Arnold van
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Jong, Dr. Peter W. de
Jongema, Yde
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Kos, Ir. Martine (NWO)
Lenteren, Prof.Dr. Joop C. van
Loon, Dr.Ir. Joop J.A. van
Mathur, MSc Vartika (Nuffic)
Menzel, Ir. Tila R. (NWO)
Mnyone, MSc Ladslaus L.
Mwingira, MSc Victor S.
Ng'habi, MSc Kija (NWO)
Ochieno, MSc Dennis (IITA)
Ondiaka, MSc Sopher
Oonincx, Dennis G.A.B.
Pineda Gomez, Dr. Ana M. (Marie-Curie)
Poelman, Dr.Ir. Erik (NWO-ALW)
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Qiu, Dr. Yu Tong (GCGH)
Smallegange, Dr.Ir. Renate (GCGH)
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Takken, Prof.Dr.Ir. Willem
Togbe, MSc Codjo (COS-SIS)
Veldhuizen, C. Dennis van
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Vet, Prof.Dr. Louise E.M. (KNAW)
Wallis de Vries, Dr.Ir. Michiel (Vlinderstichting)
Wei, Dr. Jianing (KNAW)
Westerd, Ing. Léon E.C.
Yang, MSc Ting (TTI-GG)
Yayima, MSc Midori (JSPS)
Zhang, Peng-Jun (NWO)
Zheng, Dr. Si-Jun (NWO)
Zhou, MSc Dongsheng (CAS/KNAW)

ANNUAL REPORT LABORATORY OF ENTOMOLOGY 2008-2009

CONTENTS

Laboratory of Entomology
Wageningen University
Droevendaalsesteeg 1, 6708 PB 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.insect.wur.nl

Compilation: Marcel Dicke and Angélique Bosch
Photos: Tibor Bukovisnzky, Nina Fatouros and Hans Smid
Cover design: Hans Smid

FOREWORD

On May 31st, 2010, the French-American artist Louise Bourgeois died at the age of 98 years old. Among her most remarkable works were statues of spiders, several meters high, named 'Maman'. This artist must have had a fascination for spiders, just like the Belgian artist Jan Fabre is intrigued by jewel beetles, that he uses extensively to make three dimensional statues or even to decorate the ceiling of a room in the royal palace in Brussels. This is something that we recognize.
The laboratory of Entomology consists of an international group of ca 70 people intrigued by insects and by scientific research on insects. A recent inventory indicated that the group represented 17 nationalities.

The most remarkable event of the last year were the move to a brandnew building, Radix, at the Wageningen University campus as well as the excellent evaluation by an international peer review committee that ranks the Laboratory of Entomology among the leading groups in our field, within an international context.

Wageningen University continues to attract an increasing number of students and a good proportion of them follow our classes or do an MSc thesis in our group. Moreover, there is a continued investment by the group in public outreach and we enjoy the extensive interest from the general public in our work. The public outreach is made to further improve the general view on the value of insects to our society.

This annual report informs you about the major activities and achievements in our group in 2008 and 2009. There were many memorable events.
More information about our activities, on our teaching and research programmes, on recent PhD theses, and much more can be found on our website. The URL of our website is: www.ent.wur.nl/uk.

Marcel Dicke
Head of the Laboratory of Entomology

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 ecogenomics have been initiated, combining studies of subcellular mechanisms with ecology. The fundamental research concentrates on multitrophic interactions using on the one hand molecular, sensory physiological, neurobiological and behavioural biological approaches, and on the other hand ecological, and population genetic approaches. Our strategic research focuses on finding sustainable and environmentally safe solutions to problems caused by insects in the agricultural and medical-veterinary sector in temperate and tropical zones, in collaboration with social scientists.

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

Mission and strategy
Our mission is to unravel the functioning of insects in biological interactions and in ecological communities. A deeper understanding of the biology of insects will contribute to our appreciation of the role that insects play in shaping the world around us. Moreover, it provides the basis for our strategic research that aims at finding sustainable and environmentally safe solutions to problems caused by insects in the agricultural and medical-veterinary sector in temperate and tropical zones.
The Laboratory of Entomology's goal 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 in a stimulating atmosphere and with excellent internal collaboration. The group has an outstanding reputation in multitrophic interactions, biological control, and malaria vector research. There is a strong focus on integrating ecological, physiological and molecular approaches. 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. For an optimal dissemination of scientific information to different societal groups, we aim at transferring the knowledge gained to the scientific community, to professional organisations and to the general public.

2008 and 2009
In the years 2008 and 2009 we have prepared for a major operation, namely the moving to a brandnew building, the Radix building of the Plant Sciences Group. The actual moving took place in July 2009, but preparations had started a year before that. We are now accommodated in a building together with the other groups of the Plant Sciences Group. The new facilities include glasshouses, climate rooms, laboratories and offices. The group is now housed in a more condensed way which reduces walking

distances and the quality of the new accommodation is much better than the old one. Still, there is some nostalgia connected to the old building that was our home base since 1961.

Our research has made significant progress in 2008 and 2009 and has been published in many papers in international, peer reviewed journals. These include one paper in *Science* and 5 papers in the *Proceedings of the National Academy of Sciences of the USA* in the years 2008 and 2009. Our research focused on three major themes: (a) Molecular ecology of plant-insect interactions, (b) Chemical, sensory and behavioural ecology of malaria mosquitoes and their control, (c) Participatory approach to integrated crop management in West Africa. In 2009 a research focus on entomophagy has been initiated and several PhD students are now involved in this research line.

We have continued to connect our research to the interests of the wider public. In 2008 the organisers of the major catering and restaurant fair *Horecava* in Amsterdam have invited Professor Arnold van Huis to address the issue of entomophagy and attractive insect bites yielded a major interest. In 2008 the artist Suzanne Wolf had an art exhibition ("*under the spell of insects"*) in our building. She exhibited her extensive works in which insects play a dominant role.

Several new grants have been funded, among which important VENI grants for Roxina Soler (2008) and Nina Fatouros (2009). These are the first grants in the VENI-VIDI-VICI programme of the Netherlands Organisation for Scientific Research (NWO). Erik Poelman received the Hugo de Vries Prize for the best PhD thesis in the area of the Plant Sciences in the Netherlands in 2008. The ministry of Agriculture has funded the 4.5 M€ programme 'Convergence of Sciences: strengthening innovation systems in Benin, Ghana, and Mali (COS-SiS)' that is coordinated by Arnold van Huis and the Technology Foundation (STW) funded the 6.5 M€ Perspectief research programme 'Learning from Nature to Protect Crops' that is coordinated by Marcel Dicke.

In 2009 an international peer review committee evaluated the Laboratory of Entomology in the context of similar groups in the graduate schools Experimental Plant Sciences and Production Ecology and Resource Conservation. The evaluation was highly favourable and on all aspects, i.e. Quality, Productivity, Relevance, and Vitality and feasibility we received the highest score, i.e. '5' or 'excellent'. For instance, the Science Quality was qualified as "extremely high, as evidenced by the relatively high number of papers in Nature, Science and PNAS, which has increased since the last assessment. The percentage of publications in the top 10% most cited publications in the field has also increased." This is a recognition of our work that we are proud of and that will stimulate us to endeavour to continue at this level.
In total 14 PhD students successfully defended their PhD thesis in 2008/2009.

The integration of research at different levels of biological integration will be further intensified. The research on multitrophic interactions in plant-based systems increasingly addresses the mechanisms of the responses of plants to multiple attackers or multiple interactants (insects and microbes) so as to increase insight in how induced responses of plants to different community members are integrated and how plants deal with the defence-reproduction trade-off.
In the research on vector biology and control of malaria mosquitoes there will be an increase in molecular methodology to unravel the interaction between mosquito, malaria parasites and human odours. This approach allows also for the study of vector-parasite-host interactions beyond malaria, notably of diseases circulating in temperate zones.
Furthermore, in both plant-insect and mammal-insect studies we will investigate population processes with the aid of molecular techniques including microsatellites, and information on the identity of specific genes in the insects.
The new participatory programme strengthening agricultural innovation systems in three countries of West Africa (COS-SiS) will adapt and develop a methodological and theoretical approach to enhance the capacity of development actors to combine technological understanding with the creation of institutional space for change within nested stakeholder networks to capture and enlarge opportunities for rural poverty reduction.

We continue to communicate our research to the general public. In November 2009 Louise Vet and Marcel Dicke gave invited talks at the TEDxAmsterdam ('*Ideas that change the* world') conference on the 'marriage between ecology and economy' (Louise Vet) and 'why not eat insects' (Marcel Dicke).
In March 2009 Ruud Kleinpaste received the Oustanding Almunus Award 2009 by Wageningen UR for his outstanding outreach acitivities to the general public, e.g. through TV programmes on Animal Planet and Discovery such as *The Bughouse,* and *The World's Biggest and Baddest Bugs*. He gave a masterclass on how to convey your message to the public in general and journalists in particular. In December 2008 there was extensive media attention in response to our prediction that insects will be available as food in Dutch supermarkets by 2020. The topic of insects as food continues to intrigue the public and their attitude is changing as was clear from a recent internet poll by a Dutch consumers TV programme where 30% of the participants indicated to be willing to try insects as food. In 2009 we organised the 9th edition of the lecture series 'Insects and Society' attended by 100-200 enthusiastic visitors per evening.

Laboratory of Entomology

Level of biological integration

- Community
- Population
- Individual
- Cell
- Protein
- Gene

PLANT BASED MULTITROPHIC SYSTEMS

4-Secondary carnivore
3-Primary carnivore
2-Herbivores - microbes
1-Plant + associated microbes

ecology

mechanisms

ANIMAL BASED MULTITROPHIC SYSTEMS

Parasite
Vector
Human/Animal + associated microbes

ecology

mechanisms

TEACHING

GENERAL

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

- Analysis and Prevention of Health Risks in the Tropics
- Basics of Infectious Diseases
- Biology and Management of Plant Pathogens, Pests and Weeds I
- Biology and Management of Plant Pathogens, Pests and Weeds II
- Biosystematics and Biodiversity
- Cutting Edge Ecology
- Ecological Aspects of Bio-interactions
- Ecology I & II
- Ecophysiology of plants
- Evolutionary Biology
- Frontiers in Medical and Veterinary Biology
- Fundamental and Applied Aspects of the Biology of Insects
- Honey Bee Research
- Integrated Natural Resources Management
- Insect Ecology and Conservation
- Insect-Plant Interactions
- Insects and Society
- Molecular and Evolutionary Ecology
- Molecular Aspects of Bio-interactions
- Population and System 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 2008 a total of 24 students and in 2009 a total of 22 students finished their MSc-thesis under the supervision of the staff of the Laboratory of Entomology.

MSC THESES 2008

- Broeke, C. ten, 08-23. The effects of herbivory by *Pieris brassicae,* on pollinator behaviour and nectar production in *Brassica nigra.*
- Broekhoven, S. van, 08-06. The effect of phenidone, an inhibitor of the octadecanoid pathway, on the oviposition preference of two cabbage white butterfly species.
- Bulder, S., 08-09. Natural variation in herbivore induced plant volatile emission in ecotypes of *Arabidopsis thaliana.*

- Castillo, C., 08-03. Transmission of parthenogenesis-inducing *Wolbachia* bacteria between two strains of the biocontrol agent *Eretmocerus mundus*.
- Castillo, J., 08-15. Olfactory response of *Cosmopolites sordidus* (Germar) is affected by volatiles emitted by banana plants inoculated with non-pathogenic *Fusarium oxysporum* and *Beauveria bassiana*?
- Castillo, J., 08-20. Do eggs of *Pieris rapae* induce indirect plant defense in Brussels sprouts?
- Duin, L. van, 08-19. De invloed van rupsen van het Groot koolwitje *(Pieris brassicae*) op melige koolluizen (*Brevicoryne brassicae*) en *vice versa* op spruitkoolplanten (*Brassica oleracea*).
- Duivenvoorde, L., 08-12. Artificial selection on learning rate in *Cotesia glomerata*: A behavioral and molecular analysis.
- Itterbeeck, J. van, 08-01. Entomophagy and the West. Barriers and possibilities, ecological advantages, and ethical desirability.
- Middelaar, C. van, 08-28. Circadian rhythm and olfactory choices of *Culicoides* spp. in The Netherlands.
- Middelman, A., 08-25. Biological control of *Anopheles stephensi* and *An. gambiae* larvae with the entomopathogenic fungus *Metarhizium anisopliae*.
- Muijskens, J., 08-13. The overwintering behaviour of adult *Culicoides* species on livestock farms in the Netherlands and the effect of indoor insecticidal treatment on *Culicoides* species density.
- Pashalidou, F., 08-10. Hitch-hiking parasitic wasp can associatively learn to exploit butterfly anti-aphrodisiac.
- Roey, K. van, 08-27. Does cannibalism and predation confer fitness advantage on *Anopheles gambiae sensu stricto* and *Anopheles quadriannulatus* (Diptera: Culicidae). Impact of environmental factors: Temperature and nutrition on the interaction between *Anopheles gambiae* sensu stricto and *Anopheles quadriannulatus*.
- Roosmalen, J.J.G.P. van, 08-22. Chemical espionage on male-specific compounds and anti-aphrodisiacs of *Pieris* butterflies by the egg parasitoid *Trichogramma brassicae*.
- Rijk, M. de, 08-16. Hitch-hiking behaviour of egg parasitoids on Heliconiini butterflies in a tropical lowland rainforest.
- Schoelitsz, B., 08-07. The effects of larval age composition and adult female body size on oviposition by *Anopheles gambiae* (Diptera: Culicidae).
- Swaay, A. van, 08-24. The chemical ecology of mating in *Anopheles gambiae* s.s. The influence of male-produced pheromones on insemination success.
- Veldkamp, M., 08-14. Isolation of polymorphic microsatellite loci from the flea beetle *Phyllotreta nemorum*. Mapping of resistance genes.
- Versteegh, C., 08-11. Temporal characteristics of electrophysiological activity of olfactory neurons in sensilla on the maxillary palp of the malaria mosquito, *Anopheles gambiae*.
- Viennet, E., 08-05. Predictions of West Nile Virus risk associated with *Culex pipiens* in North-West of Europe.
- Winkelman, B., 08-26. The mapping of a resistance gene in the flea beetle *Phyllotreta nemorum*.
- Woelke, J., 08-02. Hitch-hiking behavior of *Trichogramma* wasps on cabbage white butterflies and moths.
- Woelke, J., 08-21. Egg parasitoid community on Heliconiini butterflies in a Panamanian rainforest.

MSC THESES 2009

- Abma, J., 09-20. The spread, abundance and life history of *Harmonia axyridis* in the Netherlands.
- Andriessen, R., 09-02. The attractiveness of different species of skin microorganisms to the malaria vector *Anopheles gambiae s.s.*
- Andriessen, R., 09-28. Collection methods, biting behaviour and cultivation of *Anopheles aquasalis* in Paramaribo, Suriname and collection methods and biting behaviour of *Anopheles darlingi* in Palumeu, Suriname.
- Bataille, H., 09-10. Host preference of *Anopheles maculipennis* s.l in the Netherlands.
- Chiriboga, F.X.M., 09-09. Effects of variation in plant quality on densities and sizes of herbivores, primary and secondary parasitoids.
- Duijvendijk, G. van, 09-30. Effect of a *Borrelia burgdorferi* sensu lato infection on the life history and desiccation resistance of *Ixodes ricinus*.
- Duin, L. van, 09-06. Foodchoice of resistant *Phyllotreta nemorum* beetles between *Barbarea vulgaris* and *Raphanus sativus* plants.
- Duivenvoorde, L., 09-05. The contribution of the neuropeptide proctolin to the regulation of acoustic communication in the grasshopper *Chorthippus biguttulus*.
- Gent, M., van, 09-16. Assessing behavioural aspects of *Ixodes ricinus* in relation to infection with *Borrelia burgdorferi* s.l.
- Groen, S.N., 09-31. Mechanisms underlying *Pseudomonas syringae* interference with systemic plant anti-herbivore defenses.
- Heilmann, L., 09-04. Host discrimination by *Cotesia glomerata* (L.) (Hymenoptera: Braconidae), a parasitoid of *Pieris brassicae* (L.) (Lepidoptera: Pieridae), as affected by experience.
- Hendriks, K., 09-18. Plant mediated effects of *Brassica oleracea* infested with *Brevicoryne brassicae* on the performance and behaviour of *Diaeretiella rapae*.
- Hilhorst, A., 09-03. Fungi for biological control of malaria mosquitoes: the efficacy of eave curtains treated with the entomopathogenic fungus *Beauveria bassiana.*
- Ikink, G.J., 09-07. Beetles (*Phyllotreta nemorum*) against host plant defense.
- Itterbeeck, J. van, 09-23. Ammonia, nitrous oxide, methane, and carbon dioxide emissions from edible insect species.
- Lucas Barbosa, D., 09-27. Direct and indirect defense induces by *Pieris* eggs in *Brassica nigra.*
- Menzel, T.R., 09-33. Potential biological role of secondary metabolites stored in *Tanacetum cinerariifolium* seed skin and trichomes.
- Noordam, R., 09-19. Effects of different prey-infested white cabbage cultivars on the performance and behaviour of the hoverfly *Episyrphus balteatus*.
- Schoelitsz, B., 09-11. The effects of semiochemicals emitted by larvae of *Anopheles gambiae* s.s. on the oviposition behaviour of conspecific gravid adult females.
- Tiggelman, L., 09-12. The perception of farmers on Farmer Field School (FFS) in Malawi. A case study of rice FFSs in Bundi.
- Vellekoop, R., 09-01. Effect of generalist predatory bugs on aphid control by *Aphidoletes aphidimyza.*
- Warnas, M., 09-36. The influence of cattle on the phenology of the tick *Ixodes ricinus* and the prevalence of the *Borrelia burgdorferi* s.l. complex.

PHD THESES 2008 AND 2009

2008: A total of 8 PhD theses were completed and successfully defended in 2008:

- Broekgaarden, C. (2008): An array of responses to insect feeding in *Brassica*. Promotor: Prof.dr. M. Dicke. Co-promotor: Dr. B. Vosman.
- Bruinsma, M. (2008): Infochemical use in *Brassica*-insect interactions. Promotor: Prof.dr. M. Dicke. Co-promotor: Dr. ir. J.J.A. van Loon.
- Gols, R. (2008): Tritrophic interactions in wild and cultivated brassicaceous plant species. Promotor: Prof.dr. M. Dicke
- Helinski, M.E.H. (2008): Reproductive biology and induced sterility as determinants for genetic control of mosquitoes with the sterile insect technique. Promotor: Prof.dr. M. Dicke; Co-promotor: Dr. ir. B.G.J. Knols.
- Leur, H. van (2008): Genetics, chemistry and ecology of a qualitative glucosinolate polymorphism in *Barbarea vulgaris*. Promotors: Prof.dr. W.H. van der Putten and Prof.dr. L.E.M. Vet; Co-promotor: Dr. N.M. van Dam.
- Paaijmans, K. (2008): Weather, water and malaria mosquito larvae. The impact of meteorological factors on water temperature and larvae of the Afro-tropical malaria vector *Anopheles gambiae* Giles. Promotors: Prof.dr. A.A.M. Holtslag, Prof.dr. M. Dicke, Prof. dr. ir. W. Takken; co-promotor: Dr. A. Jacobs.
- Poelman, E.H. (2008): Linking variation in plant defence to biodiversity at higher trophic levels: a multidisciplinary approach. Promotors: Prof.dr. M. Dicke and Prof.Dr. L.E.M. Vet; Co-promotors: Dr. ir. J.J.A. van Loon and Dr. N.M. van Dam.
- Yang, L. (2008): Integration of host plant resistance and biological control: using *Arabidopsis*-insect interactions as a model system. Promotors: Prof.dr. M. Dicke and Prof.dr. Z.Y. Fang; co-promotors: Dr. ir. J.J.A. van Loon and Dr. Ir. M.A. Jongsma.

2009: A total of 6 PhD theses were completed and successfully defended in 2009:

- Berg, M. van den (2009): Natural differences in associative olfactory learning in two closely related wasp species. Promotors: Prof.dr. M. Dicke and Prof.Dr. L.E.M. Vet; Co-promotor: Dr. H.M. Smid.
- Imbahale, S.S. (2009): Integrated malaria vector control in different agro-ecosystems in western Kenya. Promotors: Prof.dr. W. Takken and Prof.dr. M. Dicke.
- N'Guessan, R.K. (2009): Insecticide resistance in the West African malaria vector *Anopheles gambiae* and investigation of alternative tools for its delay. Promotor: Prof.dr. M. Dicke; Co-promotor: Dr. ir. B.G.J. Knols.
- Snoeren, T.A.L. (2009) Herbivore-induced indirect defense of Arabidopsis. Promotor: Prof.dr. M. Dicke
- Toleubayev, K. (2009): Plant protection in post-Soviet Kazakhstan: the loss of an ecological perspective. Promotors: Prof.dr. P. Richards and Prof.dr. A. van Huis; Co-promotor: Dr. K. Jansen.
- Wanzala, W. (2009): Ethnobotanicals for management of the brown ear tick *Rhipicephalus appendiculatus* in western Kenya. Promotors: Prof.dr. J.C. van Lenteren and Prof. dr. W. Takken.

PHD STUDENTS (1 JANUARY 2010)		SHORT TITLE (GRADUATE SCHOOL)	PERIOD	PROMOTOR/COPROMOTOR
1.	Allema, B.	Biological control by predators, dispersal behaviour, habitat mosaics in ecological networks (PE&RC)	07-11	van Bruggen/van Lenteren
2.	Bolckmans, K.	Evaluation, natural enemies (PE&RC)	05-10	van Lenteren
3.	Broeke, C. ten	Host-plant resistance to aphids (EPS)	09-13	Dicke/van Loon
4.	Bukhari, T.	Entomopathogenic fungi for the control of malaria and dengue vectors (PE&RC)	07-11	Takken/Dicke
5.	Burns, M.	Emergency sheeting for malaria control	02-10	Dicke/Takken
6.	Dannon, E.	Biology and ecology of *Apanteles taragamae* for control of *Maruca vitrata* (PE&RC)	07-11	Dicke/van Huis
7.	Elsen, F. van der	Host-plant resistance to whiteflies (EPS)	08-12	Dicke/Vosman
8.	Farenhorst, M.	Entomopathogenic fungi for the control of malaria vectors (PE&RC)	07-11	Vet/Thomas
9.	Ferrater, J.	Adaptation of brown plant hopper to resistance rice (PE&RC)	09-13	Dicke/de Jong
10.	Gassner, F.	Ticks, *Borrelia* infections, fitness (PE&RC)	06-10	Takken/Dicke/v.Overbeek
11.	Hiwatt, H.	Monitoring malaria intervention methods (PE&RC)	06-10	Dicke/Takken
12.	Hoedjes, K.	Tailor made memory in parasitoids (PE&RC)	09-13	Vet/Dicke/Smid
13.	Howard, A.	Natural products for malaria vector control: flora, fish and fungi (PE&RC)	07-10	Takken/Dicke
14.	Huang, Y	Risks of importation of exotic organisms (extern, Univ. Beijing)	99-10	v. Lenteren/ Xu Rumei
15.	Hulshof, J.	Biocontrol of western flower thrips with predators (PE&RC)	00-10	v. Lenteren/Sabelis/Janssen
16.	Itterbeeck, J. van	Entomophagy (PE&RC)	09-13	van Huis/van Loon
17.	Jumbe, M.	Entomopathogenic fungi and control of malaria vectors	07-11	Wijffels/Takken
18.	Kos, M.	Ecological effects of plant resistance traits on non-target organisms in crucifers (EPS)	07-11	Dicke/Vet/van Loon
19.	Lof, M.	Spatio-temporal modelling infochemicals in food web context (PE&RC)	04-10	Dicke/Hemerik/deGouw
20.	Lommen, S.	Wingless ladybirds and biological control of aphids (extern)	04-08	Brakefield/de Jong
21.	Mathur, V.	Induced defence in Brassica (EPS)	08-12	Vet/van Dam
22.	Menzel, T.	Priming in indirect defence of Lima bean (EPS)	10-14	Dicke/van Loon
23.	Mnyone, L.	Entomopathogenic fungi for control of malaria mosquito (PE&RC)	06-10	Takken/Dicke
24.	Mwingira, V.	The chemical ecology of mosquito oviposition behaviour (PE&RC)	06-10	Dicke/Takken
25.	Ng'habi, K.	Genetic variability malaria mosquitoes (PE&RC)	06-10	Dicke/Knols
26.	Ochieno, D.	Enhancing banana plant resistance with endophytes (PE&RC)	06-10	Dicke/v.Huis/Dubois
27.	Ondiaka, S.	Behavioural and ecological effects of fungal infection in adult malaria mosquitoes in Kenya (PE&RC)	07-11	Takken/Dicke
28.	Oonincx, D.	Rearing insects for human consumption (PE&RC)	08-12	vanHuis/van Loon
29.	Quarmine, W.	Strengthening innovation systems (PE&RC)	09-13	vanHuis/Bulte
30.	Raak-van den Berg, L.	Harmonia, aphid control, risk analysis (PE&RC)	07-11	van Lenteren/de Jong
31.	Ramirez, A.	Selecting and engineering natural resistance to thrips in ornamental and vegetable crops (EPS)	08-12	Dicke/Bouwmeester/Jongsma
32.	Ravensberg, W.	Evaluation, natural enemies (PE&RC)	05-10	van Lenteren
33.	Sauers-Müller, A. van	Behaviour, carambola fruitfly (PE&RC)	00-10	van Lenteren
34.	Suer, R.	Olfaction in the malaria mosquito, *Anopheles gambiae*: electrophysiology and morphology (PE&RC)	06-10	Dicke/Takken/van Loon
35.	Togbe, C.	strengthening innovation systems (PE&RC)	09-13	van Huis/Bulte
36.	Trefas, H.	Intercropping, beetles (PE&RC)	01-10	van Lenteren
37.	Verhulst, N.	Disruption of malaria transmission, chemical manipulation of Anopheline olfactory responses (PE&RC)	06-10	Dicke/Takken
38.	Vermeer, K.	Ecogenomics of host plant use in a phytophagous insect (PE&RC)	07-11	Dicke/de Jong
39.	Yajima, M.	Cassava and poverty alleviation in Malawi (Ceres)	04-10	v.Huis/Jiggins
40.	Yang, T.	Selecting and engineering natural resistance to thrips in ornamental and vegetable crops (EPS)	08-12	Dicke/Bouwmeester/Jongsma
41.	Zhou, D.S.	Molecular basis of phenotypic plasticity of taste in insects (EPS)	05-10	Dicke/van Loon

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.

Our experimental research addresses (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 - www.pe-rc.nl/) and Experimental Plant Sciences (EPS - http://www.graduateschool-eps.info/).

Progress in the research programmes is presented below:

Chemical and sensory ecology

Joop J.A. van Loon, Hans M. Smid; Yu Tong Qiu, Maaike Bruinsma, Erik H. Poelman, Cindy ten Broeke, Martine Kos, Tjeerd Snoeren, Remco Suer, Dongsheng Zhou, Martine Kos

Over the past 2 years we have been setting up a new line in our insect-plant and multitrophic research by studying the interactions between pollinators and flowers. In particular we investigate if interactions between plant-feeding insects feeding on vegegative and reproductive plant tissues and pollinators occur and how such interactions are mediated. Plant-feeding insects induce defences that affect their behaviour and performance and that can also affect behaviour of their natural enemies. Little is known on the potential influence of induced defences on flower nectar chemistry and pollinator behaviour. Jasmonic acid is one of the key hormones involved in both direct and indirect induced plant defences. We have investigated the effect of jasmonic acid treatment on floral nectar production and the attraction of pollinators, as well as the effect on the behaviour of an herbivore and its natural enemy. The study system consisted of black mustard plants, *Brassica nigra,* L. (Brassicaceae), pollinators of *Brassica nigra* (i.e., honeybees and syrphid flies), a specialist herbivore, *Pieris rapae* L. (Lepidoptera: Pieridae), and a parasitoid wasp that uses *Pieris* larvae as hosts, *Cotesia glomerata* L. (Hymenoptera: Braconidae). While the herbivore

prefers control leaves over jasmonic acid-treated leaves for oviposition, the parasitoid *C. glomerata* is more attracted to jasmonic acid-treated plants than to control plants. We did not observe differences in pollinator preference, the rates of flower visitation by honey-bees and syrphid flies were similar for control and jasmonic acid-treated plants. Plants treated with jasmonic acid secreted less nectar than control plants and the concentrations of glucose and fructose tended to be lower than in nectar from control plants. Jasmonic acid treatment resulted in a lower nectar production than actual feeding damage by *P. rapae* caterpillars. In two field-settings, we conducted additional experiments to test whether the physiological stage of the plant, flowering versus non-flowering, would influence success of parasitisation of herbivores. Our results show that parasitism of caterpillars on a non-flowering plant is higher compared to caterpillars on a flowering plant. However, parasitized caterpillars on flowering plants do contain a higher parasitoid brood size. In ongoing experiments we are investigating whether parasitoid wasps discriminate among different plant parts, *i.e.* odours from flowers versus leaves. These experiments will also include the collection and chemical analysis of volatile blends produced by leaves and flowers.

Ecology, evolution and genetics of interactions between insects, their food, and their enemies.
Peter de Jong, Patrick Verbaarschot, Kim Vermeer, Susanne Lommen (Leiden), Lidwien Raak-van den Berg, Joop van Lenteren

We investigate the processes of natural selection, migration and genetic drift that are responsible for the geographical distribution of adaptive traits in insect populations.
One of the main challenges in our research is to explain the geographical distribution of two different genotypes of the flea beetle, one of which is, and the other is not, able to use an atypical host plant as food. More specifically, the question is whether rarity of the first genotype on other host plants than the atypical one is caused by limited migration of the beetles, or by processes of selection. We employ a multidisciplinary approach to answer this question and obtain more insight in the evolutionary and ecological interactions between the different genotypes of this beetle, its host plants, and its enemies, by unraveling the genetic basis of the resistance to plant defence in the flea beetles, and adopting a population genomics approach to attribute local differences in allele frequency at the adaptive locus to genome-wide processes (such as migration), versus locus-specific ones (selection). This work involves continued collaboration of our team with Dr. Jens Kvist Nielsen from the University of Copenhagen, Denmark, and Dr. Manabu Kamimura from the NIAS in Tsukuba, Japan. In the past year, exciting progress has been made in this work: mutations in a beta-glucosidase gene were shown to be correlated with the resistance of the flea beetles to the defences of the atypical host plant. The causal nature of this correlation was further investigated by the development of cell-lines differing in expression of the beta glucosidase gene, and by studying the precise mechanism by which the toxic compounds in the atypical plants are degraded by the product of the resistance gene. Furthermore, the mode of inheritance of the resistance gene in the flea beetles is also polymorphic (sex-linked vs. autosomal).
The research on the invasive ladybird beetle *Harmonia axyridis*, has shown good progress in 2009. Overwintering experiments were carried out to study whether, and to what extent, the beetles go into a true diapause. During spring/summer, field work and population cage experiments were carried out to study reproduction of this beetle in the presence, versus absence of native ladybird beetles.

Infochemicals in multitrophic interactions

Marcel Dicke, Rieta Gols, Michaël van den Berg, Cindy J.M. ten Broeke, Colette Broekgaarden, Maaike Bruinsma, Tibor Bukovinszky, Elie Dannon, Floor van den Elsen, Nina E. Fatouros, Jedeliza Ferrater, M.(Ties) E. Huigens, Iris F. Kappers, Sander Koenraadt, Martine Kos, Marjolein Lof, Roland Mumm,

Dennis Ochieno, Ana Pineda, Erik H. Poelman, Adriana Ramirez, Tjeerd A.L. Snoeren, Roxina Soler, Sven Steiner, Limei Yang, Ting Yang, Penbg-Jun Zhang, and Si-Jun Zheng.

Plants are members of complex communities consisting of herbivorous insects, carnivorous insects, pathogens and beneficial microbes. Many community members interact with each other through the plant. Most of our research focuses on brassicaceous plants. Insect herbivory induces the plant to produce volatile organic compounds (VOCs) that attract carnivorous insects such as parasitic wasps. We have exploited the molecular genetic tools available for Arabidopsis to unravel the involvement of different components of the octadecanoid signal-transduction pathway in mediating the induction of plant VOCs (Journal of Chemical Ecology 35: 1021-1031). Most research on induced plant defences relates to one plant – one attackers systems. However, plants in nature are exposed to a multitude of attackers but investigations on how multiple attack affects induced plant defences is still in it infancy (Nature Chemical Biology 5: 317-324). We demonstrated that whiteflies that induce the salicylate pathway interfere with jasmonate-dependent VOC induction in response to spider-mite feeding. Transcriptional, metabolic and behavioural analyses have unraveled the mechanisms leading to whitefly-mediated attenuation of spider-mite induced plant defence (PNAS 106: 21202–21207). Our studies of induced plant defences extend from the laboratory to field studies. We have shown that laboratory results for relative carnivore attraction of different *Brassica* cultivars match results of field experiments (Functional Ecology 23: 951–962). Parasitoids use the induced plant VOCs to locate their herbivorous host in which they oviposit. The quality of the host is dependent on the quality of the host's food plant. We have shown that parasitoids can detect even small differences in plant quality presumably through their volatile blends and that plant preference and offspring performance are 'optimally synchronized' (Oikos 118: 733-743).
The integration of laboratory and field studies that address ecological functions with laboratory studies on subcellular mechanisms yields important new insights in how community members influence plant phenotype expression and how, consequently, plants influence interactions among community members.

Evolutionary Ecology
Louise E.M. Vet, Hans M. Smid, Roxina Soler, Michaël van den Berg, Katja Hoedjes.
At NIOO: Qiu Baoli, Marjolein Kruidhof, Taia Fortuna, Nicole van Dam, Jeff Harvey, Tibor Bukovinszky

The memory gene CREB (camp responsive element binding protein) was studied to reveal possible differences in the expression levels in the brain of *C. glomerata* and *C. rubecula*. Nine different transcripts were found, resulting from alternative splicing. The two main isoforms were expressed in equal quantities in both wasp species, but two minor isoforms were differentially expressed. These results are in press in J. Insect Mol. Biol. (van den Berg et al. 2010 Insect Molecular Biology 19: 367–379). Induced CREB expression was found after learning, this work is still in progress.
Bidirectional selection was performed on the learning rate of *C. glomerata*, which resulted in a line with a low learning rate, and a line with a high learning rate. The low learning rate line lived longer and had smaller brains than the high learning rate line. The high learning rate line formed LTM after a single learning trial, whereas the low learning rate line formed only short lasting memory after a single learning trial. LTM formation was normal after 3 spaced learning trials, showing that these wasps were not affected in memory formation ability, they were learning at a lower rate. The results were published in the PhD thesis by M. van den Berg, who graduated in 2009, and 2 manuscripts were submitted in addition to work on CREB.
Memory formation was found to be very different in *C. glomerata*, depending on which host caterpillar species was offered as a reward. With the large cabbage white as reward, long-term memory was formed, but with the small cabbage white, memory lasting only 8 hrs was formed (Kruidhof et al).
A new project was started, funded by ALW, to build on the differences found in the two selection lines, to study gene expression and fitness consequences of variation in learning rate (K. Hoedjes).

Tropical entomology

Arnold van Huis, Kazbek Toulobayev, Midori Yajima, Elie Dannon, Dennis Ochieno, Codjo Togbe, Barbara Sterk

Kazbek Toulobayev defended successfully his PhD thesis entitled "Plant protection in post-Soviet Kazakhstan: The loss of an ecological perspective". This thesis illustrates how Integrated Pest Management (IPM)/ecology-based pest-control approaches were broadly developed and practised in the USSR, including Kazakhstan. Contrary to what is often believed independence was not favourable for agriculture as there was a shift from a knowledge system aiming at sustainable pest-control in the Soviet era to an exclusive focus on pesticides in post-1991 Kazakhstan. The thesis was an inter-disciplinary endeavour as the thesis was co-supervised with the chair group 'Technology and Agrarian Development'.

Midori Yajima examined the interaction between cassava cropping, livelihoods, HIV/AIDS and Farmer Field Schools. Cassava is a staple food with a high tolerance to abiotic stresses, and therefore suitable as a backup survival food crop during adversity. HIV/AIDS appeared to be just one in the continuum of numerous types of risks. She recommends increasing social immunity by strengthening the social, organisational and personal capacities of affected individuals, and by increased access to health services. Her project (thesis defence in 2010) was interdisciplinary in scope and co-supervised by the chair group "Communication and Innovation Studies".

Dennis Ochieno investigated the introduction of microbial endophytes to enhance banana plant protection against the banana weevil and the nematode *Radopholus similis* under different soil conditions.

Elie Dannon addresses the biological control of the legume pod borer *Maruca vitrata* (Lepidoptera: Crambidae), which is a serious pest of cowpea in West-Africa, by the introduction of the parasitoid *Apanteles taragamae* (Hymenoptera: Braconidae) from Taiwan.

During the first phase of the Convergence of Sciences (COS) programme (2001-2006; €2.3 million) nine PhD students conducted participatory technology development experiments in Benin and Ghana with farmers on integrated pest and weed management, soil quality and crop diversity. The lessons learned were that development is constrained by institutional issues such as labour arrangements, land tenure issues, exploitive networks, cheating, and deficient contractual arrangements.

The Directorate General of International Cooperation of the Netherlands (DGIS) now funds a second phase CoS-SIS (2008-2013; € 4.5 million) (**C**onvergence **o**f **S**ciences: **S**trengthening agricultural **i**nnovation **s**ystems in Benin, Ghana and Mali) in order to strengthen innovation systems in Benin, Ghana and Mali. Experiments will be carried out by 9 postdocs and 11 PhD students to elaborate, apply and assess an innovation system approach to sustainable rural poverty alleviation and food security. This approach implies concerted action among relevant actors (farmers, researchers, communities, companies, policy makers etc.) to realise an opportunity, such as better access to remunerative markets, inputs, knowledge and credit, more value-added activities, security of tenure, better organization for exerting political influence, post-harvest activities to allow small farmers to jointly supply supermarkets, and effective political support to combat cheap imports.

Prof. Dr. Arnold van Huis is the International Coordinator of the programme. Mid 2009 the postdoc Dr. Barbara Sterk has been appointed at the chair group of Entomology to assist him. Two PhD students appointed in 2009 are jointly supervised by the chair groups of Entomology and Development Economics: Mr. Codjo Togbe will work on alleviating technological and institutional constraints of integrated pest management in cotton in Benin, while William Quarmine will work on improving the yield and quality of (pesticide-residue-free) cocoa in Ghana; identifying strategies at the farmer and above farmer levels which will motivate smallholder farmers.

Vector biology and control

Willem Takken, Bart G.J. Knols, Jeroen Spitzen, Hans Beijleveld, Henk van den Berg, Tullu Bukhari, Gabriella Bukovinszkine, Marit Farenhorst, Fedor Gassner, Michelle Helinski, Helène Hiwat, Susan Imbahale, Frans Jacobs, Matt Kirby, Sander Koenraadt, Victor Mwingira, Kija R. Ng'habi, Krijn P. Paaijmans, Sophie Odieno, Yu Tong Qiu, Renate C. Smallegange, Remco A. Suer, Niels Verhulst, Wycliffe Wanzala

Our research addresses the chemical ecology of mosquitoes, the ecology of aquatic stages of malaria vectors, the development of entomopathogenic fungi for malaria vector control and the population biology and vector-host interactions of disease vectors in natural areas.

In western Kenya, significant differences in malaria risk between villages were found to have an environmental base, where farming activities led to enhanced production of mosquito larvae and adult mosquitoes. Simple measures like shading, use of larvivorous fish, drainage and application of the biolarvicide *Bacillus thuringiensis israliensis* led to a complete disappearance of mosquito larvae. A KAP study revealed that many farmers were not aware of their contribution to mosquito production, but were keen to learn about methods that would prevent this. The study suggests that integrated approaches of mosquito control, supported by educational activities, can lead to reduction in mosquito densities and, hence, malaria risk. In a related study in Mali, the concept of the Farmers Field School (FFS) for integrated management of vector control was practiced with training workshops involving relevant stakeholders (farmers, community leaders, administrators, public health officials), The study showed that FFS would be a workable tool for vector management, but that such activities should be evidence based in order to be successful.

Studies on the use of ethnobotanicals for tick management in western Kenya revealed that extracts from *Tagetes minuta* and *Tithonia diversifolia*, both natural plants in that region, significantly effected the behaviour of the East-coast fever tick *Rhipicephalus appendiculatus*, to that cattle treated with these extracts had a much lower tick burden than the controls. The residual activity of the treatments was up to 10 days. This strategy promises that botanicals can be implemented in sustainable tick control programmes, which depend little on external inputs and would provide livestock holders with an effective disease control method.

Our study on the sheep tick *Ixodes ricinus*, the vector of Lyme disease, showed that grazing by large herbivores (cattle) introduced in woodland areas led to significant reduction in tick densities and associated risk for Lyme disease transmission. Wood mice and bank voles were highly abundant. Tick burdens on mice were higher on ticks collected in ungrazed habitat compared to the grazed habitat. The country-wide study on tick distribution and Borrelia infections completed its 3rd year in 2009. Annual infection rate of ticks with Borrelia was 18%.

In our studies on mosquito olfaction we found that tetradecanoic acid caused a significant attraction of *Anopheles gambiae* in a blend with NH_3 and L-lactic acid. The blend of NH_3, L-lactic acid and tetradecanoic acid was subsequently also attractive in semi-field and field in Tanzania, and is used as the basis for further development of attractants. A significant result in this project was reached when we found that synthetic blends containing NH_3, L-lactic acid, tetradecanoic acid and CO_2 were significantly more attractive to wild populations of *An. gambiae* than the humans. This promises that such volatiles can potentially be used for the manipulation of malaria mosquitoes. The examination of human skin microbiota revealed attraction of volatiles produced by these microorganisms, and work is currently in progress to reveal the active compounds of these volatiles

Entomopathogenic fungi to control malaria mosquitoes

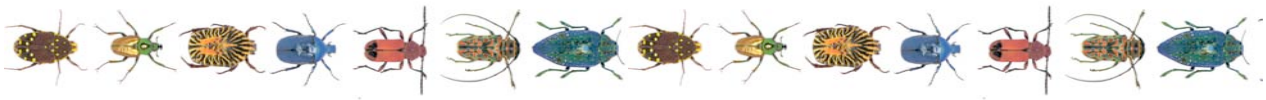
Sander Koenraadt, Bart Knols, Marit Farenhorst, Tullu Bukhari, Ladslaus Mnyone, Frank van Breukelen, Mgeni Jumbe, Matt Kirby, Sophie Ondiaka, Arjen Rinzema, Willem Takken

Significant progress has been made in terms of optimizing both quantity and quality of fungal production in collaboration with the Bioprocess Engineering group. For example, spores of the fungus *Beauveria bassiana* remained virulent up to 7 months after application. This, of course, has important implications for application in the field and makes this fungus an attractive alternative when compared to currently used pesticides. In collaboration with the Entomology Research Centre in Benin, we tested the effectiveness of entomopathogenic fungi in an area where malaria mosquitoes have high levels of insecticide resistance, because laboratory studies suggested that fungal spores can be effective against insecticide-resistant mosquito strains. *Metarhizium anisopliae* proved to be more effective than *Beauveria bassiana*. In addition, we found that effectiveness of both fungi rapidly decreases (within 7 days) when applied as dry spores on the water surface. Therefore, we are now testing different formulations that facilitate spread of spores and increase spore persistence. In Tanzania, delivery systems were further optimized in collaboration with the Ifakara Health Institute. Laboratory results showed that black cloth was the most suitable substrate to apply fungal spores in mineral oil. In subsequent tests in experimental huts, black cloth partial eave curtains seem to be the most suitable for large scale application.

Behavioural ecology, functional biodiversity and policy related entomological issues
Joop van Lenteren, Bas Allema, Lidwien Raak-van den Berg, Sara Ruschioni, Hajnalka Trefas, Valentina Lo Verde

Together with colleagues from the Universities of Perugia and Ancona (Italy), Sara Ruschioni continued to work on the host discrimination behaviour of the *Drosophila* parasitoid *Leptopilina heterotoma*. Anatomical work revealed putative chemosensory receptors on the tip of the ovipositor and their status as contact-chemoreceptors was confirmed by sensory-physiological experiments. We are now trying to find out how *Leptopilina* parasitoids are able to count eggs in their hosts. Valentina Lo Verde studied the elimination of supernumerary parasitoid larvae in *Eretmocerus mundus*, and showed that larvae were eliminated both outside and inside the *Bemisia* host. The results of her very elegant experiments have recently been published. Now that we know that elimination of parasitoid larvae frequently takes place, we might be able transfer of *Wolbachia* from one strain of *Eretmocerus* to another strain. Huang Ying (a KNAW supported PhD student from Beijing University, China) finished her analysis of the rather complicated hyperparasitism behaviour of the autoparasitoid *Encarsia tricolor* on two secondary host species with a publication.
During the past two years, our laboratory has, in collaboration with international colleagues, contributed extensively on policy-related issues. With EC and IOBC support, we have developed and published a method for Environmental Risk Assessement (ERA) of natural enemies and these methods are now used by several countries. We have applied and published this ERA to evaluate the risk posed by the import and release of the the ladybird beetle *Harmonia axyridis*. Closely related to the issue of risks posed by exotic natural enemies is the PhD research project of Lidwien Raak-van den Berg, who studies the biology of *H. axyridis* in the Netherlands to obtain insight into the causes and consequences of their rapid establishment. Last year, field experiments have been done on diapause, intraguild predation and phenology of *H. axyridis*. As a result of an EFSA panel of experts membership of one of us, we have spent quite some on theoretical and practical issues related to invasion biology of pests. Also, and again in collaboration with colleagues from abroad, we have reviewed the worldwide use of classical and augmentative biological and written a report for the FAO concerning the problematic future situation for biological control if a monetary Access and Benefit Sharing system will be compulsary for collection and export of natural enemies. This report will be used in negociations with the Convention on Biological Diversity and hopefully results in a non-monetary benefit sharing system for biological control.
The large, NWO-funded project on functional biodiversity has been completed with the publication of a number of research papers by Tibor Bukovinszky and Karin Winkler. Currently a PhD student – Hajnalka Trefas - is finishing her thesis on the searching behaviour of the generalist predatory beetle *Pterostichus*

melanarius ("See how they run" - Factors influencing the habitat choice of a generalist predator in simple and diverse agricultural systems). Another PhD student, - Bas Allema - is working with the predatory beetles *Pterostichus melanarius* and *Poecilus cupreus* with the aim to understand the relation between landscape configuration and population distribution patterns of generalist predatory beetles from insights in walking behaviour at habitat interfaces in an agricultural landscape.



Projects within graduate school Experimental Plant Sciences:

- EPS2-2d06. Induction of plant volatiles by herbivory: signal transduction and behavioural modification in a multitrophic context. M. Dicke, R. Gols.
- 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.
- EPS2-2c052. Development of a method for breeding of cucumber for improved attraction of biological control agents. 2002-2009. I.F. Kappers, L. Luckerhoff, H.J. Bouwmeester & M. Dicke.
- EPS-2c036. Phenotypic manipulation of induced plant defense in Brassica, 2004-2009. M. Bruinsma, M. Dicke, J.J.A. van Loon.
- EPS-2c037. Manipulation of plant genotype and effects on interactions with community members. 2004-2009. T.A.L. Snoeren, M. Dicke, P.W. de Jong.
- EPS-3c062. Metabolomics of indirect defence in cultivated Brassica oleracea varieties and its effects on insect biodiversity. 2004-2008. E.H. Poelman, J.J.A. van Loon, M. Dicke
- EPS-32c060. Identification and expression of genes related to herbivory, 2004-2008. C. Broekgaarden, M. Dicke, B. Vosman.
- EPS-. Molecular ecology of terpenoids in plant-insect interactions. 2004-2009. R. Mumm and M. Dicke
- EPS3-2c 038 Molecular, phytochemical and ecological aspects of glucosinolate polymorphism. 2003-2008. H. van Leur, W.H. van der Putten & L.E.M. Vet.
- EPS3-2c088. Ecological effects of plant resistance traits on above-ground non-target organisms in different genotypes of Brassica and Arabidopsis. 2007-2011. M. Kos, J.J.A. van Loon & M. Dicke
- EPS3-2b191. Development of innovative methods for selecting and engineering natural resistance to thrips in ornamental and vegetable crops. 2008-2012. T. Yang, M.A. Jongsma, S. de Vries, H.J. Bouwmeester & M. Dicke.
- EPS3-2b193. Resistance mechanisms against whitefly in tomato. 2008-2012. F.H.W. van den Elsen, A.W. van Heusden, B.J. Vosman & M. Dicke.
- EPS3-2b206. Unraveling the mechanism of resistance to *Nasonovia ribisnigri* in lettuce. 2009-2013. C.M.J. ten Broeke, J.J.A. van Loon, H.J. Bouwmeester & M. Dicke.
- EPS3-2c052. Method for breeding cucumber for enhanced attraction of bodyguards. I.F. Kappers, L.L.P. Luckerhoff, H.J. Bouwmeester & M. Dicke
- EPS3-2c073. A molecular genentic approach to chemical ecology and community ecology: Assessing gene expression patterns and developing novel genotype manipulation. 2004-2010. S. Zheng & M. Dicke
- EPS3-2c096. Plant-mediated indirect competition between congeneric parasitoid wasps. 2009-2012. E.H. Poelman, J.J.A. van Loon & M. Dicke.
- EPS3-2c097. Temporal dynamics in induced responses of *Brassica juncea.* V. Mathur, N.M. van Dam & L.E.M. Vet.
- EPS3-2c099. Plant-mediated interactions between herbivorous insects and pollinators: an ecogenomic approach. 2009-2012. T.A.L. Snoeren, J.J.A. van Loon & M. Dicke.
- EPS3-2c100. Effects of beneficial rhizobacteria on induced plant defences to aboveground herbivores. 2009-2011. A. Pineda, J.J.A. van Loon & M. Dicke.
- EPS3-2c. Priming in indirect defense of Lima bean plants against herbivorous arthropods. 2010-2014. T. Menzel, J.J.A. van Loon & M. Dicke.

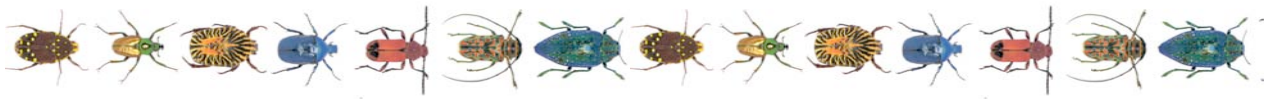
Projects within graduate school Resource Studies for Development (CERES):

- CERES 44860. Plant Protection Perspectives in the Context of Institutional Changes in the Post-Soviet Kazakhstan, 2004-2009. K. Toleubayev, A. van Huis & K. Jansen (chair group Technology and Agrarian Development)

Projects within graduate school Production Ecology and Resource Conservation:

- PE&RC 32 00s. Biological control of the greenhouse whitefly (*Trialeurodes vaporariorum*) using natural enemies. 1983-2010. J.C. van Lenteren.
- PE&RC 32 00aj. Factors affecting host location by anopheline mosquitoes. W. Takken.
- PE&RC 32 04a. Spatio-temporal modelling of infochemicals in a food web context. 2004-2010. M.E. Lof, L. Hemerik, M. de Gouw & M. Dicke.
- PE&RC 31 05d. Tailor-made memory: natural differences in associative olfactory learning. M. van den Berg, H.M. Smid, M. Dicke & L.E.M. Vet.
- PE&RC 31 00g. Functional ecology of tritrophic interactions. H.M. Smid.
- PE&RC 07067. Molecular basis of phenotypic plasticity of taste in insects. 2005-2009. D. Zhou, J.J.A. van Loon & M. Dicke.
- PE&RC 07044. Disruption of malaria transmission by chemical manipulation of Anopheline olfactory responses. 2005-2010. R.C. Smallegange, J.J.A. van Loon & W. Takken..
- PE&RC 07071. Disruption of malaria transmission by chemical manipulation of Anopheline olfactory responses. 2005-2010. Y.T. Qiu, W. Takken, J. van Loon.
- PE&RC 06034. Effect of crop management on performance of endophytic *Fusarium* spp. in tissue culture banana against the banana weevil *Cosmopolites sordidus* (Germar) and nematodes in Uganda. 2006-2010. D. Ochieno, A. van Huis & M. Dicke.
- PE&RC 06077. Behavioural characteristics of the main malaria vector *Anopheles darlingi* in Suriname (South America), and implications for vector control. 2006-2010. H. Hiwat, M. Dicke & W. Takken.
- PE&RC 07043. Chemical communication: Hitch-hiking parasitic wasps spy on butterfly anti-aphrodisiacs. 2006-2010. M.E. Huigens.
- PE&RC 06074. The chemical ecology of oviposition behaviour of *Annophylus gambiaen* in Tanzania. 2006-2010. V.S. Mwingira.
- PE&RC 06108. Olfactory physiology of the malaria mosquito, *Anopheles gambiae*. 2006-2010. R. Suer, J.J.A. van Loon & M. Dicke.
- PE&RC 06072. The effects of water management systems on malarila mosquitoes in Western Kenya. S.S. Imbahale, M. Dicke & W. Takken.
- PE&RC 06085. Cassava cropping and HIV/AIDS. M. Yajima, J. Jiggins & A. van Huis.
- PE&RC 07018. Disruption of malaria transmission by chemical manipulation of Anopheline olfactory responses. 2006-2010. N. Verhulst, M. Dicke & W. Takken.
- PE&RC 07074. Biology and ecology of *Apanteles taragamae* Viereck (*Hymenoptera braconidae*), a larval parasitoid of *Maruca vitrata* Frabricius (Lepidoptera: Pyralidae), a key pest of cowpea, *Vigna unguiculata* (L.) Walp. 2007-2011. E. Dannon, A. van Huis & M. Dicke.
- PE&RC 07040. Establishment of the aphidophagous ladybird beetle *Harmonia axyridis* in The Netherlands: successful aphid control or ecological disaster? 2007-2011. C.L. Raak-van den Berg.
- PE&RC 07066. Behavioural, ecological, and genetic determinants of gene flow in the African malaria mosquito *Anopheles gambiae*. 2007-2010. K.R. Ng'habi, B.G.J. Knols & M. Dicke.
- PE&RC 07086. Ecogenomics of host plant use in a phytophagous insect. 2007-2011. K.M.C.A. Vermeer, P.W. de Jong & M. Dicke.
- PE&RC 07088. Entomopathogenic fungal control of mosquitos in Pakistan. 2007-2011. T. Bukhari, M. Dicke & W. Takken.

- PE&RC 07045. Behavioural and ecological effects of fungal infection in adult malaria mosquitos in Kenya. 2007-2011. S. Ondiaka, M. Dicke & W. Takken.
- PE&RC 07002. Understanding success of biological pest control by predators based on their despersal behaviour across habitat mosaics in ecological networks. 2007-2011. B. Allema, A. van Bruggen & J.C. van Lenteren.
- PE&RC 08017. The effects of variations in habitat characteristics and pathogen infections on the biology *Ixodus ricinus* in the laboratory and in the field. 2008-2010. F. Gassner, L. van Overbeek, M. Dicke & W. Takken.
- PE&RC 08025. Insecticide resistance in the west-African malaria vector *Anopheles gambiae.* R. N'Guessan, B. Knols, M. Rowland & M. Dicke.
- PE&RC 08026. Insecticide treated plastic sheeting: a novel malaria control tool for complex emergency situations. Evidence from a field evaluation conducted in refugee camps in Sierra Leone. 2005-2008. M.R. Burns, W. Takken & M. Dicke.
- PE&RC 08035. Do above- and below-ground multitrophic interactions differ between native and invasive plants? T.F. Fortuna, J.A. Harvey & L.E.M. Vet.
- PE&RC 09063. Development of Entomopathogenic fungi for the control of adult African malaria vectors. 2008-2010. L.L. Mnyone, M. Dicke & W. Takken.
- PE&RC 08040. Valorisation research on entomopathogenic fungi for the control of African malaria mosquitos. 2008-2012. M. Farenhorst, M. Thomas & L.E.M. Vet.
- PE&RC 08065. Nutritional and environmental aspects of insects as a human food source. 2008-2012. D.G.A.B. Oonincx, J.J.A. van Loon & M. Dicke.
- PE&RC 09071. Multi-species plant-insect interactions: from genes to ecology. 2009-2012. R. Soler.
- PE&RC 09078. Institutional and technical constraints of integrated pest management in cotton in Benin. 2009-2012. Institutional and Technical constraints of IPM in cotton in Benin. C.E. Togbe, E. Bulte, A. van Huis.
- PE&RC 09069. Trends in the contribution of edible insects to rural and urban livelihoods and sustainable harvesting levels. 2009-2013. J. van Itterbeeck & A. van Huis.
- PE&RC 09085. Evolution of memory in *Cotesia* wasps. 2009-2013. K.M. Hoedjes, H.M. Smid, M. Dicke & L.E.M. Vet.
- PE&RC 09087. Sustainable and natural mosquito control. 2009-2010. A.F.V. Howard, M. Dicke & W. Takken.



REPRESENTATION IN EXTERNAL COMMITTEES

International:

- Commission on Biological Control and Access and Benefit Sharing, Full Member, International Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC-IUBS) (van Lenteren, full member)
- Consortium developing the SeaWaterGreenhouse, advisor crop protection (van Lenteren)
- European Food Safety Authority, Scientific Panel on Genetically Modified Organism (van Loon, consultant)
- European Science Foundation (ESF), Science Advisory Board (Vet)
- European Science Foundation (ESF), Steering committee programme Volatile Organic Compounds in the Biosphere-Atmosphere System (VOC-BAS) (Dicke)
- European Food Safety Authority, Vice Chair and Full member of Panel of Experts on Plant Health, (EFSA), Parma, Italy (van Lenteren)
- Executive Board and the Governing Council of the International Centre for Insect Physiology and Ecology (ICIPE)(van Huis)
- Expert Advisory Committee Canadian Network of Biocontrol Research (van Lenteren)
- Foundation Cradle2cradlePlanet, Board (Vet)
- Honorary Professor Beijing Normal University, China (van Lenteren)
- Honorary Professor University of Perugia, Italy (van Lenteren)
- 14th International Symposium on Insect-Plant Interactions, Wageningen, The Netherlands, 2011. (Dicke, chairman of organization committee; van Loon, de Jong, Gols, Fatouros, Poelman, Soler)
- International Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC-IUBS) (2008-2012) (van Lenteren, secretary general)
- International Congress of Entomology, Council (1998-2012) (Takken)
- International Congress of Entomology, July 2008, Durban, South Africa, organisation of two symposia: (1) 'Insects and Society' (Dicke, van Huis), (2) Omics and Ecology and Evolution of Multitrophic Interactions' (Dicke, Vet)
- International Coordinator of the DGIS funded programme 'Convergence of Sciences: strengthening agricultural innovation systems in Benin, Ghana and Mali' (van Huis)
- International Organization for Biological Control, IOBC, Steering Committee Working Group 'Induced Resistance' (Dicke)
- International Symposium 'The integrative role of plant secondary metabolites in ecological systems'. British Ecological Society: 2010 Symposium. 12-14 April 2010, University of Sussex, UK (Dicke, co-organiser)
- 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)
- Scientific Program Committee Measuring Behavior 2008 (6th International Conference on Methods and Techniques in Behavioral Research) (Vet)
- Selection committee European personal research grants (Vet)
- Society for Vector Ecology 2006 (Takken, Scientific Board)
- Visiting Professor, Institute of Zoology, Chinese Academy of Sciences, Beijing, China (van Loon)

National:

- Advisory Board Club of Rome Netherlands (Vet)
- Advisory Board for Nature Conservation, Prins Bernhard Cultuurfonds (Vet)

- Advisory Board Life sciences of the Lorentz Center (Vet)
- Advisory Board Province Gelderland on Climate policy (Vet)
- Bèta-Ambassadeursnetwerk of the Platform Bèta Techniek (PBT) for the promotion of natural sciences to students (Dicke, member)
- Biological advisory board, Biologische Raad, KNAW (Vet)
- Board Foundation Royal Netherlands Institute for Sea Research (NIOZ) (Vet)
- Board IUCN Netherlands (Vet)
- Board NWO Darwin Centre for Biogeology (Vet)
- Board 'Landbouwexport fonds 1918', Wageningen (Dicke)
- Board Uyttenboogaart-Eliasen foundation (Dicke, vice-chairman)
- Board Van Groenendael-Krijger fund (Dicke)
- Committee on Genetic Modification (COGEM), Ministry of Environment (Dicke)
- Department of Plant Sciences, Wageningen University, advisory committees and working groups (Dicke)
- Dutch BioScience Forum (Vet)
- Dutch Entomological Society (Dicke, vice-president)
- Dutch Entomological Society, Section Experimental and Applied Entomology (SETE-NEV) (de Jong, secretary).
- Earth and Life Sciences Board KNAW (Vet)
- Earth and Life Sciences council of the Netherlands Organization for Scientific Research(ALW-NWO) (Dicke)
- Ecogenomics national committee (Vet, chair)
- Evaluation committee Endowed Chair of Evolutionary Phytopathology, Wageningen University (Dicke, member)
- Evaluation committee Tenure Track. Plant Sciences Group Wageningen UR (Dicke, member)
- Examination Committee Life Sciences, Wageningen University (Takken, chairman)
- Food-security Platform (professors dealing with development cooperation within Wageningen University) (van Huis)
- Graduate School Production Ecology & Resource Conservation, Scientific Advisory Board (Vet)
- Graduate School of Production Ecology & Resource Conservation (Scientific Committee, van Huis)
- Hollandsche Maatschappij der Wetenschappen (Dicke, Vet, van Lenteren)
- Institute of Biology Leiden University, Advisory Council (Vet)
- Jury Prins Bernhard Cultuurfonds, Prize for Nature Conservation (Vet)
- Library committee, Centre for Crop Protection, Wageningen University (de Jong)
- Member several PhD Examination committees (Dicke, van Loon, van Huis, van Lenteren, Takken, Vet)
- Ministry OCW on restructuring higher education (OCW-Profielcommissie N&T/N&G), Advisory Committee (Vet)
- National Committee of the International Year of Planet Earth (IYPE) (Vet)
- National Committee on the Prevention of Head Lice Infections, Ministry of Public Health (Takken)
- National Graduate School Experimental Plant Sciences, Scientific Advisory Board (Dicke).
- National Graduate School Experimental Plant Sciences. Education committee (Dicke, chairman).
- National Graduate School Experimental Plant Sciences. Scientific Committee (Dicke).
- Natural History Museum Naturalis, Supervisory Board (Raad van Toezicht) (Vet)
- NBOL 'Netherlands Barcode of Life' (www.dnabarcoding.nl) (Dicke, member)
- Netherlands Ecological Research Network (NERN) (Vet, chair)
- Netherlands Ecological Research Network (NERN) (Dicke, representative of Department of Plant Sciences)

- Noorderlicht VPRO (science radio programme), Scientific Advisory Board (Vet)
- NWO/NGI Advisory Committee on systems biology research (Vet)
- NWO Programme committee Systems biology (Dicke, member)
- NWO Task Force Life Sciences (Vet)
- Organizer Current Themes in Ecology Lecture Series (2/year) (Vet)
- Plantum Werkgroep Koolgewassen (van Loon)
- Post graduate course of the graduate school Production Ecology and Resource Conservation "Biodiversity and Ecosystem Services in a Sustainable World" (van Huis, Chairman organization committee)
- Royal Netherlands Academy of Arts and Sciences. (van Lenteren, Vet)
- Search committee Chair in Animal Ecology, Radboud University Nijmegen (Vet)
- Search committee Chair in Genetics, Wageningen University (Vet)
- Selection committee General Director Plant Sciences Group Wageningen UR . Plant Sciences Group, Wageningen UR (Dicke, member)
- Selection committee NWO personal research grants (Vet)
- Selection committee Professor of Biosystematics, Wageningen University (Dicke, member)
- Supervisory Board National Centre for Science and Technology (NCWT, including Science Museum NEMO, Kennislink, Wetenweek) (Vet)
- Technology Foundation, Netherlands Organisation for Scientific Research (STW-NWO), Programme Committee of 6.5 M€ research programme *Learning from Nature to protect crops* (Dicke, chairman)
- Teylers Tweede Genootschap, Teylers Museum, Haarlem (Vet)
- User committee Resistance of white cabbage to the onion thrips, *Thrips tabaci*. Plant Research International (van Loon)

Journals:

- Biochemical Systematics and Ecology (Dicke, editorial board)
- British Ecological Society's Symposium Series (Vet, advisory editorial board)
- Chemoecology (Vet, associate editor)
- Ecological Entomology (Dicke, editorial board)
- Entomological Bulletin Guido Grandi, University of Bologna (van Lenteren, editorial board)
- Evolutionary Ecology (de Jong, editorial board)
- European Journal of Entomology (de Jong, editorial board)
- Insect Science (Dicke, editorial board)
- International Journal of Pest Management (van Lenteren, editorial board)
- International Journal of Tropical Insect Science (van Huis, editorial board)
- IOBC bulletins (van Lenteren, editor)
- IPM practitioner (van Lenteren, editorial board)
- Journal of Chemical Ecology (Dicke, editorial board)
- Journal of Ethology (Dicke, advisory board)
- Journal of Insect Behaviour (van Lenteren, Vet, editorial board)
- Malaria Journal (Knols, editorial board)
- Neotropical Entomology (van Lenteren, editorial board)
- Open Parasitology Journal (Knols, editorial board)
- Open Tropical Medicine Journal (Knols, editorial board)
- Plant Signaling and Behaviour (Dicke, editorial board)
- Terrestrial Arthropod Research (Knols, editorial board)
- Trends in Plant Science (Dicke, Guest editor)

PROJECTS FUNDED EXTERNALLY

- **2004-2010** Host-plant selection in *Helicoverpa* moths. Collaborative project with Institute of Zoology, Chinese Academy of Sciences, Beijing, China. Funded by Koninklijke Nederlandse Akademie van Wetenschappen, KNAW)
- **2001-2008** Genomics approach to integration of host plant insect resistance and biological control. Funded by Dutch and Chinese government.
- **2001-2009** Development of a method for breeding of cucumber for improved attraction of biological control agents. Funded by Technology Foundation (STW).
- **2004-2008** Linking variation in plant defence to higher level biodiversity. Experimental Plant Sciences, Strategic Funds. (collaboration between Entomology, NIOO and Plant Research International).
- **2004-2008** Spatio-temporal modelling of infochemicals in a food-web context. Funded by NWO-ALW (collaboration with Mathematical and Statistical Methods Group)
- **2004-2008** Ethnobotanicals for the control of *Ripicephalus appendiculatus*, the vector of East Coast Fever in East Africa. Funded by Wageningen University, IFS and ICIPE.
- **2004-2009** Assessing the contribution of Farmer Field School approach to the management of cassava, soil and family health and its role in food security in Malawi. Funded by JICA.
- **2004-2009** Crop protection perspectives in Kazakhstan: shifting interfaces between farmer practice and agricultural research. Funded by WUR and Govt. of Kazakhstan.
- **2004-2009** A molecular genetic approach to chemical ecology and community ecology. Funded by NWO-VICI.
- **2004-2009** Behavioural and ecological determinants of gene flow in African malaria vectors. Funded by NWO-VIDI.
- **2004-2009** Ecological and physiological functions of biogenic isoprenoids and their impact on the environment (ISONET). Funded by EU.
- **2005-2008** Behaviour and elimination of supernumerary parasitoid larvae in *Eretmocerus mundus*. (Financed by Univ Palermo)
- **2005-2009** Phenotypic plasticity of taste in insects. Funded by the Royal Dutch Academy of Arts and Sciences (KNAW), in collaboration with the Chinese Academy of Sciences, Institute of Zoology, Beijing, China.
- **2005-2009** Effect of crop management on performance of endophytic *Fusarium* spp. in tissue culture banana against the banana weevil *Cosmopolites sordidus* (Germar) and nematodes in Uganda (sandwich scholarship).
- **2005-2009** Assessing the contribution of Farmer Field School approach to the management of cassava, soil, and family health and its role in food security in Malawi". (funded by JICA)
- **2005-2009** Crop Protection Perspectives in Kazakhstan: Shifting Interfaces between Farmer Practice and Agricultural Research (funded by WUR and Kazakhstan)
- **2006-2009** Naturally healthy from day to day: a national interactive website for monitoring, forecasting, managing and communicating health risks from nature in space and time. (funded by RGI, the Netherlands – Space for Geoinformation)
- **2006-2008** Innovative biological control of malaria mosquitoes using fungi.
- **2006-2009** Harmonization of regulation regarding risk assessment of exotic organisms. (Financed by EU)
- **2007-2008** Overwintering behaviour of adult *Culicoides* and the impact of insecticides on livestock farms in the Netherlands. Principle investigator: Willem Takken in collaboration with Plant Research International and the Dutch Plant Protection Service.

- **2007-2010** Mosquito vectors of disease: spatial biodiversity, drivers of change, and risk. Principle Investigator: Willem Takken in collaboration with the Tropical Institute, Antwerp (Dr. W. van Bortel). Funding: Science for a Sustainable Development (SSD), Federal Government of Belgium.
- **2007-2011** Ecological effects of plant resistance traits on above-ground non-target organisms in different genotypes of Brassica and Arabidopsis. Netherlands Organisation of Scientific Research (NWO – ERGO programme).
- **2007-2011** Biology and ecology of *Apanteles taragamae,* a larval parasitoid of *Maruca vitrata,* a key pest in cowpea. NUFFIC.
- **2009-2012** Plant-mediated indirect competition between congeneric parasitoid wasps. Netherlands Organisation of Scientific Research (NWO).
- **2009-2012** Plant-mediated interactions between herbivorous insects and pollinators: an ecogenomic approach. Netherlands Organisation of Scientific Research (NWO).
- **2009-2011** Effects of beneficial rhizobacteria on induced plant defences to aboveground herbivores. EU Marie Curie.
- **2008-2012** Development of innovative methods for selecting and engineering natural resistance to thrips in ornamental and vegetable crops. Technological Top Institute Green Genetics.
- **2008-2012** Resistance mechanisms against whitefly in tomato. Technological Top Institute Green Genetics.
- **2009-2013** Unraveling the mechanism of resistance to *Nasonovia ribisnigri* in lettuce. Technological Top Institute Green Genetics.
- **2009-2013** Evolution of memory in *Cotesia* wasps. Netherlands Organisation of Scientific Research (NWO).
- **2010-2014** Convergence of Sciences: Strengthening agricultural innovation systems in Benin, Ghana and Mali). DGIS, Ministry of Foreign Affairs.

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