National Institute of Science and Technology

Semiochemicals in Agriculture

(CNPq-Fapesp)

SEMIOQUÍMICOS NA AGRICULTURA

Participating Institutions:

Proposal for Strengthening the Current INCT

September 2014

Summary

According to the final report of the CNPq Advisory Committee, the INCT Semiochemicals in Agriculture has been a considered model for the last four years (2009-2013). This INCT develops scientific research and technological innovation in a strategic area for national development – agriculture – and through this new call, is expected to further contribute to the consolidation of the country in this area in the short, intermediate and long term. Contemplating cutting-edge research of high quality, highly trained human resources, transfer of knowledge to society and businesses, and strong internationalization of activities, this new proposal aims to strengthen the current INCT Semiochemicals in Agriculture. Based on the network structure composed today and that already consolidated, laboratories and skills established in the states of **São Paulo** (College of Agriculture 'Luiz de Queiroz' - ESALQ/USP, 'Piracicaba', Institution Headquarters), **Minas Gerais** (Federal University of Viçosa - UFV, 'Viçosa'), **Paraná** (Federal University of Paraná - UFPR, 'Curitiba') and **Alagoas** (Federal University of Alagoas - UFAL, 'Maceió'), this new phase for INCT Semiochemicals in Agriculture will expand to other locations in Brazil, aiming at a greater balance and the formation of new research groups in new university *campi* and developing regions, as recommended by the Edital. To the current group, we will add laboratories represented by the states of **Sergipe** (Federal University of Sergipe - UFS, 'Aracaju'), **Bahia** (State University of Santa Cruz - UESC, 'Ilhéus'), **Rio de Janeiro** (Rural Federal University of Rio de Janeiro - UFRRJ, 'Três Rios'), **Mato Grosso** (State University of Mato Grosso - UNEMAT, 'Tangará da Serra'), **Mato Grosso do Sul** (State University of Mato Grosso do Sul - UEMS, 'Cassilândia'), **Santa Catarina** (Community University of the Region of Chapecó - Unochapecó, 'Chapecó'), and two other institutions in **Paraná** (State University of the Central West - UNICENTRO, 'Guarapuava', and State University of West Paraná - UNIOESTE, 'Cascavel'). Taking into account the objectives and clear goals, INCT Semiochemicals in Agriculture has established a strategic foundation for the country with five general lines of research, namely: (i) Semiochemicals in insect-insect and insect-plant interactions, (ii) Semiochemicals in the context of biological control, (iii) Identification and synthesis of semiochemicals, (iv) Semiochemical formulation and release technology, and (v) Use of semiochemicals in agriculture. All research subprojects proposed by the current INCT fit harmoniously into one or more of these general research lines, and are suitable for addressing problems with the main crops and pests of economic importance in current Brazilian agriculture. This proposal thus creates new possibilities for pest control and monitoring by generating new knowledge, possibly providing new sustainable technologies for farmers without the use of chemicals, making the country more self-sufficient. Because it is a well-structured network of educational and research institutions, the INCT Semiochemicals in Agriculture will continue contributing to human resources training at the highest level, expanding and disseminating innovations for many different Brazilian regions. Bolstered by leading international institutions in this area, such as the University of California-Davis, the University of California-Riverside, Penn State University, Wageningen University, University of Neuchâtel, Max Planck Institute of Chemical Ecology, Universität Hamburg, and the University of Western Ontario, among others, the INCT Semiochemicals in Agriculture will maintain constant exchange of students and researchers, promoting an increase in scientific production and improving production quality. Numerous opportunities exist for national companies to generate new products and technologies that support the agrobusiness growth, as is already being done by the pioneers companies and current market leaders supported by INCT Semiochemicals in Agriculture. Combined with these efforts, a constant pursuit of initiatives to transfer knowledge to society and science education materials for the general population has been implemented and made available by participating members and institutions.

CNPq opinion regarding INCT Semiochemicals in Agriculture in the last four years (2009-2013)

Final Comments:
"*This is a model for INCT with activities that have been intensified by the synergies enabled by the formation of a network. There was increased high-level scientific production, in parallel with the formation of human resources, as well as applications and interactions with companies*."

NATIONAL INSTITUTE of SCIENCE and TECHNOLOGY – INCT
INCT Semiochemicals in Agriculture

PERIOD (2015 to 2021)

I. DESCRIPTION OF INCT

TITLE: National Institute of Science and Technology of Semiochemicals In Agriculture
ABBREVIATION: INCT Semiochemicals in Agriculture

COORDINATOR: José Roberto Postali Parra (*Researcher Level 1A CNPq*)

HEAD INSTITUTION: ESALQ-USP

INSTITUTIONS PARTICIPATING IN INCT:

Institution Name	Institutional Abbreviation	Municipality	State
College of Agriculture 'Luiz de Queiroz' , University of Sao Paulo	ESALQ-USP	Piracicaba	SP
Federal University of Viçosa	UFV	Viçosa	MG
Federal University of Paraná	UFPR	Curitiba	PR
Federal University of Alagoas	UFAL	Maceió	AL
Federal University of Sergipe	UFS	Aracaju	SE
Rural Federal University of Rio de Janeiro	UFRRJ	Três Rios	RJ
State University of Mato Grosso do Sul	UEMS	Cassilândia	MS
State University of do Mato Grosso	UNEMAT	Tangará da Serra	MT
State University of Santa Cruz	UESC	Ilhéus	BA
State University of Midwestern Paraná	UNICENTRO	Guarapuava	PR
State University of Western Paraná	UNIOESTE	Cascavel	PR
Community University of the Chapecó Region	UNOCHAPECO	Chapecó	SC

RESEARCHERS PARTICIPATING IN INCT: (List of all doctorate-holding researchers who are part of the INTC Research - students and fellows not included).		
Researcher Name	**Researcher CPF**	**Institutional Abbreviation**
José Roberto Postali Parra (*Level 1A CNPq*)	245.783.478-34	ESALQ-USP
José Maurício S. Bento (*Level 1C CNPq*)	723.022.916-20	ESALQ-USP
Paulo Henrique G. Zarbin (*Level 1D CNPq*)	138.814.108-64	UFPR
Eraldo Rodrigues Lima (*Level 1B CNPq*)	005.335.668-35	UFV
Antônio E. Goulart Santana (*Level 1D CNPq*)	118.677.606-49	UFAL
Bianca Giuliano Ambrogi	209.925.458-38	UFS
Ângela Alves de Almeida	254.501.478-80	UFRRJ
Sérgio Roberto Rodrigues	097.611.198-58	UEMS
Mônica Josene Barbosa Pereira	563.926.644-91	UNEMAT
Carla Fernanda Fávaro	324.537.538-78	UESC
Cristiane Nardi	007.809.099-76	UNICENTRO
Miryan Denise Araújo Coracini	831.474.549-91	UNIOESTE
Daniel Albeny Simões	059.695.646-05	UNOCHAPECO

II. Management Committee

Members of the Management Committee, function on the committee and home institution

Name	**Function on Committee**	**Home Institution (Abb.)**
José Roberto Postali Parra (*Res. Level 1A CNPq*)	Coordinator	ESALQ-USP
José Maurício S. Bento (*Res. Level 1C CNPq*)	Vice-coordinator	ESALQ-USP
Paulo Henrique G. Zarbin (*Res. Level 1D CNPq*)	Regional member (South)	UFPR
Eraldo Rodrigues Lima (*Res. Level 1B CNPq*)	Regional member (Southeast)	UFV
Antônio E. Goulart Santana (*Res. Level 1D CNPq*)	Regional member (Northeast)	UFAL

III. Organizational and Functional Structure of INCT Semichemicals in Agriculture

(Includes descriptions of the group proposal detailing the activities and responsibilities of each team member; task definition and description of interaction-promoting mechanisms)

The organizational structure of INCT Semiochemicals in Agriculture will be to preserve the existing established and consolidated network from the previous four years (2009-2013), which consists of internationally recognized experts in laboratories in the states of **São Paulo** (College of Agriculture Luiz de Queiroz - ESALQ/USP, 'Piracicaba', Institution Headquarters), **Minas Gerais** (Federal University of Viçosa - UFV, 'Viçosa'), **Paraná** (Federal University of Paraná - UFPR, 'Curitiba') and **Alagoas** (Federal University of Alagoas - UFAL, 'Maceió'). To this pioneering network will be added laboratories representing the states of **Sergipe** (Federal University of Sergipe – UFS, 'Aracajú'), **Bahia** (State University of Santa Cruz - UESC, 'Ilhéus'), **Rio de Janeiro** (Rural Federal University of Rio de Janeiro - UFRRJ, 'Três Rios'), **Mato Grosso** (State University of Mato Grosso - UNEMAT, 'Tangará da Serra'), **Mato Grosso South** (State University of Mato Grosso do Sul - UEMS, 'Cassilândia'), **Santa Catarina** (Community University of the Chapecó Region- Unochapecó, 'Chapecó'), and two other institutions in **Paraná** (State University of Midwestern Paraná - UNICENTRO, 'Guarapuava', and State University of West Paraná - UNIOESTE, 'Cascavel'). With this,

the INCT Semiochemicals in Agriculture will have participation of 12 universities in total, covering 10 states in four of the five Brazilian regions (South, Southeast, Midwest and Northeast) (**Figure 1**).

From the initial experience gained by INCT Semiochemicals in Agriculture represented by ESALQ/USP, UFPR, UFV, and UFAL, and thanks to the development of human resources achieved in recent years with the group initiative in their graduate program, INCT will expand to other locations in Brazil, aiming at a greater balance and the formation of new research groups in new campi and regions, as recommended by the Public Call. The new group will contain the following institutions: UFS, UESC, UFRRJ, UNIOESTE, UEMS, UNEMAT, Unochapecó and UNICENTRO. Many of these institutions are located in agriculturally important regions of Brazil.

Considering the INCT Semiochemicals in Agriculture as a model over the last four years (2009-2013) in accordance with the final report of the CNPq Advisory Committee, this INCT includes the following activities and responsibilities of each member laboratory:

ESALQ/USP, UFPR, UFV, and UFAL laboratories will be the logistical bases for INCT Semiochemicals in Agriculture, and will assist and provide support for the new institutions being added to the network in this phase. Facilities will be created and access to group know-how will be granted in order to implement the necessary infrastructure for new institutions to development work involving semiochemicals in both the laboratory and the field.

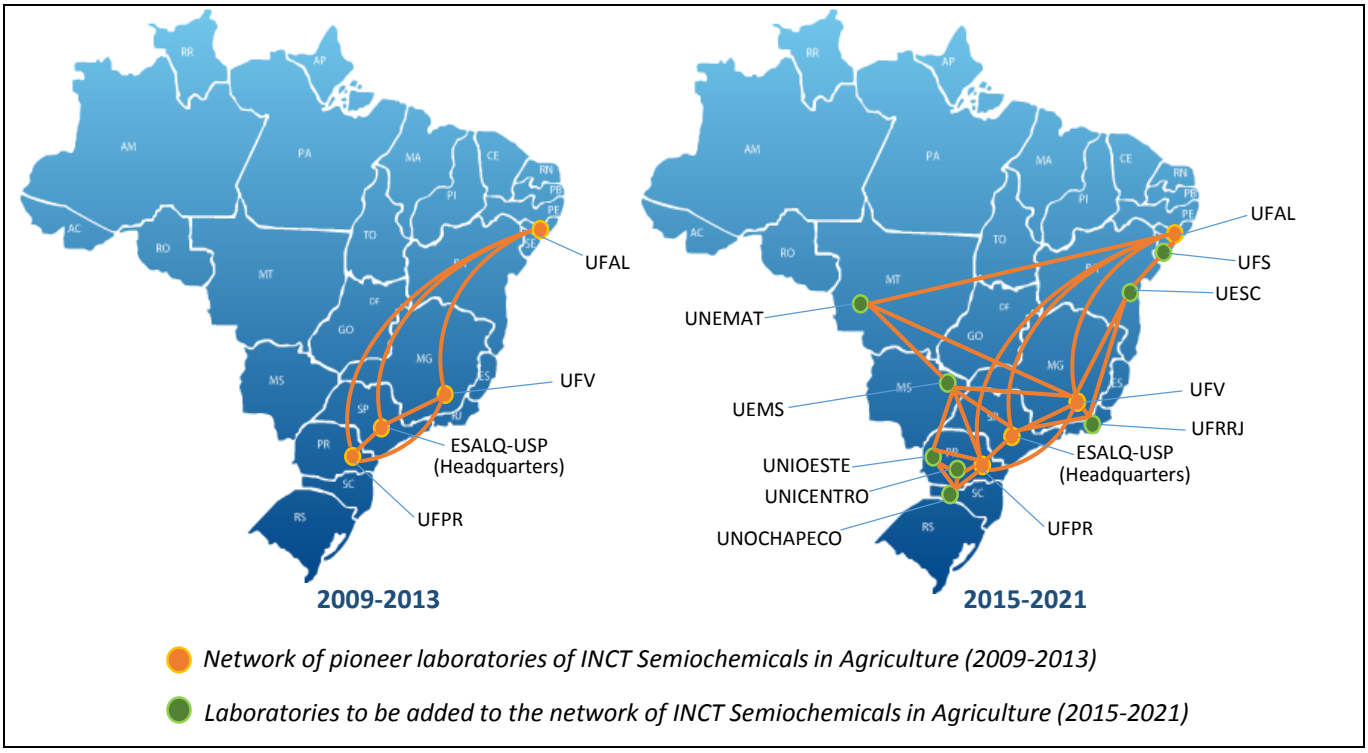

Figura 1. Map of Brazil showing the initial formation of the INCT Semiochemicals in Agriculture network in the last four years 2009-2013, and the current network proposal in this Public Call (2015-2021).

ESALQ/USP will remain the INCT institution headquarters, which is also the home institution of the Coordinator and Vice-coordinator (**Figure 2**). The Coordinator, Prof. Dr. José Roberto Parra Postali is a Professor and researcher level 1A of CNPq, a member of the Brazilian Academy of Sciences (2000) and The Academy of Science for the Developing Word - TWAS (2002). He has received a *Commander Award* (2002) and a *Grand Cross Award* (2010) from the *National Order of Scientific Merit*, among other honors. Prof. Parra has roughly 400 scientific publications, with 5,862 citations and an H-index value of 35 (Google, August 2014). Prof. Dr. Parra is responsible for the Laboratory of Insect Biology, and will be in charge of rearing insect populations for pheromone extraction and rearing parasitoids for studies of plant volatiles. His lab will command the studies involving insect-insect and insect-plant interactions, as well as the application of these findings involving pheromones and plant volatiles. The Vice-coordinator, Prof. Dr. José Mauricio Simões Bento, is an Associate Professor, a research fellow of CNPq (Level 1C), coordinator of graduate school in Entomology and vice department head of Entomology and Acarology at ESALQ/USP, and a founding member of the Latin American Association of Chemical Ecology (ALAEQ). Dr. Bento has 97 scientific publications with 877 citations and an H-index value of 17 (Google, August 2014). He is the researcher responsible for the Laboratory of Chemical Ecology and Insect Behavior, which is fully equipped and will be in charge of insect and plant studies for prospective new semiochemicals, including pheromones and allelochemicals, as well as for developing the steps of its use and assessing the potential applications of this technology in the field.

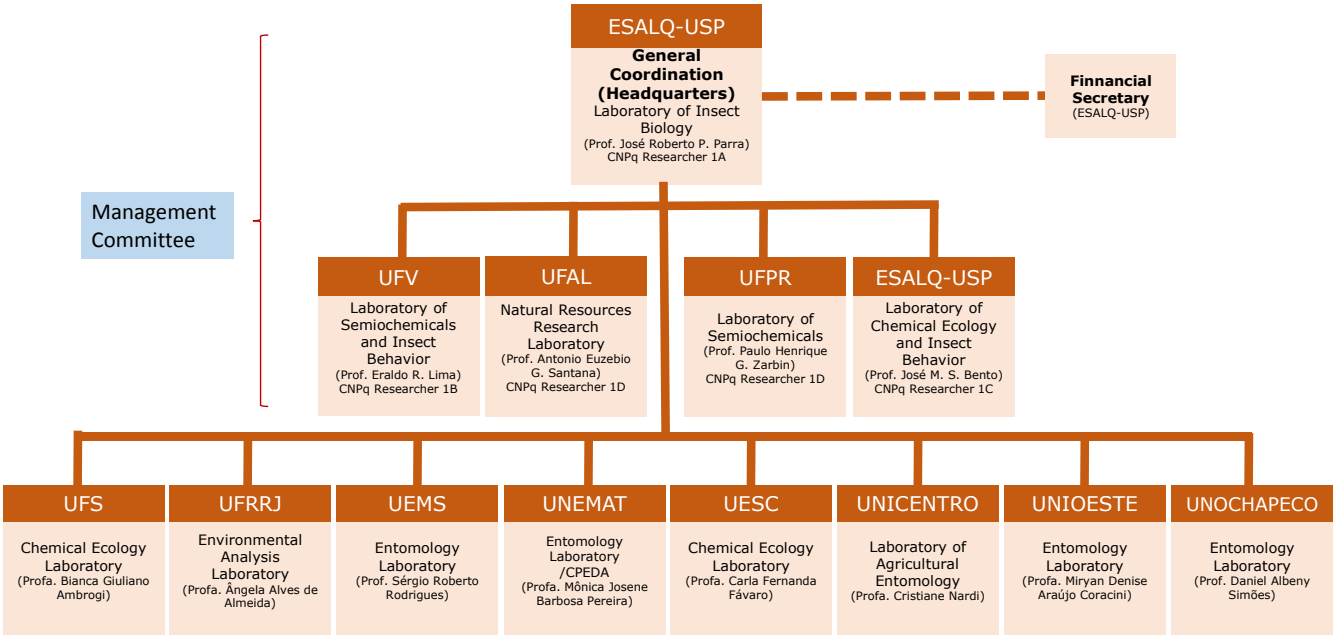

Figure 2. Organizational structure of INCT Semiochemicals in Agriculture for 2015-2021. The Management Committee consists of principal investigators from ESALQ-USP, UFV, UFAL, and UFPR.

The financial secretary will remain at ESALQ/USP. Since the beginning of the INCT Semiochemicals in Agriculture program, a financial secretary was hired exclusively for managing these resources. This employee was transferred from the USP rectory (permanent statutory employee), and has been a great advantage for INCT by reducing diversion of researchers from their main activities, namely research and teaching.

The Laboratory of Semiochemicals at UFPR is under the responsibility of Prof. Dr. Paulo Henrique Gorgatti Zarbin. Prof. Zarbin is an Associate Professor, a Level 1D CNPq researcher, and has been President of the largest chemical ecology society in the world, the International Society of Chemical Ecology - ISCE (2011-2012). He has been vice-president of the Entomological Society of Brazil - SEB (2010-2012), coordinator of PPG Chemistry/UFPR (2002-2004), and a founding member and current advisor of the Latin American Association for Chemical Ecology (ALAEQ). He has published 83 papers with 615 citations and an H-index value of 15 (Google, August 2014). This laboratory is equipped for the activities involving the chemical steps of the project, particularly the identification and synthesis of semiochemical, and therefore giving support for laboratory and field studies of all other INCT groups.

The Laboratory of Semiochemicals and Insect Behavior is located at the Federal University of Viçosa (UFV) under the responsibility of Prof. Dr. Eraldo Rodrigues de Lima. Prof. Lima is an Associate Professor, a CNPq researcher (Level 1B). Prof. Lima has been Head of the Department of Entomology at UFV since 2012, and is a co-founder and current adviser for the Latin American Association for Chemical Ecology (ALAEQ). He has 56 scientific publications with 524 citations, and an H-index value of 13 (Google, August 2014). This lab is structured for basic insect and plant studies for prospective new semiochemicals, including pheromones and allelochemicals, as well as developing usage protocol and potential applications of this technology in the field.

The Natural Resources Research Laboratory is located at UFAL, under the responsibility of Prof. Dr. Antonio Euzébio Goulart Santana. Prof. Santana is an Associate Professor, researcher level 1D (CNPq), served as coordinator of the Graduate School in Chemistry and Biotechnology/UFAL (1996-1998), coordinator of the Northeast Biotechnology Network with focal point in Alagoas (2008-2014) and titular member of the National Biosafety Technical Commission (2006-2011). He has around 230 scientific publications with 2,306 citations and an H-index value of 26 (Google, August 2014). This lab, like UFPR, is equipped for the activities and responsibilities regarding the chemical steps of the project, particularly the identification and synthesis of semiochemicals. The responsibilities of this lab will also support the laboratory and field studies of all other INCT groups.

Among the new institutions and researchers being added to the INCT, there are:

The Chemical Ecology Laboratory at UFS, under coordination by Prof. Bianca G. Ambrogi. Prof. Bianca holds a bachelor degree in agricultural engineering from the Federal University of Lavras (2001), master's degree in Entomology from the Federal University of Viçosa (2004), Ph.D. in Biological Sciences from the Federal University of Paraná (2009) and post-doctoral fellow for Scientific and Regional Development (DCR/CNPq) at the Federal University of Sergipe (UFS) (2012). She currently works in chemical ecology and insect behavior.

The Environmental Analysis Laboratory at UFRRJ is coordinated by Prof. Angela Alves de Almeida. Prof. Angela holds a bachelor degree in agronomic engineering from the Federal University of Viçosa (1999), a master's degree in crop science (plant production) from the Federal University of Viçosa (2002), and a Ph.D. in Entomology from the Federal University of Viçosa (2007). She was a visiting scholar at the Institute for Biodiversity and Ecosystem Dynamics (IBED) in Amsterdam (Netherlands, 2007-2008). She currently works in chemical ecology and insect behavior.

The Entomology Laboratory at UEMS is coordinated by Prof. Sérgio Roberto Rodrigues. Prof. Sergio holds a bachelor degree in agricultural engineering from the São Paulo State University Julio de Mesquita Filho, Ilha Solteira, SP (1993). He got his master's degree, Ph.D. and post-doctorate in Entomology from the University of São Paulo (ESALQ/USP) (1996/2000/2013). He works in

agricultural entomology, particularly with respect to the insect behavior of beetles belonging to Scarabaeidae family.

The Entomology Laboratory/CPEDA at UNIMAT is coordinated by Prof. Monica J. Barbosa Pereira. Prof. Monica holds a degree in agronomic engineering from the Federal University of Alagoas (1992), a master's degree in Entomology from the Federal University of Viçosa (1996), and a Ph.D. in Entomology by College of Agriculture 'Luiz de Queiroz' (2001). She currently works in insect behavior.

The Chemical Ecology Laboratory at UESC is coordinated by Prof. Carla Fernanda Fávaro. Prof. Carla got her bachelor degree in Chemistry at the Central University of Votuporanga (2007), and holds a Ph.D. in chemistry with an emphasis in organic chemistry from Federal University of Paraná (2012), having performed part of the doctorate at the University of California - Riverside (USA, 2011). She was previously a post-doctoral researcher at ESALQ/USP. She currently works with the isolation, identification and synthesis of biologically active organic compounds, mainly insect pheromones.

The Laboratory of Agricultural Entomology at UNICENTRO is coordinated by Prof. Cristiane Nardi. Prof. Nardi got her bachelor degree in agronomy from the Federal University of Santa Catarina (2003), a master's and Ph.D. in Entomology from the College of Agriculture 'Luiz de Queiroz' (2006, 2010). She is currently a professor at the State University of the Midwest, where she conducts research in chemical ecology and insect behavior.

The Entomology Laboratory at UNIOESTE is coordinated by Prof. Miryan Denise A. Coracini. Prof. Coracini holds a bachelor in Biological Sciences from the State University of Londrina (1992), master's degree in agricultural entomology from the Federal University of Viçosa (1997) and Ph.D. in chemical ecology from the Swedish University of Agricultural Sciences (2002). She works in semiochemicals (sex pheromones and plant volatiles) performing behavioral tests in the laboratory and field, particularly with Lepidopterans.

The Entomology laboratory at Unochapecó is coordinated by Prof. Daniel Albeny Simões. Prof. Albeny-Simões holds a bachelor degree in Biological Sciences from the Central University of Eastern Ontario (2004), and both Master's and Ph.D. in Entomology from the Federal University of Viçosa (2007, 2013). He performed part of his doctoral work at Illinois State University (Illinois, USA) financed by CNPq. He works in insect behavior, especially in Culicidae, and in chemical ecology of aquatic insects.

IV. Performance Indicators reached by INCT Semiochemical in Agriculture

Since the formation of INCT Semiochemicals in Agriculture, the involved laboratories in the states of São Paulo, Minas Gerais, Paraná and Alagoas, comprising the Southeast, South, and Northeast regions, have been consolidated in the given area. The acquisition of cutting-edge machines together with high quality research and international collaboration helped these laboratories become worldwide references. Based on the maintained and expanded structure, within the period of 2009-2013, all indicators are two to three times higher than the previously established goals. Strong **human resources training** at all academic levels, forming in total 43 Ph.D., 32 MSc., 21 post-docs and 40 scientific initiation for undergraduates (**Table 1**). There was a strong increase in **scientific production**, having achieved an average production per researcher of 26.6 indexed articles in this period (Table 1). Many publications have been featured in the international media, including news report in Nature, Science, Time, New Scientist, LeMonde, Folha de São Paulo, and FAPESP Magazine, among others. In "**Transfer of Technology**", four patents were obtained and filed by INCT Semiochemicals in Agriculture.

Table 1. Indicators of scientific production and training of human resources in INCT Semiochemicals in Agriculture in 2009-2013. Total data and items per researcher are included.

Quantitative INCT Semiochemicals in Agriculture (2009-2013)		
TYPE	**QUANTITY**	**RATIO (ITEM/RESEARCHER)**
Scientific Production		
Books	2	--
Book Chapters	15	3.0
Articles published in indexed journals *(Articles published in indexed national journals)* *(Articles published in indexed international journals)*	**133** *(24)* *(109)*	**26.6**
Patents	**4**	**0.8**
Works presented at national conferences	283	56.6
Works presented at international conferences	248	49.6
Human Resources Training		
Dissertations (Completed Masters Degrees)	**32**	**6.4**
Theses (Completed Doctorate Degrees)	**43**	**8.6**
Post-docs	**21**	**4.2**
Scientific Initiatives	**40**	**8.0**

In "**Education, Science Dissemination and Knowledge Generation**" item, a few achievements stood out: (i) Foundation of the Latin American Society of Chemical Ecology (ALAEQ) which promotes events every two years in one of the member countries (Colombia, November 2014); (ii) creation of the 'Winter School in Chemical Ecology', sponsored by the UFPR Laboratory of Semiochemicals in Curitiba-PR (the first took place in 2011 and the next is scheduled for 2015); (iii) exchange of students and researchers between INCT laboratories; (iv) International student exchanges involving USA, Germany, Switzerland, Spain, Holland, Uruguay, Colombia, Chile, UK; and (v) the organization of the biennial Brazilian Meeting of Chemical Ecology (EBEQ) (the last event was held in October 2013 in Natal-RN).

Noteworthy **partnerships with public and/or social institutions** include the Brazilian Agricultural Research Corporation (Embrapa), the Association of Erva-mate producers of Paraná, the Rural Producers Cooperative (Coopercitrus), and Citrus Defense Fund (Fundecitrus).

Regarding **internationalization**, in addition to student exchanges with laboratories abroad (see item "Education, Science Dissemination and Knowledge Generation"), researchers representing 13 countries now integrate the INCT Semiochemicals in Agriculture research network, and 15 international scientific cooperation agreements have been signed. Among the international institutions, most prominent are: University of California-Davis (USA), University of California-Riverside (USA), Penn State University (USA), Wageningen University (Netherlands), University of Neuchatel (Switzerland), Max Planck Institute of Chemical Ecology (Germany), and Universität Hamburg (Germany), among others.

Our final remarkable item is **participation and partnership with private companies**. At least 13 companies, both domestic and international have participated in the INCT Semiochemicals in Agriculture research network, including Ourofino Agribusiness, BASF, Monsanto, Bayer, Koppert Biological System Co., Fuji Flavor Co., Biocontrol, Bug Biological Agents, Coopercitrus, Fundecitrus, and Tecnano- Nanotechnology for Agriculture, among others.

V. Description of Mechanisms to Promote Groups Interactions

The INCT - Semiochemicals in Agriculture project has adopted mechanisms to maximize interaction between member groups. Research laboratories involved with parallel or complementary topics may interact and, to the greatest extent possible, share physical and intellectual resources without losing their individual identities; this promotes the circulation of ideas, exchange of researchers and students, and optimization of equipment and facilities usage. Solutions to strategic societal issues, such as agriculture, will require integration of diverse fields of knowledge, including chemical ecology, which has its origin in studying natural interactions between biology and ecology. These mechanisms were adopted in the first phase of INCT, producing remarkable effects with respect to integration between laboratories for student exchange and generation of high standard publications.

VI. Details of Staff Training Program

In addition to physical research support, strong emphasis is placed on human resources training in the most prominent institutions, as recommended by the Public Call. As such, agreements will be established with such institutions regarding the participation of students and/or teachers in graduate level (Masters and PhD) programs. Interaction of institutions supported by CAPES programs may also be incorporated into this process. Current INCT laboratories are ranked in the national graduate program ranking system, with ESALQ/USP and UFV scoring 7 (maximum score, international excellence); UFPR has a score of 6 (international level); and UFAL has a score of 5. This support and the excellence in teaching and will be made available to other institutions in the network.

VII. Detailed Description of the INCT Semiochemicals in Agriculture Program

Details of Main Lines of Research

(Includes goals and qualifications/justifications)

The INCT Semiochemicals in Agriculture program has established a strategic foundation including five general research lines harboring all subprojects of the Institute, namely: (I) Semiochemicals in insect-insect and insect-plant interactions, (II) Semiochemicals in the context of biological control, (III) identification and synthesis of semiochemicals, (IV) formulation and release technology of semiochemicals, and (V) application of semiochemicals in agriculture (**Figure 3**). All research subprojects proposed by the current INCT fit harmoniously into one or more of these general research lines, and are suitable for addressing problems with the main crops and pests of economic importance in current Brazilian agriculture. This creates new possibilities for monitoring and control of pests, potentially generating knowledge and sustainable technologies for farmers that reduce or exclude the use of agrochemicals. A hallmark of INCT Semiochemicals in Agriculture is inclusion of both basic (knowledge-based) and applied (generation of new products/technology) research activities, which has contributed to its overall success.

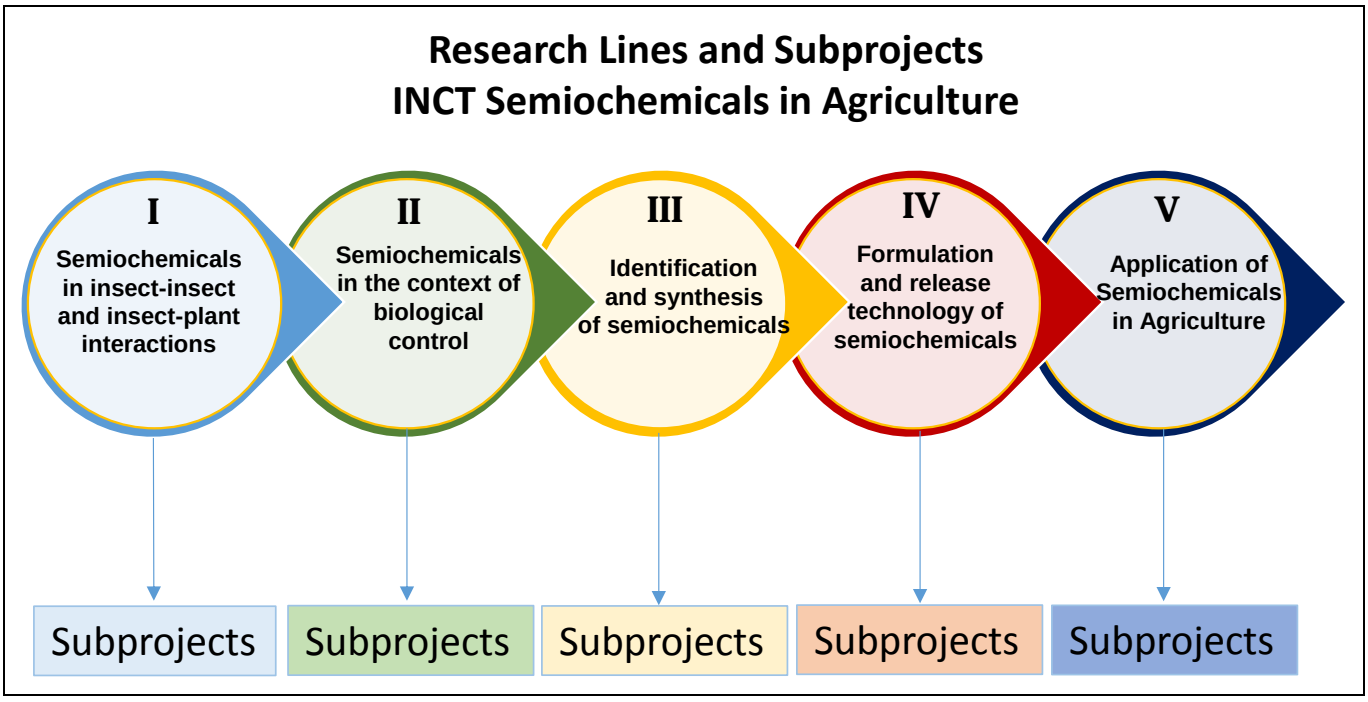

Figure 3. Functional model of the INCT Semiochemicals in Agriculture program, indicating the lines of research that incorporate the proposed subprojects. (I) Semiochemicals in insect-insect and insect-plant interactions; (II) Semiochemicals in the context of biological control; (III) Identification and synthesis of semiochemicals; (IV) formulation and release technology of semiochemicals; and (V) application of semiochemicals in agriculture.

Below we list the main projects initially selected to compose the INCT Semiochemicals in Agriculture, placed within their respective lines of research. Within each research line is the subproject title, responsible research team, qualification of the problem, general and specific objectives, and expected scientific and technological contributions. Due to limitations on document length, the schedules of these subprojects are presented as appendices. New subprojects may be added throughout the course of the INCT, provided that they are assessed and approved by the Management Committee and justified in the annual reports to CNPq/FAPESP chairpersons. In the annual reports, subprojects may also be incorporated into other research lines different than those presented herein. Once the proposed goals are reached, basic research activities may become more applied in nature (*i.e.*, activities may move along the scale of the proposed research lines from I to V).

(I) Semiochemicals in insect-insect interactions and insect-plant

Sub-Project 1
Sexual behavior and chemical ecology of *Diabrotica speciosa* (Germar) and *Diabrotica viridula* F. (Coleoptera: Chrysomelidae)

Coordinator: Cristiane Nardi, University of the Midwest (UNICENTRO), PR, CPF 00,780,909,976
Research Team: José Maurício S. Bento, CPF 72302291620, Prof. Dr. ESALQ-USP; Paul H. G. Zarbin, CPF 13881410864, Prof. Dr. UFPR; Carla Fávaro, CPF 32453753878, Professor. Dr. UESC / BA.; Franciele Santos. Msc, CPF 06314832926, ESALQ-USP

Qualification of the problem being addressed
In the Neotropics, the genus *Diabrotica* contains a large number of diverse species. Although *Diabrotica speciosa* has been pointed out as the most frequent and damaging to agricultural crops, *Diabrotica viridula* F. is the predominantly occurring species in maize crops in some regions. In Brazil, control of these insects is acheived exclusively by insecticides. Insecticide efficiency is limited to soil immatures, and results in the rapid evolution of resistance.

General objectives
Characterize sexual behavior, identify chemical compounds that act as mediators of sexual communication in *D. speciosa and D. viridula* and investigate the mode of action of such compounds.

Specific objectives
1. To study the sexual behavior of *D. viridula* and to identify the chemical compounds involved in sexual communication of this species;
2. Identify the chemicals involved in sexual activity of *D. speciosa* and *D. viridula*;
3. To assess the biological activity of pheromones in the field.

Major scientific and technological contributions of the proposed subproject
The results of this subproject favor the development and improvement of *Diabrotica* management techniques. The chemical characterization of sex pheromones will generate prospects for the monitoring and control of *Diabrotica* spp. in the field.

Schedule (see Appendices)

Subproject 2
Spodoptera frugiperda genotypes and factors involved in the perception of their host plants.

Coordinator: Eraldo Rodrigues de Lima, Dr., Federal University of Viçosa, Department of Entomology, CPF 005335668-35
Research Team: Antônio Cláudio Ferreira da Costa, Epamig CPF 699326626-15, M. Sc.; José Maurício S. Bento, CPF 72302291620, Prof. Dr., ESALQ-USP; Paulo H. G. Zarbin, Prof. Dr., UFPR, CPF 13881410864

Qualification of the problem being addressed
The Fall armyworm *Spodoptera frugiperda* (JE Smith) is a polyphagous species, which can feed on 200 host plants. Two morphologically identical yet genetically distict lines of *S. frugiperda* were identified in the 1980s: the maize gentoype, described as a pest of maize (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench subsp Bicolor.), and cotton (*Gossypium hirsutum* L.); the second genotype feeds predominantly upon rice (*Oryza sativa* L.), sugar cane (*Saccharum officinarum* L.) and grasses such as Johnson grass (*Sorghum halepense* (L.) Persoon) and Bermuda grass (*Cynodon dactylon* (L.)).

General objective
To determine the causes of the different plant host preferences of *Spodoptera frugiperda* genotypes, and the effects of their respective plant host groups on behavior and development of each insect genotype.

Specific objectives
1. Assess the responses of *S. frugiperda* genotypes to the constituents of host plants odors via

electroantennogram;
2. Evaluate the attractiveness or repellency of constituents of host plant odors to *S. frugiperda* via wind tunnel tests;
3. Assess the association between attractiveness or repellency of *S. frugiperda* to constituent odors of host plants and beneficial or harmful substances they contain;
4. Assess the association between attractiveness or repellency manifested by the insect genotypes, and the qualitative and quantitative composition of host plant odors;
5. Assess the oviposition preference of *S. frugiperda* genotypes in *Bt* maize;
6. Assess the association between oviposition preferences of *S. frugiperda* genotypes and odors of plants in conventional vs. *Bt* maize;
7. Evaluate the susceptibility of the two *S. frugiperda* genotypes to *Bt* maize.

Major scientific and technological contributions of the proposed subproject
Knowledge of the mechanisms that influence the preference of the two Spodopteran lines will contribute to the development of specific management strategies for each, contributing to the increased efficiency in control and subsequent reduction of negative impacts on agriculture.

Schedule (see Appendices)

Subproject 3
Sexual behavior of Scarabaeidae pests with the goal of obtaining pheromones for crops in Mato Grosso do Sul

Coordinator: Prof. Dr. Sérgio Roberto Rodrigues, State University of Mato Grosso do Sul, CPF 09761119858
Research Team: Imara Rosana de Oliveira (graduate student), State University of Mato Grosso do Sul, CPF 095391578-62; Fabiano dos Santos Herculaneum (majoring in agronomy), State University of Mato Grosso do Sul, CPF 011093621-37; John Gabriel Navarro Ersina (majoring in agronomy), State University of Mato Grosso do Sul, CPF 363340998-09; José Maurício S. Bento, Esalq-USP, CPF 72302291620

Qualification of the problem being addressed
Scarabaeidae comprises a group of pests which remain in the soil, obtaining nourishment from plant roots and causing damage. Effective control of this group is complex, as larvae and adults remain housed in the soil. In the Midwest region of Brazil, extensive areas are cultivated with soybeans, corn, cotton and sugar cane, and pasture areas. Several species of Scarabaeidae occur and may promote damage for these crops, and few published studies exist in Brazil with this group of pests.

General objective
To perform structural identification of the components of the pheremones of *Liogenys fusca*, *Cyclocephala verticalis* and *Leucothyreus dorsalis*. Moreover, test the efficiency and feasibility of using these materials in the field.

Specific objectives
1. Structural identification and evaluation of substances that have potential use in integrated pest management for Scarabaeidae.
2. To evaluate the efficiency of synthetic pheromones in attraction and capture of species in both the laboratory and the field.
3. To estimate the optimal number of traps per area for the control of these species.

Major scientific and technological contributions of the proposed
Based on knowledge of the mating behavior, we can extract the sex pheromone of these species, identify and then synthesizing them for use in traps for massive collections of adults in the field. Thus, one can predict that in the future decreased use of chemicals may occur, currently used in agriculture to control this group of insect pests.

Schedule (see Appendices)

Subproject 4
Prey and predator interactions in aquatic and terrestrial environments as mediated by chemical signals

Researcher Responsible: Dr. Daniel Simões Albeny - Unochapecó - CPF: 059695646-05
Reearch Team: Dr. Jennifer Ann Breaux - UFV - CPF 013027269-86, Dr. Eraldo Lima - UFV - CPF 005335668-35.

Qualification of the problem being addressed
It is known that female mosquitoes are able to assess potential oviposition sites before deciding to lay eggs. This evaluation system involves chemical perception of the nutritional quality of the environment, and clues that indicate the presence of predators.

General objective
Isolate derived chemical signals from predatory larvae of *Toxrhynchites theobaldi,* and to perform field tests to elucidate the direct and indirect effects (via chemical signals) of predation on the structure of biological communities, and on mosquito breeding. Evaluate effects on the oviposition behavior of native mosquitoes.

Specific objectives
1. To assess the direct effect of the presence of predatory larvae (*T. theobaldi*) on wealth and abundance of wild mosquitoes, and to assess the indirect effects predator presence on the richness and abundance of lower trophic levels (protozoa, rotifers) and bacteria in forest mosquito breeding sites;
2. To evaluate the direct effects of predator chemical cues on mosquito species richness and abundance, and the indirect effects of chemical cues on the richness and abundance of lower trophic levels (protozoa, rotifers) and bacteria in forest breeding sites;
3. To evaluate the effect of predator presence, predation cues, and richness and abundance of microorganisms in mosquito oviposition site choice.

Major scientific and technological contributions of the proposed subproject
The biggest innovation in the proposed study is the application of the general theory of aquatic ecology coupled with adoption of a new experimental approach, not yet addressed by any research group in Brazil, used to investigate how chemical ecology affects the structure of insect vector communities vectors that thrive in forest breeding sites near agricultural areas. The proposed study is innovative in implementing an experimental manipulation of variables relevant to mosquito larval habitat (e.g., presence of chemical cues from predators and predation); it will be carried out in the field to test both direct and indirect effects of such factors on mosquito distrubution. Furthermore, studies of mosquito ecology are still nascent in the country, and absolutely absent in graduate work involving environmental science in Brazil.

Schedule (see Appendices)

Subproject 5
Insect-plant interactions mediated by semiochemicals in conventional and transgenic soybean

Coordinator: Prof. Dr. Paulo Henrique Gorgatti Zarbin, UFPR, CPF: 138814108-64
Research Team: Dr. Delia Milagros Pinto Zevallos (702550371-12), MSc. Priscilla Strapasson

Qualification of the problem being addressed
This subproject aims to understand plant-herbivore-natural enemy interaction in transgenic and conventional grown soybeans, based on observation of their natural pests *Anticarsia gemmatalis*, *Pseudoplusia includens* and *Spodoptera frugiperda* and their natural enemies *Podisus nigrispinus*, *Meteorus* sp. and *Trichogramma pretiosum*, respectively.

General objective
Understanding insect-plant interactions mediated by plant volatiles in conventional and transgenic soybeans.

Specific objectives
1. To characterize the profiles of volatiles emitted by conventional and transgenic soybean crops, testing both undamaged and those submitted to different treatments of herbivory or oviposition;
2. To evaluate the responses of natural enemies to volatiles emitted by plants of the different treatments;
3. To evaluate oviposition and feeding preference of herbivores in conventional vs. transgenic crops.

Major scientific and technological contributions of the proposed
Understanding how semiochemicals mediate insect-plant interactions is important for basic knowledge, which can be used to develop pest control strategies, and for greater sustainability of practices through successful biological control programs.

Schedule (see Appendices)

Subproject 6
Foliar allelochemicals in the tomato (*Solanum lycopersicum)* and its effect on herbivores and their natural enemies

Coordinator: Cristiane Nardi, University of the Midwest (UNICENTRO) - PR, CPF 007809099-76
Research Team: José Maurício S. Bento, CPF 723022916-20, Prof. Dr. ESALQ-USP; Maria Fernanda GV Peñaflor, CPF 311849518-96, Dr. ESALQ / USP.; Julian T. V. Resende, CPF 860293556-00, Prof. Dr. UNICENTRO; Ronaldo John F. de Oliveira, CPF 045078289-10, MSc. UNICENTRO

Qualification of the problem being addressed
Among the allelochemicals present in tomato leaves, the acylsugars and sesquiterpenes (i.e., zingiberene, methyl ketone and 2-tridecanone) are known components to confer resistance to herbivores such as *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae), *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) and spider mites. The presence of these compounds in tomato leaves has been examined for breeding programs in order to obtain resistant plants against insects with high levels of these compounds.

General objective
To investigate the effect of tomato leaf herbivory on plant release of allelochemicals, and on host

seeking behavior of herbivores and of their natural enemies.

Specific objectives
1. To quantify zingiberene and acylsugar concentrations produced both before and after the induction of herbivory by *Tetranchus urticae* (Koch) and *T. absoluta*;
2. To study the host-seeking behavior of *T. urticae* and *T. absoluta* exposed to intact and prey-damaged tomato plants;
3. To characterize the host-seeking behavior of the predatory mites *Neoseiulus californicus* (McGregor) (Acari: Phytoseiidae) and *Trichogramma pretiosum* Riley (Hymenoptera: Trichogrammatidae) on intact and prey/host-damaged plants.

Major scientific and technological contributions of the proposed
This work will generate relevant information that enhances plant breeding programs for insect resistance, by characterizing plants with high capacity to respond defensively to herbivory and produce high concentrations of allelochemicals. Moreover, considering that the biological control of spider mites and *T. absoluta* has often been adopted, the results of this study can provide information to intensify the action of these control agents in tomato crops.

Schedule (see Appendices)

(II) Semiochemicals in the context of biological control

Subproject 7
Effect of multi-herbivory and red rot infection on attraction of the parasitoid *Cotesia flavipes* to sugarcane volatiles

Coordinator: José Roberto Postali Parra, Escola Superior de Agricultura “Luiz de Queiroz”, Universidade de São Paulo, (Esalq/USP) CPF 24578347834
Research Team: José Maurício Simões Bento, Escola Superior de Agricultura “Luiz de Queiroz”, Universidade de São Paulo, (ESALQ/USP) CPF 723.022.916-20; Dra. Maria Fernanda Gomes Villalba Peñaflor, ESALQ/USP, CPF 311.849.518-96

Qualification of the problem being addressed
Brazil stands out as the largest producer of cane sugar in the world. The main pest of this crop is the sugarcane borer, *Diatraea saccharalis* (Lepidoptera: Pyralidae), which causes huge losses by attacking the stalks and it is controlled by the parasitoid *Cotesia flavipes* (Hymenoptera: Braconidae). It is known that herbivory by *D. saccharalis* induces the emission of attractive volatiles to *C. flavipes*, however, little is known about the behavior of this parasitoid in more complex and realistic field scenarios, such as the attack by multiple herbivores and the co-occurrence of pathogens and pests.

General objective
The project will investigate the effect of two biotic factors, multi-herbivory and red rot infection (*Fusarium moniliforme*), on the tri-trophic interaction between the sugar cane plant, its pest, and the parasitoid, *C. flavipes*.

Specific objectives
The project aims to answer the following questions:
1. Is *C. flavipes* attracted to volatiles released by sugarcane leaves under attack of unsuitable host instars?

2. Does simultaneous herbivory by *D. saccharalis* in the stem and leaves by *S. frugiperda* interfere with the response of the parasitoid *C. flavipes*?
3. Does *F. moniliforme* infection alter the mix of herbivory-induced volatiles released by the sugarcane?
4. Does plant infested by the borer and infected by the red rot emit differential volatiles that serve as olfactory cues for the third trophic level, the parasitoid *C. flavipes*?
5. Does red rot infection induce susceptibility to sugarcane borer?

Major scientific and technological contributions of the proposed
Biological control is already widely used in sugarcane, but the understanding of tritrophic interactions in more complex scenarios can assist in developing tactics that help increase the efficiency of the parasitoids in the field.

Schedule (see Appendices)

Subproject 8
Plant-herbivore-parasitoid interactions mediated by melon volatiles (*Cucumis melo* L.)

Coordinator: Euzébio Antonio Goulart Santana, CPF 118.677.606-49
Research Team: PhD Talita Antonia da Silveira, CPF 319964078-80; Henrique Fonseca Goulart, Dr., Federal University of Alagoas, CPF 03797757433; Chrystian Iezid Almeida Maia and Feres, Dr., Federal University of Alagoas, post-doc, CPF 050085396-71; José Roberto Postali Parra, Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo, (Esalq/USP) CPF 24578347834; José Maurício Simões Bento, Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo, (ESALQ/USP) CPF 723.022.916-20

Qualification of the problem being addressed
Brazil is among the world's largest producers of fruits. The melon, *Cucumis melo* L. is one of the most economically important crops for the Northeast region of Brazil, accounting for 95% of crop production. The leafminer fly *Liriomyza sativae* (Blanchard) (Diptera: Agromyzidae) is one of the main pests that limit the production of melon.

General objective
By continuing the work performed with the parasitoid *O. scabriventris* to which they succeeded in classical biological control of *L. sativae* on melon crops in the Northeastern region of the country, we expect to increase understanding of the tri-trophic plant-herbivore-parasitoid relationship, which may be useful for the management of this pest.

Specific objectives
1. To evaluate olfactory responses of the parasitoid *Opius* (Gastrosema) *scabriventris* Nixon to melon volatiles induced by the leafminer fly (*L. sativae*) herbivory at different intervals of induction;
2. To identify the chemical compounds in the mixture of volatiles released from the melon;
3. To understand the tri-trophic relationship between the plant, pest and parasitoid.

Major scientific and technological contributions of the proposed subproject
With the execution of this project, we expect to develop a strategy for managing and/or controlling the leafminer fly *L. sativae* on melon crops by using its natural enemy, and to investigate plant defenses as attractants or repellents for this insect.

Schedule (see Appendices)

(III) Identification and synthesis of semiochemicals

Subproject 9
Helicoverpa armigera (Lepidoptera: Noctuidae) in Brazil: can an invasive species interfere with chemical communication of a native species?

Coordinator: Eraldo Rodrigues de Lima, Federal University of Viçosa, Department of Entomology, 005335668-35
Research Team: Hernane Araújo Dias, UFV-DDE, CPF 064385526-23, doctoral student in Entomology, Prof. Dr. Paulo Henrique Gorgatti Zarbin, UFPR, CPF 138814108-64

Qualification of the problem being addressed
The caterpillar *Helicoverpa armigera* was recorded for the first time in Brazil during the 2012/2013 harvest, causing unexpected losses in soybean, corn and cotton. Several measures are being implemented to reduce the damage caused by this pest, including the use of sex pheremone traps. However, these crops are also hosts of other native noctuids such as *Helicoverpa zea* and *Heliothis virescens*, whose sex pheromone blends contain the same compounds of *H. armigera* pheromone. Pheromone specificity may be crucial for reproductive isolation between sympatric species.

General objective
To identify the sex pheromone of Brazilian populations of *H. armigera, H. zea* and *H. virescens* (Lepidoptera: Noctuidae), and to assess behavioral and electrophysiological responses of these species to hybrid mixtures of their sex pheremone components.

Specific objectives
1. To verifiy the formation and viability of the potential F1 hybrids by crosses between *H. zea, H. armigera* and *H. virescens*;
2. To determine the biology of the potential F1 hybrids;
3. To identify sex pheromones of Brazilian populations of *H. zea, H. armigera, H. virescens* and their hybrids;
4. To assess electroantennographic response of virgin males of *H. zea, H. armigera, H. virescens* and their F1 hybrids to mixtures of components of their sex pheromones;
5. To test behavioral responses of *H. zea, H. armigera, H. virescens* virgin males and their F1 hybrid to mixtures of the components of their sex pheromones in wind tunnel;
6. To assess the attractiveness of traps containing the sex pheromone in the field, and the efficiency of traps in capturing males of the three species.

Major scientific and technological contributions of the proposed subproject
The sex pheromones of the Brazilian populations of *H. zea* and *H. virescens* are not well established, and there may be qualitative and/or quantitative differences in pheromonal components compared to other populations previously studied in other countries. This work, then, is a first step to further study the chemical ecology of Brazilian populations of these species. As the species are phylogenetically close (mainly *H. armigera* and *H. zea*), the pheromone of one species may be attractive to the other, and may confound the formation of hybrids. In practical terms, if this occurs the use of sex pheromone traps should be employed carefully in places where species are sympatric and synchronic, so that only the species intended for monitoring are captured.

Schedule (see Appendices)

Subproject 10
Isolation, identification and synthesis of *Sphenophorus levis* pheromones (Coleoptera:Curculionidae)

Coordinator: José Maurício Simões Bento, College of Agriculture "Luiz de Queiroz", University of São Paulo, (ESALQ / USP), CPF 723022916-20
Research Team: MSc Lucila Wadt, ESALQ / USP, CPF 129762958-24; Euzébio Antonio Goulart Santana, UFAL 118677606-49; Dr. Carla Fernanda Fávaro, UESC, CPF 324537538-78.; Arodi Prado Favaris, ESALQ / USP, CPF 358547168-44, Dr. Weliton Dias da Silva, ESALQ / USP CPF 305249598-46; Prof. Dr. Paulo Henrique Gorgatti Zarbin, UFPR, CPF: 138814108-64.

Qualification of the problem being addressed
Brazil is the largest producer of sugarcane in the world, with 9.7 million hectares producing about 650 million tons/year. São Paulo state is responsible for over 50% of the sugarcane produced, where the sugarcane weevil *S. levis* is currently considered one of the main pests.

General objective
This subproject aims to obtain the pheromone of *S. levis* for its use in integrated pest management of the sugarcane weevil.

Specific objectives
1. To test the concentration and durability of synthetic *S. levis* pheromone, and their ability to attract adults of this species in the field;
2. To determine the optimal type, size and color of synthetic pheromone traps for *S. levis* on sugarcane plantations;
3. To establish the necessary number of traps for monitoring and capturing of *S. levis* on sugarcane.

Major scientific and technological contributions of the proposed subproject
Obtaining a pheromone for the monitoring and control of *S. levis* will result in direct economic benefits for producers of sugarcane, in addition to reducing environmental pollution and enhancing conservation of the pest's natural enemies.

Schedule (see Appendices)

Subproject 11
Population control of weevil pests of coconut, açaí, cocoa and cupuaçu through the use of aggregation pheromone complex.

Coordinator: Paul HG Zarbin, UFPR - CPF 138814108-64
Research Team: Diogo Vidal Montes, UFPR - CPF 053493309-26; Prof. Dr. Antonio Euzébio Goulart Santana, UFAL, CPF118.677.606-49

Qualification of the problem being addressed
This subproject aims to replace and/or reduce the use of pesticides in important agricultural crops in the Amazon region, such as coconut, açaí berry, cocoa and cupuaçu. The target pests are the weevils *Homalinotus depressus, Ozopherus muricatus* and *Conotrachelus humeropictus*.

General objective
To perform structural identification and synthesis of aggregation components of pheromones of *H. depressus, C. humeropictus* and *O. muricatuse*. Moreover, to test the effectiveness and feasibility of use of these compounds in monitoring and controlling populations of these species (i.e., as an

alternative phytosanitary method).

Specific objectives
1. To identify the structure and evaluate substances for potential use in integrated pest management using chromatographic, spectrometric and spectroscopic techniques;
2. To establish an efficient synthetic route for obtaining all previously identified components of the pheromones;
3. To evaluate the attractiveness and capture efficiency of synthetic pheromones both in laboratory and field assays;
4. To estimate the optimal number and spatial distribution of traps for sufficient insect monitoring, and their usefulness in estimating the level of crop damage;
5. To estimate the appropriate pheromone dosage and the optimal number of traps for control of pest populations.

Major scientific and technological contributions of the proposed subproject
Considering the fragility of the Amazon region ecosystem, pheromone use for control and monitoring of *H. depressus, C. Humeropictus and O. muricatus* is of paramount importance for environmental viability for the cultivation of cocoa, cupuaçu, coconut, and acai already established in that region.

Schedule (see Appendices)

Subproject 12
Identification and use of sex pheromones for control of *Diatraea saccharalis* (Lepidoptera: Crambidae) populations in sugarcane

Coordinator: Paul HG Zarbin, UFPR - CPF 138814108-64
Research Team: Diogo Vidal Montes, UFPR - CPF 053493309-26; José Maurício Simões Bento, College of Agriculture "Luiz de Queiroz", University of São Paulo, (ESALQ / USP), CPF 723022916-20

Qualification of the problem being addressed
This subproject aims to develop the sex pheromone of the sugarcane borer, *Diatraea saccharalis*, which is considered one of the main pests for this crop. Despite progress achieved so far by the INCT Semiochemicals in Agriculture program, attempts to capture males in the field have been ineffective. This indicates the need for further studies to identify of alternate components involved in the chemical communication system of these insects.

General objective
To review the chemical ecology of *D. saccharalis* in order to extract, structurally identify and synthesize sex pheromones, and to test the feasibility of such pheromones in monitoring and controlling pest populations.

Specific objectives
1. To isolate, identify and evaluate substances with potential use in integrated pest management;
2. To establish a synthetic route by which to obtain the pheromonal components previously identified that do not have commercial synthetic standards;
3. To evaluate the efficiency of synthetic sex pheromones in collecting *D. saccharalis* males both in the laboratory and under field conditions.

Major scientific and technological contributions of the proposed subproject

Brazil has not yet developed methods using this proposed technology for monitoring or control of *D. saccharalis* in sugarcane crops.

Schedule (see Appendices)

Subproject 13
Use of pheromones to control palm pest population

Coordinator: Antonio Santana Euzebio Goulart; Dr. Federal University of Alagoas, CPF 11,867,760,649.
Research Team: Henrique Fonseca Goulart, Dr., Federal University of Alagoas, CPF 037977574-33; Ricardo Silva Porto, Dr., Federal University of Alagoas, CPF 037387556-83; Chrystian Iezid Almeida Maia and Feres, Dr., Federal University of Alagoas, post-doc, CPF 050085396-71; Prof. Dr. José Maurício Simões Bento, ESALQ / USP, CPF 723022916-20; Prof. Dr. Paulo H. G. Zarbin, UFPR, CPF 138814108-64; Prof. Dra. Bianca Giuliano Ambrogi, UFS, CPF 209925458-38; Prof. Dra. Carla Fernanda Fávaro, UESC, CPF 324.537.538-78

Qualification of the problem being addressed
Palm trees are important not only as a source of food but also for production of raw materials for production of biodiesel. There are several pests that attack palms, particularly coconut and oil palms, causing huge losses in all stages of the life cycle.

General objective
To study the chemical ecology of the Lepidopteran palm borer species *Eupalamides cyparissias* and the Coleopteran palm borer species *Rhynosthomus barbirostris* for the synthesis of pheromones, in order to employ them for use in coconut and oil palm farming (i.e., as alternative to integrated pest management, potentially replacing use of pesticides).
Specific objectives
1. To verify the presence of the pheromone in *Eupalamides cyparissias* and *Rhynosthomus barbirostris*;
2. To isolate and structurally identify compounds for potential use in integrated pest management;
3. To synthesize this pheromone in the laboratory;
4. To assess attractiveness of *Eupalamides cyparissias* and *Rhynosthomus barbirostris* to synthetic compounds;
5. To evaluate the efficiency of the synthetic pheromone in collecting male *Eupalamides cyparissias* in the lab, and to assess synthetic pheromone attractiveness to *Eupalamides cyparissias* and *Rhynosthomus barbirostris* in the field;
6. To determine appropriate pheromone dosage for insect capture;
7. To estimate the optimal number and spatial distribution of traps for monitoring and control of populations of both species.

Major scientific and technological contributions of the proposed subproject
Acquisition of these two pest pheromones may potentially reduce pesticide use. As a result, use of pheromones will benefit the environment and workers, as well as preserve natural enemies and pollinators that are important for palms.

Schedule (see Appendices)

Subproject 14

Population control of the main pests of Araucaria (*Araucaria angustifolia*), *Cydia araucariae* (Lepidoptera: Tortricidae) and *Dirphia araucariae* (Lepidoptera: Saturniidae) through use of sex pheromones.

Coordinator: Paulo Henrique Gorgatti Zarbin, UFPR, CPF 318.814.108-64
Research Team: Post-doc Dr. Camila Borges da Cruz Martins, CPF 044.528.629-69

Qualification of the problem being addressed
Besides being overexploited by man, the few remaining areas of Araucaria forest suffer from attacks by the moths *Cydia araucariae* (Pastrana) (Lepidoptera:Tortricidae) and *Dirphia araucariae* (Jones) (Lepidoptera, Saturniidae), threatening species conservation and recovery of genetic diversity.

General objective
In order to promote conservation and maintain genetic diversity in remaining Araucaria forest areas, this work aims to develop a methodology for control and/or monitoring for *D. araucariae* and *C. araucariae* pest populations through the use of sex pheromones.

Specific objectives
1. To extract and analyze compounds in female pheromone glands;
2. To discover biologically active compounds in female extracts from both species, and to test the attractiveness of these extracts to both males and females;
3. To propose the chemical structure of the target compounds and through organic synthesis of target compounds in order to produce them in sufficient quantity to test in the field;
4. To confirm the biological activity of the synthetic compounds;
5. To test the attractiveness of the synthesized compounds in the field;
6. To determine required parameters such as pheromone concentration, and the appropriate height and type of trap to efficiently monitor and control pest populations with sex pheromones.

Major scientific and technological contributions of the proposed subproject
Contribute to Araucaria forest conservation by means of a simple and practical methodology for controlling and monitoring the main pest of Araucaria, *C. araucariae*, as well as the defoliating pest, *D. araucariae*.

Schedule (see Appendices)

<u>*Subproject 15*</u>
Evidence and use of sex pheromone for monitoring and control the coconut moth *Atheloca subrufella* (Lepidoptera: Phycitidae) in coconut groves

Coordinator: Bianca Giuliano Ambrogi, Federal University of Sergipe, CPF 209.925¬¬.458-38
Research Team: Dr. Sinara Maria Moreira, Federal University of Sergipe, CPF 325506798-73; Undergraduate Jucileide Lima Santos, Federal University of Sergipe, CPF 048973815-09; Prof. Dr. Antonio Euzebio Goulart Santana; UFAL, CPF 11867760649.

Qualification of the problem being addressed
Coconut groves (*Cocos nucifera* L.) exist almost in the whole country and they are of great social and economic importance for Brazil. There are several different pests that attack coconut flowers and fruits causing huge losses, and the coconut moth *Atheloca subrufella* (Hulst) *(Hyalospila ptychis)* (Lepidoptera: Phycitidae) is the one of the main pests.

General objective
To study the chemical ecology of the coconut moth, *A. subrufella,* in order to synthesize its pheromone for use in pest control, thereby reducing or replacing the use of pesticides.

Specific objectives
1. To isolate and structurally identify the sex pheromone of this pest;
2. To synthesize the pheromone in the laboratory;
3 .To evaluate the efficiency of synthetic sex pheromones in collecting male *A. subrufella* under field conditions;
4. To determine appropriate pheromone dosage for insect capture;
5. To estimate the optimal number and spatial distribution of traps for monitoring *A. subrufella*.

Major scientific and technological contributions of the proposed subproject
The identification and synthesis of *A. subrufella* pheromone can potentially allow developing monitoring tactics based on the number of insects caught in traps and therefore pesticides can be selectively sprayed. The overall effect is reduction in pesticide use and preservation of natural enemy populations. The use of pheromone in mating disruption strategy can also be potentially employed for pest control.

Schedule (see Appendices)

(IV) Formulation and release technology of semiochemicals

Subproject 16
Synthesis and formulation of pheromones in preparative scale for pest control

Coordinator: Euzebio Antonio Goulart Santana, Dr., Federal University of Alagoas, CPF 11867760649
Research Team: Alessandro Riffel, Dr., Federal University of Alagoas -Embrapa, CPF 71542507049; Henrique Fonseca Goulart; Dr., Federal University of Alagoas. CPF 03797757433; Ricardo Silva Porto, Dr., Federal University of Alagoas, CPF 03738755683; Ruth Rufino do Nascimento, Dr., Federal University of Alagoas, CPF 45429804487; Carla Fernanda Fávaro, Dr., UESC, CPF 324537538-78; Paulo H. G. Zarbin, Dr. UFPR – CPF 13881410864; José Roberto Postali Parra, Esalq/USP, CPF 24578347834

Qualification of the problem being addressed
Brazil still lacks a 'Technology platform for synthesis and use of semiochemicals in agriculture. As a result, the production of pheromones to control and/or monitor agricultural pests using previosuly identified pheromones is still needed. The goal is to produce and formulate pheromones for controlling and monitoring species of *Helicoverpa* (*H. armigera, H. zea*), as well as *Elasmopalpus lignosellus*, *Plutella xylostela*, *Grapholita molesta, Heliothis zea, Spodoptera frugiperda* and species of *Diatraea*; these pheromones can potentially be used as an alternative pest management method for replacement and/or reduction of insecticide use on important national crops.

General objective
To create a platform to obtain the constituents of pheromones by "scale up" reactions for production scale and use for pest control and monitoring in agriculture.

Specific objectives

1. To create an efficient synthesis pathway for obtaining pheromonal components of *Helicoverpa armigera, H. zea, Elasmopalpus lignosellus, Plutella xylostela, Grapholita molesta* and species of *Diatraea*;
2. To scale up pheromone synthesis;
3. To formulate attractive baits;
4. To prepare attractive baits;
5. To perform field trials with prepared baits.

Major scientific and technological contributions of the proposed subproject
This project will create opportunities for new products and business, which will significantly contribute to Brazilian agriculture. Besides, release of pheromone products can strengthen agricultural industry through the development of innovative products already available in other countries, yet not currently in Brazil.

Schedule (see Appendices)

(IV) Application of Semiochemicals in Agriculture

Subproject 17
Review of the chemical composition of *Pseudaletia sequax* sex pheromone.

Coordinator: Angela Alves de Almeida, Federal Rural University of Rio de Janeiro. CPF 254501478-80
Research Team: Dr. Carla Marques Cristina Arce - UFV CPF 007862901-47, Prof. Dr. Paulo Henrique Gorgatti Zarbin, UFPR, CPF: 138814108-64, Dr. Eraldo Lima - UFV - CPF 005335668-35.

Qualification of the problem being addressed
Pseudaletia sequax is an important pest of wheat in southern Brazil. Early studies have described its biology, reproductive behavior and pheromone chemical composition. We hypothesize that this insect has both migrant and resident representatives, indicating that differences in pheromonal blend may exist.
General objective
To perform a structural review of the components of *P. sequax* sex pheromone and test the synthetic versions in the field for population control and monitoring.

Specific objectives
1. To perform laboratory and field tests with pheromonal mixture of *P. sequax* populations;
2. To test the hypothesis of migrant and resident populations in the species;
3. To compare chemical composition of its sex pheromones among populations;
4. To determine the appropriate dosage, optimal quantity, spatial distribution of traps for monitoring as well as estimating the damage level basd on the number of trapped moths;
5. To test the attractiveness of pheremones in the field;
6. To control populations of these species through sexual confusion.

Major scientific and technological contributions of the proposed subproject
Establishing a strategy for monitoring and control of this species.

Schedule (see Appendices)

Subproject 18
Prospective use of pheromone molecules as a phytosanitary strategy for cotton crops in Central Brazil

Coordinator: Dr. Monica Josene Barbosa Pereira, University of Mato Grosso, CPF 563926644-91.
Research Team: Dr. Antonio Goulart de Euzébio SantAna, Federal University of Alagoas, CPF 118667606-49; Dr. Alessandra Butnariu Regina, University of Mato Grosso, CPF 832765139-00; Mestranda Ana Lucena Regina Hoffmann - (PPGASP-UNEMAT), State University of Mato Grosso, CPF 025124561-61; Mestranda Edilaine Viana Souza (PPGASP-UNEMAT), State University of Mato Grosso, CPF 030666531-02; MSc student Camila Silva Patricia Ribeiro (PPGASP-UNEMAT), State University of Mato Grosso, CPF 025578541-07; Mestranda Joice Garden (PPGASP-UNEMAT), State University of Mato Grosso, CPF 321307978-22; Majoring in Agronomy Leonardo Morais Türchen, State University of Mato Grosso, CPF 033165431-80; Majoring in Biological Sciences Bruna Gualda Camila Bersani, University of Mato Grosso, CPF 046317821-10.

Qualification of the problem being addressed
The state of Mato Grosso is the greatest producer of cotton in Brazil with more than half of the national production. Such production requires large areas, high technology management strategies and intensive use of pesticides, which have generated negative environmental impacts.

General objective
To implement monitoring and control strategies for Lepidopteran and Hemipteran pests in cotton with the use of pheromones already available or currently in development in Mato Grosso.

Specific objectives
1. To test, in laboratory and field trials, volatile compounds obtained from glands of Hemipteran pests attacking cotton shoot and roots;
2. To test pheromonal mixtures of Lepidopteran cotton pests;
3. To estimate the optimal number and spatial distribution of traps for monitoring and control of insects.

Major scientific and technological contributions of the proposed subproject
This project is expected to disseminate technology for monitoring and controlling populations of insect pests in farms of Central region of Brazil. Moreover, it is expected to improve the system by defining the number of traps per area and developing the mating disruption technique.

Schedule (see Appendices)

Subproject 19
Application of jasmonic acid as an elicitor of pest resistance in sugarcane.

Coordinator: Prof. Dr. Maurício José Bento, ESALQ / USP, CPF
Research Team: Dr. Maria Fernanda Gomes Villalba Peñaflor, ESALQ / USP, CPF 311849518-96; Alessandra Patricia Sanches, a student of Scientific Initiation, ESALQ / USP, CPF 408927018-97; Msc. Franciele dos Santos, ESALQ / USP, CPF 063148329-26

Qualification of the problem being addressed
The sugarcane borer *Diatraea saccharalis* (Lepidoptera: Cambridae) is considered one of the main pests of sugarcane, attacking the stalks and causing huge yield losses. Although there are studies examining the effect of Jasmonic Acid (JA) on defenses of some plant species, so far there is no report on the influence of JA in the induction of sugarcane direct and indirect defenses against insect attack.

General objective
This project will investigate the effect JA on the direct defenses of sugarcane against the specialist herbivore *D. saccharalis* and the generalist *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Furthermore, it will assess the effect of JA on indirect defenses, such as the emission of attractive volatiles to the borer parasitoid *Cotesia flavipes* (Hymenoptera: Braconidae).

Specific objectives
The project aims to answer the following questions:
1. Can JA induce direct sugarcane defenses against *D. sachharalis*?
2. Can JA induce direct defenses against the generalist herbivore *S. frugiperda*?
3. Can JA induce indirect defenses of sugarcane against *D. sachharalis*?

Major scientific and technological contributions of the proposed subproject
The results of this study may facilitate the development of efficient control tactics that are more sustainable and less harmful to the environment. In addition to the applied importance, this study may reveal interesting aspects of ecological interactions involving *Diatraea saccharalis, Cotesia flavipes* and sugarcane mediated by plant volatiles.

Schedule (see Appendices)

VIII. Methodology

(General - complementary to the electronic form)

Collection of plant volatiles
Plant headspace collection will be performed in a push-pull system (ARS, Gainesville, FLA, USA) in the laboratory as described in Tholl *et al.* (2006) and Proffit *et al.* (2011). Plants previously grown in pots will be placed inside sealed glass chambers of 2-5 L of capacity depending on plant size. A brief description of the system is as follows: a current of air is filtered by activated charcoal and a humidifier, then conducted to the treatment chamber and pulled through a filter containing 50 mg of adsorbent polymer (HayeSep Q - 80/100 mesh), which is connected to a vacuum pump. Collections can last from 4-24 h, time that will be adjusted depending on the amount of volatiles emitted by plants. Thereafter, HayeSep Q filter will be washed with 300 µL Hexane (HPLC Grade) and 500 nanograms of internal standard will be added (heptyl acetate 99.8% chemical purity, Sigma Aldrich). Sample volume is reduced to 50-60 µL at room temperature using Francke tubes with elongated tips (5mm length x 2cm diameter). Samples are then stored in closed microcapillary tube (both ends) in a freezer at -30° C for later analysis in GC-MS and GC-FID. Method used for chromatographic analysis is detailed in Engelberth et al. (2004). Plant headspace collections will be performed in a room under controlled conditions (22-25° C and 14L:10D photoperiod). Prior to assays, all glassware will be washed with acetone and hexane, and heated at 300° C for 8 hours to eliminate organic impurities. An adaptation of this system will be used with portable vacuum pumps for collection of plant volatiles in the field. At least 5 samples will be conducted for each treatment.

Alternatively, to measure plant volatiles, a solid-state microextraction (Solid-phase microextraction - SPME) will be used. In this case, plant parts are packed in airtight jars and exposed to SPME fiber for 30-60 minutes, and then directly analyzed in the GC-MS.

Collection of insect semiochemicals
Extractions of lepidopteran female glands will be conducted when insects are calling. The extractions will be made by removing the pheromone gland located between the VII and IX abdominal segment, and immersing it for 60 sec in 50 µL of organic solvent (Hexane or Pentane, grade, HPLC grade)

containing 100 ng of internal standard, to be chosen depending on the insect. These extracts will be stored and in sealed React-Vials (300 µL conical vials) with screw caps with Teflon covering, and stored in a freezer at -20° C until analysis and assays. This type of pheromone extraction can be used for preliminary tests of male behavior. However, for identification, released odors must be collect from females. For this type of collection (airborne) (Svensson et al. 2014), females are stored in sealed glass tubes in a similar way as collection method for plant volatiles. The HayeSep-Q filters will be washed with 200 µL of Hexane (HPLC Grade), and 500 nanograms of internal standard (99.8% chemical purity) added, substance which will be chosen according to the pheromone molecule. Sample volume will be reduced to 20-30 µL at room temperature with Francke tubes with elongated tips (5 mm x 2 cm diameter).
Semiochemicals released from glands located on male and female body surface, as in Diptera and Coleoptera, will be collected using the same procedure described above for Lepidoptera (Yasui et al. 2007). A general model for the identification, isolation, synthesis and use of semiochemicals in agriculture is described in **Figure 4**.

Collection of organic compounds from water
For the collection of volatile and non-volatile compounds released from water, a dynamic and static system will be used, respectively. To collect water volatiles, an aeration system will be used; retained non-volatile compounds in the water will be adsorbed using SPME fiber. The water from different treatments will be collected and conditioned in a hermetically sealed 2 L chambers and kept under constant agitation. Stream of filtered air with activated charcoal will be conducted through the chamber from top to bottom, and subsequently through a filter containing 50 mg of an adsorbent polymer (HayeSep-Q 80/100 Mesh) using a vacuum pump. The tube containing the charcoal and the filter containing HayeSep-Q are then connected to the flask. After 24 hours of extraction, the filter with Super Q. HayeSep-Q is washed with 300 µL of hexane, and 300 mg of heptyl acetate (99.8% chemical purity) is added as an internal standard. Sample volume is reduced to 30-40 µL at room temperature using Franckie tubes with elongated tips. Samples are stored in microcapillary tubes sealed at both ends, in a freezer at -80° C for later analysis. Prior to use, all glassware is washed with solvents and heated at 280° C for 8 hours to remove organic impurities. To collect by SPME, fiber DVB/CAR/PDMS are used. Water samples are in contact with the fibers for 30 minutes. Immediately after exposure of the fibers, they will be directly thereafter injected into the (GC-MS) for analysis.

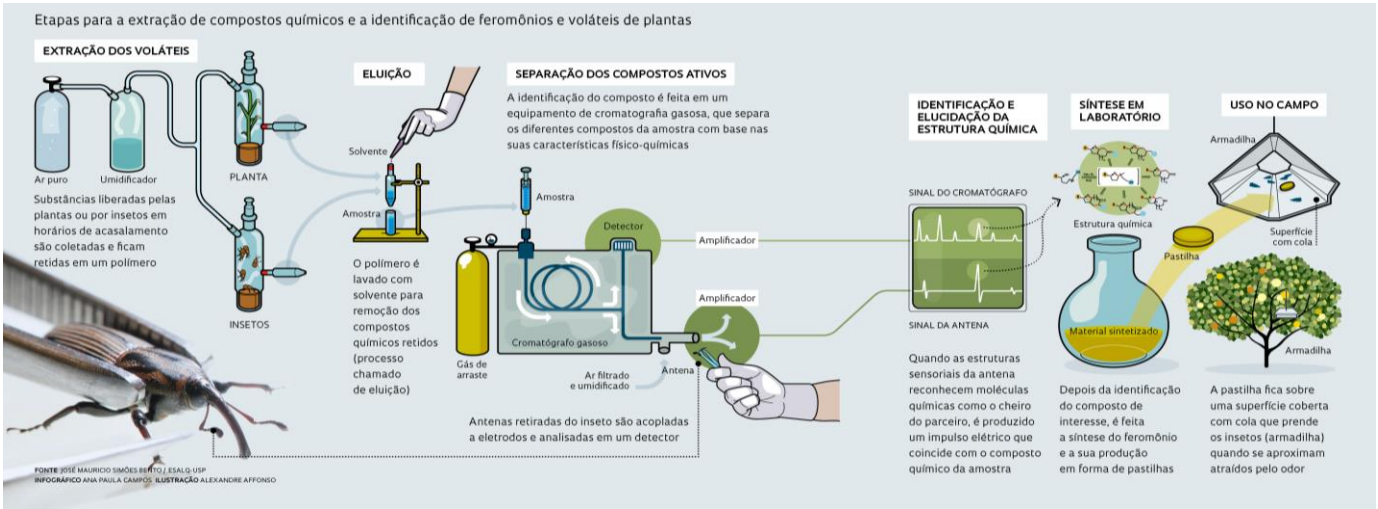

Figure 4. General steps for the extraction, isolation, identification, synthesis and use of chemical compounds from insects and plants in the field (Taken from the FAPESP Magazine report conducted at the headquarters of INCT Semiochemicals in Agriculture, published on 24.04.2014 – *in portuguese*)

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Appendices

Schedules

Subproject 1: Sexual behavior and chemical ecology of *Diabrotica speciosa* (Germar) and *Diabrotica viridula* F. (Coleoptera: Chrysomelidae)
Coordinator: Cristiane Nardi, UNICENTRO, PR, CPF 00780909976
Research Team: José Maurício S. Bento, CPF 72302291620, Prof. Dr., ESALQ-USP; Paulo H. G. Zarbin, CPF 13881410864, Prof. Dr., UFPR; Carla Fávaro, CPF 32453753878, Profª. Drª. UESC/BA; Franciele Santos. Msc, CPF 06314832926, ESALQ-USP

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**	**Jan-Jun/19**	**Jul-Dec/19**
Insect maintenance and rearing in laboratory										
D. viridula behavioral bioassays										
D. viridula electroantennograph bioassays										
Semiochemicals extraction and fractionation										
Semiochemical isolation and idetification										
Bioassays to biological activity evaluation in laboratory – olfactometers										
Bioassays to biological activity evaluation in Field - traps										
Results statistical analysis										
Preparation of scientific papers in order to publish										

Subproject 2: *Spodoptera frugiperda* genotypes and factors involved in the perception of their host plants

Coordinator: Eraldo Rodrigues de Lima, Dr., UFV, Entomology Department, CPF 005.335.668-35
Research Team: Antônio Cláudio Ferreira da Costa, EPAMIG, CPF 699.326.626-15, M. Sc.; José Maurício S. Bento, Prof. Dr., ESALQ-USP, CPF 72302291620

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**	**Jan-Jun/19**	**Jul-Dec/19**
Strain collection and separation										
Insect rearing										
Volatiles collection and electroantennograph										
Non-volatiles compounds extration										
Oviposition bioassays										
Performance bioassays										
Behavioral tests in Wind tunnel										
Data analysis										
Manuscript and report preparation										

Subproject 3: Sexual behavior of Scarabaeidae pests with the goal of obtaining pheromones for crops in Mato Grosso do Sul
Coordinator: Prof. Dr. Sérgio Roberto Rodrigues, UEMS, CPF 09761119858
Research Team: Imara Rosana de Oliveira (mestranda), Universidade Estadual de Mato Grosso do Sul, CPF 095.391.578-62; Fabiano dos Santos Herculano (graduando em agronomia), UEMS, CPF 011.093.621-37; João Gabriel Ersina Navarro (graduando em agronomia), UEMS, CPF 363.340.998-09; José Maurício S. Bento, Prof. Dr., Esalq-USP, CPF 72302291620

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**	**Jan-Jun/19**	**Jul-Dec/19**
Field collection and laboratory rearing of *Liogenys fusca*										
Liogenys fusca semiochemicals extraction and fractionation										
Semiochemicals isolation and structural identification										
Cyclocephala verticalis field collection and laboratory rearing										
Cyclocephala verticalis semiochemicals extraction and fractionation										
Semiochemicals isolation and structural identification										
Leucothyreus dorsalis field collection and laboratory rearing										
Leucothyreus dorsalis semiochemicals extraction and fractionation										
Semiochemicals isolation and structural identification										
Data analysis										
Patent and scientific papers elaboration in order to publish in international journals										

Subproject 4: Prey and predator interactions in aquatic and terrestrial environments as mediated by chemical signals
Coordinator: Dr. Daniel Albeny Simões – UNOCHAPECÓ – CPF: 059.695.646-05
Research Team: Dr. Jennifer Ann Breaux – UFV – CPF 013.027.269-86, Dr. Eraldo Lima – UFV – CPF 005.335.668-35.

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**	**Jan-Jun/19**	**Jul-Dec/19**
Maintanance and rearing of insect colonies in laboratory										
Predation signals extraction										
Semiochemicals isolation and structural identification										
Bioassays to biological activity evaluation in laboratory										
Bioassays to biological activity evaluation in field										
Results statistical analysis										
Patent and scientific papers elaboration in order to publish in international journals										

Subproject 5: Insect-plant interactions mediated by semiochemicals in conventional and transgenic soybean
Coordinator: Prof. Dr. Paulo Henrique Gorgatti Zarbin, UFPR, CPF: 138814108-64
Research Team: Dra. Delia Milagros Pinto Zevallos (702550371-12), MSc. Priscila Strapasson

ACTIVITIES	Jan-Jun/15	Jul-Dec/15	Jan-Jun/16	Jul-Dec/16	Jan-Jun/17	Jul-Dec/17	Jan-Jun/18	Jul-Dec/19	Jan-Jun/19	Jul-Dec/19
Maintanance and rearing of insect in laboratory										
Seedlings growth in laboratory										
Plant volatiles collection and analysis										
Antennograph studies										
Performance and oviposition bioassays										
Bioassays to biological activity evaluation in laboratory - olfactometers										
Results statistical analysis										
Patent and scientific papers elaboration in order to publish in international journals										

Subproject 6: Foliar allelochemicals in the tomato (*Solanum lycopersicum)* and its effect on herbivores and their natural enemies
Coordinator: Cristiane Nardi, UNICENTRO – PR, CPF 00780909976
Research Team: José Maurício S. Bento, CPF 72302291620, Prof. Dr., ESALQ-USP; Maria Fernanda G. V. Peñaflor, CPF 31184951896, Dra. ESALQ/USP; Juliano T. V. de Resende, CPF 86029355600, Prof. Dr. UNICENTRO; João Ronaldo F. de Oliveira, CPF 04507828910, Msc. UNICENTRO

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**	**Jan-Jun/19**	**Jul-Dec/19**
Herbivores rearing in laboratory										
Natural enemies rearing in laboratory										
Tomato plants growing and selection										
T. urticae bioassays										
T. absoluta bioassays										
N. californicus bioassays										
T. pretiosum bioassays										
Plants alelochemicals levels quantification										
Results statistical analysis										
Scientific papers elaboration in order to publish										

Subproject 7: Effect of multi-herbivory and red rot infection on attraction of the parasitoid *Cotesia flavipes* to sugarcane volatiles
Coordinator: José Roberto Postali Parra, Escola Superior de Agricultura “Luiz de Queiroz”, Universidade de São Paulo, (Esalq/USP) CPF 24578347834
Research Team: José Maurício Simões Bento, Escola Superior de Agricultura “Luiz de Queiroz”, Universidade de São Paulo, (ESALQ/USP) CPF 723.022.916-20; Dra. Maria Fernanda Gomes Villalba Peñaflor, ESALQ/USP, CPF 311.849.518-96

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**	**Jan-Jun/19**	**Jul-Dec/19**
Maintanance and rearing of insects in laboratory										
Plants growth										
Olfactometry bioassays with *C. flavipes* to test multiple herbivory treatments										
Olfactometry bioassays with *C. flavipes* to test infection by rot treatments										
Collection and identification of volatiles released by herbivory damaged sugar cane										
Collection and identification of volatiles released by herbivory damaged sugar canes and infected by rot sugar canes										
Behavioral assays with *D. saccharalis*										
Results statistical analysis										
Scientific papers elaboration in order to publish										

Subproject 8: Plant-herbivore-parasitoid interactions mediated by melon volatiles (*Cucumis melo* L.)
Coordinator: Antonio Euzébio Goulart Santana, CPF118.677.606-49
Research Team: Doutoranda Talita Antonia da Silveira, CPF 319.964.078-80; Henrique Fonseca Goulart, Dr., Universidade Federal de Alagoas, CPF 037977574-33; Chrystian Iezid Maia e Almeida Feres, Dr., Universidade Federal de Alagoas, pos-doc, CPF 050085396-71; José Roberto Postali Parra, Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo, (Esalq/USP) CPF 24578347834; José Maurício Simões Bento, Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo, (ESALQ/USP) CPF 723.022.916-20

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**
Maintanance and rearing of insects in laboratory								
Behavioral bioassays with *L. sativae*								
Electroantennograph bioassays with *L. sativae*								
Semiochemicals extraction and fractionation								
Semiochemicals isolation and identification								
Bioassays to biological activity evaluation in laboratory - olfactometers								
Bioassays to biological activity evaluation in field - traps								
Results statistical analysis								
Scientific papers elaboration in order to publish								

Subproject 9: Helicoverpa armigera (Lepidoptera: Noctuidae) in Brazil: can an invasive species interfere with chemical communication in a native species?
Coordinator: Eraldo Rodrigues de Lima, Universidade Federal de Viçosa, Departamento de Entomologia, 005.335.668-35
Research Team: Hernane Dias Araújo, UFV-DDE, CPF 064.385.526-23, doutorando em Entomologia, Prof. Dr. Paulo Henrique Gorgatti Zarbin, UFPR, CPF: 138814108-64

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**	**Jan-Jun/19**	**Jul-Dec/19**
Maintanance and rearing of insect colonies in laboratory										
Bioassays to interspecific mating evaluation										
Pheromone glands extraction										
Pheromone identification and quantification										
Experiments of electrophysiological responses to compounds - electroantennogram										
Activity evaluation in wind tunnel										
Attractiveness evaluation of field traps										
Results statistical analysis										
Papers elaboration										

Subproject 10: Isolation, identification and synthesis of *Sphenophorus levis* pheromones (Coleoptera:Curculionidae)
Coordinator: José Maurício Simões Bento, Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo, (ESALQ/USP), CPF 723.022.916-20
Research Team: MSc Lucila Wadt, ESALQ/USP, CPF 129.762.958-24; Antônio Euzébio Goulart Santana, UFAL, 118.677.606-49; Dra. Carla Fernanda Fávaro, UESC, CPF 324.537.538-78; Arodí Prado Favaris, ESALQ/USP, CPF 358.547.168-44, Dr. Weliton Dias da Silva, ESALQ/USP CPF 305.249.598-46; Prof. Dr. Paulo Henrique Gorgatti Zarbin, UFPR, CPF: 138814108-64.

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/18**	**Jan-Jun/19**	**Jul-Dec/19**	**Jan-Jun/20**	**Jul-Dec/20**
Insect collection in field												
Insects volatiles collection												
Natural extracts in GC-EAD												
Natural extracts in GC-MS												
Isolation, identification and synthesis,												
Synthetic pheromone analysis in GC-EAD												
Synthetic pheromone analysis												
Data analysis												
Scientific papers submission												
Pheromone patent registry												

Subproject 11: Population control of weevil pests of coconut, açaí, cocoa and cupuaçu through the use of aggregation pheromone complex.
Coordinator: Paulo H. G. Zarbin, UFPR – CPF 138.814,108-64
Research Team: Diogo Montes Vidal, UFPR – CPF 053.493.309-26; Prof. Dr. Antonio Euzébio Goulart Santana, UFAL, CPF118.677.606-49

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**	**Jan-Jun/19**	**Jul-Dec/19**
Maintanance and rearing of insect colonies in laboratory										
Semiochemicals extraction and fractionation										
Semiochemicals isolation and structural identification										
Bioassays to biological activity evaluation in laboratory										
Bioassays to biological activity evaluation in field - traps										
Results statistical analysis										
Patent and scientific papers elaboration in order to publish in international journals										

Subproject 12: Identification and use of sex pheromones for control of *Diatraea saccharalis* (Lepidoptera: Crambidae) populations in sugar cane crops
Coordinator: Paulo H. G. Zarbin, UFPR – CPF: 138.814.108-64
Research Team: Diogo Montes Vidal, UFPR – CPF: 053.493.309-26; José Maurício Simões Bento, ESALQ / USP, CPF 723022916-20

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**	**Jan-Jun/19**	**Jul-Dec/19**
Maintanance and rearing of insect colonies in laboratory										
Semiochemicals extraction and fractionation										
Semiochemicals isolation and structural identification										
Development of new synthetic methodolgies to identified molecules										
Bioassays to biological activity evaluation in laboratory - olfactometer										
Bioassays to biological activity evaluation in field - traps										
Results statistical analysis										
Patent and scientific papers elaboration in order to publish in international journals										

Subproject 13: Use of pheromones to control palm pest population
Coordinator: Antonio Euzebio Goulart Santana; Dr. UFAL, CPF 11867760649.
Research Team: Henrique Fonseca Goulart, Dr., UFAL, CPF 03797757433; Ricardo Silva Porto, Dr., UFAL, CPF 03738755683; Chrystian Iezid Maia e Almeida Feres, Dr., UFAL, pos-doc, CPF 05008539671; Prof. Dr. José Maurício Simões Bento, ESALQ / USP, CPF 723022916-20; Prof. Dr. Paulo H. G. Zarbin, UFPR, CPF 138814108-64; Prof. Dra. Bianca Giuliano Ambrogi, UFS, CPF 209925458-38; Prof. Dra. Carla Fernanda Fávaro, UESC, CPF 324.537.538-78

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**	**Jan-Jun/19**	**Jul-Dec/19**
Maintanance and rearing of insect in laboratory										
Behavioral bioassays with *Eupalamides cyparissias* and *Rhynosthomus barbirostris*										
Electroantennogram bioassays with *Eupalamides cyparissias* and *Rhynosthomus barbirostris*										
Semiochemicals extraction and fractionation										
Semiochemicals isolation, identification and synthesis										
Bioassays to biological activity evaluation in laboratory - olfactometer and EAD, CG/EAG										
Bioassays to biological activity evaluation in field - traps										
Results statistical analysis										
Scientific papers elaboration to publish										

Subproject 14: Population control of the principle pests of Araucária (*Araucaria angustifolia*), *Cydia araucariae* (Lepidoptera: Tortricidae) and *Dirphia araucariae* (Lepidoptera: Saturniidae) through use of sex pheromones.

Coordinator: Paulo Henrique Gorgatti Zarbin, UFPR, CPF 318.814.108-64
Research Team: Pós-doc Dr. Camila Borges da Cruz Martins, CPF 044.528.629-69

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**	**Jan-Jun/19**	**Jul-Dec/19**
Maintanance and rearing, permanent or temporary, of *Cydia araucariae* and *Dirphia araucariae* in laboratory										
Females glands extraction										
Semiochemicals isolation and structural identification										
Determination of biologically active extracts obtained from females of both species										
Target compounds chemical structure proposal and organical synthesis of these compounds for biological and field tests										
Biological activity confirmation of the synthetic compounds										
Field activity test of the synthesized compounds										
Field parameters determination										
Patent and scientific papers elaboration in order to publish in international journals										

Subproject 15: Evidence and use of sex pheromone for monitoring and control the coconut moth *Atheloca subrufella* (Lepidoptera: Phycitidae) in coconut groves
Coordinator: Bianca Giuliano Ambrogi, UFS, CPF 209.925.458-38
Research Team: Dra. Sinara Maria Moreira, UFS, CPF. 325.506.798-73; Graduanda Jucileide Lima Santos, UFS, CPF 048.973.815-09; Prof. Dr. Antonio Euzebio Goulart Santana; Dr. UFAL, CPF 11867760649.

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**	**Jan-Jun/19**	**Jul-Dec/19**
Collection of Coconut with field signal infection										
Maintanance and rearing of insect in laboratory										
Maintanance and rearing of insect in laboratory										
Calling behavior										
Pheromone glands extraction										
Bioassays – Y olfactometer										
Analysis and identification of the compounds										
Synthesis of the identified compounds										
Attractiveness evaluation of the synthetic compounds in laboratory										
Field tests										
Results divulgation in events										
Results statistical analysis										
Patent and scientific papers elaboration in order to publish in international journals										

Subproject 16: Synthesis and formulation of pheromones in preparative scale for pest control
Coordinator: Antonio Euzebio Goulart Santana, Dr., Universidade Federal de Alagoas, CPF 11867760649
Research Team: Alessandro Riffel, Dr., UFAL-Embrapa, CPF 71542507049; Henrique Fonseca Goulart; Dr., UFAL. CPF 03797757433; Ricardo Silva Porto, Dr., UFAL, CPF 03738755683; Ruth Rufino do Nascimento, Dr., UFAL, CPF 45429804487; Carla Fernanda Fávaro, Dr. UESC, CPF 324537538-78; Paulo H. G. Zarbin, Dr. UFPR – CPF 13881410864; José Roberto Postali Parra, Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo, (Esalq/USP) CPF 24578347834

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**	**Jan-Jun/19**	**Jul-Dec/19**
Determine a efficient synthetic route to pheromone compounds obtainment from: *Helicoverpa armigera, H. zea*, *Elasmopalpus lignosellus, Plutella xylostela, Grapholita molesta* and other similar species										
Develop the pheromone compounds synthesis										
Perform the pheromone synthesis 'scale up'										
Develop the pheromone formulation and prepare attractive baits										
Bioassays to biological activity evaluation in field - traps										
Results statistical analysis										
Patent and scientific papers elaboration in order to publish in international journals										

Sub-Projeto 17: Review of the chemical composition of *Pseudaletia sequax* sex pheromone

Coordinator: Ângela Alves de Almeida, Universidade Federal Rural do Rio de Janeiro. CPF 254.501.478-80
Research Team: Dr Carla Cristina Marques Arce – UFV CPF 007.862.901-47, Prof. Dr. Paulo Henrique Gorgatti Zarbin, UFPR, CPF: 138814108-64, Dr. Eraldo Lima – UFV – CPF 005.335.668-35.

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**	**Jan-Jun/19**	**Jul-Dec/19**
Collection and maintanance of *P. sequax* colonies										
Sexual pheromone extraction and fractionation										
Behavioral bioassays in laboratory										
Bioassays in wind tunnel to the mixture attractiveness evaluation										
Bioassays to biological activity evaluation in field - traps										
Results statistical analysis and scientific papers elaboration										

Subproject 18: Prospective use of pheromone molecules as a phytosanitary strategy for cotton crops in Central Brazil
Coordinator: Dr. Mônica Josene Barbosa Pereira, Universidade do Estado de Mato Grosso, CPF 563.926.644-91.
Research Team: Dr. Antônio Euzébio Goulart de SantAna, UFAL, CPF 118.667.606-49; Dr. Alessandra Regina Butnariu, UNEMAT, CPF 832.765.139-00; Mestranda Ana Regina Lucena Hoffmann – (PPGASP-UNEMAT), UNEMAT, CPF 025.124.561-61; Mestranda Edilaine Souza Viana (PPGASP-UNEMAT), UNEMAT, CPF 030.666.531-02; Mestranda Camila Patrícia Ribeiro Silva (PPGASP-UNEMAT), UNEMAT, CPF 025.578.541-07; Mestranda Joice Jardim (PPGASP-UNEMAT), UNEMAT, CPF 321.307.978-22; Graduando em Agronomia Leonardo Morais Turchen, UNEMAT, CPF 033.165.431-80; Graduando em Ciências Biológicas Bruna Camila Gualda Bersani, UNEMAT, CPF 046.317.821-10.

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**	**Jan-Jun/19**	**Jul-Dec/19**
Insects maintanance in laboratory and green houses										
Extraction and identification of pheromones from bug pests										
Semiochemicals isolation and structural identification										
Pheromonal mixture synthesis from lepidoptera pests										
Biological activity bioassays in laboratory with olfactometers										
Field experiments to evaluate pheromones biological activity										
Evaluate the burrower bug host preference in laboratory and green house										
Results statistical analysis										
Patents and scientific papers elaboration to publish										

Subproject 19: Application of jasmonic acid as an elicitor of pest resistance in sugarcane.
Coordinator: Prof. Dr. José Maurício Bento, ESALQ/USP, CPF
Research Team: Dra. Maria Fernanda Gomes Villalba Peñaflor, ESALQ/USP, CPF: 311.849.518-96; Patrícia Alessandra Sanches, aluna de Iniciação Científica, ESALQ/USP, CPF: 408.927.018-97; Msc. Franciele dos Santos, ESALQ/USP, CPF: 063.148.329-26

ACTIVITIES	**Jan-Jun/15**	**Jul-Dec/15**	**Jan-Jun/16**	**Jul-Dec/16**	**Jan-Jun/17**	**Jul-Dec/17**	**Jan-Jun/18**	**Jul-Dec/19**	**Jan-Jun/19**	**Jul-Dec/19**
Rearing and maintanance of insects in laboratory										
Plants growth										
Standardization of jasmonic acid (JA) concentration										
Behavioral assays with *D. saccharalis* from goal *(i)*										
Behavioral assay with *S. frugiperda* from goal *(ii)*										
Olfactometer bioassay with *C. flavipes* from goal *(iii)*										
Collection and identification of AJ treated plants volatiles and plants damaged by *D. saccharalis*										
Results statistical analysis										
Scientific papers elaboration to publish										