Bees as pollinators in Brazil

assessing the status and suggesting best practices

Edited by
Vera Lucia Imperatriz-Fonseca, Antonio Mauro Saraiva, David De Jong

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Edited by:
Vera Lucia Imperatriz-Fonseca, Antonio Mauro Saraiva, David De Jong

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Cynthia Pinheiro-Machado; Fernando A. Silveira; Claudia Maria Jacobi; Breno Magalhães Freitas; Marina Siqueira de Castro

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pollinating assai flowers (*Euterpe oleracea* - Arecaceae)
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Dedication

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Pioneer in Brazil in studies of the role of bees as pollinators, in classic research on pollination of the Bourbon variety of coffee. He is known world-wide for his innovative techniques for rearing indigenous stingless bees and his involvement with environmental conservation.

Warwick Estevam Kerr

Pioneer in the study of bee genetics in Brazil, focusing especially on the Meliponini. During all of his life, he has encouraged and supported the rearing of these bees, creating regional research groups across the country and disseminating the importance of the environmental services provided by pollinators.

Both have inspired us with their principles, stimulation and dedication to science.

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The Editors.

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Acronyms

API African Pollinators Initiative

ARS Agricultural Research Service

BPI Brazilian Pollinators Initiative

CBD Convention on Biological Diversity

CI Conservation International

COP Conference of the Parties

CRIA Reference Center on Environmental Information

EMBRAPA Brazilian Agricultural Research Corporation

EPI European Pollinators Initiative

EPUSP Polytechnic School, University of São Paulo

FAO Food and Agriculture Organization of the United Nations

FUSP São Paulo University Foundation

GBIF Global Biodiversity Information Facility

GEF Global Environmental Facility

ICIMOD International Centre for Integrated Mountain Development

INESP Internacional Network for Expertise in Sustainable Pollination

INPA National Institute for Amazonian Research

IPI International Pollinator Initiative

ITIS International Taxonomy Information Service

MMA Ministry of Environment

NAPI North American Pollinators Initiative

OREADES Brasilian NGO

PDF B Project Development Facility phase B

SBSTTA Subsidiary Body on Scientific, Technical and Technological Advice

TDWG Taxonomic Database Working Group

UFC Federal University of Ceará

USDA United States Department of Agriculture

USP University of São Paulo

Presentation

Workshop preparation

In October 1998, *São Paulo Workshop on Sustainable Use* of *Pollinators for Agricultural Use* was held, and as a result from this meeting the *São Paulo Declaration on Pollinators* was constructed. It was submitted to the Convention of Biological Diversity (CBD), in its 5th Conference of Parties (COP), in Nairobi, 2000, where the International Pollinators Initiative (IPI) was approved as a new program related to sustainable agriculture. Food and Agriculture Organization of the United Nations (FAO) was invited to be a facilitator of this process. In COP6 from CBD, 2002, a plan of action for IPI was approved for guiding the actions of regional pollinator initiatives, proposing goals to be attained in 10 years.

Meanwhile, regional efforts related to IPI developed. In Brazil, several activities were performed, coordinated by a committee informally established by the focal point in Ministry of Agriculture, in 2002, during the main Brazilian meeting on bees (*V Encontro sobre Abelhas*, Ribeirão Preto). Among these activities was the FAO proposal of a workshop related to discuss standardized methodologies and assessment of best practices in agriculture to promote biodiversity in agro ecosystems. The title *SP Declaration on Pollinators +5*, for meeting to be realized in 2003, was suggested by M. Ruggiero during a workshop in Mabula, Africa, and promptly accepted.

The preparation of this workshop focused the awareness in the issue to the potential participants of the Brazilian Pollinator Initiative (BPI) program, in this initial phase: scientific community in consolidate and emergent groups, including here the agricultural staff from EMBRAPA and other agronomic schools that could be engaged in this initiative. For discussing common routes for the International Pollinator Initiative, we also invited the leaders of other already established Pollinator Initiatives, like that of the International Centre for Integrated Mountain Development (ICIMOD): North American, European, African, and Asian. In Brazil, EMBRAPA and bee researchers from all country (15 research centers, from 15 states) were invited. We had 77 attendants to this workshop. Eleven countries participated in this *SP Declaration on Pollinators plus 5*. International Taxonomy Information Service (ITIS), Internacional Network for Expertise in Sustainable Pollination (INESP) and FAO were also organizations that were present. Federal government ministries from Science and Technology and Environment also gave their support for this workshop, a counterpart to FAO support.

Taking advantage of the audience at the SP +5 Forum, a second workshop, *Pollinators Initiatives and The Role of IT: Building Synergism and Cooperation*, was proposed to discuss and disseminate the importance of Information Technology for the Pollinator Initiatives, to help to promote partnership and exchange experiences on the development and use of these technologies, and to discuss funding opportunities.

International Pollinators Initiatives

The *North American Pollinator Initiative* (NAPI) comprises an established net of institutions, associations and researchers involved in the pollinators' issue, as well as in the ecological services provided by pollinators. It is a public-private partnership of pollinators' conservation programs. Among the milestones of pollinators programs are *The Forgotten Pollinators Campaign* (1996), the *São Paulo Declaration on Pollinators Conservation and Sustainable Use* (1998), the *North American Pollinator Protection Campaign* (NAPPC) in 1999, the *International Pollinator Initiative (IPI) in CBD* (2000; 2002). This is a science-based program, "a portfolio of programs, projects and activities from the public and private sector, connected by a spirit of cooperation" (Ruggiero, *et al.*, 2004)

The *European Pollinator Initiative* (EPI) has adopted the same framework of the IPI, the four key components being: assessment, adaptive management, capacity building and mainstreaming. To assess pollinator loss, the ALARM (Assessing of LArge-scale Environmental Risks with tested Methods) project was developed, combining the expertise of 54 partners from 26 countries. This program started on February 1st., 2004, and it is planned for 5 years initially. In particular, risks arising from pollinators' loss in the context of current and future land use in Europe will be assessed. SUPER (Sustainable Use of Pollinators as an European Resource) will be built directly upon ALARM to address identified declines in European pollinators resources in a socially and economically viable manner (Potts, 2004).

The *African Pollinator Initiative* (API) was established in 1999, as the African network of the IPI. "It strives to improve communication channels between all people and organizations interested in pollinators and pollination biology, including biodiversity conservation, agriculture and general awareness, and to facilitate collective achievements" (Eardley, *et al.*, 2004). In 2002, its first Secretariat was formed, and the *Plan of Action of African Pollinator Initiative* was published. At this time, API comprises Ghana, Kenya and South Africa, but it is open for other participants. A major need that exists in Africa is to identify the pollinators. Rapid assessments, taxonomic efforts and capacity building are among the main needs.

ICIMOD initiated its pollinator/pollination program in 1991, to address applied research, development and related issues of pollinators and pollination. The overall goal of ICIMOD is to improve the livelihood of mountain people by enhancing agricultural productivity and biodiversity conservation through conservation of indigenous pollinator species in order to ensure sustainable pollination of crops and other indigenous plant species of the Hindu Kush-Himalayan region. Several activities are being undertaken concerning pollinators (Partap, 2004).

The *Brazilian Pollinators Initiative* (BPI) was constructed based on the São Paulo Declaration on Pollinators, which stimulated international interest and provided strategic direction for pollinator conservation planning (Dias, *et al*., 1998; Kevan and Imperatriz-Fonseca, 2002; Imperatriz-Fonseca & Dias, 2004; Imperatriz-Fonseca, *et al*., 2004).

API, BPI and ICIMOD are together in a GEF (Global Environmental Facility) project entitled *Conservation and Management of Pollinators for Sustainable Agriculture Through an Ecosystem Approach*, with FAO as the facilitator. In this global scenario, with pollinators in mainstreaming in developed countries and almost unknown in undeveloped countries, a partnership among scientists and stakeholders will improve capacity building and sustainable use of pollinators. As the general framework of IPI is adopted by all initiatives, including here standardized methodologies for assessments, it was considered essential to join leaderships to discuss goals, needs and opportunities. For global comparisons, assessment methods must be standardized.

Methodological discussions

The talks were organized in order to give support for the discussion on which standard methodologies should be used in the development of the Brazilian Pollinator Initiative. In oral presentations, several aspects of the methodologies applied until now in pollination research and pollinators assessment were presented by the specialists, showing how some important issues should be considered in future actions. Subjects, such as the influence of individual collector performance in assessment, methods to be applied in assessment research, long-term and short-term evaluations, introduction and restoration of pollinators, performance evaluation in solitary pollinators, meta analysis of data on plant-pollinator relationships, and priorities for pollinators programs, were presented. Gene flow, bee species visiting flowers of important crops and pollinator breeding possibilities in Brazil were also part of oral presentations and specific group discussions.

Protocols and discussions

The sessions' coordinators established a protocol to be discussed during the workshop. The groups were directed to discuss the methods to be standardized, and to suggest themes for the PDF B (Project Development Facility phase B) of the GEF project. We needed to consider the enormous task for some themes, which obviously could not be concluded within a 5-day workshop. Some general comments follow.

The first group discussed assessment methods for pollinators' status. Although they advanced in the analysis of different methods, the task was not concluded. The main methods to be applied were pointed out, but only indications for the manual of standard methods were made. Coordinators answered the proposed questions, gave orientation for case studies and suggested the next steps in the PDF B of the GEF project.

The gene flow group presented a conclusive report. They also indicated the chosen methods to be used for different purposes, without describing them. Gene flow studies must be included in the full project, and a selection of subjects was suggested by the group for next steps.

Management of bees that could be used as crop pollinators was the next subject, divided into 3 parts: honey bees; stingless bees; and bumblebees and solitary bees.

In Brazil, as well as in other countries, honey bees are used as generalist pollinators because they are abundant, easy to breed and to manage in crops. Honey bees were focused on for crop pollination in the important McGregor's book, *Insect pollination of cultivated crop plants*, still very useful and updated on line. However, Brazil has the Africanized honey bee, which requires special management practices, and knowledge related to their performance as pollinators. In fact, they are quite effective in pollination, as Roubik (2002) pointed out for coffee production in Panama, and as Couto (2002) discussed for several crops. The honey bees study group presented a very comprehensive report, with valuable suggestions and guidelines for further applications of bees as pollinators. Pollination by honey bees could be much improved by technology advances in management, nutrition, pathology and mechanization, especially for transport to pollination sites. Farmers need to be made aware of the benefits of incorporating pollination into their management practices

Brazil has only seven species of bumblebees (*Bombus*); nevertheless they are abundant all over the country. They are generally very aggressive, and are not reared for pollination purposes in Brazil. The carpenter bee, *Xylocopa*, can be reared and is a good pollinator of passion fruit, among other crops. There are 49 species of carpenter bees in Brazil (Silveira, *et al.*, 2002) that are potentially important in agriculture. The solitary bees management group did a very comprehensive report, presented the main plants that should benefit from their use as pollinators and the needs for breeding them in large quantities. An effort for a workshop focusing only on these bees as pollinators was indicated as a need, and was held in April 2004.

Stingless bees are native in Brazil, with more than 500 species in the country. Breeding techniques are known for some species. Most stingless bees species have not been studied yet. Their use as pollinators is effective for some species (see Heard, 1999; Malagodi-Braga, *et al.*, 2000), but they are not bred on a large scale to be available for agricultural purposes. They have a high potential for the use as pollinators: they are diverse, have perennial nests, are generalists, but also show floral preferences (Ramalho, *et al.*, 1990; Biesmeijer, *et al.*, 2005), they communicate floral resources to nestmates, they do not sting, and they store food inside the nests. The use and conservation of stingless bees was discussed by this group, and next steps for related activities suggested.

It is important to point out that if funding is not available to develop bee biology projects and to improve the local knowledge and for capacity building concerning the other bee species, Africanized honey bees will soon be the only available pollinators in sufficient quantity for agricultural use in our country. Loss of habitat and increasingly intense agricultural practices are clearly reducing the native bee populations. Introduced into the Americas, honey bees are generalists and in most cases less effective for biodiversity conservancy. The result will be a drastic loss in plant biodiversity and in agricultural production, especially in the more tropical regions.

Information Technology and the Pollinators Initiatives

For this one-day workshop, held during the last day of the *SP+5 Forum*, speakers representing the various Pollinators Initiatives present were invited. Other presentations focused on local initiatives: the Brazilian Pollinators Initiative and local projects that make a strong use of Information Technology (IT) and are related to pollinators. The speakers were asked to give a short presentation focusing on how IT is used presently and how, in their own point of view, it might contribute for the advancement of the national, regional and international Pollinators Initiatives. Some time was allowed for discussions on issues such as technology and data sharing, systems integration and also funding needs and strategies.

Workshop results, as well as the oral presentations, are on line at http://www.webbee.org.br.

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WORKSHOP I

Survey methods for bees as pollinators in Brazil: assessing the status and suggesting best practices

Group 1

Surveying and monitoring of pollinators in natural landscapes and in cultivated fields

Participants: Cynthia Pinheiro Machado (Coordinator), Fernando A. Silveira (Coordinator), Patricia Albuquerque, Jacobus Biesmeijer, Maria José de Oliveira Campos, Connal Eardley, Barbara Gemmill, Terry Griswold, Peter Kwapong, Paulo de Marco, Favízia Freitas de Oliveira, João Rodrigues Paiva, Carmen Pires, Simon Potts, Francisco Ramalho, Mauro Ramalho, Anthony Raw, Márcia Rego, Michael Ruggiero, Fernando Zanella.

Abstract

This workshop aimed the establishment of standard methodologies for bee surveys and monitoring of natural landscapes and crops. As there are countries and regions with practically no information about pollinator fauna, three strategies for pollinator investigation were addressed: 1) rapid assessments; 2) surveys and 3) monitoring programs. The expected product was a manual for standard methodologies for bee surveys and monitoring in natural landscapes and cultivated fields. Some basic principles were observed: data must be reliable and adequate for statistical analyses, and all suggested strategies were to be realistic, considering time, personnel and costs constraints, and flexible enough to be applied in different environments. Surveys should be question oriented. It became obvious that no rigid protocol could be built for all situations across the world, then only general guidelines, not protocols, were suggested in order to meet the basic principles listed above. Since no comparative data exist in those methodologies, no consensus was reached on which methods to recommend for given situations, but comparative data should be sought for before any definitive recommendations can be built in the context of the Brazilian Pollinator Initiative. Three case studies, in a cotton field, in the Atlantic Forest and in open savanna, illustrate how recommendations could be used in the development of survey and monitoring protocols.

Aim

Establishment of standard methodologies for bee surveys and monitoring of natural landscapes and crops.

Expected Product

Production of a manual of standard methodologies for bee surveys and monitoring of natural landscapes and cultivated fields.

The pollination crisis and the need for surveys and monitoring programs

The impact of deforestation, habitat fragmentation, introduction of exotic species and unfriendly agricultural practices is believed to be causing a decrease in wild pollinator populations. This, in turn, is suspected to be the cause of low fruit and seed productivity in many crop plants, with economic consequences in many parts of the world. Also the productivity of wild plants may be affected, and this can lead to local extinction of populations of those plants, as well as of the animals depending on them.

Since this "pollination crisis" was recognized, much effort has been put into initiatives to conserve and sustainably use wild pollinators. However, it is widely recognized that we lack much of the knowledge we need to propose effective actions to achieve conservation and management practices. We are not even certain about the geographic extension and intensity of pollinator population decreases. We also lack basic information on how the different factors affect wild populations of flower visiting organisms.

Two basic questions stand out as being of surmount importance for any conservation or sustainable management initiative to succeed: 1) which pollinator species exist in any given place? 2) how are their populations fluctuating along time?

For these questions to be answered, we need to invest in pollinator faunistic surveys and in monitoring programs.

Results

The group discussed the general structure of standard procedures to survey and monitor bees in cultivated fields and natural areas.

Rationale

- Data to be obtained by the suggested guidelines will be used in the context of the Brazilian Pollinator Initiative and should be useful for other initiatives around the world.
- As there are countries and regions with practically no information about pollinator fauna, three strategies for pollinator investigation were addressed: 1) rapid assessments; 2) surveys and 3) monitoring programs.

Recommendations

Basic principles

The group agreed that suggested actions should:

- Assure data quality, i.e., data must be reliable and adequate for statistical analyses.
- Be realistic, considering time, personnel and costs constraints.
- Be flexible enough to be applied in different environments.
- Be question oriented.

Difficulties

Members of the group suggested and discussed various methods in use across the world. Different people had different experiences with different methods. For example, some had very good results in using pan traps for collecting bees, while others obtained meager data from their use. Such differences could be due to different designs, different environmental conditions, etc. It became obvious that no rigid protocol could be built that could be recommended for all situations across the world; even within Brazil; the group was not able to decide on specific methods to be employed, due to the varying opinions on their efficiency.

Thus, it was decided that only general guidelines would be built, so that data obtained from surveys and monitoring programs, using any combination of the suggested methods, would meet the basic principles listed above. It was hoped that further comparison of the different methodologies would enable sound choice of methods in the future.

Considering the difficulties exposed above, the following recommendations should be accepted as guidelines, not protocols, in order to assure their applicability.

Rapid Assessments and Surveys

Aims	
To best describe given local faunas. To maximize number of species recorded.	
Type of data	
Species records	Through collection and deposit as vouchers in public collections.
Species Abundance	Not necessary. Priority should be given to increase the number of new species detected.
Habitat description	Follow a basic protocol** that describes the collection site on many scales. Geographical coordinates must be taken for species distribution analysis. When GPS is not available, geographical clues should be used*.
Association with plants	Whenever possible, plants visited by pollinators should be recorded, in order to give clues on possible target plants for future surveys.
Sampling design	
Plan a pilot study to verify the adequacy of techniques.	
Plan data collection to be useful in the future as meta data.	
Sampling efforts must be measurable and recorded.	
Sampling techniques	
A combination of methods may be used, but sampling effort for each method should always be recorded. Whenever possible, hand netting should be applied. Other recommended methods are: trap nesting; aspirators, malaise traps, and pan traps.	
Statistical analysis	
Use recommended statistical analysis. Statistical techniques should be known in advance. A guide of statistical procedures or references should be part of the manual.	

Observations Species identification should be made by trained people, with the aid of taxonomic keys and reference collections. Those responsible for identifications should be contacted in advance. Manuals should include information on national collections and taxonomy services.

Aims	
To obtain the best estimate of local fauna and bee plant relationships, in order to allow for comparison among areas.	
Type of data	
Species records	Through collection and deposit as vouchers in public collections.
Species Abundance.	Number of individuals must be recorded in a manner that allows post collection analysis based on numbers per plant, per hour, per species, and any other relevant unit.
Habitat description	Follow a basic protocol** that describes the collection site in many scales. Geographical coordinates must be taken for species distribution analysis. When GPS is not available, geographical clues should be used*.
Association with plants	Plants should be collected and deposited as vouchers in public collections for identification. Record the resource used by plant visitor. Weather conditions and time of the day must be recorded for resource availability analysis.
Sampling design	
Use previous data to plan collection and build a list of expected species.	
Plan a pilot study to check the adequacy of techniques.	
Plan data to be useful in the future as meta data.	
Sampling effort must be measurable and recorded.	
Adequate number of replications should be employed. Environment patchiness and plot design should be taken into account to define the number of replicates.	
The sampling area should be visited before sampling, and plant collection and individual plant labeling should be done whenever possible to facilitate plant identification.	
Consider time to be spent in obtaining information on habitat and surroundings that may be useful in the future.	
Identify data that should be collected and only collect data that will be useful for future analyses.	
Sampling techniques	
A combination of methods may be used, but sampling effort for each method should always be recorded. Whenever possible, hand netting should be used. Other recommended methods are: trap nesting; aspirators, malaise traps, and pan traps.	
Statistical analysis	
Use recommended statistical analysis. Statistical techniques should be known in advance. A guide of statistical procedures or references should be part of the manual.	

Observation: Species identification should be made by trained people, with the aid of taxonomic keys and reference collections. Those responsible for identifications should be contacted in advance. Manuals should include information on national collection and taxonomy services.

Monitoring

Aims	
To identify and describe patterns and variations through time and changing conditions of selected variables. To evaluate population fluctuations To guide decisions in conservation actions; To guide decisions in management actions; To generate basic data for selecting potential pollinators for further studies.	
Type of data	
Species records	Species can be counted or collected, depending on the facility of identification and objective of the program.
Species Abundance	Number of individuals must be recorded in a manner that allows post collection analysis based on numbers per plant, per hour, per species, and any other relevant unit.
Habitat description	Follow a basic protocol** that describes the collection site on many scales. Geographical coordinates must be taken for species distribution analysis. When GPS is not available, geographical clues should be used*.
Association with plants	Plants should be collected and deposited as vouchers in public collections for identification. Record the resource used by plant visitor. Weather conditions and time of the day must be recorded for resource availability analysis.
Sampling design	
Use previous data to plan collection and build a list of expected species.	
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A combination of methods may be used, but sampling effort for each method should always be recorded. Whenever possible hand netting should be used. Other recommended methods are: trap nesting; aspirators, malaise traps, and pan traps.	
Statistical analysis	
Use recommended statistical analysis. Statistical techniques should be known in advance. A guide of statistical procedures or references should be part of the manual.	

Observations: Species identification should be made by trained people, with the aid of taxonomic keys and reference collections. Those responsible for identifications should be contacted in advance. Manuals should include information on national collection and taxonomy services.

Final Remarks

It was obvious that no fixed protocol could be provided for all situations. Moreover, different people had different experiences with different sampling methods. Since no comparative data exist on those methodologies, no consensus was reached on which methods to recommend for given situations. Thus, such comparative data should be sought for before any definitive recommendations can be built in the context of the Brazilian Pollinator Initiative.

Case Studies – an exercise

Aim

To provide examples of how the above recommendations could be used in the development of survey and monitoring protocols.

The group was divided into three subgroups, each of which worked on one case study. The resulting protocols presented below were constructed based upon literature information and the expertise of group members, with surveys and monitoring of bees on specific crops and in different kinds of environments taken as examples.

1) MONITORING FLOWER-VISITING BEES IN COTTON FIELDS

Background

According to Barroso & Freire (2003), three species of cotton are found in Brazil, *Gossypium hirsutum* (L.), *G. barbadense* (L.) and *G. mustelinum* (Mier). Of these, only herbaceous cultivars of the introduced *G. hirsutum* are currently cultivated on a commercial scale in Brazil. However, cultivation systems are not homogeneous across the large cotton-producing regions of Brazil. An evident contrast exists, for example, between the small-scale production found in the small family-held farms in the northeastern region of Brazil, which employ a low technology crop system, and the large scale production system employed in the huge commercial farms in central Brazil.

The cotton plant can produce nectar in five different kinds of nectaries distributed inside and outside the flower. However, not all of these nectaries occur in every cultivar (Free, 1970; McGregor, 1976). Many different organisms are attracted to the cotton flower by the nectar and pollen it produces. Among these, insects and especially bees are the most abundant. These flower-visiting species may contribute to increases in fiber production and/or quality (Free, 1970; McGregor, 1976).

The suggestions below were constructed considering a small-scale system. Considerations on how to expand this protocol to a large-scale, high-technology system are presented at the end of this exercise.

Survey

The survey of cotton-flower visiting species is proposed for 1 ha fields, considered here as sampling units. This is an average size field for cotton in Northeastern Brazil. In each such sampling unit, two sampling procedures would be executed in parallel:

A) Arbitrary sampling. This protocol aims to maximize the number of flower visiting species recorded on cotton plants. The field is slowly inspected and all bees found on the cotton flowers or flying above them are collected. It is important to call attention to the fact that the deep corolla of the cotton-flower makes the use of hand nets relatively inefficient, as the flower protects the visiting insects. For this reason, complementary capture methods are suggested: forceps, insect aspirators and hand nets, depending on the size and position of the bees.

B) Systematic sampling. This protocol aims to quantify the relative density and abundance of flower-visiting species. Sampling is to be done weekly in 10 plots, each including 80 cotton plants, 20 in each of four neighboring rows. Those plots should be homogeneously distributed across the field, including areas close to its border and center. Areas close to patches of natural vegetation and other special environments around the field also should be considered. Each plot is sampled for 10 min by slowly walking between the rows. Any bees found inside the flowers and on extra floral nectaries will be collected.

Both sampling procedures should be executed weekly, between 8:00 and 12:00, along the flowering season. Sampling should be done preferably during sunny days, when bees are most active at flowers. Any cultivation practice proceeded between and on sampling days should be recorded.

Monitoring

Monitoring can be done by repeating yearly the systematic sampling procedure described above. In this way, average abundance of the whole flower-visiting assemblage and of target species can be compared between years and along longer periods. These numbers can also be associated with factors such as climatic parameters and the amount of pesticide application.

Adapting the protocols for large-scale, high-technology systems

The same 1 ha sampling units could be used, each with 10 sampling plots, as explained above. Such sampling units should be homogeneously distributed inside the cotton fields, the number of such units being proportional to the size of the fields, with some of them close to the borders and others within the interior of the fields.

2) BEE SURVEYS AND MONITORING OF A FRAGMENTED LANDSCAPE IN THE ATLANTIC RAIN FOREST BIOME

Background

The Atlantic Tropical Rain Forest is a recognized biodiversity hot spot. Its original vegetation cover has been reduced to 8%, and what is left is threatened by human presence. Population growth has led to destruction of the forest through uncontrolled urban expansion, industrialization and migration of people from other areas (Galindo –Leal & Câmara 2003). About 100 million people live in the mega cities located in the Atlantic Forest Region, along with the largest industrial and silvicultural centers. On the other hand, the biodiversity harbored by the Atlantic Forest is one of the greatest in the world. We believe that 60% of the terrestrial species of the planet live within the remaining areas of this forest. This is probably a result of the large range of latitude it covers, its variation in altitude, the diverse climatic regimes, and the availability of water and energy to the system (Pinto & Brito 2003). These forests are highly stratified, with a canopy as high as 35 meters.

Survey

Pollinator surveys should be made along transects. The determination of size, placement and number of transects will depend on the heterogeneity of the forest community, which should be understood beforehand. The size of the transects should be such that they can be covered in one day. They should be 100 m long.

The sampling units will be flowering plants, with all bees found being collected at all the flowering plants that they visit. Hand nets will be the principal collection method and will be complemented by euglossine baits. Additional methods such as pan, malaise and light traps and also new baits such as salt/ammonia and antifreeze should be tried.

Sampling should be repeated 3 to 5 times a month for 8 to 12 months per year, depending on flowering phenology and flower density.

Monitoring

The goal of the suggested monitoring program is to detect differences in bee diversity in disturbed and undisturbed forests over time. It could also be used to compare different degrees of disturbance.

Sampling units are similar to those used in the survey. Monitoring subjects may be selected, based on survey results. For example, euglossines or *Melipona*. Such subjects a) include species sensitive to deforestation; b) occur in large numbers and c) can easily be identified. Still other subjects could be considered, such as *Apis mellifera*, trap-nesting *Centris* or specialist taxa.

The monitoring design should include site in or adjacent to undisturbed area (control), disturbed area (treatment 1) and intermediate area (treatment 2).

A minimum of five years of sampling is needed for conclusions to be drawn.

3) SURVEY OF POTENTIAL POLLINATORS IN THE BRAZILIAN SAVANNA, AND A MONITORING PROGRAM TO EVALUATE THE IMPACT OF GRAZING ON FLOWER VISITORS´ RICHNESS

Background

The biome of the Cerrado is a gradient of vegetation physiognomies, including open fields, savannas and open-canopy forests. It covers about 25% of the Brazilian territory and was included among the world's hotspots (Myers, *et al.* 2000), for combining high biodiversity and high rates of disturbance. Until 40 years ago the Cerrado was primarily used for extensive cattle raising. By 1988 Klink & Moreira (2002) estimated that 35% of the natural cover had already been removed. In a recent study, using MODIS satellite images of 2002, (Machado, *et al.*,2004) concluded that the natural cover loss has changed to 55% .

Agriculture occupies 6% of the total area, but this figure is increasingly stimulated by present national agricultural policy. Pastures and large plantations of soybean and cotton are the major threats for the biome, causing soil loss, water pollution, habitat loss, habitat fragmentation, introduction and spread of very agressive invasive species, like African grasses, among others (Buschbacher, 2000; Fearnside, 2001; Klink & Machado, 2005). Forecast is not optimistic, according to Machado, *et al.* (2004), based on present vegetation removal rates by 2030 the whole biome may have given place to agricultural and cattle raising activities.

Major impacts on pollinators are apparently caused by intense use of chemicals, aerial spraying, and habitat removal; the latter provokes reduced nesting opportunities and food availability.

According to Silberbauer-Gottesberger and Eiten (1987), the plant species richness of the Cerrado open areas is among the highest known for non-forest vegetation. Seasons are very well defined. The dry season lasts from 3 to 5 months, during winter, and the wet season peaks in December-January. Flower resource availability varies through the seasons

(Oliveira & Gibbs, 2002), but flowers are found throughout the year (Batalha, 1997). Bee surveys in the Cerrado area have been carried out in Central Brazil, around Brasília, in Minas Gerais State, in the Northeast and in some peripheral areas in São Paulo state (Pinheiro-Machado *et al.*, 2002), allowing for a baseline data set for native fauna.

Survey

The Cerrado vegetation is a natural mosaic, with many vegetation types, varying from open grass fields to dry forests. Therefore a previous analysis of the sampling area has to be done before designing the survey. The following steps can be used to guide the sampling procedures.

1. The very first task must be the definition of the question that the survey is aiming to ask; all of the succeeding steps depend on a very clear and objective question.
2. A good view of the large area, using satellite images or local driving around to picture the heterogeneity of the area to be sampled.
3. Accessing previous studies in the area, or similar areas, to create estimates of diversity and sampling effort necessary to best describe the focal fauna. Some calculations involving sampling curves in a standardized way with previous data may be necessary; the studies should indicate period of activity, both seasonally and daily.
4. Visits to collections will produce a better species list and expected richness numbers, because collections are believed to include many unpublished data.
5. Local evaluations prior to the surveys provides familiarization with flora and allows identification of potential plant species for a target survey. This may be crucial, especially in the case of very short budgets. Simple things that might turn into difficulties in the field can be observed, like the height of trees to be sampled. Previous studies may also provide information about plant species intensively visited by bees.
6. Although Brazilian researchers use hand netting as the main technique for sampling bees, examination of previously published studies that have used other methods can indicate what part of the community is not being sampled if hand netting is the only technique.
7. Plan the type of analyses that will be carried out and assure that the experimental design will provide proper data.
8. Sampling area should be marked at the field.

Site selection must be guided by the question proposed for the survey. The chosen site must be representative of the environmental situation to be investigated. If a unique type of vegetation or physiognomy is targeted, an evaluation will need to be made to determine if the chosen site adequately represents the situation to be surveyed. This also applies when gradients or mosaics are the case. Replication and control areas are important parts of some surveys and have to be considered during site selection.

Another very important point is the accessibility of the site and all the permits that should be obtained, both from private landowners and governmental agencies.

Sampling design and sampling techniques

Sampling design involves choices of sampling unit format, size, number and spatial distribution. For instance, if an overview of diversity in the area is the aim, sampling units will be need to be randomly distributed; if diversity information is to be linked to habitat, sampling units should be selected in a way that they represent all desired situations (Alonso & Agosti, 2000). The sampling design has to consider areas greater than 2 ha because of the typical spatial distribution of plants in the Cerrado. At least 10 transects 2 m wide by 1 km long, or 5 quadrats of 40x100m, should be established. The method should be calibrated against known areas by follow-up procedures using species accumulation curves (Soberón & Llorente, 1993) to inform about the efficiency of the chosen design and techniques. Species accumulation curves are produced from species-by-sample matrices in a spreadsheet, and they can be carried out by the EstimateS program (Colwell, 1997).

Sampling techniques that minimize the collectors' interference are preferred, but the best results in Brazil have so far been achieved using hand nets. To minimize differences among collectors, previous training is mandatory. Different species have different behaviours at flowers; some of them can be very fast and sensitive to movement. Collectors must be advised to collect any bees and all wasps and small flies, because some bee species looks like wasps or are too small to be differentiated from another insect when observed in the field.

Recommended techniques are hand nettingand sweep netting in transects. Although pan traps have not had good acceptance among Brazilian researchers, good results and new fluorescent colors reported from other countries speak for its use. Pan traps tend to be selective for certain groups, so they should not be used as the only technique for inventories. The best method may vary according to site and logistics, but best results in species numbers are usually achieved when multiple methods are applied.

The length of the transect needs to be standardized, but it will depend on the aim of the survey, as discussed above. If the transect is divided into sub samples, these should be kept separated for posterior analyses. The starting point of the transect should be picked at random, in order to avoid always collecting during the peak activity period at the same part of the transect. One needs to be sure that the peak activity period is always covered by sampling effort. Collectors should also be randomized along sites to minimize bias from collecting ability.

Complementary data is very important for data analysis, so a protocol should be applied to every survey. Recommended data to be gathered are the following:

- site location with coordinates; use a GPS; if this is not available, report local geographic references like roads, bridges, or equivalents;
- date, including month/day/year ;
- time of the day, indicating sampling hours;
- a clear vegetation classification, informing not only details about the vegetation found in the sampling areas, but also the characteristics of the landscape in which is it situated;
- the size of the total area from which samples are taken must be indicated, because results are expected to vary if collecting sites are a part of a 1 ha, a 100 ha or a larger area of Cerrado;
- general climate description and classification are very useful and must be complemented with local weather conditions during the collection days and information about average temperature and rainfall whenever possible.

Floral associations are important complementary information, but time can be saved if collectors add flowers to a bag, identify it, and leave a numbered tag on the plant to proceed with plant identification later on.

Field equipment must include spare hand nets, and enough vials to avoid jamming various insects into each vial. All material is to be labeled in advance allowing quick field information to be made promptly.

After fieldwork some procedures are recommended that will make data easy to analyze for anyone interested:

- standardize the format of data presentation and codes to facilitate understanding at all instances of the study;

- present results by simple summary descriptors, like species richness, and common and popular diversity indices;
- feed data bases that provide access to the general pubic; indicate the collection where voucher material was deposited.

Monitoring

The proposed exercise for this group was to give directions for monitoring the impact of cattle raising activities on the biodiversity of pollinators. The group started with the statement of the leading question: What is the impact of introducing cattle "on pollinators"?

To address this question, previous data about bees and their relationship with flowers of open areas will be gathered. This information will be used to choose focal groups for monitoring activities. Preference will be given to bees sensitive to gradients that are in this case understood to range from original non-grazed areas to heavily grazed areas. If preliminary data fails to point out the taxa to be monitored, the initial monitoring is used to establish a baseline for further comparisons. The preliminary data will be tested for correlation with desired variables, like bee diversity. Once a strong and significant statistical relationship is found, collections will be repeated through time. The sampling design is the same one proposed for the survey, but will be repeated through time.

HOW DATA FROM MONITORING WILL BE USED IN THE CONTEXT OF BPI?

Monitoring depends on the choice of sound and easy to measure variables. Variable selection can be made based upon previous data. It is recommended that a selected taxa or a guild is used for monitoring, but the relationship between the measured variable and the object of monitoring should be understood and supported by a strong significant positive correlation. Direct relationships are preferred. If the relation between the measured variable and the object of monitoring is not already known, assumptions must be stated clearly at the beginning of the monitoring program. The selection of a specific taxa or guild must take into consideration the characteristic that the focal organisms are abundant and easy to identify. A previous survey is mandatory for areas where data is lacking, to improve the chance of choosing good taxa to be monitored.

Some general recommendations could be made for all situations involving pollinator surveys and monitoring:

Training. One problem raised about the use of "manual" collection methods, such as hand-netting is the effect of different abilities of different people to find and capture bees. This problem can be reduced by properly training collectors before actual sampling is begun.

Replication. An appropriate number of replicates should be set, according to environment heterogeneity and/or other important factors. Pseudo-replication should be avoided. For instance, 12 monthly samples collected at one site cannot be considered as replications of different disturbance grades or environment types. In these cases, different areas should be sampled as replications of each treatment.

Identification and voucher specimens. Specimens both of target (pollinators) and associate (e.g. food sources) taxa should be properly collected, preserved and labeled to facilitate proper identification. Such identification should preferably be done by experienced personnel. Moreover, voucher specimens of all taxa involved should be deposited in public collections that should be indicated in reports and publications, so that their identification can be checked at any time.

Final remark

The group was composed of a number of researchers with experience in bee surveys and monitoring. However, the members had different thoughts about the different methods. In part, this may be a consequence of the effect of different environments (including composition of regional bee fauna) on sampling methods. Consequently, methods that were reported by some as very efficient, did not produce good results in other places, when used by other people. It was suggested that experiments (like those going on under the auspices of the European Pollinator Initiative) should be made on a regional scale, so that a final choice of methods can be made for each region.

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Group 2

Assessment of Pollinator – Mediated Gene Flow

Participants: Claudia Maria Jacobi (coordinator), Edivani Villaron Franceschinelli, Rogério Gribel, Peter G. Kevan, Alfred Ochieng, Eda Flávia Lotufo Rodrigues Alves Patrício, David W. Roubik.

Abstract

This group discussed the interaction between plant and pollinator, emphasizing the importance not only of pollination, but also of good agricultural, forest management, and conservation practices for sustainable development. The group was comprised of researchers whose areas of expertise encompass floral biology, plant breeding systems, plant population genetics, and pollination of tropical plants. The recommendations made below are intended to contribute to future discussions regarding the Brazilian Pollinator Initiative (BPI), although some of them are general enough to be considered more broadly. Emphasis was given to recommendations other than methods, since there is a vast literature available (including FAO publications) on the above-mentioned subjects.

Pollen-mediated gene flow in plants is affected by abiotic agents, such as wind, and a number of biotic agents, of which the single most important pollinator group worldwide is the bees. Also of great importance for many native fruit trees in the tropics are bats, beetles and flies. The production of fruits, seeds, and of more individuals of the pollinated species depends directly on these agents in the majority of plants, and very often in commercially-important ones. Exceptions are self-fertilizing plants, but even these frequently benefit from cross-pollination provided by these agents. Traditional selective breeding of plants, habitat fragmentation and overexploitation of natural stands are currently narrowing the genetic base, and are leading to genetic erosion of economically important plants. In addition, genetically modified varieties resistant to herbicides or pesticides could create potential "superweeds" through pollen-mediated gene flow.

Among the methods proposed to help perform the recommendations, rapid assessment protocols (RAP) are suggested, for the collection of data on bee behaviour, pollination syndromes and landscape diagnosis. These protocols allow data collection in the field by people with little or no formal biological training. Other methods, including statistical and genetic analyses, require both expertise and specific facilities, and will usually be performed by researchers and trained personnel.

Aim

To propose standard methodologies for the assessment of pollen transfer in crops and in natural areas.

Expected products

To produce a list of methodologies, such as rapid assessment protocols, experimental desing for testing breeding systems and monitoring methods, making use of case studies as exemples.

To produce a list of recommendations for the gene flow assessment and management of plant species regarding containment measures or enhanced productivity.

This working group focused on the assessment of pollinator-mediated gene flow of economically important plant species.

Discussion

The discussions occured in two sessions; one on monitoring of flower visitor behaviour, morning October 29th; other on pollination requirements and on apllied issues in pollinator gene flow, afternoon October 29th.

The goals were to discuss ways of producing a database containg comparative behaviour of visitors in different plant species within an area; how to produce a list of important plant species and their pollinator requerements, including their breeding system, pollination syndrome, and resource offer; and how to increase awareness/knowledge of mechanisms for containment measure or enhanced productivity for selected plant species.

The questions guiding those discussons were:

- How to adapt the observational methods proposed to different plant habits and morphologies, and landscapes (ex: trees vs. shrubs; natural vs. agricultural systems)?
- Should these methods be made widespread and user-friendly?
- Should we encourage their use by laymen in order to increase the number of areas and situations?
- If so, how to standardize the use and application of the RAP with a minimum of mistakes?
- Will it be feasible to recommend pollen containment measures based on this information?
- How to determine the need to assess gene escape (ex. in the case of unwanted hybridization between crop varieties and wild relatives, or related contamination problems concerning GMOs)?
- Should recommendations be made on a case-by-case basis, or could we generalize part of them?

In order to orientate the discussions a list of general guideline of method were drew:

- Observations of bee behaviour on the flower/inflorescence: pollinator or visitor? (frequency and kind of stigmatic contact)
- Amount and availability of pollen carried: where in the body, how tightly packed?
- Bee flight among plants: do individuals follow nearest neighbour pollination rules (optimal foraging)? Is there along-row behaviour? Is there flower constancy? How to estimate carryover?
- Energy economics of foraging: measure temperature, wind, RH.
- Creation of user-friendly protocols for bee behaviour assessment and comparison.
- Application of simple statistics to determine pollen shadow.
- Standard methodology to test for breeding system (includes bagging, hand pollination

and emasculation, followed by fruit/seed set), adapted to each case.
- Creation of user-friendly protocols for breeding system assessment.
- Application of simple statistics to analyse results.
- Estimates of gene flow through genetic markers compared with estimates of pollen transport (see above).
- Estimates of pollen shadow with dyes.
- Comparison of crop productivity under different pollinator regimes.
- Selection and discussion of case studies (e.g. cotton).

Results

Pollinator mediated gene flow

Pollen-mediated gene flow in plants is affected by abiotic agents, such as wind, and biotic agents, such as bees, butterflies and moths, beetles, flies, bats, birds, and other less frequent agents like rodents, marsupials, and thrips (Proctor, *et al.*, 1996). Many pollinator populations are probably suffering nowadays from stress resulting from habitat loss, parasites, insecticides, and misunderstanding by the general public. Meanwhile, the need for their services in natural, agricultural and agroforestry systems is growing day by day. In the tropics, pollination is affected not only by bees (natives and introduced *Apis*), but also by less known animals, whose service is poorly understood by the general public. Among these, bats are particularly important because they pollinate several species of fruit trees, while beetles and flies are responsible for high yields in palms. With such a variety of pollinator species and of plants that need animal pollination, it is important that the characteristics that affect gene flow are well understood for each pollinator and likewise the plants that they pollinate.

The pollinator requirements of a plant species depend on its breeding system. Standard methods to test for self-fertility and self-pollination are among the first features assessed when evaluating the need for pollinators. Other usual procedures allow us to evaluate if a flower visitor is an effective pollinator. When focusing on gene flow, several techniques have been tested to assess how far can pollen go from a focal plant of group of plants. This latter parameter involves knowledge of the amount of pollen harvested from a flower, flight range, and resource distribution, and it is directly related to the pollinator morphology, the flower morphology, and whether the resource is a crop or grows wild. Evaluating the extent of pollinator-mediated gene flow also requires knowledge of the pollinator's fidelity to a given plant species, and of the type of resource it is being visited for. Finally, commercial parameters that increase crop value are usually taken into account to compare differences in yield among different pollination regimes.

The understanding of pollinator behaviour with respect to each plant species is vital not only to establish adequate agricultural actions that increase yield, but also to adopt measures that lead to sustainability. Among these are actions to reduce genetic loss in forest species due to isolation, to determine levels of isolation or contamination of crops, to prevent invasiveness of exotic plants and improve conservation of native genetic diversity, and to enhance awareness of pollinators' services to humanity.

At present, given the enormous variety of pollinators and commercially important tropical plant species (Roubik, 1995), only a small percentage of plants, be they wild or cultivated, have undergone comprehensive studies, and most of the gene flow data which are needed to support conservation and management initiatives are still lacking.

Importance of pollinator-mediated gene flow in crop management and silviculture

Pollinator services have been traditionally considered expendable in many crops. However, case studies have shown that yield is significantly improved when pollinators are introduced. Such is the case for coffee (Roubik, 2002), and various crops in Brazil (cited in a recent survey by Couto, 2002): passion fruit, red pepper, strawberry and orange. Possibly, many others, such as sunflower and soybean, will also show increased yield with insect-mediated pollination. Although pollinators are not essential for fruit or seed set in many species, on account of their self-fertility, it is clear that cross-pollination usually enhances crop performance, when evaluated by commercial parameters. For example, cashew (*Anacardium occidentale*), which is partially self-fertile, requires a high rate of visitation to obtain good nut yields, since most of the fruits derive from cross-pollination (Holanda-Neto, *et al.*, 2002). The introduction of bee management to increase yield in crops should be carefully evaluated case by case, since additional costs are involved.

On the other hand, alleged low productivity of some cultivated plants may simply be the result of incorrect agricultural practices that have led to low genetic diversity of crop or forest stands. Poor fruit and seed production can be the result of inbreeding, not a lack of pollinators. The common practice of plantations based on seeds from very few trees or even clonal orchards should be analyzed carefully since this may lead to genetic erosion, low productivity and inbreeding depression. It is possible that premature fruit drop in cashew is also related to genetic causes.

Current practices of natural stand exploitation for timber, pharmaceuticals, rubber, fruit, seeds, and dyes may be reducing genetic variability and gene flow to levels that permanently affect the viability of populations. Some studies from Brazilian economically important species are available. Recent data (Peres, *et al.*, 2003) from 23 populations throughout the Brazilian, Bolivian and Peruvian Amazon have shown that the historical levels of exploitation of Brazil nuts (*Bertholletia excelsa*, Lecythidaceae) have a major impact on recruitment into natural populations. Populations subjected to moderate and high levels of harvest over many decades lack juvenile trees; in contrast, only populations with a history of light, recent or no exploitation contain large numbers of juvenile trees.

At present, there are still few laboratories in Brazil (governmental or private) that are involved in genetic studies of native plant populations. We are hopeful that this situation will be resolved in future years, since many laboratories are nowadays well equipped and their personnel already prepared for this task.

Habitat fragmentation and reduction of genetic diversity

Some Brazilian biomes have undergone extensive clearing in the past decades, notably for agricultural purposes. This has resulted in the inclusion of the Cerrado (savanna) in the latest list of "hotspots" (threatened world regions that should be given priority in biodiversity programs). This biome is home to several commercially important plant species that are intensively used by local populations.

A typical case of plant populations already suffering from habitat fragmentation is that of *Caryocar* (Caryocaraceae) species. The piqui (*C. brasiliense*) from the Central Brazil Cerrado vegetation, and the piquiá (*C. villosum*) from the Amazonian forest, yield fruits and seeds that are an excellent source of edible oil. Pollination studies in both species (Gribel & Hay, 1993; Martins, 2002) have shown a moderate degree of self-compatibility, and pollination by bats and sphingid moths. Habitat and roost disturbance may affect the populations of these sensitive pollinators. Genetic data for *C. brasiliense* from 10 microsatellite *loci* indicated a high level of biparental inbreeding, which could be attributed to the limited flight range of its pollinators and restricted seed dispersal. Habitat fragmentation would isolate populations and their pollinators, aggravating the scenario of fruit overexploitation (Collevatti, *et al.*, 2001). In the case of mahogany (*Swietenia macrophylla*, Meliaceae), the most valuable neotropical timber species, habitat degradation caused by selective logging and, most importantly, by conversion of forest into soybean plantations and cattle ranch pastures with recurrent use of fire, have clearly reduced local population sizes and have led many populations to local extinction (Grogan, 2001). Recent studies using polymorphic microsatellite markers (Lemes, *et al.*, 2003) suggest that the small, isolated, remnant populations may not constitute viable units in the long term, owing to the loss of genetic variation caused by genetic drift and inbreeding.

Brazilian legislation has contemplated the habitat loss problem by establishing, among other protection measures, that a percentage of uncultivated land be maintained in private properties (known as reserva legal) in Brazilian biomes such as the Amazon forest and Cerrado. These areas are important both to sustain ecological services such as pollination, and to maintain gene flow and diversity of native plant species by behaving as corridors between fragments. There is, however, intense debate nowadays concerning the reduction of those percentages. Attempts to change the law decreasing the proportion of these reserves should be contested with scientific and economic arguments. In addition to habitat preservation, habitat rehabilitation programs might benefit from the introduction and management of pollen and seed dispersers. This action is a cheap alternative that could increase gene flow among fragments and accelerate rehabilitation.

Pollinator-mediated genetic contamination

It is known that crops easily hybridize with wild relatives (Ellstrand, *et al.*, 1999). The visiting patterns of pollinator forage can create crop-to-wild and crop-to-crop pollen exchange. If genetically modified varieties (GMO) are involved, there is the risk that non-target plants (wild relatives or conventional crop varieties) acquire the characteristics of resistance to herbicides or pesticides through pollen-mediated gene flow and turn into unmanageable weeds (the so-called "superweeds"). The occurrence of agricultural weeds from GMO crop releases has already been reported. In Canada, the presence of unwanted herbicide-resistant canola (*Brassica napus*, which is bee pollinated) is becoming an agricultural nuisance (Simard, *et al.*, 2002).

Other genetically engineered varieties (modified to resist attack by insects), such as sunflower (*Helianthus anuus*, which is bee pollinated), and papaya (*Carica papaya*, pollinated by bees, birds and moths) have also shown enhanced fitness. They are less attacked by insects (moths) and in turn produce more seeds that are themselves more resistant to insect attack. This suggests that non-managed populations may in turn accelerate development of resistant insect pests. It is evident that to maintain the utility of herbicides and pesticides in agriculture (i.e., to reduce the risk of hastening the development of superweeds), modifications in agricultural practices, which include herbicide management (such as rotation and combination with other actions), are mandatory.

Existing containment measures are mostly designed to assure seed purity levels, and may not be adequate for preventing or, more realistically, reducing gene escape from GMO crops (Kareiva, *et al.*, 1994). Physical barriers, such as bare land or non-GMO crops around the target variety, have been used to prevent pollen contamination, but they have been inefficient in many cases, partly because of a lack of knowledge on the dynamics of pollen flow in each case.

If reducing the risk of contamination is a main concern, then the choice of managed pollinators of a given crop (most notably if it is a GMO) should weigh not only commercial aspects but environmental safety as well. The risk of gene escape to non-target species is related to the behaviour of the pollinator, such as flight range and its effectiveness as pollinator, which varies according to aspects associated involving both pollinator and crop characteristics. Purity standards should be stricter in cases of gene escape risk than in cases of seed purity, more so in centers of diversity, such as the tropics, where traditional varieties, including progenitors, may disappear.

In addition, environmental monitoring actions focusing on gene escape should give priority to high-risk crops. These are those with little domestication (that is, that are still ecologically and reproductively similar to wild relatives), that grow sympatrically with wild relatives or cross-compatible domesticated species, which can turn into weeds themselves, and those whose commercialization requires that the crop blooms or sets fruits/seeds. In Brazil, cotton would be one of the best candidates.

Recommendations

Crop and silviculture management
1. Commonly accepted ("common wisdom") practices of crop pollination should be re-evaluated to extend the knowledge of the mechanisms of pollination, and of pollinator role and benefits. Case studies have shown that fruit yield is improved with pollinator service in crops where pollinators had traditionally been considered expendable.
Proposed methods: • Standard breeding system tests and exclusion experiments. • Pollination syndrome. • Pollinator behaviour in flower and among plants. • Statistical comparison of productivity parameters between traditional methods and hand cross-pollination experiments.
2.Traditional genetic improvement methods, such as by phenotype selection of tree crops, should be re-evaluated.
Alleged low productivity of some plantations may be due to inbreeding depression, not a lack of pollinators.

Proposed methods:

- Molecular techniques (microsatellites, allozymes) to evaluate genetic diversity and dynamics; inbreeding depression, levels of outcrossing, pollen flow, cross-compatibility between varieties of cultivars and clones.
- Pollinator behaviour in flowers and among plants.
- Statistical comparison of productivity parameters between cultivars.

3.Traditional methods of exploitation of timber and NTFP (non-timber forest products) should be re-evaluated.

Natural stand exploitation practices may be reducing genetic variability and gene flow.

Proposed methods:

- Molecular techniques (microsatellites) to evaluate genetic diversity, mating systems, and gene flow.
- Observation of flight patterns of each pollinator species.

4. GMO crops with geographically close wild relatives should receive priority in environmental impact assessment actions.

Crops such as cotton and corn may hybridize with wild relatives and these may become "superweeds".

Proposed methods:

- Paternity analysis (microsatellites).
- Investigate time (phenology) or biological barriers (common pollinators).
- Observation of flight patterns of each pollinator species.

5. Containment measures should be tested and proposed in the case of any crop that has a risk of gene escape or has to maintain its purity.

Existing containment measures are still under development and have shown to be inefficient in many cases.

Proposed methods:

- Test and adoption of physical barriers that discourage pollinator flight.
- Observation of flight patterns of each pollinator species.
- Paternity analysis (microsatellites).
- Production of gene flow curves.

Pollinator conservation

1. The percentage of legally determined uncultivated land in private properties (known as "reserva legal") in Brazilian biomes such as the Amazon forest and Cerrado (savanna) should be maintained and enforced by law.

These areas are important both to sustain ecological services, such as pollination, and to maintain gene flow and diversity of native plant species.

Proposed methods:

- Molecular techniques (microsatellites, allozymes) to evaluate geneticdiversity and gene flow.
- Statistical comparison of reproductive parameters of native plants inisolated versus connected forest fragments.
- Legal actions.

2. Exotic plants or pollinators should be priority in long-term, in-depth monitoring programs, to detect overall impact in the ecosystem.

The invasiveness of an exotic plant may be benefited by a native pollinator, or the exotic pollinator may outcompete native species for resources and reduce productivity and regeneration patterns of native plants.

Proposed methods:

- Observation of pollinator behaviour in flower and among plants.
- Survey of pollinators in the area.
- Monitoring of the invasive plant spread.

3. Pollen and seed dispersal by animals should be encouraged in habitat rehabilitation programs. Their action enhances seed set and accelerates the rehabilitation process, besides being a cheap alternative.

Proposed methods:

- Introduction of meliponiculture in rehabilitation areas.
- Introduction of nesting and roosting places.

4. Native species cultivation in urban areas, instead of exotics, should be preferred and encouraged, as well as urban ecological interactions among native plants and their pollen and seed dispersers.

Their use in public parks will preserve native plant-pollinator interactions, aid in the conservation of genetic diversity, and promote awareness of native species by the public.

Proposed methods:

- Promote urban ecology awareness programs.
- Distribute material (specimens, seeds) and know-how among theauthorities responsible for urban green areas.
- Introduce nesting and roosting places, and artificial trapnests for bees.

Other recommendations

1. National programs should be promoted to increase public awareness on the need for pollination studies and conservation.

Efforts should be made to create awareness of the services to humanity performed by pollinators, to change the perception concerning a variety of animals whose important service as pollinators is currently unknown to the public, so as to reduce the pressure on these animals caused by pesticides, deforestation and others.

Proposed methods:

- List flagship plant species and explain their need for pollinators.
- Stress the beneficial role of non-charismatic animals, such as bats.
- Invent popular, appealing names for pollinators.
- Promote courses on the use of urban green areas.
- Produce and distribute user-friendly, informative material.

2. Leading laboratories should be encouraged to participate in the mapping of genetic diversity and structure of native plant populations of economic importance.

Currently many laboratories throughout Brazil are well equipped for the task, but few of them are involved in studying these organisms.

Proposed methods:

- Cooperative training courses.
- Government funding through public calls.
- Propose charismatic national or local species to obtain private or public funds.

3. Government agencies should produce, support and make widely available user-friendly material (printed, electronic, training courses), so that the above recommendations are put to practice by final users.

There are currently many comprehensive studies of economically important plants and pollinators whose results are unknown to the final user because of restricted (academic, technical) circulation. It is important that the initiative of producing this material be officially sponsored and supervised by scientists so as to gain credibility.

Proposed methods:

- Books could be transformed into PDF with the authors' consent and be made available at official sites linked to agriculture, such as FAO, EMBRAPA, and WebBee (Brazil).
- Production and distribution of user-friendly, informative material, such as leaflets and booklets.
- Training courses.

Final remarks

Methods

Explanations of some recommended techniques follow, with emphasis on Brazilian study case examples. Among the methods proposed to help perform the recommendations, several rapid assessment protocols (RAP) could be developed, grouped broadly into two: botanical (phenology, flower density, pollination syndromes, plant breeding systems) and pollinator (bee behaviour in the flower and among plants, flight range) RAPs. There is a vast literature on the parameters to be considered within each of these two, and on how to measure them. These protocols will allow data collection in the field by people with little or no formal biological training. Other methods, including statistical analyses, require both expertise and specific facilities, and will usually be performed by researchers and trained personnel.

Genetic diversity

Isozyme electrophoresis is a technique for measuring the rate and direction of movement of organic molecules (in this case, enzymes) in response to an electric field (Alfenas, *et al.*, 1998; Pinto, *et al.*, 2001). The rate and direction of enzyme movement in a starch or and agar gel will depend on the enzyme's net surface charge, size and shape. Enzymes can then be stained, resulting in a series of bands in the gel. Those enzymes that migrate to the same place in a slab of agar or starch gel and yield similar banding patterns when stained are considered to represent homologous enzymes (isozymes). When the isozymes are controlled by alleles of one gene, they are called allozymes. The banding patterns of specific types of enzymes in the gel may vary from plant to plant. Allozyme electrophoresis is most useful to analyze genetic diversity and outcrossing rate (the proportion of the progeny generated from cross-pollination) of populations within species. As a codominant marker, allozymes may directly identify heterozygous genotypes. Heterozygosity indices may be easily calculated for populations or samples of plants.

The visualization of electrophoretical patterns of isozymes requires simple procedures, since isozyme bands are obtained through the reaction that identifies the enzyme. The technique of isozyme electrophoresis is simple to learn, and it is cheaper and involves faster procedures than DNA markers.

This method has been used in a number of studies on the genetic diversity and population structure of Brazilian species, such as the commercially important palmheart (*Euterpe edulis*, Conte, *et al.*, 2003), rubber (*Hevea brasiliensis*, Yeang & Chevallier, 1999), and "cagaita" (*Eugenia dysenterica*, Telles, *et al.*, 2001). However, some native and most cultivated plants have shown either very low or no isozyme variability. In this case, molecular techniques can provide a larger number of markers than isozymes.

DNA markers, on the other hand, show a higher number of alleles *per locus* and can be more useful and accurate than isozymes. Higher numbers of markers can give more accurate genetic diversity indices and paternity analysis. However, most markers, such as random amplified polymorphic DNA (RADP) and amplified fragment length polymorphisms (AFLP), are dominant and cannot show heterozygous genotypes. In some cases, however, the high sensitivity of these techniques may limit the detection of the same markers among genetically divergent individuals. Molecular markers require specialized training and more sophisticated and expensive equipment, since their protocols are more elaborated. These techniques are also more expensive than for isozymes, but their prices are dropping (Ferreira & Grattapaglia, 1996).

Microsatellites are stretches of DNA that consist of tandem repeats of a simple sequence of nucleotides. These repeats can easily be amplified using PCR (polymerase chain reaction). The number of repeat units that an individual has at a given *locus* can be easily determined using polyacrlyamide gel electrophoresis. Using these gels, we can see two genetic marks for most individuals; each individual inherits one length of nucleotide repeats from its mother and one from its father (individuals with one band received the same band from both their mother and their father). Primers to the microsatellite flanking regions can be labelled with fluorescent dyes, allowing the amplified products to be separated in a polyacrylamide gel electrophoresis on an automated DNA Sequencer.

In the last decade, microsatellites or simple sequence repeats (SSR) markers have become an attractive tool for population genetic studies in plants due to their co-dominant inheritance, high allelic diversity and their abundance in plant genomes. The variability observed at SSR *loci* allows the accurate discrimination of individuals in natural populations and the estimation of genetic parameters, such as levels of inbreeding, heterozygosity, gene flow and mating system, which are relevant for the genetic conservation and management of tropical trees under intensive human pressure. Microsatellite markers have recently been developed for a number of tropical tree species, such as the edible piqui (Collevatti, *et al.,* 1999) and palmheart (Gaiotto, *et al.*, 2001), and the timber species mahogany (*Swietenia macrophylla*, Lemes, *et al.*, 2002, 2003), "anani" (*Symphonia globulifera*, Aldrich, *et al.*, 1998), "andiroba" (*Carapa guianensis*, Dayanandan, *et al.*, 1999), and "angelim-vermelho" (*Dinizia excelsa*, Dick & Hamilton 1999).

Plant reproductive biology and pollinator behavior

The importance of pollinator visits to a plant species depends on its breeding system. Two aspects are usually evaluated through experimental manipulation: self-compatibility and self-pollination. The first evaluates if a flower receiving pollen from the same plant is capable of producing viable seeds, and to what degree. If the species is self-incompatible, then it will need to be visited by pollinators that carry pollen from another plant in order to effect cross-pollination. Dioecious plants are obligate outcrossers. To test for self-compatibility, manual self-and cross-pollination experiments are performed on flowers, and the results (usually fruit and seed set) are then compared to those from control (unmanipulated) flowers. The difference in fruit or seed set also indicates if natural pollination is deficient in a population. If this is the case, further observations should follow to see if low fruit or seed set is caused by a reduced number of visits or by their quality. Poor quality visits are a result of visitors who do not perform pollination (thieves, for example), or who deposit the wrong kind of pollen (self-pollen if the plant is self-incompatible, or pollen from other species if the pollinator carries pollen from other plant species). If the plant is self-compatible, then it might not need the help of pollinators to set seeds. This is usually checked by bagging buds to exclude visitors and then verifying fruit and seed set. These procedures are standard and well explained in a number of books (Dafni,1992; Kearns & Inouye, 1993; Proctor, *et al.*, 1996). In addition, data on commercially important parameters may be measured and compared among treatments, such as color, weight, shape, size and nutrient contents of the fruits.

Different pollinators respond to resource landscapes and this in turn has consequences on the extent of pollen dispersal (Bronstein 1995). Foraging flights may vary according to the homogeneity of resources (crop *vs.* natural environments), plant spacing (Manasse, 1992; Morris, *et al.*, 1994; Morris 1993), and their flight range (Jacobi, 2000; Turchin 1998), among others. Several statistical and mathematical methods have been used to compare flight behaviour of pollinators, particularly insects. They rely on field data that involve tracking techniques, such as telemetry for vertebrates, the use of dyes and the direct observation and mapping of flight trajectories in some cases (Turchin, 1998). These flight path analyses are sometimes compared with gene flow curves using marked pollen or, if available, genetically marked seeds (Kareiva, *et al.*, 1994).

All the above procedures are the basis for pollen flow estimation, and they are useful for establishing actions concerning gene escape, contamination risk, and plant population isolation.

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Group 3

Bee Management for Pollination Purposes

Abstract

Pollinating agents, especially insects, are clearly essential for agricultural production. The central point of discussions here are the importance, the possibilities, and the management of native bees, both solitary and stingless bees, as well as honey bees, as pollinators. The participants were divided in subgroups and so the results here presented.

Aim

The establishment of standard methodologies for managing native bees (solitary and social) as well as Africanized honey bees as pollinators of economically and locally important agricultural crops. To assess the biodiversity of local bees important for pollination and to evaluate their status; to define the basic procedures to be developed for rearing bees on a scale to allow their use as pollinators in agriculture; and to improve capacity building and training, at all levels.

Expected Product

- Updated report on knowledge about native and Africanized bees and their use as pollinators.
- A list of recommendations for study cases during the PDF B project in Brazil.
- Manual of protocols, according to the species, for rearing and managing native and Africanized bees for greenhouse and field pollination.
- Protocols for using native and Africanized bees to pollinate crops defined for study cases.
- A guide for sanitary care of migratory activities (transportation of bees from one area to another) for pollination purposes.

Discussions

The group was divided into three subgroups, according to the number of participants.

Subgroup 1: Africanized bees rearing and management to be used as pollinators.

Subgroup 2: stingless bees rearing and management to be used as pollinators.

Subgroup 3: solitary and bumble bees rearing and management to be used as pollinators

The whole group discussed together at the end of each session, for one hour. Each subgroup was composed by, at least one person familiar with the crop, one person familiar with pollination biology, and one person familiar with bee surveys. These discussions sections were divided according to the following aspects: state of art, perspective of the use of native and Africanized bees for pollination purpose; rearing and managing bees on a large scale for pollination purpose, colony production on a large scale and best practice in migratory apiculture and meliponiculture for pollination; and case studies.

Some questions orientated those discussions, such as:

- Which are the native bee species that pollinate Brazilian crops?
- Are there species normally being used as crop pollinators?
- What are the main constraints for the use of native and Africanized bees as pollinators? How to overcome these problems?
- How to measure the efficiency of each method for multiplying colonies on a large scale?
- Which species are included in this methodology?
- What are the solutions for the problems of rearing bees in greenhouses?
- How to measure the result of using bees in greenhouses?
- Do we know how to manage native and Africanized honey bees for pollination?
- What are the main difficulties with managing native bees and Africanized bees for pollination?
- Is it possible to standardize breeding and managing methods for solitary and stingless bees?
- Is it possible to overcome parasitism problems for rearing bees in the tropics?
- Can we already provide plant growers with native bees for pollination?
- How should people become involved in breeding solitary and stingless bees for agricultural use?
- Is it necessary to change established cropping practices for the sustainable use of bees as pollinators?
- What are the conservation measures necessary to maintain a stable population of native bees in crop areas?
- What and how detailed should these protocols be?
- Is it possible to expand these protocols to other crops/bees?
- Are there other interesting plants species to be included in the study cases?
- How to build awareness in crop growers about the role of native and Africanized bees as pollinators?
- How to involve government institutions with bees as pollinators?
- Is it possible to develop government policy on the use of native and Africanized bees as pollinators?
- What is necessary to make native and Africanized bee pollination feasible in Brazil?

The case studies discussed are represented on the table below.

Study Cases

Stingless Bees	Bumble Bees	Solitary Bees	Africanized Bees
Strawberry Tomato (Melipona) Melon Umbu-Spondias	Tomato (Bombus)	Passion fruit Cashew Cotton Acerola	Cucurbitaceae Eucalyptus Melon Coffee

The results will be presented here by groups: solitary bees and bumbles bees; honey bees; and stingless bees.

A) Bumble Bees and Solitary Bees

Participants: Breno Magalhães Freitas (Coordinator), Celso Feitosa Martins, Clemens Peter Schlindwein, Dieter Wittman, Isabel Aves dos Santos, James H. Cane, Márcia de Fátima Ribeiro, Maria Cristina Gaglianone.

Abstract

Solitary bees have potential for use as pollinators of various crops cultivated in Brazil, but no solitary bees are yet commercially available to growers, and rearing techniques are only available for a few species, such as *Xylocopa spp*. Ground-nesting bees of the genera *Exomalopsis*, *Epicharis* and *Centris* are good pollinators of various crops, such as tomato (*Lycopersicum esculentum*) and acerola or west Indian cherry (*Malpighia emarginata*), but they are difficult to manage. In most cases, there is no practical way to colonize areas with new nests, and merely providing suitable nesting substrates (e.g. sand) rarely yields productive nesting for many years. For ground-nesting bees that are effective and abundant pollinators of a crop (or desired tree species) or its close relatives, the farmer must manage the crop (care with spraying, for instance) and the surrounding land (size of monoculture acreage, proximity to fallow nesting sites), as these bees' nests cannot be moved, and artificial or "created" nesting sites are unlikely to be reliably and quickly colonized. Promising taxa of cavity-nesting species of solitary bees are *Xylocopa*, *Centris*, *Megachile*, *Anthidiini* and *Tetrapedia*, but there is lack of knowledge on these species' natural histories, floral hosts, parasites, diseases, etc. Cost-effective technological improvements are needed to reliably provide large numbers of manageable bees for commercial pollination. However, methods/techniques will need to be tailored to each bee species. The use of solitary bees as pollinators could be initiated with small growers, who probably will own their own bees. They should be stimulated to show the results that growers can have when they use pollinators (in numbers, value, amount of profit). Other growers will be very rapidly convinced once they see the profits of their neighbors. As it is not common in Brazil to value pollination services of bees in general, especially solitary bees, it is important to disseminate pertinent information (about simple concepts, such as pollination, pollinators, their services, etc.), distributed by extension programs (for example in small plantings of *Passiflora*, since techniques to rear and use *Xylocopa* as pollinators are already available in the country). In the case of *Bombus* species, it is necessary to investigate the economic value of greenhouse crops in Brazil to assess the need or not of using *Bombus* as pollinators. If necessary, native species such as *B. atratus* and *B. brevivillus* (not so aggressive when in small colonies) and meliponinine bees, such as *Melipona quadrifasciata* (at least for tomatoes), should be considered. There should be national regulations forbidding the importation of exotic *Bombus* species and a monitoring program of invasive *B. terrestris* from Uruguay, where it was first introduced in 1995 and is now free-living in nature. Finally, research on *Bombus* and solitary bee natural histories, floral hosts, parasites, diseases, foraging behaviour, rearing techniques, management and pollination effectiveness in

various crop species are necessary in order for these bees to be used as large-scale reliable pollinators in Brazilian agriculture.

Solitary bee species

Considering nesting habits, solitary bees can be split into two distinct groups:
1. grounding nesting bees;
2. cavity nesting bees.

Currently promising taxa to be worked on are:
- *Exomalopsis* (there are reports of tomato pollination);
- *Epicharis* (There are reports of West Indian cherry or acerola pollination);
- *Centris* (There are reports of West Indian cherry or acerola pollination).

Grounding nesting bees are difficult to manage; in most cases there is no practical way to colonize areas with new nests, and merely providing suitable nesting substrates (e.g. sand) rarely yields productive nesting for many years.

There is little knowledge about ground nesting bees as pollinators and about their management for this purpose. Three main approaches are suggested to help identify potential pollinating bee species:
1. selection of areas with less intensive agriculture for visitation to crop species (e.g. home plantings of *Cucurbita*) where insecticide use is unlikely, so that bee populations can increase without extermination by pesticides;
2. search for promising species of non-social pollinators (or social Halictidae) on wild crops and their wild relatives (co generics). ex. Rhambutan, which is visited and pollinated by *Euglossa*;
3. investigate pollen use by any large aggregations where solitary bee species are found and discovered (e.g. *Oxaea*) to judge if they might be using flowering species of agricultural interest (e.g. aggregations of Peponapis).

Recommendations

In order to promote ground-nesting bees that are effective and abundant pollinators of a crop (or desired tree species) or of a close relative to this crop species, the farmer must manage the crop (care with spraying, for instance) and the surrounding land (size of monoculture acreage, proximity to fallow nesting sites), as these bees' nests cannot be moved, and artificial or "created" nesting sites are unlikely to be reliably and quickly colonized.

There is considerably more information on and well-succeeded examples of the use of cavity nesting species of solitary bees. Species such as *Osmia lignaria pronpiqua* and *Megachile rotundata* are widely used and managed for apple (*Malus domestica*) and alfalfa (*Medicago sativa*) pollination, respectively, and their commerce amounts to millions of American dollars per year.

Other promising taxa, such as *Xylocopa*, *Centris*, *Megachile*, *Anthidiini*, *Tetrapedia*, already nest in artificial nesting-sites and can potentially be managed to attain large populations for use in pollination. Among these taxa, *Xylocopa* can be considered special in Brazil because there is a demand for these bees and there is some knowledge on its biology and rearing techniques for use especially in *Passiflora* plantings. Serious constrains have been identified and must be overcome in order to achieve large scale production and economic viability for exploiting these bees as crop pollinators:
- ants are serious predators of bee nests and must be controlled;
- there is a need to eliminate parasites and diseases (clean management) before establishing populations for increase;

- there is a need for improved pest management so that insecticide sprays are not applied during blooming periods;
- there is a lack of knowledge of techniques and species' potential to produce bees in large numbers;
- there is a lack of knowledge of what crops benefit most from pollination by solitary bees;
- agricultural lands lack margins/fallow/ hedgerow areas for grounding nesting bees;
- we need good methods for field assessment of pollination value;
- affordable nesting materials/trap nests need to be developed and made available, based on knowledge of which bees are going to be used;
- there is a lack of taxonomic pollen analysis or floral visitation analysis to establish floral use.

Other main recommendations are to compile Brazilian studies of past trap-nesting experience in Brazil and produce a starting point for those species that are present in the country and can be reared in trap-nests. It is also important to develop an insecticide management program, in which pest control practices should minimize bee mortality (label requirements on insecticides, for instance, should emphasize scouting and economic thresholds). This program could be developed by the honey bee management group due to their greater experience in using bees for pollination purposes.

Some cultivated plants that probably benefit from pollination by solitary bees.

Botanic Family	Scientific name	Common names - English	Common names - Portuguese
Apocynaceae	*Hancornia speciosa*		Mangaba
Anacardiaceae	*Anacardium occidentale*	cashew	Caju
	Spondias tuberosa		Umbu
	Spondias spp		Caja, Cajarana, Umbu-caja
Bixaceae	*Bixa orellana*		Urucum, Coloral, Açafrão
Cucurbitaceae	*Cucurbita pepo*	pumpkin	Moranga
	Cucurbita moschata	squash	Abóbora
	Cucumis melo	melon	Melão
	Cucumis sativus	cucumber	Pepino
Fabaceae	*Glycine max*	soybean	Soja
	Vicia faba	field bean	
	Phaseolus vulgaris	kidney bean	Feijão
	Lens esculenta	lentils	Lentilha
	Pisum sativum	pea	Ervilha
	Vigna sinensis	cowpea	Feijão de corda
Lecythidaceae	*Bertholletia excelsa*	Brazil nut	Castanha do Pará

Malpighiaceae	*Malpighia emarginata*	West Indian cherry	Acerola
	Byrsonima crassifolia	wild cherry /nance	Murici
Malvaceae	*Hibiscus esculentus*		
	Gossypium hirsutum	cotton	Algodão
Passifloraceae	*Passiflora edulis*	passionfruit	Maracujá
	Passiflora quadrangularis	giant granadilla	Maracujá-açu
	Passiflora mucronata		Maracujá
	Passiflora alata		Maracujá-doce
Solanaceae	*Lycopersicum esculentum*	tomato	Tomate
	Solanum melongena	egg-plant	Beringela
	Capsicum annuum	sweet pepper	Pimentão
	Capsicum spp.	Pepperony	peperoni

Study Cases - Recommendations for some individual crops

Passion Fruit (*Passiflora edulis*)	
Bees:	*Xylocopa frontalis*, *X. grisescens*, *X.augusti*, *X. ordinaria*, *X. suspecta*, and other large *Xylocopa spp.*.
Nests:	dead tree trunks, trap nests, *Xylocopa* nests.
Bee density:	25 females/ha in the case of *X. frontalis*.
Crop management:	need of complementary floral resources: buzz pollinated species (Melastomataceae, *Cassia*, *Sena*, *Solanum*, etc).
Cashew (*Anacardium occidentale*)	
Bees:	*Centris* species. *Centris tarsata* tested, but other species can also be important. Take into account bee behavior, pollen distribution on the bee body; pollen viability is important: it is only viable for 4 hours.
Nests:	trap nests.
Bee density:	unknown.
Crop management:	There is a need to supply pollen and oil producing plants (*Byrsonima crassifolia* for wild cashew), possibly through mixed culture with West Indian cherry (acerola) in commercial plantations.
Cotton (*Gossypium spp.*)	
Bees:	*Emphorini spp.*; *Augochlorini*; *Bombus*; *Xylocopa.*
Nests:	depends on species used.
Bee density:	very large crops will need hundreds of bees (to be estimated).
Crop management:	depending on variety, there is a possibility of gain in the fruit production period.

Cucurbitaceae	
Bees:	several taxa of ground-nesters (Peponapis, Augochlorines).
Nests:	natural, in the ground (see discussion above).
Bee densitiy:	unknown.
Crop management:	local conservation should be promoted through education of growers. Free pollinators when available, but impossible to re-colonize once exterminated.
West Indian cherry (*Malpighia emarginata*)	
Bees:	*Centris* (both ground and cavity nesters), *Epicharis* (ground-nester).
Nests:	both natural, in the ground, and trap-nests, depending on the species.
Bee density:	unknown.
Crop management:	Not visited by bees that do not use oil (ex. honey bee). Will need to understand bee behaviour, pollen distribution on the bee body, optimize trap nesting techniques; could be beneficial to grow near cashew plantings.
Vegetable or oil seed crops	
Production of high-value specialty seed, such as onion and carrot, or hybrid seed crops (sunflower) on small acreages.	
Regional or specialty fruits	
Some solitary bee species can be important pollinators of regional or specialty fruits like mangaba (Apocynaceae: *Hancornia speciosa*) and umbu (Anacardiaceae: *Spondias tuberosa*).	

Recommendations

Bee biologists should participate in crop symposia sponsored by the International Society for Horticulture Science (ISHS), in order to exchange expertise with the world's most knowledgeable producers, breeders and processors of specific crops.

Protocol with general recommendations to use solitary bees as crops pollinators

1. Complementary floral resources should be provided.
2. Plants for nidification (trunks) initially, later provide nesting substrates (although these also may be made from natural materials, such as stick nests, rather than drilled nesting blocks).
3. Conservation of natural areas (in order to maintain natural populations); need not be proximate to crop of interest (sustainability extractive reserves for initiation of trap-nesting programs).
4. Spray management - toxic sprays must be avoided during bloom.
5. Different *Xylocopa* nest substrate structures should be compared (Freitas & Oliveira Filho *vs.* Camillo models).
6. Cultivation of other crops simultaneously for year-round forage (no extensive monocultures at a scale greater than flight range).
7. Adequacy of local/regional conditions.
8. Management of ruderal plants where necessary.

Cost-effective technological improvements needed to reliably provide large numbers of manageable bees for commercial pollination

1) Paper nesting straw inserts

Reason:	need these in large numbers for selection of precise sizes for both a trap-nesting program and for handling large numbers of managed species (ex. for *Centris*, anthidiines).
Advantages:	easy re-use of drilled nesting blocks, better control of disease and parasites (esp. mites) from generation to generation, opportunity to X-ray nest contents to eliminate diseased or parasitized cells prior to establishing new populations. Plastic straws unsuitable, as many bees do not like the slick surface, plus lack of air permeability leads to serious mold problems.
Options:	purchase paper straws from manufacturers in North America (list of suppliers at: www.loganbeelab.usu.edu or Europe). Should consider technique of thin-walled paper straw inserted in hole in nesting block. The benefits are analogous to the moveable-frame hive for honey bees.

2) Use of X-ray units

Reason:	needed for evaluating nest contents, progress of development and metamorphosis, location of diseased or parasitized cells (for surgical removal from nest) and other applications.
Advantages:	quick and reliable.
Options:	could be a central unit at one laboratory to which samples can be sent by researchers from all over Brazil. Consider purchase of a used unit from a hospital, possibly from overseas if not available within country. Applications detailed in published studies with *Osmia lignaria* and *Megachile rotundata*. Alternatively, can use stick nests of soft, easily split wood or possibly reeds (Japanese *Osmia* system). Choice will be guided by practicality, cost, use by bees, and local availability.

3) Mass-production for drilled nesting blocks

For Brazil's economy and labor market, what is the most cost-effective method for mass production of acceptable nesting materials for cavity-nesting bees? Are manufacturers of hive equipment interested in producing interchangeable, easily assembled components of *Xylocopa* nest boxes? Are there manufacturers interested in producing drilled wooden nesting blocks in large numbers, or clever methods for using paper straws inserted within cardboard tubes within boxes (holes must be straight and approx. 15 cm deep for larger species, although research with individual species will demonstrate the hole diameters and depths that yield the greatest number of daughters per nest)?

The mass production for drilled nesting blicks can begin by mimicking techniques already in use with *Megachile* and *Osmia* in the US, Japan and Europe. Aspects of those programs will clearly need adaptation to Brazil's tropical environments (for instance, how to handle multivoltine species, irrelevance of refrigerated overwintering), although some aspects may be more applicable in the south, such as for apple pollination in Santa Catarina.

4) Control of enemies

Simple techniques needed for excluding ants from nesting blocks, especially blocks managed for crop pollination (would be nice for trap-nesting too, but perhaps not practical).

Options: Physical barrier over which ants cannot walk. Must persist and not catch bees.

Final considerations regarding solitary bees

1. Measuring effectiveness of methods for population increase

a. The only practical species to manage are those whose populations can be increased (more daughters than mothers).

b. Methods that produce populations with limited parasites and disease.

c. Affordable nesting materials that are practical to make and endure for *Xylocopa* and *Megachile*; there is a possibility of adaptation of existing methods.

2. Greenhouse pollination

The main difficulty in using solitary bees as pollinators in greenhouses is that glass and plastic absorb UV, which interferes with bee orientation during flight. How to measure their pollination efficiency in greenhouses is not relevant; at this stage it is known which species can be used.

3. Stimulating people to get involved in rearing and selling solitary bees.

Stimulate small growers who probably will own their own bees; to show the results the growers can have when they use the pollinators (in numbers, value, amount of profit). We only have to convince about 1% of them; the rest will be very rapidly convinced once they see the profits of the neighbours. As it is not common in Brazil to value pollination services, and bees in general, especially solitary bees, it is important to disseminate information (about simple concepts such as pollination, pollinators, their services, etc.), distributed by extension programs (for example in small scale plantings of *Passiflora*).

Final considerations regarding *Bombus*

1. No importation of non-native species

There should be regulation on importation of bees:

- brazilian laws must be made controlling Bombus importation;
- seek an agreement among South American countries or in the Mercosul related to bumblebees importation;
- establish a monitoring program of invasive *Bombus terrestris* from Uruguay. This species was introduced into Uruguay in 1995 and now is free-living in nature, colonizing new areas and spreading towards the Brazilian border.

2. Need for importation of non-native *Bombus* species

There is no need for importation, because:

- these bee species are used only for pollination of greenhouse crops;
- they are used mainly for tomato pollination, but recent studies have shown that native stingless bees *Melipona quadrifasciata* and *Nannotrigona pirilampoides* are good tomato pollinator in greenhouses;
- exotic *Bombus* species may bring parasites and diseases to native species.

3. Using native *Bombus* species for crop pollination

We do not currently have knowledge to handle native *Bombus*. If it is going to be used, research is needed on biology and rearing methods. Two species are promising:

- *B. atratus* - not so aggressive when in small colonies;
- *B. brevivillus* - in Northeast Brazil, not aggressive; has potential as a pollinator of crops of glasshouses and in open areas.

Final Remarks

Bombus are used commercially only to pollinate greenhouse crops. This agricultural segment is still small in the country, compared to the size of the Brazilian agricultural system, and does not justify the risk and unknown consequences of importing or allowing the entry of exotic *Bombus* species. Also, most greenhouse cultivation is done with tomatoes and the stingless bee *Melipona quadrifasciata* has been shown to be a good alternative to pollinate this crop in enclosures, and there are promising native *Bombus* species that could also be studied for this purpose. Finally, Brazil should create laws prohibiting and punishing *Bombus* importation, follow the spread of *B. terrestris* in Uruguay, and authorities should monitor its arrival in the southern part of the country.

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B) Honey Bee

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Abstract

Pollinating agents, especially insects, are clearly essential for agricultural production. Honey bees have become increasingly important, as field sizes have increased and native bees have decreased, due to intensive land use and pesticides. An important advantage of honey bees is that they can be quickly taken to and removed from the fields in large numbers, facilitating the integration of these pollinators into pest management programs. A single truckload can carry 20 million potential pollinators. Honey bees contribute to more than 80% of the agricultural produce pollinated by insects. Unfortunately, Brazil does not have a strong tradition of using bees for pollination, different from the USA, where more than 2 million colonies are rented annually. Beekeeping in Brazil has grown considerably during the last few years, especially due to honey market conditions. Brazil now has about 2,5 million colonies available for bee products production (honey, wax, propolis, pollen, royal jelly and bee venom) and for pollination purposes. There are beekeepers specialized in pollination, especially for apples, melons and cashews. All of these products are both consumed in country and exported. To obtain export quality fruit, insect pollination is absolutely necessary.

Unfortunately, many of the crops that could benefit from pollination, are either not pollinated at all, or are incidentally and haphazardly pollinated by wild honey bee colonies or by apiaries that happen to be nearby, resulting in production losses due to inefficient pollination. Africanized honey bees are seen much more as honey producers than as pollinators.

For many crops that do not traditionally use honey bees for pollination, such as oranges, peaches, strawberries, sunflowers and forage soybeans, we have data indicating significant increases in fruit and seed production and improved fruit quality with pollination by Africanized honey bees in Brazil (Nogueira-Couto, *et al.*, 1998, Couto 2002). Africanized honey bees are very active pollen collectors, making them good pollinators, and they have been found to remain on the target crop longer than do the European honey bees that are traditionally used for pollination in other countries (Basualdo, *et al,*. 2000). Africanized bees also are more active on the flowers, fly faster and are quicker to recruit other hive mates, than are European bees, making them more active and efficient pollinators. Africanized bees forage at lower light levels than do European bees, so that they work longer days. They also do not reduce brood production during winter, so the colonies remain strong, with abundant foragers for pollination activities. It is relatively easy to establish new colonies by collecting swarms with bait hives, and Africanized colonies grow quickly, so that beekeepers can easily produce the large numbers of colonies needed for pollination of crops. There are well-established migratory

beekeeping techniques, and truckloads of bees can be quickly and timely moved to flowering crops (De Jong, 1996).

Discussion

Africanized honey bees have been used for pollination in greenhouses in Brazil. However many bees are lost from the colonies and it is difficult to maintain the colonies alive under greenhouse conditions. Some researchers and beekeepers have been able to overcome these problems, but the techniques that they use are not published, nor is there an established system that works uniformly under all circumstances. Most attempts to use honey bees in greenhouses are initially unsuccessful, however after numerous trials some researchers have been able to maintain colonies for long periods, efficiently pollinating the crop. In order to make efficient use of this resource, it will be necessary to make controlled studies, and develop standard, practical techniques that should be made widely available to beekeepers and growers.

We can measure the result of using honey bees in greenhouses by examining the crop quantitatively and qualitatively. Normally, this is done by measuring the weight, size and number of fruits, by determining the time till production of the fruits (which may be anticipated by adequate pollination), and by calculating the percentage fruits that are considered of high quality. Another important quantitative aspect is the cost and benefit of the pollination activities. Using honey bees has a cost, and this should be compared with the gain in crop production attained with pollination. Photos of fruit that are produced by plants exposed to bees, *versus* those that are produced without bees, are often quite useful for illustrating the value of bee pollination. Appearance is important, as the color and shape of the fruit is often affected by pollination. Photos of cross sections of the fruit can show the number and distribution of the seeds, which are clear indicators of pollination efficiency. The fruit quality can also be evaluated by measuring sugar and protein and other substances, and by evaluating organoleptic (taste) factors.

We already know how to manage Africanized honey bees as polinator for some crops, such as apples and melons, however this is not always done in the most efficient way. Many crops that would clearly benefit from the introduction of bee colonies are not routinely pollinated. Generally speaking, pollination is little valued or understood by farmers, nor are beekeepers aware of the true value of the services that their bees provide. We have data indicating significant increases in fruit, seed and vegetable production due to pollination by Africanized honey bees, however little of this information is available to the growers. Often objective studies on commercial varieties are lacking. This is true both for field crops and for greenhouse crops. The latter are unviable commercially unless adequate pollination is provided. Many crops are in fact pollinated incidentally by honey bees from nearby apiaries, or by wild honey bee colonies, however the grower is not aware of the importance of these services. Frequently he has low production, without realizing that the reason is a lack of pollinators.

The main difficulties with managing Africanized bees for pollination can be listed as:

1. there are no established techniques for using Africanized bees under Brazilian conditions on most crops;
2. often the hives are not made with standard measures, or with inferior materials, making transport and management difficult;
3. the bees are quite defensive and growers are often reluctant to place them in or near the crops that need pollinating;

4. there is not sufficient care in the transportation of colonies, so that accidents are common and this discourages their use for pollination;
5. beekeepers are not aware of disease problems, and often incorrectly try to treat their colonies, and some have introduced contaminated bee products and equipment from abroad, threatening beekeeping throughout the country;
6. there is a lack of central laboratories that can provide timely and accurate diagnoses of bee diseases, and also there are no field personnel to advise beekeepers about this kind of problem;
7. growers are frequently unaware of the importance of bees and pollination, and in fact they often prohibit the introduction of bees into their properties; they use insecticides indiscriminately and incorrectly without any concern for the effects on the bees and the beekeepers;
8. there is no tradition for making pollination contracts that include a provision for compensation for the beekeeper in the case of losses due to pesticides or the stealing of hives on the grower's property. There should also be a provision for responsibilities in the case of an accident with the bees.

Problems to be overcome

Changes in agriculture have created an increased need for honey bees.

There is pressure to convert natural areas into agricultural land, without concern about maintaining habitat for pollinators. Loss of natural pollinators due to the loss of habitat increases the need for honey bees. More intensive farming and larger fields of crops overcomes the capacity of local native bees to pollinate. We need to develop techniques and policies that will increase the availability of honey bees to satisfy these increasing needs for pollination. Landowners need to be made aware of the value of having bees placed near the crops.

The extension service (Agriculture House - Casa de Agricultura) does not provide appropriate information about pollination. Unfortunately, even in the case of crops for which we have clear evidence that honey bees significantly increase production, growers frequently do not include pollination in their management programs, and often even prohibit the introduction of bee colonies onto their property, or they may charge the beekeepers, while in other countries the beekeepers are paid for their services. This lack of tradition to include bees greatly diminishes the potential gain of the growers. We need to have more good quality data and then convince the growers by using demonstration plots.

Bee diseases

Some new diseases from other countries threaten beekeeping and hence can affect the availability and quality of honey bee colonies for pollination. Unfortunately, these incidents of new diseases have not been sufficiently controlled and studied by competent researchers and authorities. Beekeepers are also unaware of the need for good practices that will avoid the introduction of these new diseases. For instance, honey and pollen that has been imported (both legally and informally) is often exposed to the bees. Honey is handled in processing plants, and often some of it is inadequate for commerce; beekeepers feed such discarded honey to their bees (Message & De Jong, 1998). This has resulted in the introduction of American Foulbrood Disease (*Paenibacillus larvae*) spores from imported honey into honey bee colonies. This situation needs to be more closely investigated, and the beekeepers should be made aware of the danger of such practices (De Jong, 1996). A similar problem has occurred with a fungus disease, Chalkbrood, caused by *Ascosphaera apis*, which entered Brazil in imported pollen. The beekeeper normally separates the pollen pellets in the bags of imported pollen and the powdered pollen that is left is fed to the bees. Chalkbrood has now become established in several parts of Brazil as a result of these practices; we need to have more information about the impact of this exotic disease on Africanized honey bees.

There are no central laboratories to identify diseases.

Beekeepers need to have a place to send samples in order to learn what diseases they have, and to determine whether their problems are really caused by parasites or disease organisms. This service exists in nearly all major beekeeping countries and now should be implemented in Brazil.

Beekeepers do not know diseases

Diseases are normally not a big problem in Brazil, but beekeepers sometimes incorrectly try to treat colonies with antibiotics and acaricides whenever they suspect a disease. Their lack of knowledge and the lack of government infrastructure to help them cope with disease problems often makes them take inappropriate actions. Besides the unnecessary costs and damage to the bees due to such home-brew treatments, there is a danger of contaminating the bee products. We need to study the actual disease problems and determine nutritional needs. A lack of information about nutrition, especially protein needs, actually causes many problems that are mistaken for disease. Techniques have been developed to more objectively evaluate honey bee diets (Cremonez, *et al.*, 1998), but these new methods need to be used systematically in order to develop economically viable pollen substitutes.

There is no sanitary control of the movement of colonies.

Though Chalkbrood, a fungus disease, has recently been diagnosed in Brazil, and American Foulbrood is suspected, there is no sanitary control of the movement of colonies. Consequently these new bee diseases could be spread to new regions, causing damage to apiculture, which could affect the availability of bees for pollination. It is recommended intensive studies of those new diseases, to determine their occurrence and their impact on the colonies. Government agencies should be prepared to diagnose diseases in the laboratory and to train bee colony inspectors who can make field diagnoses and develop and implement appropriate control policies.

Problems with quality and standardization of the beekeeping equipment

In some parts of the country, non-standard hives are used. Many times, among those who use standard Langstroth equipment, there are problems with non-standard measurements. Beekeepers are often not aware of the correct standards and they make their hives based on equipment that they have purchased. As the purchased hives are frequently not exactly built, badly dimensioned hives are perpetuated. Many times new beekeepers have purchased bad equipment with funds that they have received on credit. These can be badly built hives, with uncured "green" wood, or made with wood that is inappropriate for apiculture. Such hives start to bend and open within a few months. Unfortunately, the funding agencies that set up programs to foment apiculture often provoke these kinds of purchases of substandard materials due to costcompetitive purchasing policies. Later, the beekeepers have a difficult time repaying the cost of the equipment, as it is commonly discarded within a short time.

The handling and transport of beehives in Brazil is not mechanized

Now all hives and honey supers are transported from trucks to the apiary, and back, by hand. Hives are heavy, especially when they are full of honey. This hand carrying often causes back problems for small-scale beekeepers, which depend on family labor. Beekeepers with larger numbers of colonies must hire help, and this makes their management expensive. A beekeeper in the USA or Canada can handle more than a thousand colonies by himself, or with only a single helper. A similar number of colonies in Brazil would need at least five or six laborers, and the moving process takes much longer than in other countries. Transporting colonies for pollination requires specialized labor, at specific times. If beekeeping had mechanized alternatives then this transport would be cheaper and more efficient. However, the fork lifter tractors (bobcats) currently used in other countries are too expensive for Brazilian conditions. It would be more cost efficient to pursue intermediate, less costly, alternatives for mechanization. We need to identify appropriate techniques for hive lifting and transportation, and test and adapt them to local conditions.

There are problems with transporting bee colonies

Beekeepers are not aware of their responsibilities and correct procedures when they have an accident during transportation of hives from one region to another. They are unaware of the best ways to transport bees, and therefore accidents are more common than they should be. Frequently they lose bees that escape from the hives, and many colonies die due to overheating. The local authorities are unaware of the importance of the need for timely movement of colonies, and may interfere with transport.

Problems with a deterioration of natural areas

The lack of natural areas means that bees have no wild flowers for supporting and maintaining colony growth. This means that the colonies are weak or can even die and therefore are not available for pollination services. In various parts of the country there is so little natural forage that beekeeping is uneconomical, especially in regions where there is intensive agriculture and therefore with a great need for bees for pollination. We need to find ways to promote the maintenance of natural areas on farms (possibly through tax incentives) and to have states and municipalities plant trees that provide forage (nectar and pollen) for pollinators.

There is lack of natural forage for the bees

The lack of natural forage during various times of the year can be partially overcome by artificial feeding of sugar and protein diets. However, sugar is often too expensive, so it would be useful to have a means to provide sugar or sugar syrups at a low price for the beekeepers to properly prepare their colonies for pollination. The most important nutritional problem is a lack of appropriate protein when pollen from flowers is not available. At the moment, no adequate artificial diet is available. Such diets need to be developed and tested. A relatively simple laboratory technique developed in Brazil is available for the initial screening of food by-products that could be used as protein sources for bees. Large scale testing should be done, with field testing and demonstration of the most promising alternatives (Cremonez, *et al.*, 1998).

There are misconceptions about how bees could impact on crops

In some crops, such as oranges, there are misconceptions about the danger of bees transmitting plant diseases. Generally, decisions are made without any real evidence of such a problem.

There are problems with beekeepers obtaining permission to place bees on farmland - due to fear of the bees interfering with cultural practices, while growers are unaware of the value of pollination. We need to have case studies about how bees interact with crops and to have documented information that will help growers and beekeepers understand the real effects of bees on crops. Some of this information is available from other countries, and can be adapted and appropriately communicated. However local experimental work should also be done to test the impact of bees under local conditions.

Beekeepers have problems with hives being stolen

Apiaries often have to be placed in remote places where the colonies are easily stolen, due to inappropriate management and fear of the bees. The government and the police normally gives little support to the colony owners, and often take no action, even when there is proof that colonies or colony products have been stolen. Policies should be developed to provide legal and police support to reduce this colony thievery problem. Case studies need to be made to find ways to maintain apiaries in ways that there is less impact on farm workers and animals, so that apiaries can be kept in more protected areas. Insuring colonies against robbery is also unknown, making financial security for the beekeeper nearly impossible.

Problems with pesticides

Presently many honey bee colonies are killed by pesticides. Beekeepers avoid crops where insecticides are used; this reduces honey production and agricultural production. Crops such as cotton would be more productive if the bees could pollinate them. Native bees and wild honey bee colonies are killed by excessive and inappropriate use of pesticides, making it necessary to bring in commercial honey bee colonies for pollination purposes. Labeling of these pesticides should include information about toxicity to bees.

Case studies to assess main pesticide problems that affect bees

Develop a manual about the use, value and care of honey bees. Take advantage of case studies about improvement of production and quality of farm products to educate farmers about how to best incorporate pollination into their management practices. The impact of the most commonly used pesticides on flowering crops should be investigated.

Farmers and policy makers are often unaware of the need for pollination

Growers are often unaware of need for pollinators and of pollinizer varieties. International pollination techniques need to be adapted to local conditions. The agricultural policies normally ignore the need for pollinators. EMBRAPA, SEBRAE and other appropriate institutions, such as universities, should develop projects to test the value of pollination on crops and varieties. They should also develop crop management schemes that minimize the impact of insecticides on honey bees. This information should then be made available to the farmers. There should be demonstration fields and courses to make the farmers aware of how much they can gain by including pollination in their management scheme.

We need clear recommendations about number and size of colonies needed, and how to place them. Agricultural extension does not currently train farmers about ways to manage their crops for maximum pollination. Extension services need to develop courses and educational material. They should develop case studies in cooperation with local growers (on-farm experiments).

Consumers are not aware of how to select good quality (well pollinated) fruits and vegetables

Demonstration materials should be developed to help the consumer recognize and choose good quality products. Fruits and vegetables, such as melons, watermelons, apples and cucumbers, often have fewer than normal seeds, which results in inferior products with a bad taste. Such an awareness and educational programs will create a more sophisticated consumer and will encourage growers to use bees to produce high quality fruit.

Other problems:

- beekeepers generally are not concerned about determining the pollinating efficiency of their colonies, but are only trying to produce the largest possible amount of honey;
- beekeepers do not know how to stimulate the bees to collect pollen, which increase pollination efficiency, instead of nectar;
- beekeepers do not know how to direct bees to a crop that needs pollination;
- beekeepers distribute their beehives in a manner that is convenient for management, without concern or knowledge about the most efficient arrangement to facilitate pollination;
- beekeepers manage their bees only for honey production because the farmers normally do not pay for pollination services;
- we do not know the support capacity of agricultural areas for honey bee colonies or how many honey bee colonies can be placed in a specific area.

Rearing and management of Africanized honey bees in greenhouses

Current problems:

- lack of knowledge of the minimum requirements necessary to use Africanized bees in greenhouses (size of the colony, best time to introduce the bees to the crop, culture specifics and management techniques);
- misconceptions about Africanized bees as effective pollinators;
- aggressiveness of the bees;
- lack of technical and practical experience.

Proposals:

- make producers aware of the usefulness of honey bees for pollinating in green houses;
- inform public and private agencies involved in rural extension, technical assistance and promotion;
- encourage research institutions to make studies on this subject, through specific guidelines and financing;
- develop informative material, as a tool to encourage increased use of honey bees in greenhouses, informing about successful experiences in Brazil and from other parts of the world, and by examining economic criteria;
- develop incentives for using honey bees as pollinators in greenhouses and reducing the use of pesticides (tax deductions, low interest loans, etc.);
- publicity campaigns informing about the better quality of well-pollinated fruits and vegetables, uncontaminated by pesticides;
- encourage and make available techniques for producing food in greenhouses;
- capacitate technicians involved in extension and who assist farmers so that they can help them use honey bees as pollinators in greenhouses.

State of the art of the use of Africanized honey bees for pollination

Currently, honey bee colonies are rented for pollinating apples, melons, cashews and some vegetable crops in Brazil. There are efficient techniques for transporting the bees, but data on other cultures are lacking. Isolated experiments have demonstrated the value of bees for many crops in Brazil, but these have not influenced the growers, and more objective and thorough experiments are needed, preferably with demonstration plots to show the value of pollination to the farmers.

Rental prices for bee colonies

Beekeepers and growers are generally unaware of how much they can or should charge for their services. There is little tradition for this activity, and beekeepers often have a difficult time to determine their real costs and the monetary benefits for the farmers. This requires economic studies, which should then be made available to both parties.

Case studies to determine the need for pollination of major crops
Use of Africanized bees for pollination Recommendations for case studies

Cotton	
Principal Producer:	Mid Eastern states, high tech production in the NE: MA, CE, PA, PE, AL, BA.
Problems:	• incorrect use of pesticides; • lack of knowledge about natural pollinators; • though this plant produces abundant nectar, the intensive use of insecticides results in extremely reduced pollinator populations in and around the fields; • we have some data that cotton is benefited by honey bee pollination; • we need to determine the real effect of honey bees on cotton yield and quality, and determine the integrated pest management techniques that will permit co-existence of the bees with the crop; • economic studies should be made to determine the costs and benefits of including honey bees in cotton production.
Melons	
Principal producers:	CE, RN.
Export product	Initiated and expanded continuously during the last six years, always with honey bee pollination.
Problems:	• incomplete information about the benefits of using pollination to improve the quality and the quantity of the fruits produced; • fear of the strong defensive behavior of the africanized bees; • productivity can be increased more than 40% with adequate pollination, however the responsibilities of the farmer and the beekeeper are often not well defined; • we need to have good data on the real economic advantages of using honey bees for melon pollination, and how to maximize this contribution, taking into account the negative effects of cultural practices on the honey bee colonies; • we also need to determine the most efficient means to improve pollination efficiency.

Citrus	
Export crop (juice concentrate).	
Problems:	• intensive use of insecticides; • spraying during flowering; • the increased quality and quantity of fruits that come with pollination is generally unknown; • the growers unjustly fear that the bees will spread diseases; • fear of the strong defensive behavior of the bees; the farmers may reject having them near their orchards; • we need good data on the benefits of pollination for fruit production and quality for all the various varieties of oranges; • we need to demonstrate these benefits to the farmers and work with them to reduce the impact of pesticides used in the groves on the bees.
Coffee	
One of the principal Brazilian export products.	
Problems:	• lack of financial incentive for beekeepers to introduce their colonies into the coffee fields; • flowering is very fast, less than a week; • flowering occurs at a time when the bees are in orange orchards; • coffee honey is not highly valued; • use of pesticides; • though we have some good data on the value of honey bees for improving coffee production, we need more thorough testing in modern cultivars and fields to determine the best recommendations for pollination; • as beekeepers would not normally take their hives to coffee plantations, economic studies should be made to determine adequate pollination fees, taking into consideration the benefits for the growers.

Recomendations

1. A document should be developed about the state of art of the use of Africanized honey bees for pollination.
2. Preparation and distribution of a manual on standard methodologies for rearing Africanized bees for pollination purposes.
3. Development of a central library with all the available Brazilian literature on pollination, including theses and congress proceedings, and that those be made available via Internet. This has been initiated at the University of São Paulo campus in Ribeirão Preto, SP, but it needs to be improved and made more widely available. There is a book with a collection of 300 thesis abstracts (in Portuguese and English) and a list of over 2000 publications on bees made in Brazil until 1992 (Soares & De Jong 1992). This material is updated periodically and is kept in a database, which is available to some researchers. We need to create means to archive and digitalize all of those articles and theses, so that this information will be more widely available, and will not be lost.

4. Initiate a scientific journal on pollinator biology in Brazil. Brazil has many bee researchers, however much of the information is not readily available. A scientific journal will help remedy this problem and will help direct students and professors to study pollination problems. This journal could be produced online at relatively low cost, and could help consolidate bee research in Brazil.
5. Develop a manual on research techniques for pollinator studies, especially to determine the value of pollinators for crop production.

Rational Program of Pollination

1. **Determine how well crops are pollinated currently and investigate the production potential if there were full, adequate pollination.** Some crops are already well pollinated, and additional pollinators do not increase production. In other crops and regions, there are so few natural pollinators that supplemental pollination can make the difference between uneconomical production and profit.
2. **Estimate economic viability of pollination program.** The producer needs to have an idea about whether it will be economically viable to use pollination for his crop, considering the costs involved with personnel, transport, and renting bee colonies, compared to the increases in production.
3. **Identification of the requirements of the crop and determination of the pollination needs.** Each vegetal species has its own specific pollination needs and appropriate pollination techniques are needed to fulfill these needs.
4. **Determine the pollination strategy that should be used.** There is a need to determine the number of colonies per hectare, the arrangement and temporal placement of the colonies and integration with other cultural practices.
5. **Design and install apiaries and infrastructure necessary for pollination.** Determine the number of apiaries and colonies that will be needed at appropriate times to give support to the pollination activities.
6. **Training of personnel responsible for maintaining the colonies in conditions adequate for pollination.** Preparing colonies for pollination requires specific management so that they will be at an adequate stage of development and with sufficiently large populations to adequately pollinate the crop.
7. **Training of personnel to collect pollination data in the field or hire such help.** The results of pollination should be constantly monitored.

Final recommendations

Considering what are the conservation measures necessary to keep a stable population of Africanized bees in the cropping areas:

1. incentives, such as tax exemptions for beekeepers and for growers for pollination of crops in Brazil;
2. PDF-B should make a policy of recognizing the need for Africanized bees for pollination;
3. conduct case studies to show the importance of wild pollinators in respective habitats;
4. stop indiscriminate logging and commercial felling of trees by enacting laws;
5. promote and encourage re-conversion of a certain percentage of intensively cultivated areas to provide rescue space for the multiplication of wild honey bee colonies by providing incentives (tax exemptions, subsidies etc.);

6. train farmers in making judicious and safe use of carefully selected, less toxic, pesticides in safer formulations;
7. promote IPM (Integrate Pest Management);
8. provide nesting strips/spaces near the cultivated areas and encourage multiplication and growth of native plants that can provide food for wild bees;
9. encourage agro-biodiversity by planting some areas with native plants.

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C) Stingless bees

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Abstract

Stingless bees are social bees that live in tropical regions of the world. They are poorly studied and known, even though they are the main visitors of numerous flowering plants in the tropics and likely the principal pollinators of many of them (for a review, see Heard, 1999). Only recently attention on their role as pollinators has been paid. Here we evaluated the knowledge obtain worldwide until now on the role of stingless bees as pollinators, identified some crops that could be pollinated by them, as well as the constraints for their use as pollinators in large scale for agricultural demand in Brazil.
Data for this report were updated until 2006.

Introduction

Stingless bees are diverse in tropics and can potentially be used as pollinators for several native and exotic crops cultivated in Brazil (Nogueira-Neto, *et al.*, 1959; Bego, *et al.*, 1989 a and b; Heard, 1987, 1993, 1994, 1999; Heard & Exley, 1994; Ish-Am, *et al.*, 1999; Malagodi-Braga, *et al.*, 2000; Slaa, 2000; Castro, 2002; Malagodi-Braga, 2002; Cauich, *et al.*, 2004; Cruz, *et al.*, 2004). The native Brazilian stingless bees richness is estimated in 500 species (Camargo, p.c.). Due to the high stingless bee diversity, basic research is still needed, although many studies had been done in the last years. Among the 13 Australian epiphytic orchids whose pollinators are confirmed, 9 are pollinated by stingless bees (Adam & Lawson, 1993, *apud* Heard 1999). Males of some stingless bees are important pollinators of native Brazilian orchids of *Maxillaria* genus (Singer, 2002; Singer & Koehler, 2004) who offer fragrances and colors that attract workers of *Trigona*. Recently, Slaa, *et al.* (2006) reviewed the role of stingless bees as pollinators and the crops that they effective pollinate doubled in number since the excellent review of Heard (1999)

Although their breeding techniques are available to beekeepers, at least for some taxa such as *Melipona*, *Scaptotrigona* and *Tetragonisca*, no stingless bees are yet commercially available to growers for pollination purposes. The unique example where protocols for greenhouse pollination are well established is the use of *Tetragonisca angustula* and other small stingless bees for strawberries (*Fragaria x ananassa* Duchesne, Rosaceae) pollination (Malagodi-Braga, 2002; Malagodi-Braga & Kleinert, 2004). Some species of *Melipona* could be good pollinators of some Solanaceae crops that need "buzz pollination", as *Melipona quadrifasciata* for tomatoes (*Lycopersicum esculentum*) growing in greenhouse (Del Sarto, *et al.*, 2005). For native tropical fruits, as umbu (*Spondias tuberosa*), açaí (*Euterpe oleraceae*) and cupuaçu (*Theobroma* *grandiflorum*), the pollination requirements are being studied (see table 1).

Coevolution between local flora and stingless bees should occur in high diverse habitats. Despite of their generalist use of floral resources, stingless bees show floral preferences (Ramalho, *et al.*, 1990; Biesmeijer, *et al.*, 2005; Biesmeijer & Slaa, 2006). It is necessary to improve this knowledge in order to determine preferences and the main plants indicated as food source for their successful breeding, as well as for using in habitat restoration programs.

A huge problem for Brazilian stingless bees breeders and for capacity building activities is that relevant literature is in English or not easily available; most bee species have not been studied yet. A recommendation is to make available, in Portuguese, a synthesis of the present knowledge, written for different stakeholders, and to provide basic knowledge needed for rear them. The WebBee (Saraiva, *et al.*, 2004) was constructed in order to be our infoway in this task.

Considering the high biodiversity of stingless bees, and the new meliponiculture regulation for research and for beekeeping (CONAMA_346, 2004), it is necessary to improve the development of breeding techniques, in order to provide bees for research and for meliponiculture. Nests can be obtained by using trap nests in nature; a nest census and a bait-trap survey in natural and agricultural areas for stingless bees is also a priority for investigation. A recent research developed in Sarawak, Asia, showed the effects of human disturbance on a stingless bee community in a tropical rainforest, as a result of changes in resources availability (Eltz, *et al.*, 2002 and Eltz, *et al.*, 2003; Samejima, *et al.*, 2004). Such changes in the bee community may affect the reproductive success of plants and ultimately forest composition. Nests sites are considered as essential resources, and have some requirements, as specialization in use of logs of some plant species or diameters at breast height bigger than 50cm. This has implications for reforestation programs as well for the sustainable use of forest and the conservation of stingless bees, important native pollinators (Venturieri, 2004).

The use of stingless bees for pollination purposes should consider the settlement of corridors between patches of native vegetation for keeping native populations of pollinators as well as trees for nesting and flowers for food (nectar and pollen). As agriculture is increasing in Brazil, the land management of surrounding agricultural areas is also very important. Finally, stingless bees could be excellent pollinators to be used by small farmers (family growers) because they do not sting, are easy to manage, and are appropriate to small lands and cheap to rearing. Besides that, some small farmers have the traditional knowledge to rearing them, using their honey as medicine. They need to learn how to manage them for pollination and conservation purposes.

State of art

Stingless bees as greenhouses pollinators

In 1988, Luci Rolandi Bego, from São Paulo University, went to Japan with a grant of Brazilian Academy of Sciences to work with Y. Maeta on the use of stingless bees as pollinators in strawberry greenhouses. She carried with her a colony of *Nannotrigona testaceicornis*, a colony of *Plebeia droryana* and one of *Tetragonisca angustula*, in rational hives, chosen by chance among the other species available at São Paulo University Bee Laboratory, where they were know to be very strong. *Nannotrigona testaceicornis* was tested in strawberry greenhouse, and the results of its efficiency is in Bego, *et al.*, The other colonies were used to study foragers' behaviour under greenhouse condition (Bego, *et al.*, 1989a). Later on, *Trigona minangkabau* from Sumatra was also tested in strawberry greenhouses, and the result compared with the efficiency of *Apis* in the same greenhouses (Katutani, *et al.*, 1993).

In Brazil, stingless bees as pollinators for strawberries in greenhouses were tested by Malagodi-Braga (1992); Malagodi-Braga and Kleinert (2004). Protocols for greenhouse pollination are well established related to the use of *Tetragonisca angustula* and other small stingless bees. Malagodi-Braga & Kleinert (2004) showed the efficiency of *Tetragonisca angustula* as a pollinator in "Oso Grande" cultivar: in a greenhouse with 1350 plants almost 100% of flowers developed into well-shaped fruits compared to 88% with open pollination in the field.

Sweet pepper (*Capsicum annuum*, Solanaceae) is another crop cultivated around the world, in open fields and in greenhouses (where its cycle is extended for production all year round). Although sweet pepper is a self-pollinating plant, it benefits from bee pollination (Rasmussen, 1985). In Brazil, Cruz, *et al.*, (2005) tested the efficiency of *Melipona subnitida* as a greenhouse pollinator of sweet pepper, variety All Big. They used four treatments in their research: hand cross-pollination, hand self-pollination, pollination by bees and restrict pollination. The fruit set was not improved by the use of *M. subnitida* as pollinators, but the number of seeds per fruit, the average fruit diameter and fruit weight increased; a lower percentage of malformed fruits were also found, comparing with self-pollinated sweet pepper.

Another important crop also often kept in greenhouses in Brazil and worldwide is the tomato, *Lycopersicum esculentum*. Velthuis (2002) tells the successful story of the bumblebee *Bombus terrestris* used as tomatoes pollinators in greenhouses in the Netherlands and Belgium that resulted in a big industry of bumble bee rearing in various pary of the world. Nowadays 1 million colonies of *Bombus terrestris* are yearly sold for using in agriculture (Velthuis & Van Doorn, 2004). However, exotic pollinators are to be avoided in many countries including Brazil. In search of local solutions, Brazil found that the use of some species of *Melipona* could be good pollinators of some Solanaceae crops that need "buzz pollination", such as the relatively large *Melipona quadrifasciata* for tomatoes (*Lycopersicum esculentum*) growing in greenhouse (Del Sarto, et al., 2005). Nevertheless, Macias & Macias (2001) and Cauich, *et al.*, (2004) verified that *Nannotrigona pirilampoides* is a very successful pollinator for tomatoes in greenhouses, opening new possibilities for small stingless bees use in those.

Open field pollination and stingless bees

Heard & Exley (1994) already considered the importance of agricultural landscape and natural vegetation for providing pollination services (the abundance of *Trigona carbonaria* in orchards of macadamia was correlated with the extent of natural surrounding Eucalyptus vegetation). Venturieri (1993) also remarked the importance of natural vegetation around the cupuassu crop in order to provide the needed pollinators. Kremen (2004) considered the importance of bee community as crop pollinators, pointing out that if we maintain several bee species from natural environments visiting flowers, the shortage of one species in one year could be compensated by the other visitor's species, diminishing the impact of pollinators' shortage on crops.

Coffee, a special commodity

Most of the world coffee production is originated from *C. arabica* shrubs, which are native to southwestern Ethiopia, as well as from *C. canephora* var. *robusta* (also known as *C. robusta*), native to equatorial Africa. *Coffea arabica* plants are typically grown in cold but frost-free areas at elevations of 500-200m, and *C. canephora* typically from sea level to 1000m (Klein, *et al.*, 2003a, Donald, 2004). *Coffea canephora* is a self-sterile, diploid species, and *C. arabica* is a self-sterile tetrapoid species (Klein, *et al.*, 2003a).

Traditionally, coffee farming involves the planting of coffee bush under a selectively thinned canopy of existing rainforest trees. This combination of shading trees and coffee shrubs form an integrated agroforestry system (Donald, 2004). There are many benefits originated from this way of production; first, shade cover up to 50% increases yields, and the presence of shade trees can control pest problems; furthermore, the quality and size of coffee beans, as well as the taste of the final product are better under shade systems than under systems without trees. However, this method was replaced for a full-sun production in many places. Where good soils and favorable climates are present, this method produces higher yields per unit area, although not necessarily per plant. Nevertheless, this method also produces some collateral effects, as an increased rate of pest problems and secondary pesticide problems. Nowadays, shading is only used where it is necessary to reduce yields to keep production sustainable in poor-nutrient soils, where shade-loving varieties are grown, and where shade trees form part of economic agroforestry systems (Donald, 2004).

Another important issue related with coffee production is the presence or absence of pollinating insects. Formerly, the importance of pollinators for coffee shrubs was neglected (Free, 1993), but in recent years their importance is being evidenced after a series of experiments made in several countries. Here we describe these results in order to show the importance of pollinators for the coffee harvest.

A pioneer work in this area was performed by Nogueira-Neto, *et al.*, (1959), which investigated the effect of the exclusion of pollinating insects on the yield of the variety Bourbon (*C. arabica* var. Bourbon) in a farm in São Paulo State, Brazil. They found a tendency (although the differences were not significant) towards a higher production of fruits on the plants that were allowed to receive the visit of pollinating insects, in contrast to a control group, which plants were not allowed to be visited. They also observed several species of native and introduced bees visiting coffee flowers, as the introduced *Apis mellifera* and the stingless bee *Melipona quadrifasciata*, both relatively big sized bees, the most effective pollinators of coffee flowers in their observations (a total period of observations of six years). According to the authors, the smaller bees (*Nannotrigona testaceicornis*, *Plebeia sp*., *Tetragonisca angustula*, *Trigona hyalinata* and *T. spinipes*) observed in the flowers, collecting pollen and/or nectar were not so effective pollinators as these big sized bees. They concluded that for this variety of coffee (Bourbon), insect visits are not so important as for the diploid self-sterile species of *Coffea arabica*, which needs the visiting of insects, especially bees, as well as the wind, for their pollination (Nogueira-Neto, *et al.*, 1959).

Roubik (2002) strongly suggested the importance of honey bees and native bees for the increasing of pollination of *C. arabica* plants in the New World, as well as in the Old World. He found a positive correlation between the coffee yields and the presence of honey bees in the New World. As Africanized honey bees were introduced in the New World in the middle 1960´s, and they reached Central America in 1985, he compared the coffee yields of the period before and after its introduction. After the arrival of Africanized bee in Central America, coffee yields in most countries of this region increased substantially, except for the Caribbean countries (e.g. Haiti), where native and introduced pollinators were absent. In the Old World, where honey bees were always present, coffee production did not varied in the same rate than the New World. Countries that experienced an intensive land usage and loss of habitats for pollinators had reduced yields (loss of 20-50%), although they had increased cultivated areas (Ivory Coast, Ghana, Kenya, Cameroon, Indonesia, El Salvador and Haiti) (Roubik, 2002). This work stressed the importance of native and introduced pollinators for coffee yields, although he did not analyze the pollination behaviour itself.

Ricketts (2004), in experiments performed at Costa Rica during 2001-2002, showed that eleven eusocial bees (10 native plus *A. mellifera*) were the most common visitors of coffee (*C. arabica*) shrubs, and that the distance of the forest fragments to the cultivated areas significantly influenced coffee visiting by these bees. Bee richness, overall visitation rate, and pollen deposition rate were all significantly higher in sites within approximately 100m of forest fragments than in sites far away (up to 1.6km). *Apis mellifera* foragers accounted for more than 90% of all visits in distant sites, and where *Apis* were not present, native species as meliponine bees accounted for most of the visits at near sites. This is due to the smaller flight range of meliponine bees which have a typical flight range of 100-400m (van Niewestadt & Iraheta, 1996, Heard, 1999), although maximum observed flights ranged from 1 to 2 km (Roubik & Aluja, 1983). When *Apis* abundance declined substantially, from 2001 to 2002, visitation rates dropped about 50% in distant sites, but only 9% in near sites. This can be explained by the compensating effect of native bees, which replaced *Apis* as the most important visitor in nearby sites. So, according to the author, forest fragments provided nearby coffee with a diversity of bees that increased both the amount and stability of pollination services by reducing dependence on a single introduced pollinator (Ricketts, 2004).

Similar results were found in Brazil (De Marco & Coelho, 2004) and Indonesia (Klein, *et al.*, 2003b,c). Coffee (*C. arabica*) branches with free access to pollinators produced more fruits in farms where there were forest fragments nearby. Coffee production increased 14.6% when the services of pollinators were available (De Marco & Coelho, 2004). Similarly, *C. canephora* and *C.arabica* fruit set increased with the increase of diversity and abundance of flower-visiting bees (*C. arabica*: 90% when 20 bee species were present and 60% when only three species were present, Klein, *et al.*, 2003b; *C. canephora*: 95% when 20 or more bee species were present and 70% when only six species were present, Klein, *et al.*, 2003c), and the number of social bees species decreased with distance to forest fragments and the number of solitary bees increased with light intensity (less shade) and greater quantities of blossoms. Additionally, Klein, *et al.*, (2003b,c) found that solitary bees had an important participation in the pollination of *C. canephora* shrubs, leading to higher levels of fruit set that originated by members of social bee assemblages.

These services can be translated into economic advantages. For example, De Marco & Coelho (*op.cit.*) found, as previously stated, that coffee production increased 14.6% when the services of pollinators were available. This increase represents an extra income of US$1860.55 per ha per year. Ricketts, *et al.*, (2004), showed that pollinating services from two small fragments (46 and 111 ha) could be translated into ~US$60,000 per year for one Costa Rica farm.

All these results stressed the importance of conserving forest fragments and nesting places for social and solitary bee species (Klein, *et al.*, 2003c, Ricketts, *et al.*, 2004), which can act as service-providing units (Luck, *et al.*, 2003) for coffee pollination. The costs of maintaining conservation areas are far exceeded by the economic benefits that the service of pollinators brings for agriculture. In this way, conserving natural areas nearby coffee farms can be translated into advantages for biodiversity and agriculture (Allen-Wardell, *et al.*, 1998, Ricketts, *et al.*, 2004).

Stingless bees management practices for use in agriculture

Agricultural intensification worldwide includes a decline in the proportion of natural habitat, an increase in pesticide usage, a decrease of floral resource on farm sites, as well as larger field sizes, crop monocultures, intensive soil and water usages and the use of synthetic fertilizers. Of course, the sustainability of agriculture following these patterns of land use is under concern by 21 Agenda for Agriculture.

Best management practices in agriculture for sustainable use and conservation of pollinators are focused in recent literature, and mainly by several authors that study pollinators' conservation. This means to carry on pesticides and their use in the crops; gene flow studies; environmental friendly agricultural practices, including land preparation, in order to keep nests of solitary bees that occur in the soil; agricultural area and maintenance of their borders with native vegetation, or hedges that can keep pollinators; to decrease herbicides use in agricultural crops, that helps the foraging supply for pollinators and crop attractiveness for them, in larger areas.

Although the already identified importance of pollinators in agriculture (see also weevils for oil palm; bumble bees for tomatoes, among others; solitary bees for apple, pears and alfalfa, for instance; stingless bees for strawberry, guarana, assai, coffee, among several other crops; honey bees for several crops) is well known, until now their use is not remarkable in undeveloped countries. However, this situation will change very soon, because of new initiatives concerning pollinators use in crops (for instance, the Brazilian Pollinators Initiative) as well as from successful crops competing in world market, resulting from the pollinators use in greenhouses, for instance. Developed countries are working with pollinators' shortage, although only a small number of them (a dozen, according to Kremen, 2004) are successful bred for agricultural use. If they are not available nearby due to the intensive agricultural patterns using large areas, they are bought from biotech companies that breed them successfully. These companies are multinational and have the technology of large scale breeding. The introduction of alien pollinators with defined breeding techniques is also undesirable, and studies of ecological impact are asked in importation process. This stimulates the breading of native pollinators for the same service in countries with capacity building in pollination area. In many tropical and subtropical areas of the world, a new scenario opens focusing stingless bees use as crop pollinators (Macias, *et al.*, 2001; Cunningham, *et al.*, 2002). An infant industry arises with stingless bees breeding in Australia (Heard & Dollin, 2000) and Brazil (Rosso, *et al.*, 2001), growing in the world (Cortopassi-Laurino, *et al.*, 2006).

Best management practices of pollinators in crops mean best crop economic value, and in this aspect both issues are together: economic value of pollinators and economic value of crops. Generally, producers are not interest in resistance (ability to retain community properties under disturbance) or resilience (ability to recover from disturbance) of crops when intensifying agriculture, but in their economic value in this season. Short time actions and market simulations are important in the producer's decisions on what crop to use in next season. They are linked to unpredictable weather conditions, as well to the market fluctuation on crop values (Kevan & Viana, 2003), as well as to the economic advantage in having better fruits. Long-term activities concerning natural resources are almost not considered.

The potential use of stingless bees' nests in large scale is for using in crop pollination. How to get nests in nature and to breed them successfully is a challenge. Another point of consideration in relation to the social bees of Brazil is the new law no. 02000.006608.2000-81. This law pretends to protect these insects and has only recently became effective. To protect these social bees, it mainly prohibits the exploration of natural nests. Unintentionally, this law makes it harder to access biological material of these bees for who needs to do the necessary, legal studies. Above all, the restriction put on by this law makes that the artificial multiplication of colonies is the only option to obtain enough colonies to study these bees and, thereafter, to use them in large scale projects. This fact once more demonstrates that knowledge about the reproductive biology of these bees is indispensable. We need more biological information on nest sites, food sources for improving colony development, colony multiplication, diseases.

Artificial offering of nests sites

Another possibility of deal with nest sites as a limited resource is to establish artificial trap nests, offering nests sites for stingless bees. Inoue, *et al.*, (1993) did these experiments in order to know more about the population dynamics of stingless bees. They studied an area of the Horticultural Experimental Station in Lubuk Mintrum, in Sumatra, where the main vegetation was a plantation of tropical fruits, rambutan, *N. lappaceum*, and durian, *D. zibethinus* (ca 480x200m, 8-6ha), where 24 species of stingless bees were found. The species *Trigona (Tetragonula) minangkabau* was the most common, and suitable for their study. They censused tree cavities and possible artificial nesting sites to estimate the number of natural colonies. At these censuses, 2 persons searched 4 days/month. They also set 362 trap nests in the field, of which 248 were perforated bamboo stems and 114 wood boxes with glass tops. Trap nests were set in January 1981 (100), December 1981/January 1982 (138), December 1982 (75) and October 1983 (49). Nests were observed during 56 months. The results were:

- trap nests were used by many animals, as social insects (mainly ants) and vertebrates (geckos, for instance);
- only *T. (Tetragonula) minangkabau* occupied the trap nests;
- ants occupied 20% of empty nets;
- bees occupied 6% of empty nests;
- colonies were found monthly during all experiment;
- successful in nest establishment was also recorded.

This experiment showed that additional nest sites offer could improve the bee density in the area, and that trap nests are suitable only for some bee species.

Antonini & Martins (2002) used nest traps in Cerrado without any result, in an area where they found 46 nests of *Melipona quadrifasciata*. Beekeepers sometimes mention that this bee species nests in abandoned nests of *Apis mellifera*.

In Brazil, recently stingless bee's keepers are using pet bottles as traps nests. In a beekeeping meeting this year in Rio Grande do Sul (III Encontro dos Meliponicultores) some of them reported that *Tetragonisca angustula* use these pet bottles. A deeper research on this subject is urgent, and is suggested as a recommendation.

Recommendations

Key stingless bees species for large scale breeding in Brazil

The selection of some stingless bees' species for large scale breeding is needed. They should be effective as pollinators, easy to maintain in strong rational hives that could be transported, easy to multiply, with a high range of temperature and humidity for flight activity. Species should be selected for greenhouses pollination as well as for pollination in open field.

Due to the large size of Brazilian territory, the selection should be regionally determined, to facilitate breeding and colony trading. In table 1 there are indications of stingless bee species already known as good pollinators. Our first selection should include:

1. ***Tetragonisca angustula***. This species has a wide geographical range in Latin America. Very common in several habitats, including cities, it frequently swarms, accepting artificial traps for establishing new nests. More data on queen and males rearing in natural nests, on queen rearing *in vitro* under laboratory conditions, and controlled reproduction of the queens under laboratory conditions are needed. The minimum population of bees necessary to begin a new nest, as well as their age composition must be evaluated. This bee also produces a honey that is considered as medicine, and how to conserve it should be investigated. At this moment, splitting colonies in two is possible, but this is not enough to allow their large use as pollinators.
2. ***Melipona quadrifasciata.*** The queen fertilization under controlled conditions was done in *M. quadrifasciata* by Camargo (1972), that verified to be possible to put a gyne and a male in a box and they immediately copulate. This result opens conditions for genetic manipulations of colonies. Besides, this bee can provide buzz pollination. Nevertheless the same result was not obtained with other *Melipona* species until now.
3. ***Melipona subnitida***. In Northeast Brazil (dry regions, Caatinga) this bee species is bred for its honey, very appreciated by local people. Until now, their role as pollinator was studied in sweet pepper under greenhouse, with good results (Cruz, *et al.*, 2005)
4. ***Melipona scutellaris.*** This species is already used as a very good honey producer in Northeast Brazil, and bred by successfully by beekeepers. Domesticated and well adapted in hives, this is one of the promising species to be used as pollinators where they occur.
5. ***Nannotrigona spp.*** The use of *Nannotrigona* in greenhouses was shown to be effective in pollination. Very common in urban areas, and with a wide geographical range, must be studied concerning biology and reproduction. The important results from Cauich, *et al.*, 2004, in Mexico, showing that they are as effective in tomato pollination as other pollination treatments gives

to this genus a high importance for additional investigation.

6. At least 9 species of stingless bees from Amazon (*Melipona* spp., *Aparatrigona* spp., *Plebeia* spp. and *Scaptotrigona* spp.) could be kept massively to be used on pollination programs. Tropical crops as cupuassu (*Theobroma grandiflorum*), urucum (*Bixa orellana*), assai (*Euterpe oleracea*), hogplum (*Spondias mombim*), guaraná (*Paullinia cupana*) are some examples of Amazon plants witch demands pollination services from stingless bees.

Improving knowledge base

1. Improve regional stingless bees collections and the use of molecular techniques needed to help identification.
2. Automatic monitoring of flight activity for modeling in climate change issues.
3. Promote stingless bees' conservation in areas where logging is allowed.
4. Study nest sites; nests populations; nests sizes and densities.
5. Improve nests availability through the establishment of ecological corridors.
6. Establish techniques for ecological restoration and pollinators.
7. Identify pollinators assemblages in ecotones and fragments.
8. Promote stingless bees conservation in agricultural landscapes, also promoting heterogeneity in landscapes.
9. Study exotic and native pollinators' ecological relationships.
10. Study species acceptation in trap nests of different materials.
11. Use molecular tools to evaluate: density of colonies; males provenience; population-characteristics; relatedness among nests; number of nearby nests (through the analysis of male clouds near the nest entrance, or by analyzing workers collected in a transect).
12. Develop metanalysis, data analysis and scientific publication diffusion of pollinators issues.
14. Improve techniques for nests development in hives.
15. Evaluate queen survivorship in the colony.
16. Compare the characteristics of initial and mature nests.
17. Study sex-ratio and queen production in selected species.
18. Improve honey production, quality and conservation.
19. Evaluate pollen availability and quality.
20. Study foragers' lifetable in different seasons.
21. Study seasonal aspects of life cycle, mainly in subtropical environment.

Final remarks

Concerning stingless bees' biology, there is an urgent need for implement the research groups in the different Brazilian regions for improving the local knowledge basis. Regional groups should be trained in standard methodologies to apply in their region.

Improve capacity building and training in all levels, as well as concentrate studies in nests requirements in order to implement the new law 02000.006608.2000-81 concerning to stingless bees beekeeping.

Conservation of stingless bees in logging areas is an important issue, due to the large Brazilian area that will be used for logging in Amazon region.

Develop life history studies for a selected number of stingless bees species that are potential generalist pollinators.

Provide literature in Portuguese and available on line.

Table 1: Stingless bees used as crop pollinators

Crop	Stingless Bee Pollinator (s)	Results	Author
Averrhoa carambola (Oxalidaceae) carambola	In Malaysia, *Trigona thoracica*;	Efficient pollinator after one visit	Phoon et al,1984
Bixa orellana (Bixaceae) annatto	*Melipona melanoventer* and *Melipona fuliginosa*; *Melipona seminigra merrilae*	Buzz pollinated by stingless bees	Maués & Venturieri, 1995; Wille, 1976;Absy & Kerr, 1997
Capsicum annuum (Solanaceae) suit pepper	*Trigona carbonaria* in Australia; *Melipona subnitida*	*M. subnitida* increased fruit weight (by 29%) and the number of seed per fruit (86%); 65% decrease of deformed fruit	Cruz et al, 2005; Silva et al, 2005
Cocos nucifera (Arecaceae) Coconut	*Apis mellifera* and stingless bees contribute to the pollination of this crop	Stingless bees are the dominant visitors in Costa Rica	Hedström, 1988; Engel and Dingemans-Bakels, 1980
Coffea arabica var. Bourbon (Rubiaceae)	*Melipona* spp.		Nogueira-Neto et al 1959
Coffea arabica (Rubiaceae)	*Bee pollination*	Higher fruit set and heavier mature fruits	Roubik 2002
Coffea canephora (Rubiaceae)	*Bee biodiversity*	Coffee fruit set was higher in areas with high bee biodiversity (from 70 to 95%)	Klein et al, 2003a
Coffea canephora	*Trigona (Lepidotrigona) terminate*	84% fruit set	Klein et al, 2003b
Cucumis sativus (Cucurbitaceae)	*Partamona bilineata*	Frequent visitor	Meléndez et al., 2002
Cucumis sativus (Cucurbitaceae)	*Scaptotrigona* aff. *depilis*	Higher fruit production, higher fruit weight and higher % of perfect fruits	Santos et al, 2004
Euterpe oleraceae – (Arecaceae) "assaí"	*Melipona melanoventer, Melipona flavolineata* and *Melipona fasciculata* (Meliponinae, Apidae)	In development	G. C. Venturieri et al, 2005
Fragaria x *ananassa* (Rosaceae) strawberry	*Tetragonisca angustula* (Meliponini, Apidae)	"Oso Grande" cultivar 100% primary flowers developed; higher fruit fresh weight	Malagodi-Braga & Kleinert, 2004

Fragaria x ananassa (Rosaceae) strawberry	*Tetragonisca angustula* (Meliponini, Apidae)	Sweet Charlie Cultivar Misshapen fruit reduced by 86%	Malagodi-Braga & Kleinert, 2004
Lycopersicum esculentum (Solanaceae) tomato	*Nannotrigona pirilampoides*	As effective as mechanical vibration in terms of fruit set, fruit weight and number of seeds per fruit	Macias & Macias, 2001; Cauich et al, 2004
Lycopersicum esculentum (Solanaceae)	*Melipona quadrifasciata*	Tomato flowers in absence of vibration do not produce fruits	Del Sarto et al, 2005
Macadamia integrifolia (Proteaceae) Macadamia nut	*Trigona carbonaria* (in Australia)	Yields and fruit quality benefit from bee pollination	Heard, TA; 1987
Mangifera indica (Anacardiaceae) mango	Stingless bees are the more common visitors; *Tetragonisca angustula* in Chiapas	Important for cross pollination, Trigona bees move from tree to tree.	Simão & Maranhão, 1959
Myrciaria dubia (Myrtaceae) camu-camu	*Melipona sp* and *Scaptotrigona postica*		Peters & Vasquez, 1986
Nephelium lappaceum (Sapindaceae) rambutam	*Scaptotrigona mexicana* and T*etragonisca angustula*	Caged and open pollination treatments yielded a mean of 9.1 times the mature fruit of flowers from which bees were excluded	Rabanales et al, in press
Persea americana (Lauraceae) avocado	8 species of stingless bees	Efficient as pollinators	Ish-am et al., 1999
Persea americana (Lauraceae)	*Trigona nigra*; *N. pirilampoides*	Potential efficient pollinators	Can-Alonso et al, 2005
Psidium guajava (Myrtaceae) guava	Pollen found in *Melipona marginata*,*T. spinipes* and *M. quadrifasciata* pots *Frieseomelitta* spp.	Studies under development	Kleinert –Giovannini & I-Fonseca, 1987 Castro, p.c.
Psidium guajava (Myrtaceae) guava	*M. subnitida*	together with solitary bees, are efficient pollinators	Alves & Freitas, 2005
Salvia farinaceae (Labiatae)	*T. angustula* and *N. pirilampoides*	Produce good quality seeds in greenhouses	Slaa et al, 2000
Salvia splendens	*Geotrigona spp*. and *Partamona*		Bustamante 1998

Sechium edule (Cucurbitaceae) chayote, choko	28 stingless bees species are important visitors; T. corvina and *Partamona* cupira are important	Stingless bees enhance fruit production	Wille et al. 1983
Spondias tuberosa (Anacardiaceae) "umbu" or "imbu"	*Frieseomelitta languida* and *T. angustula*	In development	M. S. Castro
Theobroma grandiflorum (Sterculiaceae) cupuassu	*Plebeia minima* and small weevils. Most plantas are self incompatible; *Ptilotrigona lurida* may be a pollinator		Venturieri, GA et al, 1993
Theobroma grandiflorum (Sterculiaceae) "cupuassu"	*Plebeia* spp., *Paratrigona* spp. & *Frieseomelitta* spp. (Meliponini, Apidae)	In development (Probio)	R. Gribel
Paullinia cupana (Sapindaceae) guarana	*Melipona* spp	together with *Apis mellifera*	Aguilera, FJP, 1983

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WORKSHOP II

Pollinator Initiatives and the role of Information Technology (IT): building synergism and cooperation

Abstract

The *São Paulo Declaration on Pollinators plus 5 Forum* was organized by the Brazilian Pollinators Initiative, BPI, and held in São Paulo with the support of FAO to discuss standardized methodologies for assessing pollinator' status and management practices to stop their decline.

The main objectives of the IPI (International Pollinators Initiatives, in which BPI take part) are:

- monitor pollinator decline, its causes and its impact on pollinator services;
- address the lack of taxonomic information on pollinators;
- assess the economic value of pollination and the economic impact of the decline of pollination services;
- promote the conservation, the restoration and sustainable use of pollinator diversity in agriculture as well as in related ecosystems;

Those tasks demand a huge effort, including a lot of data acquisition (in the field and in laboratory), and data analysis for building knowledge on pollinators and pollination.

Many of those tasks can benefit from the use of a variety of Information Technology (IT) tools that can help the scientist, the policy maker, the extensionist, the student.

Taking advantage of the presence of a very distinguished audience at the Forum, this workshop was proposed to discuss and disseminate the importance of IT for the Pollinator Initiatives, to help promote partnerships and exchange experiences on the development and use of those technologies, and to discuss funding opportunities.

This event was designed as an extension of the Forum, open to all of its participants.

Workshop objectives

The purpose of this workshop was to discuss the role of Information Technologies (IT) for the development and for the effectiveness of the Pollinators Initiatives in a broad sense, from building a species catalog to providing knowledge for policy making.

The program included reviews of relevant activities and broader trends in biodiversity informatics, and their impact for Pollinators Initiatives.

Efforts, from local to global, were presented and their relationships and contributions to the larger goals were discussed, as well as the possibilities of networking and of sharing tools, systems and data. Funding opportunities was another important topic discussed.

Organization and content

Organizing Committee

Antonio Mauro Saraiva, Escola Politécnica, Universidade de São Paulo.
Vanderlei Perez Canhos, Centro de Referência em Informação Ambiental - CRIA.
Vera Lucia Imperatriz Fonseca, Instituto de Biociências, Universidade de São Paulo.

The workshop was held in 31st. October 2003, at Escola Politécnica da Universidade de São Paulo. It was organized as a series of presentations of local, regional and global initiatives and projects followed by discussion on broader issues.

The local (Brazilian) initiatives presented:

- **WebBee** – The WebBee project, an information network on bee diversity was presented by prof. Antonio Mauro Saraiva, from Escola Politécnica - USP, Agricultural Automation Laboratory, Brazil.
- **Brazilian Pollinators Initiative** - BPI – was presented by Bráulio Dias, from the Brazilian

Ministry of the Environment (MMA), Brazil.
- Pollinators e-Journal – The proposal of an electronic journal on pollinator biology was presented by prof. David de Jong, from Genetics Department, Faculdade de Medicina, Universidade de São Paulo – FMRP-USP, Brazil.
- speciesLink - The speciesLink project, that integrates many biological collections was presented by prof. Vanderlei Peres Canhos, from Reference Center of Environmental Information - CRIA, Brazil
.

The regional initiatives presented:
- the International Centre for Integrated Mountain Development (ICIMOD), was presented by Dr. Uma Partap and Dr. Farooq Ahmad, from ICIMOD, Nepal .
- the North American Pollinators Initiative (NAPI), was presented by Dr. Mike Ruggiero, from the International Taxonomy Information Service (ITIS) and the National Museum of Natural History, Smithsonian Institution, USA.
- the European Pollinators Initiative (EPI), was presented by Dr. Simon Potts, from the Centre for Agri-Environmental Research, Reading University, UK.
- the International Network for Expertise in Sustainable Pollination (INESP), was presented by prof. Peter Kevan, from University of Guelph, Canada.
- the African Pollinators Initiative (API), was presented by Dr. Barbara Gemmil, from Environment Liaison Center International (ELCI) (Kenya) and Dr. Connal Eardley, from Agricultural Research Council, Plant Protection Research Institute, South Africa.
- the IABIN Pollinators Network and the New World Bee Catalog were presented by prof. Vanderlei Peres Canhos, from CRIA, Brazil.

The Global Initiative presented:
- the International Pollinators Initiative (IPI), was presented by Linda Collette from the United Nations Food and Agriculture Organization (FAO).

Discussion

The topics suggested for discussion were:
- towards a common agenda - building the shared infrastructure;
- how to integrate actions;
- standards, protocols and systems interoperability;
- on-line directory of institutions, experts, programs and projects;
- on-line databases: taxonomic authority files, specimen DB, species DB, phenological datasets for meta-analysis;
- computational tools for data mining, analysis, synthesis and visualization;
- funding opportunities and co-financing requirements - GEF projects and local Funding;
- recommendations.

Expected Results

Expected results of the workshop included:
- a clearer understanding of the role of IT in the Pollinator Initiatives;
- the establishment of partnerships for the development and sharing of the IT infrastructure required for the Pollinator Initiatives: tools and systems developers and data providers;
- the identification of funding opportunities for the development of the IT infrastructure on a local, regional and global scale.

Introduction

As was pointed out by Saraiva & Imperatriz-Fonseca (2004), Information Technology (IT) has a decisive role to play on the development of the Pollinators Initiatives (PIs), and that can be analyzed based on the core objectives of both the International Pollinators Initiative (IPI).

These core objectives are:

- monitor pollinator decline, its causes and its impact on pollinator services;
- address the lack of taxonomic information on pollinators;
- assess the economic value of pollination and the economic impact of the decline of pollination services;
- promote the conservation, the restoration and sustainable use of pollinator diversity in agriculture as well as in related ecosystems.

It is not difficult to see that one way or another those objectives involve issues related to data, information and knowledge: their acquisition and analysis, their transformation from raw data to useful knowledge, their use for sound decision and policy making, their dissemination for wider audiences to increase awareness and education.

Those are typical tasks for Information Technology in a broad sense and, more specifically speaking, those are simply the goals of Biodiversity Informatics, a new discipline or denomination created to deal with the application of IT to Biodiversity.

The complexity of biodiversity and its processes, the huge figures involved, the amount of variables and data that are to be dealt with, the regional and global coverage that is usually necessary, all demands IT tools to acquire data, to store and manipulate them, to help analyze them, and to convey the results and findings in different formats and media to different target audiences.

It is not different in the case of the PIs. Monitoring pollinator decline demands more accurate and automated methods and tools that will help researchers collect more and better data with less effort, while allowing them to concentrate on the design of field experiments, on data analysis, i.e., on turning data into information and knowledge.

As for the taxonomic information, on one hand the information gathered after decades and maybe centuries of research is not readily available even for the scientific community because it is spread around the world in museum collections or the like. Digitizing the collections and publishing them on the Internet will increase the accessibility while still providing control over the data whenever this is required. On the other hand, IT tools can be used to help automate species identification, be it with instrumentation systems or with identification keys whose rules can be embedded in computer programs.

Once data is acquired, different types of analysis need to be made taking into account the species distribution, the effect of changes on the environment, the economic value and impact, and different strategies for conservation, restoration and use. These analyses would benefit from the use of simulation tools that can be used to develop different scenarios upon which decisions can be made.

One of the most important points stressed in the PIs is increasing awareness raising: it is urgent to demonstrate the importance of pollinators and the risk of their decline. The internet can play a very important role on that. However, the web can also have a strategic function for the integration of the research community, which can share data, communicate and cooperate more efficiently, even though remotely.

Results

The presentations made at the workshop (which are available at WebBee portal) showed a wide range of uses, systems and future possibilities for IT applied to the PIs.

They unanimously stressed the advantages and importance of the use of IT tools and techniques to help achieve the goals of the International Pollinators Initiative and of the national/regional PIs. The project *Conservation and Management of Pollinators for Sustainable Agriculture Through an Ecosystem Approach*, under the auspices of FAO and GEF, will require an intensive use of IT on the development of its four components. The preliminary phase of the project, the PDF-B phase, will provide an opportunity to review, identify and analyze gaps on the technology regarding its application to the PIs. The full-size project that will subsequently be developed may accommodate part of that development.

According to what was presented, software tools seem to be the most widely used components. Websites for various purposes were reported for all PIs though their content and complexity differed significantly. In some cases, simple webpages are used to convey project information, educational information, etc. Despite that simplicity, their effectiveness is acknowledged and they fulfill some basic needs of the developers and users.

At a higher level, there are the databases that can be accessed via Internet. Specimen information from biological collections at museums, for instance, is being digitized and is increasingly available on-line. Though the percentage of the specimens of the known world's collections that is already available on-line is small, that number is increasing consistently and some international and global efforts in that direction were mentioned. It was stressed the need to join and to strengthen that digitization effort, which faces many difficulties related to funding and data ownership.

This brings up the problem of the integration of all that data. Such integration is important for many different purposes, such as for building a global catalogue of life on Earth (such as the *Catalogue of Life*, from Species 2000 and ITIS), and for creating checklists of species and resolving naming problems. Further use of integrated data is made by analysis software, such as that for modeling species distribution, extinction risk, and protection strategies. Analyses tools are of utmost importance as they can be used to guide the development of environmental public policies on a more solid foundation.

This integration requires the use of standards and protocols for data exchange. These standards are under development with the support of institutions such as GBIF, TDWG, among others, with the participation of groups from many countries. This is another area that needs more support, as it is essential to allow more seamless access to and share of biological data. It was suggested that FAO and GEF should participate of that effort. An example of the use of those standards to integrate different sources via internet was presented at the SpeciesLink project .

As the use of such information increases in its complexity, more tools are necessary to allow automation of many of the boring and repetitive tasks.

An important part of the remote access to data is related to bibliography. An on–line peer-reviewed journal on pollinators and pollination is being designed within the BPI, and it was suggested that this journal should be supported within the FAO/GEF project. Such a journal would both facilitate information exchange and encourage research and publications on pollinators, especially in the developing countries. Much research on pollinators and pollination in developing has been traditionally done in a haphazard manner, and often the results are not readily accessible. A specific journal on pollinators would both provide means to guide and improve such research, through examples and through peer review, and would also facilitate publication of such information.

It is important that other media, such as images and videos, be used to convey information via internet. They must be complemented by texts but they have a strong impact and should be incorporated especially for specific audiences and for some purposes. An example of an information system that is based on species information (rather than on specimen information) and which makes intensive use of visual information was presented on the project WebBee.

Another set of IT tools not very much mentioned was instrumentation, though it became clear that it is fundamental for increasing the capacity of data acquisition and the quality of this data. It is also important for allowing the application and the replication of the standard methodologies discussed at the other workshops of the Forum. Part of the WebBee project involves the development and use of a set of instruments applied to pollinators monitoring. Those experiments can be accessed via internet and can be shared among many users collaboratively.

Difficulties and recommendations

Along with the discussions that arose during the workshop sessions one important point that stood out was the need for IT support personnel. Most institutions that were present at the workshop do not have IT support personnel or at least not at level required nowadays, considering systems development and infrastructure.

Another issue related to support is the maintenance of such systems. Many of them are developed with funds from research projects but it is often hard obtain funding for sustaining them on the long term. The same applies to the issue of updating the system with new information and data: that task requires people and this is sometimes forgotten, and often hard to obtain funding.

Considering the end-users that are expected to benefit from those systems another point that was discussed was the access to internet in rural areas, especially in developing countries. That should be considered in the technical design of the systems and on other actions at the level of public policies for digital inclusion.

Another topic is related to the question of data ownership and sharing by researchers and countries. That question is sometimes delicate, both at the personal level and at the country level, since national legislation differ and sometimes restrict the access to biological data fearing biopiracy.

Final remarks

The workshop provided a very good opportunity to show to the audience a wide range of cases, tools, systems and initiatives regarding the application of IT to pollinators and pollination and related areas. For a significant part of the audience some of the topics covered presented novelties. The presence of a public with many end-users was important to help collect their feelings and experiences with respect to the technology. It also allowed a discussion about some critical issues, technical and political, that must be dealt with so that IT can be effective for the Pollinators Initiatives; and promoted opportunities for strengthening contacts and relationships, for showing areas of interest and competencies that may evolve to future cooperation, which is a central part of the IPI and of the GEF/FAO project.

The workshop achieved its expected results and, being the first of its kind, showed the importance of further discussion and meetings to increase the use of IT for the advancement of the Pollinators Initiative.

Notes

1. http://www.webbee.org.br/bpi/english/workshop_ 2003.htm
2. http://www.species2000.org/2005/search.php
3. http://splink.cria.org.br/

Reference

Saraiva, A.M & Imperatriz-Fonseca, V.L. 2004. A proposal for an information network for the Brazilian Pollinators Initiative – BPI. In: *8th.IBRA International Conference on Tropical Bees and VI Encontro sobre Abelhas*, 2004, Ribeirão Preto, Brazil. Proceedings. International Bee Research Association – IBRA; FFCLRP-USP, 2004. CDROM.

ILLUSTRATIONS AND PHOTOGRAPHS

Xylocopa bee pollinating a *Lecythis pisonis* flower. Copyright Michael Rothman 1999. Courtesy of the *New York Botanical Garden*, *Institute of Systematic Botany*

Solitary bees are specialized pollinators. *Centris* is important for cashew pollination. Above left, nests of *Epicharis Dejeanii*; above right, nest of *Ptilothrix plumata*; below left, nest of *Centris tarsata*. Solitary bees can be attracted to trap nests (below right), and moved to crops for pollination purposes.
From Schlindwein, *et al.*, 2003, *A quantitative approach to assess specialized bee plant pollinator systems*, in http://www.webbee.org acessed in March 10th 2006.

Biotic pollination dependence in melon farming: malformed (left) and export quality (right).
Photos by Raimundo Maciel de Souza.

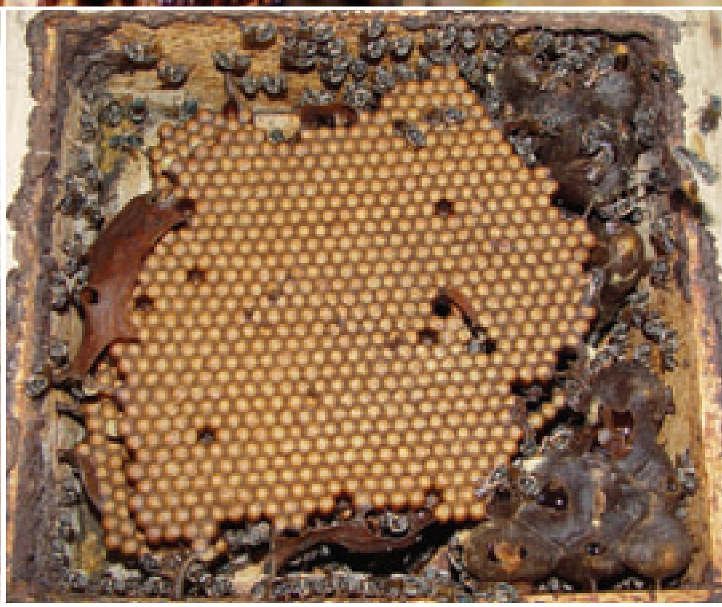
Africanized honey bees are important pollinators. Above, orange flower. Photo by Tom Wenseleers.

Africanized honey bee visiting assai flower. Photo by Giorgio Venturieri.

Above left, assai is the second most important crop for Amazonian. Below, male and female flowers of assai need bees as pollinators.

Above, assai flower visited by *Melipona fasciculata*. Below, assai flower visited by Trigona spp. Photos by Giorgio Venturieri.

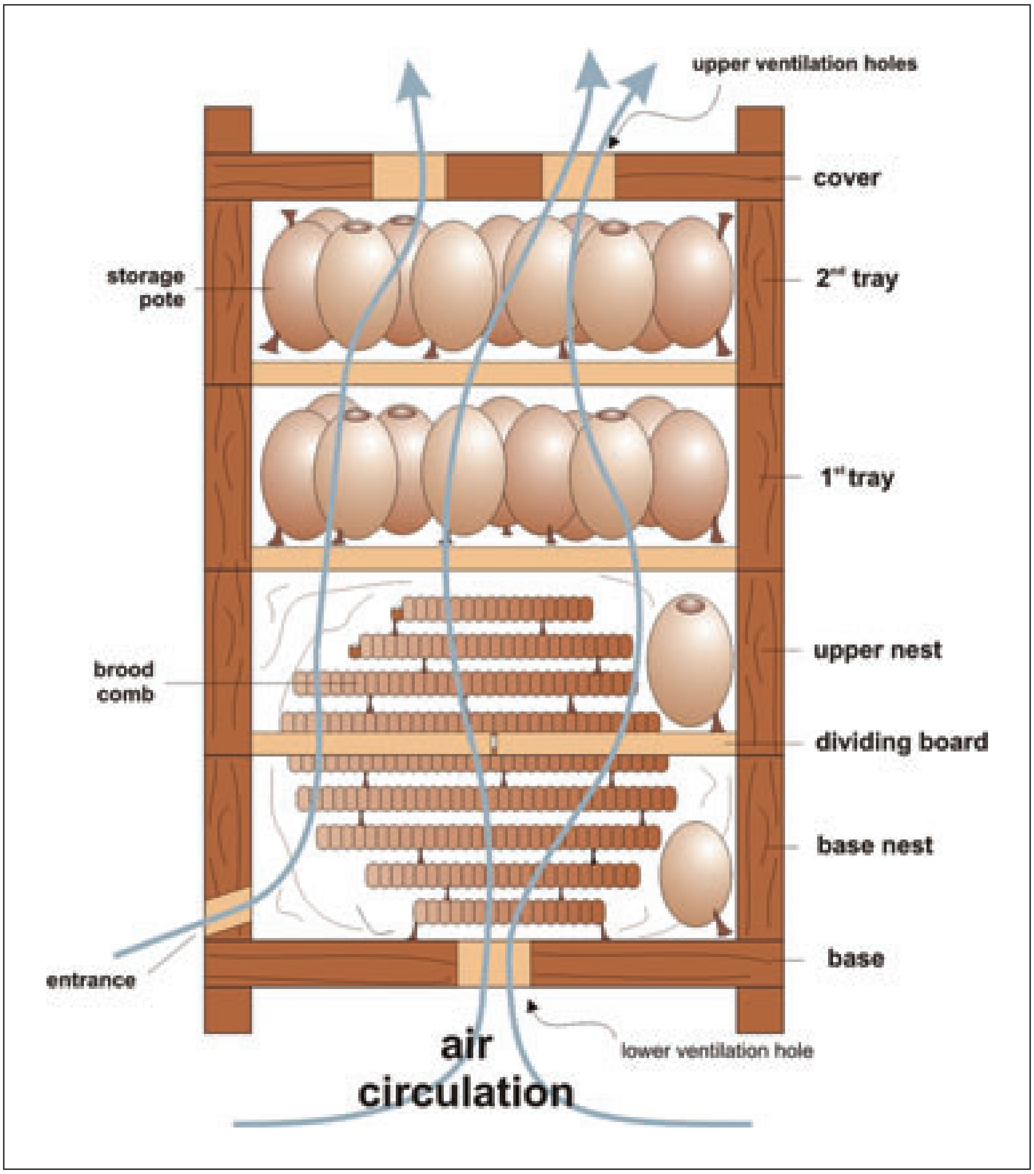
Melipona fasciculata hives in assai crop.



Melipona fasciculata nest entrance (above). Below, honey tray from a *Melipona fasciculata* hive; right, brood cells tray.
Photos by Giorgio Venturieri.

Malformed strawberry's fruits (above left) and pollinated wellformed fruits (above right). Below, *Tetragonisca angustula* visiting strawberry flower. Photo by Katia Malagodi-Braga.

Tetragonisca angustula nest entrance. Photo by Tom Wenseleers.



Vertical hive with special ventilation system for stingless bees of tropical areas (from Giorgio C. Venturieri in www.cpatu.embrapa.br/paginas/meliponicultura.htm)

Embrapa provides field training is stingless bees breeding for Kumenê indians from Indigenous land Uacá, Oiapoque, Amapá state. Giorgio C. Venturieri teaches how to transfer a natural nest to a hive. Photo by Marcos Sztutman.