
Coordinator: Dr. Marcelo Tabarelli (Associate Professor, CNPq 1A)

Graduate Program: Graduate Program in Plant Biology

Link for CV Lattes: http://lattes.cnpq.br/3749494329725967

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1. Project Summary (Describe the state of the art of the topics to be investigated focusing on their international relevance and how the project will impact the field)

   The GRADUATE PROGRAM IN PLANT BIOLOGY (PPGBV) is dedicated to the training of human resources in the fields of Systematics, Ecology, Applied Botany, and Plant Conservation (i.e., the Science of Biodiversity), qualifying professionals to teach, conduct research, and apply practical measures in these fields and associated areas of knowledge. Given its potential for both research and teaching in Biodiversity Sciences, the PPGBV is already a national reference center in the field of biodiversity research for the ecosystems of the Brazilian Northeast, as shown by the large number of papers and books published on the natural history and conservation of these environments.

   The NUCLEUS FOR THE PROSPECTION AND MANAGEMENT OF THE BIODIVERSITY OF THE BRAZILIAN NORTHEAST (NPGBio)/UFPE, which is integrated with the PPGBV, was created in 2009, using resources obtained from the FINEP CT-INFRA calls for projects in 2008 and 2010. Coordinated by Prof. Marcelo Tabarelli, the NPGBio is occupying a recently-constructed building in the UFPE.
Biosciences Center (CB/UFPE) in Recife. The NPGBio is based on three fundamental divisions, which constitute the principal tenets of modern biodiversity science: (1) Characterization, (2) Use of natural resources (with emphasis on Bioprospection), and (3) Conservation of biological diversity. The first theme (Characterization) is based on the use of molecular tools and state-of-the-art bioinformatic analyses (including Next Generation Sequencing, NGS) to integrate studies in systematics, phylogenetics, cytogenetics, biogeography, and population genetics, which will contribute to the development of effective measures for the conservation and management of natural populations. Together with theme 2 (use of biodiversity), theme 3 (conservation) is directed at the understanding of how the impact of anthropogenic disturbance and climate change are affecting the biota of the Caatinga at different levels of biological organization, and the implications of these changes for the sustainability of the systems based on cattle ranching, subsistence farming, and the extraction of natural resources.

In this context, the NPGBio reinforces the integration of researchers involved in biodiversity science, which is fundamental to the training of human resources for the management of biodiversity (systematists, bioprospectors, and conservation biologists), the implementation of productive chains based on the sustainable use of regional biodiversity, and the production of key scientific knowledge at an international level. From this perspective, it is hoped that the NRGBio will consolidate its position as a national reference institution for the use of natural resources and sustainable development of the region, as well as an internationally renowned center of excellence for biodiversity science. In addition to the PPGBV, the graduate programs in Animal Biology (PPGBA) and Fungal Biology (PPGBF) are partners in the study of the region’s biodiversity and share the infrastructure of the NPGBio. The themes of the present proposal are also part of the global agenda supported by a number of prominent international agencies, such as
the World Bank and the Global Environmental Fund (GEF). Given this, the NPGBio intends to expand the international profile of the research developed by the PPGBV, as already achieved by some of its members and their research groups, impacting the Science of Biodiversity at international level.

In this context, the present proposal intends to expand the participation of the NPGBio in the three principal themes of Biodiversity Science, and increase its profile as an international center of excellence in this field of research. Specifically, the proposal has four principal objectives: (1) expand the network of formal collaborations involving the PPGBV through the establishment of formal partnership agreements with other institutions and research groups, (2) support the interchange of PPGBV students and scientists with renowned research groups around the world, (3) expand the offer of graduate courses at the PPGBV given in the English language, as a means of attracting greater numbers of foreign students and researchers, (4) increase the academic impact of the papers published with PPGBV students, supported by the international collaborations established by the NPGBio. To achieve these objectives, the present proposal includes 11 subprojects that encompass the three principal fields of Biodiversity Science, involving partnerships with 14 foreign researchers at 11 different institutions in eight countries.

2. Goals (Please provide the scientific goals and tasks in the format listed below)

The main goal of this proposal is ....

The present proposal intends to consolidate the position of the NPGBio as an internationally renowned center of excellence for research in the fields of the characterization, use and conservation of biodiversity. For this, we intend to:
- expand the network of collaboration involving the PPGBV through the establishment of formal agreements with other institutions and research groups;

- support the interchange of PPGBV students and scientists with established groups at research institutions around the world;

- expand the offer of graduate courses at the PPGBV given in the English language, to attract greater numbers of foreign students and researchers;

- increase the academic impact of the papers published with PPGBV students, supported by the international partnerships established by the NPGBio.

To achieve these goals, we propose 11 subprojects within the scope of the three principal themes of Biodiversity Science. These subprojects have the following specific objectives:

- **SUBPROJECT 1: Phylocytogenetic studies of the *Caesalpinia* (Leguminosae) group**

  Investigate the mechanisms responsible for the correlation between genomic changes (including DNA content, abundance of the principal families of repetitive DNA and distribution of heterochromatin) and the environmental/biogeographic variation found in the *Caesalpinia* (Leguminosae) group.

- **SUBPROJECT 2: Reconstruction of the phylogeny and karyotype evolution of *Melocactus* Link & Otto (Cactaceae: subfamily Cactoideae).**
Reconstruct the phylogeny of the genus *Melocactus* through the comparison of the plastidial DNA sequences, as well as the identification of the mechanisms of karyotype evolution involved in the diversification of the genus.

- **SUBPROJECT 3: Systematics and evolution of *Cryptanthus* Otto & A. Dietr. (Bromelioidae, Bromeliaceae)**

  Investigate the levels of genetic diversity and population structure of the morphologically similar *Cryptanthus* species found in the Atlantic Forest north of the São Francisco River to provide insights into the processes of diversification in the group (e.g., incomplete lineages or hybridisation), re-evaluate the conservation status of the different species, and propose conservation strategies.

- **SUBPROJECT 4: Systematics and evolution of *Piptolepis* Sch. Bip. (Compositae, Vernonieae)**

  Investigate the evolutionary history and a systematics of *Piptolepis* Sch. Bip. (Compositae), through phylogenetic and phylogeographic studies using Next Generation Sequencing (NGS) of the DNA, contributing to the understanding of the diversification, speciation, evolution, and biogeography of the Neotropical region.

- **SUBPROJECT 5: Karyotype evolution and phylogeny of *Ameroglossum* Eb. Fisch., S. Vogel & A. V. Lopes and related genera, based on chromosomal analyses and Restriction-Associated DNA sequencing (RADseq)**

  Investigate the phylogenetic relationships and the mechanisms of karyotype evolution in the species of the genus *Ameroglossum* and related genera using the RADseq technique and chromosomal analyses, in order to understand the intra- and inter-genus
relationships within this group, whose evolutionary history is associated with the occupation of mainland environments similar to those of oceanic islands.

- **SUBPROJECT 6: Same origin, different result? Effects of diploidization in allotetraploids of the Dilatata group of the genus *Paspalum* (Poaceae)**

  Analyze the genomes of the allotetraploid species of the Dilatata group of the genus *Paspalum* to determine the consequences of the process of diploidization in the genomic diversification of species with a common origin or closely-related lineages.

- **SUBPROJECT 7: The potential role of ecological restoration in the sustainability of the Caatinga**

  Comprehend the application of ecological restoration as a structuring component for research activities and the establishment of public policy, as an approach to two principal questions: (1) How are biological communities organized in biological systems disturbed by human activities? and (2) What is the potential role of ecological restoration in the sustainability of water, food and energy security in the Caatinga?

- **SUBPROJECT 8: Anthropogenic impacts, climate change, and keystone organisms in the regeneration dynamics of the Caatinga**

  Understand how chronic anthropogenic impacts, including climate change and subsistence farming affect specific biological groups (e.g., plants, leafcutter ants, and the biological crust of the soil), and the regeneration dynamics of the Caatinga.

- **SUBPROJECT 9: Recuperation of the services provided to plants by ants during the regeneration of Caatinga vegetation**
Verify whether the seed dispersal and anti-herbivore services provided to plants by ants are recuperated with the regeneration of the Caatinga vegetation.

- **SUBPROJECT 10: Land use, natural regeneration and ecosystem services provided by the Caatinga: connecting conservation units and sustainability**

  Comprehend the relationships between land use, regeneration dynamics, and the ecosystem services provided by the Caatinga vegetation, in order to (1) determine the potential for the provision of ecosystem services by Caatinga conservation units at different spatial scales, (2) define management guidelines for the management of these conservation units and the surrounding environments that will maximize the potential for the provision of ecosystem services, and (3) incorporate the conservation units in strategies of adaptation to climate change and the transition to sustainability.

- **SUBPROJECT 11: Floral odors in specialized Neotropical pollination systems**

  Analyze the chemistry of floral odors in different specialized systems of pollination in the family Malpighiaceae, in particular those involving bees, sphingid moths, and bats. The questions to be analyzed include (1) What is the composition and the quantity of the scents exhaled by the flowers of the plants that produce essential oils? (2) What is the role of these signals in the selective attraction of species of pollinator bees? (3) In the species that have flowers with and without elaiophores, does the aroma vary between flowers of different morphotypes? and (4) How does the presence of these signals interfere in the frequency of pollinator visits?
Please indicate deliverables and targets of the Project in terms of:

i) Scientific and technological outcomes (papers, books, patents, etc);

The scientific products will include the 15 doctoral dissertations of the students contemplated with sandwich (exchange) stipends over the next four years. We also hope to achieve an improvement in the impact factor of the papers produced through the collaborations, with a progressive increase in the number of papers published in Qualis A1–2 and B1 (nB1+) journals with students each year. We intend to prepare, submit, and publish (or at least have accepted) a total of at least 15 nB1+ papers. We also expect to produce a further 15 papers as the result of postdoctoral projects and the research of visiting professors, as well as the improvement in the standard of the papers produced by other students not directly involved in this project.

ii) Graduating PhDs;

15 PhDs will benefit directly from sandwich (exchange) stipends (mean of one or two per SUBPROJECT).

iii) Exchanging faculty and PhD students;

This proposal includes exchanges involving:

- 15 doctoral students, who will each receive a six-month sandwich (exchange) stipend (mean of one or two per SUBPROJECT));

- 1 Work Mission (SUBPROJECT 5);
- 2 Junior Visiting Professor for 6 and 3 months (SUBPROJECTS 3 and 4);

- 5 Senior Visiting Professor for 3 months each (SUBPROJECTS 7, 8, 9, 10 and 11);

- 1 visiting professor in Brazil for a period of 6 months (SUBPROJECT 6);

- 1 young talent with foreign experience for a period of 6 months (SUBPROJECT 1).

iv) National and international funding as support for running out the project:

Some of the collaborations proposed here have already received funding through Brazilian or international projects, and are presented here as counterparts. These projects include:


- Dra. Inara Roberta Leal (2016 – Atual). Anthropogenic disturbances and key organisms in the regeneration dynamics of the Caatinga - a threatened tropical rainforest in Brazil (PROBRAL CAPES-DAAD Program, Process number 99999.008131 / 2015-05) R $ 154,000.00. Partnership with Dr. Rainer Wirth of the University of Kaiserslautern, Kaiserlautern, Germany.

- Dr. Marcelo Tabarelli (2016 – Atual). Anthropogenic disturbances, climatic changes and the future biota of the Caatinga (Long Term Ecological Research Program, PELD -
CNPq, Process number 441386 / 2016-4). Partnership with Dr. Rainer Wirth of the University of Kaiserslautern, Kaiserslautern, Germany; Dr. Alan N. Andersen of the Research Institute of Environment and Livelihoods, Australia; Dr. Victor Arroyo-Rodrigues, Research Institute on Ecosystems and Sustainability, Mexico.

Other projects will be submitted to a number of different funding agencies.

v) Academic Innovation at graduate and undergraduate level regarding courses, schools, teaching of foreign language as well as for promoting the international visibility of research and graduate programs.

Visiting researchers, either those contemplated with stipends provided by the present proposal or supported by other agreements, will give optional courses in the English language in the PPGBV. These courses will be announced on the PPGBV website, and will cover state-of-the-art themes of strategic importance for the training of students in all three of the principal fields of research of the present proposal, and will include “Phylogenomics” (Magdalena Vaio) and “Field Course in the Ecology and Conservation of the Caatinga” (Rainer Wirth).

3. Methodology (briefly describe the methodologies involved for running out the research project)

The 11 subprojects included in this proposal will be based on a diversity of methods, ranging from new generation molecular analyses for genomic, phylogenetic and phylogeographic studies, to ecological analyses on different scales, focusing on the
restoration and sustainability of the Caatinga. The methods to be used in each subproject are described briefly below:

- **SUBPROJECT 1: Phylocytogenetics of the *Caesalpinia* (Leguminosae) group**

  New Generation Sequencing (NGS: Illumina MiSeq) will be used to cover 0.1× of the genome of species of the genus *Caesalpinia*, representing all the principal clades of the group. The original Illumina sequencing data will be analyzed in the RepeatExplorer program (www.repeatexplorer.org) to identify the repetitive sequences for the comparative analysis of the different species. The divergence patterns of the repetitive sequences and the relationships among species will be determined by a phylogenomic approach based on the comparative abundance of the repeats (Dodsworth et al. 2015). These data will also be correlated with ecological traits through comparative phylogenetic methods.

- **SUBPROJECT 2: Reconstruction of the phylogeny and karyotype evolution of *Melocactus* Link & Otto (Cactaceae: subfamily Cactoideae).**

  In addition to a plastidial molecular phylogeny and basic cytogenetic characterization of the species of the genus *Melocactus*, a NGS approach, similar to that described above, will be used to characterize the molecular cytogenetics of the species.

- **SUBPROJECT 3: Systematics and evolution of *Cryptanthus* Otto & A. Dietr. (Bromeliioideae, Bromeliaceae)**

  A sample of 20–30 specimens of each of the *Cryptanthus* and *Orthophytum* species distributed to the north of the São Francisco River will be collected for the extraction of DNA and molecular analyses. The plastidial and nuclear primers used in
previous studies of the Bromeliaceae are being used for the identification of polymorphic and informative regions (see e.g., Givnish et al. 2011 [atpB-rbcL, matK, ndhF, psbA-trnH]; Louzada et al. 2014 [PHYC, trnL-trnF, trnH-psbA]). Once amplified, these polymorphic regions will be sequenced in a partnership with the Vale Technological Institute and the molecular data produced will be used for phylogenetic reconstructions.

- **SUBPROJECT 4: Systematics and evolution of *Piptolepis* Sch. Bip. (Compositae, Vernonieae)**

Young leaves of species of the genus *Piptolepis* and other closely-related species (Loeuille et al. 2015b) will be collected and preserved in silica gel for phylogenetic and phylogeographic studies. The molecular data will be obtained by NGS in the Illumina iScan Sequencing Module platform. The probes of 763 loci designed specifically for the Asteraceae (Mandel et al. 2014) will be used. The analyses will include parsimony and Bayesian approaches (Huelsenbeck & Ronquist 2001). The phylogeographic analyses of the *Piptolepis* ericoides complex will be based on samples of the different morphotypes found along the length of the Espinhaço mountain range in Minas Gerais. The informative data at a population level obtained by NGS will be used in the phylogeographic analysis.

- **SUBPROJECT 5: Karyotype evolution and phylogeny of *Ameroglossum* Eb. Fisch., S. Vogel & A. V. Lopes and related genera, based on chromosomal analyses and Restriction-Associated DNA sequencing (RADseq)**

The evolutionary relationships in *Ameroglossum* and related genera will be evaluated using a classic molecular cytogenetic approach, together with fluorochrome staining, and new generation RADseq. The total DNA will be extracted from the leaves by the CTAB method (Tel-Zur et al., 1999) with minor modifications, for the preparation of the RAD library for high performance Illumina sequencing, as in Baird et al. (2008).
These libraries will be sequenced in an Illumina Genome Analyzer, following the manufacturer’s instructions. The phylogenetic relationships among the *Ameroglossum* species will be analyzed using Maximum Parsimony, Maximum Likelihood, and Bayesian Inference approaches, run in the specific software.

**- SUBPROJECT 6: Same origin, different result? Effects of diploidy in allotetraploids of the Dilatata group of the genus *Paspalum* (Poaceae)**

Samples of the allotetraploids of the Dilatata group of *Paspalum*, as well as the possible diploid ancestors will be maintained in culture for analysis. The genome of *Paspalum juergensii* will be drafted, and the repetitive DNA will be sequenced, to support the comparison of the closely-related tetraploid and diploid species. The RepeatExplorer pipeline (www.repeatexplorer.org), which uses a plot-based cluster analysis, will be used to characterize the repetitive fractions of these genomes. The post-diploidization restructuring of the chromosomes will be analyzed by mapping the repeat and unique sequences in the related tetraploid and diploid species with oligo-FISH chromosome painting probes.

**- SUBPROJECT 7: The potential role of ecological restoration in the sustainability of the Caatinga**

This project is divided into two modules. The first module focuses on the identification of the bottlenecks in the promotion of ecological restoration and the practical opportunities for the application of this approach at a biome scale in the Caatinga. For this, opportunities for restoration will be mapped, with a focus on the promotion of sustainability. The maps will be derived from the integration of biological, physical, social, and economic data covering the whole Caatinga biome. The second module will focus on the identification of the ecological factors that determine the
potential success of practical measures of restoration. This will be based on field experiments that analyze a number of questions related to the establishment of tree communities in the Caatinga. This module will focus specifically on functional ecology and the relationship between biodiversity and ecosystem services in the Caatinga.

- **SUBPROJECT 8: Anthropogenic impacts, climate change, and keystone organisms in the regeneration dynamics of the Caatinga**

  To comprehend the relationship between farming, biological groups, and ecosystem function, in particular, the assimilation, storage, and cycling of nutrients, during the regeneration of forests, it will be necessary to (1) estimate the productivity of the ecosystem and quantify the above-ground biomass, (2) estimate the assimilation, flux, and spatiotemporal distribution of nutrients (principally carbon and nitrogen) in distinct sections of the ecosystem, and (3) quantify the foraging activity of the ants and the physiological activity of the crusts, and their abundance over time and in space, in the context of the chronological sequence of the regeneration process. An ecophysiological profile will also be produced for the woody Caatinga plants that are most abundant in the most and least preserved areas of the biome, as well as the driest and most humid portions of the Catimbau National Park, in Pernambuco. This profile will estimate the energetic costs of the production of leaf tissue, and the capacity and benefits of plant-fungus mycorrhizal symbiosis, as well as describing the morphoanatomy of the root, stem, and leaves.

- **SUBPROJECT 9: Recuperation of the services provided to plants by ants during the regeneration of Caatinga vegetation**

  Seed removal tests will be used to evaluate the services of seed dispersal in plant species selected during the course of the study. The ant species that remove seeds will be
identified, removal rates and dispersal distances will be quantified, and the seed deposition sites will be determined. For the analysis of anti-herbivore services, the attacks by ants on simulated herbivores will be monitored simultaneously in selected plants species.

- SUBPROJECT 10: Land use, natural regeneration and ecosystem services provided by the Caatinga: connecting conservation units and sustainability

This subproject is divided into six operational modules, including two scales of analysis, a local scale (within the Catimbau National Park and surrounding areas) and a regional scale (different polygons on broader scales).

**Module 1:** Land use and the distribution of the Caatinga vegetation (local scale) – Characterization of the relationships among (1) land use, (2) qualitative and quantitative distribution of the vegetation, and (3) demographic variation in the human populations of the study area, centered on the Catimbau National Park;

**Module 2:** Value of conservation and ecosystem services (local scale) – (1) Woody plants, ants, butterflies, and euglossines bee will be used as indicators of the value of the conservation of the native vegetation, (2) Above-ground plant biomass will be used to estimate the services associated with nutrient storage, (3) The ecosystem services, such as pest control, seed dispersal, and pollination, provided by specific organisms will be estimated, and (4) indicators obtained using satellite images will be used to estimate the services provided by the vegetation in relation to nutrient storage and cycling, soil protection, and climatic regulation;

**Module 3:** Regeneration dynamics and limiting factors (local scale) – This module will test the role of ecological processes (e.g., dispersal limitations) and keystone organisms
(goats, leafcutter ants, and the biological crust of the soil) in the regeneration of Caatinga vegetation;

**Module 4:** Natural capital and provision of services by Caatinga conservation units (regional scale) – Quantification of the natural capital and ecosystem services provided by strict conservation units in the Caatinga;

**Module 5:** Socioeconomic factors limiting the native vegetation cover (i.e., natural capital): dialog with sustainable development (regional scale) – (1) Determine how socioeconomic influence the provision of vegetation services at a regional scale, including the presence of conservation units, (2) Identify how public policy on a regional scale contributes to the regional degradation of the vegetation of the Caatinga and as a consequence, its services, (3) The principal public policies on sustainable development will be evaluated in the context of capital and services, and (4) Capital and services will be incorporated into a proposal for the adaptation of conservation units to climate change and sustainability;

**Module 6:** Divulgation of data and training of human resources – This module will be based on the training of human resources and the divulgation of the results of the research to a number of different sectors, including academics, local communities, administrators of conservation units, decision-makers, and proponents of public policy. In addition to proposing new products and tools, this module will support the measures currently under development in the Catimbau region (PELD-PRONEX-Catimbau).

- **SUBPROJECT 11: Floral odors in specialized Neotropical pollination systems**

  Samples (N = 10) will be collected from each species of the family Malpighiaceae using the dynamic headspace method (Raguso and Pellmyr, 1998) to characterize the
chemical profile of the volatile scents of each taxon. The inflorescences will be bagged in polyethylene pouches and the air will be sucked out using a suction pump. Control samples of the air and the foliage will be collected to ensure the absence of potential contaminants. The samples will be eluted with hexane and stored at -24°C. The compounds will be identified by gas chromatography-mass spectrometry (GC-MS). The equipment and procedures will be the same as those described by Maia et al. (2014).

4. Team expertise and collaboration records (List team members and affiliation and describe briefly):

i) the expertise of the members of the scientific team (Brazilians and foreigners) and its most relevant scientific contributions to the topics of the project;

PPGBV/UFPE - Brazil:

• Dr. Andrea Pedrosa-Harand (ORCID 0000-0001-5213-4770; Associate Professor; PQ 1-C). Specialist in the molecular cytogenetics and cytogenomics of plants, with experience in phylogeny and phylogeography. (SUBPROJECTS 1, 2 and 6).

• Dr. Ariadna Valentina de Freitas e Lopes (ORCID 0000-0001-5750-5913; Associate Professor; PQ 1D). Specialist in plant reproductive biology with a focus on the diversity of reprodutivas strategies, the functional diversity of these strategies, and reproductive success in the biological communities of the Caatinga and Atlantic Forest. (SUBPROJECT 10).

• Dr. Benoît Francis Patrice Loeuille (ORCID 0000-0001-6898-7858; Adjunct Professor). Specialist in the systematics and phylogeny of the Vernonieae (Asteraceae).
Conducts research on the evolution of the morphological and phytochemical diversity of the Neotropical Asteraceae from a phylogenetic perspective. (SUBPROJECT 4)

- Dr. Felipe Pimentel Lopes de Melo (ORCID 0000-0002-1271-3214; Adjunct Professor, PQ 2). Specialist in plant ecology. Researcher and collaborator at the Environmental Research Center of the Brazilian Northeast (CEPAN). (SUBPROJECT 7)

- Dr. Inara Roberta Leal (ORCID 0000-0001-9202-9828; Associate Professor, PQ 1B). Specialist in the plant ecology of the Caatinga and Atlantic Forest environments, with emphasis on the processes of habitat loss and fragmentation, and the proliferation of herbivores, in particular leafcutter ants. (SUBPROJECTS 8 and 9).

- Dr. Isabel Cristina Sobreira Machado (ORCID 0000-0001-5015-2393; Reader, PQ 1A). Experienced in the field of Floral Biology and reproductive systems, working principally in the fields of phenology, pollination, melittophyly, ornithophily, sphingophily, chiropteroiphily, Atlantic Forest, Caatinga. (SUBPROJECT 11).

- Dr. Leonardo Pessoa Felix (ORCID 0000-0001-9202-9828; Adjunct Professor). Specialist in the taxonomy of the phanerogams, with a primary focus on the floristics and cytogenetics of the species found on inselbergs, in particular the Orchidaceae. (SUBPROJECTS 2 and 5).

- Dr. Luiz Gustavo Souza (ORCID 0000-0002-5700-6097; Adjunct Professor). Specialist in the molecular cytogenetics and cytogenomics of plants, with experience in phylogeny and phylogeography. (SUBPROJECTS 1 and 2)

- Dr. Marcelo Guerra (ORCID 0000-0003-1438-9742; Reader; PQ 1-A). Specialist in the molecular cytogenetics and cytotaxonomy of plants, with emphasis on the
organization of the chromosomes (banding, epigenetic markers, holokinetic chromosomes, etc.). (SUBPROJECT 5)

- Dr. Mauro Guida dos Santos (ORCID 0000-0001-5146-4591; Associate Professor, PQ 2). Specialist in Ecophysiology, with emphasis on the hydrological relationships, gas exchange, carbon metabolism, and ecological anatomy of plants adapted to the semi-arid zone. (SUBPROJECT 8)

- Dr. Marcelo Tabarelli (ORCID 0000-0001-7573-7216; Associate Professor; PQ 1A). Specialist in plant ecology and conservation, collaborates with a number of entities working in favor of the conservation of biological diversity, such as Conservation International-Brazil, as a member of the executive council, the Boticário Foundation for the Protection of Nature, and the Environmental Research Center of the Brazilian Northeast (CEPAN). (SUBPROJECT 7, 8 and 9)

- Dr. Rafael Batista Louzada (ORCID 0000-0002-0040-7690; Adjunct Professor). Specialist in the systematics of Angiosperms, in particular the taxonomy, phylogeny, and biogeography of the Bromeliaceae. (SUBPROJECTS 3 and 4)

International partners:

**Australia: James Cook University**

- Katharina Nargar (née Schulte; ORCID 0000-0002-0459-5991; Adjunct Researcher). Specialist in the molecular systematics and phylogeography of tropical plants, focusing primarily on the families Orchidaceae and Bromeliaceae, in particular, phylogenetic studies of the subfamily Bromelioideae, including co-authorship of a paper on the phylogenetics of the genus *Cryptanthus*. (SUBPROJECT 3)
Australia: Research Institute for the Environment and Livelihoods

- Dr. Alan Neil Andersen (ORCID 0000-0003-1487-3323; Senior Researcher). Dr. Andersen works at two prestigious Australiana institutions, the CSIRO Land & Water, Tropical Ecosystems Research Centre, Darwin, and the Research Institute for the Environment and Livelihoods at Charles Darwin University, Darwin. Dr. Andersen has published more than 200 papers during his career and is one of the world’s foremost authorities on the ecology and conservation of ants. (SUBPROJECT 9)

Austria: University of Salzburg

- Dr. Stefan Dötterln (ORCID 0000-0001-5228-1332; Professor). Renowned researcher with innumerable publications on the chemistry of the floral odors that play a fundamental role in the attraction of insects. (SUBPROJECT 11)

Canada: University of Montreal

- Dr. Edeline Gagnon (ORCID 0000-0003-3212-9688; Plant Biology Research Institute and Department of Biological Sciences, University of Montréal, Canada, in collaboration with Dr. Lewis). Taxonomist of the *Caesalpinia* group and author of the principal molecular phylogeny of this group. (SUBPROJECT 1)
Germany: Bayreuth University

• Dra. Bettina Engelbrecht (ORCID 0000-0002-2546-5504; Professor). Specialist in the distribution patterns of trees along environmental gradients. Interested in particular in the relative importance of factors such as water, and the availability of sunlight and nutrients, herbivory, pathogens, seed dispersers, and historical processes (SUBPROJECT 8).

Germany: University of Kaiserslautern

• Dr. Burkhard Büdel (ORCID 0000-0002-1257-260X; Professor). Specialist in the ecology and ecophysiology of algae and pro-eukaryotic lichens, focusing on systematics, phylogeny, and phylogeography, and the diversity, ecology, and ecophysiology of biological crusts and biofilms on the soil and rock of arid and semi-arid zones, and microenvironments. (SUBPROJECT 8)

• Dr. Rainer Wirth (ORCID 0000-0001-8042-3123; Professor). Specialist in the study of species interactions and the stability and functioning of forest ecosystems in temperate and tropical regions. Studies include the impact of silvicultural land use and the fragmentation of the forest on the performance of herbivores, and plant-herbivore interactions (networks) in a landscape of temperate forest. (SUBPROJECT 8)

Mexico: National Autonomous University of Mexico

• Dr. Víctor Arroyo Rodríguez (ORCID 0000-0002-0858-0324; Reader, level B). Research focuses on the understanding of the factors that determine the maintenance of
the biodiversity of fragmented tropical landscapes, and the generation of data and theories that support the conception of strategies for the conservation of the species that inhabit these environments. (SUBPROJECT 7)

United States: University of Memphis

- Jennifer Mandel (ORCID 0000-0003-3539-2991; Assistant Professor). Specialist in population genetics, quantitative and evolutionary genetics, and phylogenetics. Uses field and laboratory techniques to understand the processes and mechanisms that determine the genetic, phenotypic, and ecological diversity of the natural world. (SUBPROJECT 4)

United Kingdom: Royal Botanic Gardens, Kew

- Dr. Mark Chase (ORCID 0000-0002-9927-4938; Senior Research Professor). Specialist in angiosperm phylogeny (Angiosperm Phylogeny Group), the classification and evolution of orchids, polyploidy, and epigenetics. (SUBPROJECTS 2 and 5)
- Dra. Ilia J. Leitch (ORCID 0000-0002-3837-8186; Senior Research Leader). Specialist in cytogenomics and the analysis of the variation in the size of plant genomes. (SUBPROJECT 1 and 2)
- Dr. Gwilym P. Lewis (ORCID 0000-0003-2599-4577; Research Leader). Principal taxonomist of the *Caesalpinia* group and leader of an international study group focusing on the integrative systematics of the legumes. (SUBPROJECT 1)
United Kingdom: University of East Anglia

- Dr. Carlos Peres (ORCID 0000-0002-1588-8765; Professor). Studies the community ecology of the wildlife of Amazonian forests, the population ecology of the principal resources of tropical forests, and the biological criteria for the development of major nature reserves. Has published approximately 280 papers over his career, and supervised and initiated the careers of 96 graduate students from 19 countries. In 1995, he was the recipient of the Bay Foundation (USA) “Leadership Prize for Biodiversity Conservation”, and in 2000, he was elected “Environment Leader for the New Millenium” by Time Magazine and the CNN network. (SUBPROJECT 10)

Uruguay: UDELAR, Montevideo, Uruguay

- Dra. Magdalena Vaio (ORCID 0000-0001-8377-6485; Professor). Specialist in the molecular cytogenetics of Paspalum, was a post-doctorate in the cytogenomics of repetitive sequences. (SUBPROJECT 6)

ii) previous and/or on going international collaborations;

- Dr. Andrea Pedrosa-Harand and Dr. Luiz Gustavo Souza com:

  - Dr. Andreas Houben (2018–2021), Leibniz-Institute of Plant Genetics and Crop Plant Research, Gatersleben, Germany: “Evolution and structure of holocentric chromosomes in plants” (PROBRAL/CAPES, project no. 88881.144086/2017-01).

  - Dr. Andrea C. Premoli (2016–2018), Comahue National University-CRUB, Bariloche, Argentina: “Techniques for genomic sequencing applied to the study of the evolution and
phylogenetics of genera considered to be key biogeographic groups” (Fund for Scientific and Technological Research (FONCYT), ANPCyT - PICT-2015-1563).

• **Dr. Andrea Pedrosa-Harand with:**

- Dr. Andreas Houben (2013–2015), Leibniz-Institute of Plant Genetics and Crop Plant Research, Gatersleben, Germany: “Centromeric structure and meiotic adaptations in *Rhynchospora pubera* (Cyperaceae), a species with holokinetic chromosomes” (Special Visiting Scientist Program, Science without Borders/CAPES, project no. 23038.009777/2012-50).


• **Dr. Ariadna Valentina Lopes with:**

- Dr. Emilio Bruna (2013–2016), University of Gainesville, USA: Functional diversity of plant reproductive traits in the Atlantic Forest and Caatinga.

- Dr. Lynn Dicks (2014–2017), University of East Anglia, UK: Thematic Assessment of pollination and pollinators, and food production of the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services).
• **Dra. Ariadna Valentina and Dr. Marelo Tabarelli with:**

  - Dr. Carlos Peres (2008–2013), University of East Anglia, UK. Loss of the diversity of the reproductive attributes of trees in remnants of the Atlantic Forest in northeastern Brazil.

• **Dr. Benoît Francis Patrice Locuille with:**


• **Dra. Inara Roberta Leal with:**

  - Dr. Alan Andersen (Research Institute for the Environment and Livelihoods, Australia)

  Professor Andersen has collaborated with our research group on a number of previous projects investigating the effects of anthropogenic impacts on the ant communities of the Caatinga (“Network of interactions and the ecology of seed dispersal in the Caatinga” Edital APQ FACEPE, process no. 0140-2.05/08; “The influence of
anthropogenic impacts on the network of interactions and the ecology of seed dispersal in the Caatinga” Edital Universal CNPq process no. 477290/2009-4; “Effects of the increase in disturbance and the reduction in rainfall on ant communities and their interactions with plants and herbivores”, Special Visiting Professor – PVE MEC/MCTI/CAPES/CNPq/FAPs process no. 88881.030482/2013-01).

- **Dr. Inara Leal and Dr. Marelo Tabarelli with:**

  - Dr. Burkhard Büdel (University of Kaiserslautern, Germany). Influence of leaf cutting ants on the vegetation structure of the Atlantic Forest Northeast (PROBRAL CAPES / DAAD. Project process number 257/07).

  - Dr. Bettina Engelbrecht (2017 - Current, University of Bayreuth, Germany). Soil use, natural regeneration and ecosystem services provided by the Caatinga: Connecting Conservation Units and sustainability (CNPq-ICMBio Research in Conservation Unit process number 421323 / 2017-5).


  These German researchers established an ongoing partnership with Leal and Tabarelli in 2001, which has generated substantial results in terms of the training of human resources and the production of high standard scientific papers. This partnership has resulted in the qualification of more than 49 graduate students (both Brazilian and German), and the publication of 26 papers, 10 book chapters, and almost a hundred
presentations in scientific events, made possible by continuous funding from programs such as CAPES-DFG, PROBRAL CAPES-DAAD, and CNPq-DFG.

- **Dr. Leonardo Félix with:**

- **Dr. Luiz Gustavo Souza with:**
  - Dra. Ilia J. Leitch (05-10/2017), Royal Botanic Gardens, Kew, UK: "Using genomic repeat abundance and cytogenomic approaches to infer phylogenetic relationships in *Caesalpinia* sensu lato (Fabaceae)” (bolsa de Estágio Pós-Doutoral no Exterior/CAPES).

- **Dr. Marcelo Guerra with:**
  - Dr. Cristina Mazzela (2007–2008), Universidad of the Republic, Faculty of Agronomy, Department of Plant Biology, Montevideo, Uruguay: “Taxonomic determination and genetic variability of species of the families Asteraceae and Alliaceae used actually or potentially as medicinal plants: *Baccharis* (section *Cauloptera*), *Achyrocline* and *Nothoscordum*” (Edital CNPq nº 027/2006 – Selection of proposals for joint research projects, development and innovation in the scope of bilateral agreements on international cooperation/CNPq).


- Dr. Rafael Batista Louzada with:

  - Katharina Nargar & Georg Zizka (2009–2013), Senckenberg Institute, Germany: Phylogeny of *Orthophytum* and related genera (Bromeliaceae).

**iii) perspectives of consolidating international collaborations;**

The international collaborators listed in section 4(i) have, in most cases, already initiated their interchange with the PPGBV researchers, and have manifested their interest in consolidating these partnerships, and establishing formal agreements through the present proposal (see Appendices).

**iv) ongoing or potential collaboration between the researchers belonging to different graduate programs at UFPE on the topics of the project.**

Dr. Daniela Navarro, of the UFPE Graduate Program in Chemistry collaborates with our research group on the projects that involve the analysis of floral scents (SUBPROJECT 11).
Dr. Ana Maria Benko Iseppon, of the UFPE Graduate Program in Genetics collaborates with our research group on the projects that involve the expression of transcription factors in plants under stress (SUBPROJECT 8).
5. Budget outline (see Funding items and values at [https://goo.gl/b98cwi](https://goo.gl/b98cwi) and suggestions provided in Item 9.1 of this call)

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<th>Budget</th>
<th>Subproject</th>
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<th>Country</th>
<th>quotas/months/days</th>
<th>Total R$ with additional</th>
<th>Total R$ without additional</th>
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<th>Country</th>
<th>quotas/months/days</th>
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<th>Total R$ without additional</th>
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<td>Total R$ without additional</td>
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<td>summer/winter schools (S/WS), up to 3 months</td>
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<td>COST: Maintenance of Projects (up to R $ 10,000.00 per year)</td>
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6. Outcomes (Describe the expected impacts the project will bring to the graduate programs at UFPE and for the Institutional Internationalization Policy)

It is hoped that the results of the present proposal will contribute to the a progressive increase in the number and quality of the papers published by the UFPE Graduate Program in Plant Biology (PPGBV) and the NPGBio, through the consolidation of existing partnerships, and the establishment of new collaborations with foreign institutions, in particular those involving the youngest members of the PPGBV staff, who have yet to establish an extensive network of international collaboration. As the PPGBV is currently a CAPES level 6 program, it is hoped that the expansion of nB1+ involving its students will contribute to an increase in the impact of the program’s scientific production in relation to its international partners, thus contributing to the consolidation of the internationalization of the program, which will hopefully contribute to its eventual upgrade to CAPES level 7.

7. References


Louzada RB, Schulte K, Wanderley MGL et al. 2014. Molecular phylogeny of the Brazilian endemic genus Orthophytum (Bromelioidae, Bromeliaceae) and its implications on morphological character evolution. Molecular Phylogenetics and Evolution 77: 54-64.


