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## **Towards the optimization of botanical insecticides research: *Aedes aegypti* larvicidal natural products in French Guiana**

Michaël Falkowski, Arnaud Jahn-Oyac, Guillaume Odonne, Claudiane Flora, Yannick Estevez, Seindé Touré, Isabelle Boulogne, Jean-Charles Robinson, Didier Béreau, Philippe Petit, et al.

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## Manuscript Details

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<b>Title</b>	Towards the optimization of botanical insecticides research: <i>Aedes aegypti</i> larvicidal natural products in French Guiana
<b>Article type</b>	Research Paper

### Abstract

Natural products have proven to be an immeasurable source of bioactive compounds. The exceptional biodiversity encountered in Amazonia, alongside a rich entomofauna and frequent interactions with various herbivores is the crucible of a promising chemodiversity. This prompted us to search for novel botanical insecticides in French Guiana. As this French overseas department faces severe issues linked to insects, notably the strong incidence of vector-borne infectious diseases, we decided to focus our research on products able to control the mosquito *Aedes aegypti*. We tested 452 extracts obtained from 85 species originating from 36 botanical families and collected in contrasted environments against an *Aedes aegypti* laboratory strain susceptible to all insecticides, and a natural population resistant to both pyrethroid and organophosphate insecticides collected in Cayenne for the most active of them. 8 species (*Maytenus oblongata* Reissek, Celastraceae; *Costus erythrothyrus* Loes., Costaceae; *Humiria balsamifera* Aubl., Humiriaceae; *Sextonia rubra* (Mez) van der Werff, Lauraceae; *Piper hispidum* Sw., Piperaceae; *Laetia procera* (Poepp.) Eichl., Salicaceae; *Matayba arborescens* (Aubl.) Radlk., Sapindaceae; and *Cupania scrobitulata* Rich., Sapindaceae) led to extracts exhibiting more than 50% larval mortality after 48h of exposition at 100 µg/mL against the natural population and were considered active. Selectivity and phytochemistry of these extracts were therefore investigated and discussed, and some active compounds highlighted. Multivariate analysis highlighted that solvents, plant tissues, plant family and location had a significant effect on mortality while light, available resources and vegetation type did not. Through this case study we highlighted that plant defensive chemistry mechanisms are crucial while searching for novel insecticidal products.

**Keywords** Mosquito larvicides; Culicidae; Amazonian chemodiversity; screening optimization; quasi-Poisson generalized linear model; chemical defense

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**Suggested reviewers** John Arnason, Murray Isman, Charles Cantrell

## Submission Files Included in this PDF

### File Name [File Type]

Acta\_Trop\_\_Insecticides\_French\_Guiana\_letter\_rev.docx [Cover Letter]

Response\_reviewer\_ActaTrop.docx [Response to Reviewers]

Falkowski\_Botanical insecticides\_Acta\_Trop\_highlights.docx [Highlights]

Falkowski\_Botanical insecticides\_Acta\_Trop\_graph\_abstract.pdf [Graphical Abstract]

Falkowski\_Botanical insecticides\_Acta\_Trop\_revised\_clean.docx [Manuscript File]

Falkowski\_Botanical insecticides\_SI\_Acta\_Trop.docx [Table]

declaration-of-competing-interests.docx [Conflict of Interest]

To view all the submission files, including those not included in the PDF, click on the manuscript title on your EVISE Homepage, then click 'Download zip file'.

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Cayenne, August 23th, 2019

Dear Editor,

Please find attached the revised version of the manuscript now entitled "Towards the optimization of botanical insecticides research: *Aedes aegypti* larvicidal natural products in French Guiana" for consideration as a research article in *Acta Tropica*. This manuscript now has an abstract of 254 words; a main text of 5634 words from introduction to conclusion section; 90 references; 5 tables and 2 figures. Please also find attached 2 tables and 1 figure of supporting information. All of the co-authors have read this manuscript and have agreed to its content and conclusions.

Alongside you will find a file including the point-by-point response to the reviewers. We thank them and the editor for their valuable suggestions and addressed their remarks as carefully as possible to improve our manuscript and make it suitable for publication in *Acta Tropica*.

We hope that you will find it worthwhile for publication and look forward to hearing from you.

On behalf of the authors,

Dr Emeline Houël

A handwritten signature in black ink, appearing to read 'Houël', is written over a white rectangular background.

Michaël Falkowski

Jean-Charles Robinson

Arnaud Jahn-Oyac

Didier Béreau

Guillaume Odonne

Philippe Petit

Claudiane Flora

Didier Azam

Yannick Estevez

Maïra Coke

Seindé Touré

Isabelle Boulogne

Jean Issaly

Pascal Gaborit

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Didier Stien

A handwritten signature in black ink. It features a large, bold 'V' followed by a series of loops and a long horizontal stroke at the bottom.

Véronique Eparvier

A handwritten signature in black ink. It is a cursive signature with a large initial 'I' and a long horizontal stroke at the end.

Isabelle Dusfour

A handwritten signature in black ink, identical to the one above. It is a cursive signature with a large initial 'I' and a long horizontal stroke at the end.

Dear Editor,

We thank you and the 3 reviewers for the positive comments and valuable suggestions that helped us to improve our manuscript. You will find herewith a revised version that addresses editor's and reviewers' questions, comments and suggestions. We provide our replies below (in blue).

**Comments from the editors and reviewers:**

**- Editor**

- Nice work, well conceived and presented!

The authors warmly thank the editor for having taken the time to review the manuscript and for this very positive comment.

In addition to the corrections required by reviewers please consider the following points:

- Title: according to its aim, Acta Tropica does not welcome case studies and reports. Please use a more appealing title, may I suggest something like: "Towards the optimization of botanical insecticides research: *Aedes aegypti* larvicidal natural products in French Guiana"? Feel free to rework as you prefer.

The title was modified as suggested.

- Avoid using keywords (e.g. *Aedes aegypti*) already in the title: this is not suitable for indexing purposes.

Keywords were modified as follows: "Mosquito larvicides; Culicidae; Amazonian chemodiversity; screening optimization; quasi-Poisson generalized linear model; chemical defense" instead of "Botanical insecticides; *Aedes aegypti*; larvicidal; French Guiana; quasi-Poisson generalized linear model; chemical defense" (lines 58-59)

- Please add Highlights and a Graphical Abstract. This would boost the appeal of this work.

Highlights and a Graphical Abstract were added as suggested. The designer of the graphical abstract was added in the acknowledgments section.

- Line 526: add publication year here!

Done.

- I noted that Rev. 1 suggested to cite a very recent review on Acta Tropica (Pavela et al. 2019) covering more than 400 plants extracts and also focused on botanical insecticide development in the real-world, where I am also coauthor. I should agree with his/her suggestion since this review really fits well the topic of your study. On the other hand, since I am a coauthor of it, I want to clearly highlight that you are not forced in any way to cite it. I just hope you find it of interest for your knowledge; then consider it for improving your

references in this occasion if you feel it can add something to the theoretical background of the study.

We added the suggested reference in the introduction (lines 67-70). This reference was also mentioned in the text (lines 289-290; 451; 461) to provide complementary discussion elements.

An article cited in the suggested reference (Pavela et al., 2015) was also added to improve the manuscript (lines 298-299).

We sincerely thank Reviewer 1 and the Editor for this suggestion. Some members of the team indeed currently work on a novel project concerning the development of larvicidal formulations based on *Sextonia rubra* wood extract, identified as promising in the presented work. The objective is to deepen the results obtained in the laboratory concerning the crude extract and isolated compounds. We hope to progress towards the development of a marketable product through semi-operational bioassays and the investigation of the mode of action and eco- and cytotoxicity. Therefore we found in the suggested reference many considerations and articles that will be more than useful for this new project.

Again, thanks for submitting this nice work to Acta Tropica.

Thank you again for having taken the time to review this manuscript, and for these encouraging comments!

#### **- Reviewer 1**

- In this work authors tested 452 extracts obtained from 85 species growing in French Guiana against different strains of *Aedes aegypti* (both susceptible and resistant to pyrethroid and organophosphate insecticides). They found out that some extracts exhibited more than 50% mortality at 100 ppm. Furthermore, they determined cytotoxicity and non-target effects of plant extracts. Although, this work is well written and scientifically sound, I found some areas that need improvement. Please see the comments below.

The authors thank Reviewer 1 for the positive comments. Responses to the questions and suggestions are presented below.

- Only the extract of *Costus erythrothyrus* was chemically characterized by column chromatography and NMR. Why only this one? What about the other active extracts? For instance, authors did not analyze the extract from *Piper hispidum* and they justified that with the fact that *Piper* species have been much investigated so far. In my opinion, this is not enough. For *Sextonia rubra* authors limited to cite some references rather than performing chemical analysis. I suggest to chemically characterize the most active extracts.

The phytochemical analysis of *C. erythrothyrus* extract was indeed initially the only one presented integrally (materials & methods and results) in this article. However some other

phytochemical studies were performed during the project, even if some choices were made and did not allow us to fully characterize all the active extracts. In particular, we chose to work more intensely on two species, *M. oblongata* and *S. rubra*. The authors therefore hope that the following comments and modification will increase the clarity of the text concerning this point, and answer Reviewer 1 questions and suggestions.

Concerning *L. procera* bark extract, preliminary phytochemical studies were performed but were unfortunately inconclusive. This information was added in the text as follows (lines 437-439): “Preliminary phytochemical studies were performed but did not lead to a clear conclusion concerning the pure compounds responsible for the bioactivity of the extract.” and the last sentence of the paragraph modified (lines 439-441): “It would thus be interesting to pursue the evaluation of the larvicidal activity of the pure compounds, and correlate *L. procera* bark extracts chemical profiles and larvicidal activity for example through a metabolomic approach.”

*M. oblongata* extract bioguided fractionation was performed by our team in the context of the same project. This work having been published earlier in the *Journal of Natural Products* (Touré et al. 2017) due to the important amount of NMR data to be displayed, only the reference of this article was cited here.

The full extract and active compounds characterization having indeed been performed in the context of the same project, we added the following sentence to clarify this point (lines 448-451): “Whereas published elsewhere, this work was performed by our team in the context of the same project, as bioguided fractionation of active extracts is indeed a key step to progress towards the development of novel botanical insecticides (Isman and Grieneisen, 2014; Pavela 2015; Pavela et al. 2019).”

Concerning the choices we made (for example not further studying *H. balsamifera* and *P. hispidum* extracts, which were not the most active in our hands), the following sentence was added (lines 459-465):

“Moreover, if the potential development of a novel botanical insecticide is logically based on its biological activity and its selectivity, other criteria such as the availability of the resource are also fundamental when it comes to valorization (Borges et al. 2019; Pavela et al., 2019). We therefore chose to concentrate on *S. rubra* extract, the most active extract but also the 4th species exploited in the forest industry in French Guiana, leading to wood wastes that could represent a source of valuable material and undisclosed as larvicidal product before the work of our team.”

Concerning *S. rubra*, it was indeed not clear which part of the cited work was performed by our team in the context of the project and which was only external literature. The text was therefore modified as follows:

Lines 466-467: “*Sextonia rubra* (Mez) Van der Werff (Lauraceae) wood and bark extracts were actually shown to possess excellent larvicidal activities in the context of this study.”

Lines 473-476: “As part of the cited work was performed by member of our team, we were able to characterize the chemical composition of the larvicidal extract and confirm the presence of the two  $\gamma$ -lactones rubrenolide and rubrymolide according to the previously



described protocols, to characterize the chemical composition of the larvicidal extract and confirm the presence of the two  $\gamma$ -lactones rubrenolide and rubrynolide.”

Lines 476-477: “We also highlighted during this project the strong larvicidal activity of these two compounds against *Ae. aegypti*”

To clarify this point, the Material and Methods section was modified in point 2.6. (lines 223-262) to give more technical details, or indicate references to the work concerning chemical characterization and published elsewhere by our team.

- Introduction: Insert a paragraph dealing with the vector, *Aedes aegypti*, on which they assayed the plant extracts.

Some information and references were added in the introduction concerning *Ae. aegypti* (lines 81-88).

- You may consider to cite in Introduction this important review on plant extracts as mosquito larvicides: *Acta Tropica* 2019, 193, 236-271; in this review some very active (LC50 < 10 ppm) plant extracts against mosquito larvae have been reported and described in detail.

The reference to the review was added in the introduction. For a more detailed response please refer to the editor’s comments section above.

- It is not clear the aim of the work at the bottom of Introduction.

The presented study had as principal aim to discover novel botanical insecticides from the Amazonian biodiversity. In this context we also 1/ wanted to investigate the link between plants chemical defense and insecticidal properties 2/ discuss some methodological issues, both points aiming at optimizing plant screening protocols.

Some modifications were done in the introduction (lines 110-118) in an attempt to improve its clarity, according to Reviewer 1 and Reviewer 3 suggestions (for Reviewer 3 see further comments below):

“The objective was to consider plants having various growth-defense trade-offs in order to potentially improve our capacity to discover insecticidal compounds, and investigate ecological trends governing insecticidal properties. This approach has been inspired by the concept of “human chemical defenses” presented by Berenbaum (Berenbaum 1995). Literature-based chemotaxonomy was also included as a criterion for plant selection in our search for novel larvicidal extracts and compounds. As a consequence of the project, some methodological issues had to be discussed considering the huge amount of scientific literature already dealing with botanical insecticides research (Isman and Grieneisen 2014). The present contribution therefore also addresses some of these issues through illustrative examples encountered along the study, in an attempt to optimize plant screening for natural insecticides discovery.

- Sect. 2.3.: replace LD50 with LC50.

The modification was done throughout the text.

- Table 2 : Insert the LC50/90 values for the most active extracts.

To remain consistent with the mortality values given after 48h of exposition, LC<sub>50</sub> values calculated at 48h for the active extracts (extracts exhibiting larvicidal activities ≥ 50% against Cayenne resistant strain and highlighted in bold characters in Table 2) were inserted in Table 2.

- Table 3: Report the IC50 values on KB and MRC5 cells.

The test performed on KB and MRC5 cells were only performed at the two concentrations indicated in the table (10 µg/ml and 1 µg/ml) for each extract. It therefore does not allow us to calculate an IC50. At this stage of the project, as cytotoxicity was only used as a tool to restrain the screening to the most promising extracts in terms of activity and selectivity, the measured values were sufficient to fulfill this aim. But we agree to the fact that the complete characterization of the extract and compounds through IC50 measurement is an important step, and this will be performed for *S. rubra* in the context of the ongoing above-mentioned project.

- Only 3 out of 8 active plant extracts were assayed on non-target organisms. What about the remaining ones?

In the context of the reported project we only had the opportunity to test 3 extracts. During the novel ongoing project concerning *S. rubra* and already mentioned above, we will assess the crude extract and pure compounds ecotoxicity, as well as the bioactivity of formulations on non-target organisms. More results will therefore be available at the end of this second project.

- It is unlikely that the active compounds of *Costus erythrothyrus* extract are fatty acids. I suggest to analyze further this extract in order to highlight some bioactive compounds. Otherwise, I suggest to assay the identified fatty acids in order to confirm authors' hypothesis.

As described in the manuscript (lines 407-408): "In the case of this extract, bioguided fractionation allowed us to isolate an active mixture of 3 fatty acids." So to our knowledge these compounds reasonably seems linked to the larvicidal activity, which is also consistent with the existing literature (Harada et al. 2000; Rahuman et al. 2008; Ramsewak et al. 2001; Santos et al. 2017). However, we agree with Reviewer1 concerning the fact that further studies would be of great interest, in particular due to the variability observed concerning *C. erythrothyrus* extracts activity, and some of them were indeed discussed by our team. However, as we unfortunately do not have any more of the active fraction available in the laboratory, and as we chose to further investigate *S. rubra* wood extract as explained above, these studies would be the object of a future work. To underline this point the following sentence was added in the text: "Further studies to investigate these mechanisms and the compounds responsible for the biological activity would thus be of great interest." (lines 406-407).

- **Reviewer 2**

- Accept.

The authors thank Reviewer 2 for having reviewed and accepted the submitted work.

### - Reviewer 3

- While this manuscript basically reports a screening study of crude plant extracts, its' value is enhanced because (i) extracts are tested against both insecticide-susceptible and – resistant populations; (ii) extracts are tested against indicator non-target aquatic organisms to determine ecotoxicity; (iii) extracts are tested against two human cell lines to assess general cytotoxicity; and (iv) a very large number of extracts from a wide range of plant taxa are evaluated. The inclusion of deltamethrin and extracts of *Muelleria* as positive controls is applauded, although these were only tested against the mosquito larvae and not against the non-targets nor the cell cultures. I didn't see any reference to permethrin effects on the mosquitoes in the Results and Discussion section, although I may have missed it.

The authors are grateful to Reviewer 3 for the comments and suggestions.

Concerning the use of insecticide-resistant mosquito populations, a sentence was rephrased in the abstract (lines 43-44 of the revised manuscript): we added “for the most active of them” at the end of the sentence as the text was not completely clear about the number of extracts tested against the insecticide-resistant population.

Other points:

1. Why were the *Sextonia* extracts included in Table 3 if they were not tested? This seems strange.

Thank you for this comment, it is indeed not logical. The lines corresponding to *S. rubra* extracts were deleted from the table. As the cytotoxicity of these extracts will be further evaluated in a currently ongoing project, a sentence was added in the text (Lines 490-492): “This point will thus be further evaluated in the context of an ongoing project which aims at deepening the above-described results regarding the crude extract and isolated compounds and progressing towards the development of a marketable product.”

The beginning of the sentence was also rephrased as asked (see the last point of the responses to reviewers): “Complementary results have also been published, which highlighted notable toxicity for rubrenolide against several human cancer cell lines (Tofoli et al. 2016).

2. The pairwise comparisons between plant parts and between extracting solvents is logical and useful, but I don't see the value in the comparisons between pairs of plant families.

Our objective through the multivariate analysis was to evaluate the importance of several parameters considering the larvicidal activity. The chosen factors were as well related to the extraction method (solvents) as to plant collection criteria. As these criteria were based both on chemical defense concerns and on chemotaxonomy, pairwise comparisons between plant families were also included. To clarify this point the word “chemotaxonomic” was added in

the Material and Methods section (point 2.7, line 271): “to relate mortality responses to the technical, chemotaxonomic and environmental predictor variables.”

3. The paragraph starting on line 78 seems a bit ecologically gratuitous to me. It would be much simpler to say that plant biodiversity is highest in the tropics, and especially in Amazonia (with a reference), and that herbivore and pathogen selection pressure on plants is probably highest in the tropics as well (with a reference).

In this paragraph we described the various biotic and abiotic parameters which lead to modifications of the growth/defense trade-offs concerning resource allocations to explain why we chose to collect various plant parts coming from ecologically contrasted environments and different vegetation types. However, the link between this paragraph and the following could indeed be better explained. To clarify this point the following paragraph was modified as follows (lines 108-113):

“For a few years, our team has therefore built a collection of plant extracts from ecologically contrasted Amazonian environments, including long-lasting trees and herbaceous plants, extracted from different plant organs. The objective was to consider plants having various growth-defense trade-offs in order to potentially improve our capacity to discover insecticidal compounds, and attempt to investigate ecological trends governing insecticidal properties.”

But I believe that the logic between natural plant chemical defense and the search for natural insecticides is flawed. Why? When we screen plants, we are searching for exceptions to the rule, i.e., plant natural products that are acutely toxic to insects. This is searching for needles in a haystack, for the simple reason that the *modus operandi* for plants in nature is to discourage herbivory (or fungal infection) – either behaviorally or physiologically, rather than to kill the challenger outright. Yet the latter is what humans attempt to do when using chemicals (natural or otherwise) to manage pest populations. How many botanical pest control products work strictly as feeding/oviposition deterrents or as larval growth inhibitors? None that I know of.

Thank you for this interesting comment! This is a complex subject that could be intensively discussed. Indeed, and even if the authors globally agree with the rather exceptional presence of acutely toxic substances for insects in plants, this discussion may also be replaced in a Darwinian perspective. As far as there is no determinism in plant-insect coevolution, finding highly insecticidal substances remains in fact probable, as what gives extra fitness to an individual tends to be selected positively as far as the cost is not exaggerated. In particular, the publication written by Doyle McKey (Am. Nat. 1974) about the adaptive patterns in alkaloid physiology highlight many points of great interest concerning this subject and the defensive role of these highly toxic compounds, also presenting other biological characteristics (bitter taste in case of herbivory, feeding stimulant for some species...).

As an extensive discussion about this point was to our opinion difficult to integrate in the article, we however added the following sentence in the conclusion to highlight this point to the readers (lines 581-583): “Moreover, we also exemplified that plant defensive chemistry

mechanisms are crucial while trying to discover insecticidal products, even if the search for toxic compounds only encompasses a small facet of this highly complex machinery.

4. Line 373: "It can be assumed that defense compounds were produced by the plant on this occasion." I think this is a pretty big assumption. It is a possibility, but there are other reasons why this particular sample was bioactive. I don't think you can make this claim without some supporting chemistry from your sample.

Thank you for this comment. This part of the sentence was modified as follows, and the end of the paragraph modified according to this comment and a suggestion made by Reviewer 1:

Lines 405-407: "Defense compounds may have been produced by the plant on this occasion, and further studies to investigate these mechanisms and the compounds responsible for the biological activity would thus be of great interest."

Lines 418-419: "Therefore the fact that a single extract was found active might be correlated with the activation of defense mechanisms in response to herbivory damage and this observation could be the subject of complementary studies."

5. Line 438: "Complementary results..." This is an incomplete sentence. Please rewrite it.

This sentence was rephrased (now line 488): "Complementary results have also been published, which highlighted notable toxicity for rubrenolide against several human cancer cell lines (Tofoli et al. 2016)."

## 1 **Highlights**

- 2 • French Guiana biodiversity was explored for the search of novel botanical insecticidal
- 3 products
- 4 • 452 extracts from 85 plant species were tested for larvicidal activity against *Aedes aegypti*
- 5 • Bioassays included both insecticide-susceptible and -resistant *Ae. aegypti* populations
- 6 *Sextonia rubra* wood extract and its main components were highlighted as promising
- 7 products
- 8 • Correlations between extracts larvicidal activity and plants chemical defense were
- 9 investigated

1 **Graphical abstract**

2 **Towards the optimization of botanical insecticides research: *Aedes aegypti* larvicidal**  
3 **natural products in French Guiana**

4 Michaël Falkowski<sup>a</sup>, Arnaud Jahn-Oyac<sup>a</sup>, Guillaume Odonne<sup>b</sup>, Claudiane Flora<sup>a</sup>, Yannick  
5 Estevez<sup>a</sup>, Seindé Touré<sup>a,c</sup>, Isabelle Boulogne<sup>a,d,e</sup>, Jean-Charles Robinson<sup>f</sup>, Didier Béreau<sup>f</sup>,  
6 Philippe Petit<sup>d</sup>, Didier Azam<sup>g</sup>, Maïra Coke<sup>g</sup>, Jean Issaly<sup>h</sup>, Pascal Gaborit<sup>h</sup>, Didier Stien<sup>i</sup>,  
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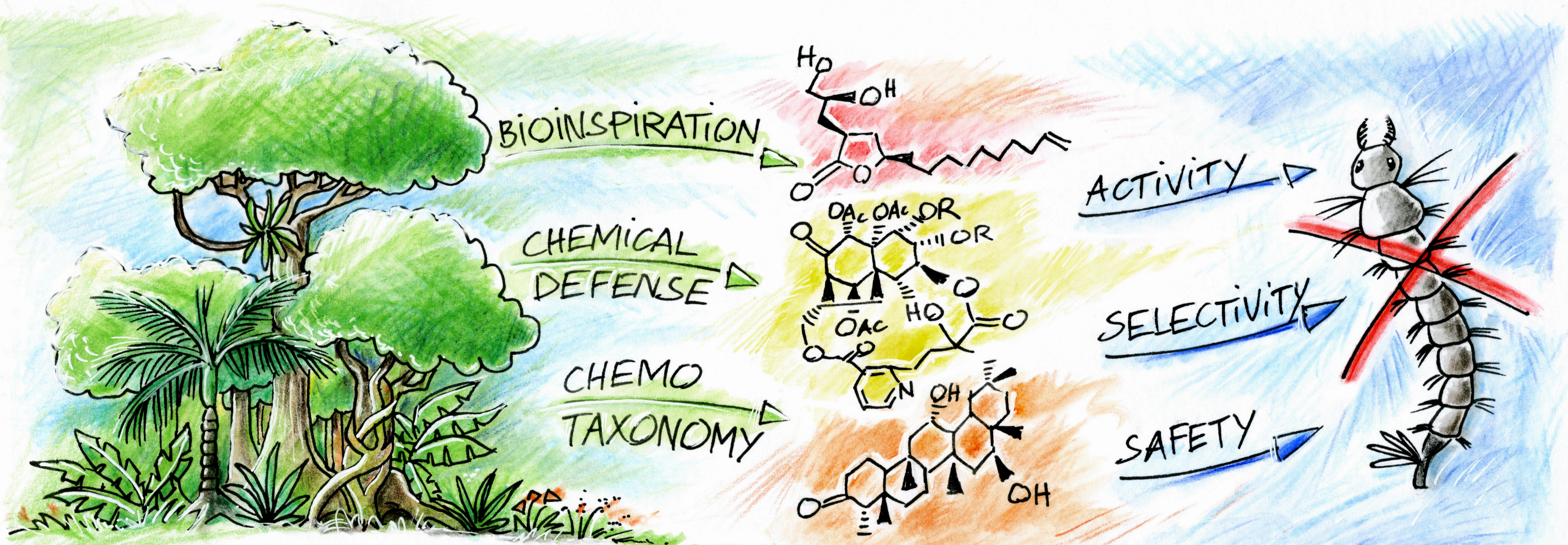
## 35 **Summary**

36 French Guiana biodiversity was explored for the search of novel larvicidal products against  
37 both insecticide-susceptible and -resistant *Aedes aegypti* populations.

38

39





RAINFOREST BIODIVERSITY — CHEMODIVERSITY — BOTANICAL INSECTICIDES

1 **Towards the optimization of botanical insecticides research: *Aedes aegypti* larvicidal**  
2 **natural products in French Guiana**

3 Michaël Falkowski<sup>a</sup>, Arnaud Jahn-Oyac<sup>a</sup>, Guillaume Odonne<sup>b</sup>, Claudiane Flora<sup>a</sup>, Yannick  
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### 33 **Abstract**

34 Natural products have proven to be an immeasurable source of bioactive compounds. The  
35 exceptional biodiversity encountered in Amazonia, alongside a rich entomofauna and  
36 frequent interactions with various herbivores is the crucible of a promising chemodiversity.  
37 This prompted us to search for novel botanical insecticides in French Guiana. As this French  
38 overseas department faces severe issues linked to insects, notably the strong incidence of  
39 vector-borne infectious diseases, we decided to focus our research on products able to  
40 control the mosquito *Aedes aegypti*. We tested 452 extracts obtained from 85 species  
41 originating from 36 botanical families and collected in contrasted environments against an  
42 *Aedes aegypti* laboratory strain susceptible to all insecticides, and a natural population  
43 resistant to both pyrethroid and organophosphate insecticides collected in Cayenne for the  
44 most active of them. 8 species (*Maytenus oblongata* Reissek, Celastraceae; *Costus*  
45 *erythrothyrus* Loes., Costaceae; *Humiria balsamifera* Aubl., Humiriaceae; *Sextonia rubra*  
46 (Mez) van der Werff, Lauraceae; *Piper hispidum* Sw., Piperaceae; *Laetia procera* (Poepp.)  
47 Eichl., Salicaceae; *Matayba arborescens* (Aubl.) Radlk., Sapindaceae; and *Cupania*  
48 *scrobitulata* Rich., Sapindaceae) led to extracts exhibiting more than 50% larval mortality  
49 after 48h of exposition at 100 µg/mL against the natural population and were considered

50 active. Selectivity and phytochemistry of these extracts were therefore investigated and  
51 discussed, and some active compounds highlighted. Multivariate analysis highlighted that  
52 solvents, plant tissues, plant family and location had a significant effect on mortality while  
53 light, available resources and vegetation type did not. Through this case study we highlighted  
54 that plant defensive chemistry mechanisms are crucial while searching for novel insecticidal  
55 products.

56

## 57 **Keywords**

58 Mosquito larvicides; Culicidae; Amazonian chemodiversity; screening optimization; quasi-  
59 Poisson generalized linear model; chemical defense

60

61

## 62 **1. Introduction**

63 Although botanical insecticides are at the origin of all insecticidal compounds, they have  
64 been laid or put aside by the agrochemical industry. However due to the great damages  
65 caused by the overuse of synthetic compounds, natural products and molecules obtained  
66 from plants are again considered suitable pest control alternatives (George et al. 2014;  
67 Gerwick and Sparks 2014; Isman 2015). The considerable needs, efforts, challenges and  
68 limitations of this research are in particular described in a recent review, also presenting a  
69 wide range of plant extracts tested for larvicidal activity against various mosquitoes (Pavela  
70 et al., 2019).

71 Intensification of research on natural insecticides is in particular due to the crucial  
72 need of effective products to control mosquito vectors of pathogens, particularly viruses and  
73 *Plasmodium* parasites (Benelli 2015; Benelli and Mehlhorn 2016). Indeed during last years,  
74 the world has regularly experienced the emergence or re-emergence of arthropod-borne  
75 viruses such as yellow fever, dengue, chikungunya, and more recently Zika viruses. As  
76 vector control remains an important, if not the sole tool to fight diseases spread, this

77 increasing number of outbreaks alongside the expansion of insecticide resistance urge the  
78 development of novel molecules to control invasive mosquito populations such as *Aedes*  
79 *aegypti* (L., 1762) and *Aedes albopictus* (Skuse, 1895) (Carvalho and Moreira 2017; Fauci  
80 and Morens 2016; Faucon et al. 2015; Higgs and Vanlandingham 2015; Moyes et al. 2017).  
81 In particular *Ae. aegypti* Linnaeus (Diptera: Culicidae) is a cosmopolitan species originating  
82 from Africa but now well-established in all tropical and subtropical regions. This mostly  
83 diurnal anthropophilic mosquito is found in urban communities and surrounding area, its  
84 presence being favoured by the existence of artificial breeding sites such as used tires, water  
85 tanks or flower pots. Its opportunistic behavior, high adaptation ability and biological  
86 characteristic such as eggs resistant to desiccation, alongside with trade globalization and  
87 rapid urbanization are some keys of this species' ecological success (Carvalho and Moreira  
88 2017; Simmons et al., 2012; Abilio et al., 2018). As sessile organisms, plants must have  
89 developed a wide range of secondary metabolites as defense compounds against predators  
90 and pests during their evolution (Agrawal and Weber 2015; Fraenkel 1959). The exceptional  
91 biodiversity of plants, entomofauna and herbivores in the tropics leads to a promising  
92 chemodiversity, due to the constant and dynamic interactions between plants and their  
93 environment (Becerra 2007; Ehrlich and Raven 1964; Richards et al. 2015). Some factors  
94 were highlighted for playing a major role in the effectiveness of defense. According to the  
95 optimal defense theory, the allocation of defense chemicals is driven by the predation  
96 pressure exercised on a given plant organ, and the fitness value of this organ for the plant  
97 (McCall and Fordyce 2010; McKey 1974). Besides, not only this fitness value but also  
98 resources from a given environment would drive both the type and the amount of secondary  
99 metabolites (Coley et al. 1985; Endara and Coley, 2011). Open environments also represent  
100 places of higher herbivorous insects' abundance, and therefore larger insects-plants  
101 interactions, which could lead to the production of more, and/or more diverse insecticidal  
102 compounds (Lamarre et al. 2012). The type of defense may also differ between plants. Long-  
103 living, slow-growing species including woody plants would allocate resources to highly  
104 concentrated quantitative defenses such as polyphenols and tannins, while short-lived

105 species, e.g. herbaceous plants, would synthesize smaller amount of low molecular weight  
106 toxic compounds such as alkaloids, phenolic compounds or cyanogenic glycosides (Feeny  
107 1976; Rhoades and Cates 1976; Smilanich et al. 2016).

108 For a few years, our team has therefore built a collection of plant extracts from  
109 ecologically contrasted Amazonian environments, including long-lasting trees and  
110 herbaceous plants, extracted from different plant organs. The objective was to consider  
111 plants having various growth-defense trade-offs in order to potentially improve our capacity  
112 to discover insecticidal compounds, and investigate ecological trends governing insecticidal  
113 properties. This approach has been inspired by the concept of “human chemical defenses”  
114 presented by Berenbaum (Berenbaum 1995). Literature-based chemotaxonomy was also  
115 included as a criterion for plant selection in our search for novel larvicidal extracts and  
116 compounds. As a consequence of the project, some methodological issues had to be  
117 discussed considering the huge amount of scientific literature already dealing with botanical  
118 insecticides research (Isman and Grieneisen 2014). The present contribution therefore also  
119 addresses some of these issues through illustrative examples encountered along the study,  
120 in an attempt to optimize plant screening for natural insecticides discovery.

121

## 122 **2. Materials and methods**

### 123 *2.1. Plant material*

124

125 All plant species (Table 1) were collected in French Guiana. They are not protected species  
126 and their collection was allowed without restriction at the concerned locations. Collection  
127 authorizations were given by the ONF (National Forest Office) where necessary. Herbarium  
128 vouchers were deposited in French Guiana Herbarium (CAY) where specialists confirmed  
129 botanical identification. All collection data are available at: [http://publish.plantnet-](http://publish.plantnet-project.org/project/caypub)  
130 [project.org/project/caypub](http://publish.plantnet-project.org/project/caypub).

Botanical families	Plant species	CAY	Location <sup>a</sup>	Plant part
<b>Annonaceae</b>	<i>Anaxagorea dolichocarpa</i> Sprague & Sandwith	Odonne 721	Ko	Leaves, stems
	<i>Guatteria ouregou</i> (Aubl.) Dunal	Odonne 718	Ko	Leaves, stems
	<i>Xylopia cayennensis</i> Maas	Odonne 788	Ma	Leaves, bark
	<i>Xylopia frutescens</i> var. <i>ferruginea</i> R.E. Fr.	Odonne 774	Ma	Leaves, stems, bark
<b>Apocynaceae</b>	<i>Tabernaemontana siphilitica</i> (L.f.) Leeuwenb.	Odonne 724	Ko	Aerial parts
	<i>Lacmellea aculeata</i> (Ducke) Monach.	Odonne 749	Si	Leaves, stems
<b>Asteraceae</b>	<i>Bidens cynapiifolia</i> Kunth	Odonne 760	Mc	Whole plant
<b>Bignoniaceae</b>	<i>Handroanthus capitatus</i> (Bureau & K. Schum.) Mattos	Odonne 795	Rg	Leaves, stems
	<i>Adenocalymma moringifolium</i> (DC.) L.G.Lohmann	Odonne 727	Ko	Aerial parts
<b>Boraginaceae</b>	<i>Varronia schomburgkii</i> (DC.) Borhidi	Odonne 789	Ma	Aerial parts
<b>Celastraceae</b>	<i>Maytenus oblongata</i> Reissek	Odonne 726	Ko	Leaves, stems
	<i>Maytenus</i> sp.	Odonne 797	Rg	Leaves and fruits, stems
<b>Chrysobalanaceae</b>	<i>Couepia bracteosa</i> Benth.	Odonne 775	Ma	Leaves, stems
	<i>Licania affinis</i> Fritsch	Odonne 716	Ko	Leaves, stems
<b>Clusiaceae</b>	<i>Clusia palmicida</i> Rich.	Odonne 798	Rg	Leaves, stems
<b>Combretaceae</b>	<i>Terminalia amazonia</i> (J.F. Gmel.) Exell	Odonne 783	Ma	Leaves, bark
<b>Convolvulaceae</b>	<i>Ipomoea lepieurii</i> D.F. Austin	Odonne 791	Rg	Aerial parts
<b>Costaceae</b>	<i>Costus erythrothyrus</i> Loes.	Odonne 742	Si	Leaves, stems, inflorescence
	<i>Costus</i> cf. <i>spiralis</i> (Jacq.) Roscoe	Houël 3	Rm	Inflorescence
	<i>Costus spiralis</i> var. <i>villosus</i> Maas	Houël 4	Ko	Inflorescence
	<i>Costus spiralis</i> var. <i>villosus</i> Maas	Houël 5	Ro	Inflorescence
<b>Cyperaceae</b>	<i>Scleria cyperina</i> Willd. ex Kunth	Odonne 793	Rg	Aerial parts

<b>Dilleniaceae</b>	<i>Tetracera asperula</i> Miq.	Odonne 781	Ma	Leaves, fruits
<b>Euphorbiaceae</b>	<i>Cnidocolus urens</i> (L.) Arthur	Odonne 790	Mc	Aerial parts
	<i>Conceveiba guianensis</i> Aubl.	Odonne 722	Ko	Leaves, stems
	<i>Croton guianensis</i> Aubl.	Odonne 786	Ma	Leaves
	<i>Croton macradenis</i> Görts & Punt	Eparvier 202	Mo	Aerial parts
	<i>Croton matourensis</i> Aubl.	Eparvier 167	Mt	Leaves, bark
	<i>Croton nuntians</i> Croizat	Eparvier 199	Si	Leaves, stems
	<i>Croton nuntians</i> Croizat	Odonne 743	Si	Leaves, stems
	<i>Sapium argutum</i> (Müll. Arg.) Huber	Odonne 794	Rg	Leaves, stems
<b>Fabaceae</b>	<i>Alexa wachenheimii</i> Benoist	Odonne 719	Ko	Leaves, bark
	<i>Bocoa prouacensis</i> Aubl.	238 <sup>b</sup>	Si	Bark
	<i>Chamaecrista desvauxii</i> var. <i>saxatilis</i> (Amshoff) H.S. Irwin & Barneby	Odonne 806	Rg	Aerial parts
	<i>Chamaecrista diphylla</i> (L.) Greene	Odonne 758	Mc	Aerial parts
	<i>Dalbergia monetaria</i> L.f.	Odonne 762	Mc	Leaves, stems
	<i>Desmodium barbatum</i> (L.) Benth.	Odonne 746	Si	Whole plant
	<i>Dimorphandra polyandra</i> Benoist	Odonne 779	Ma	Leaves, bark
	<i>Entada polystachya</i> (L.) DC.	Odonne 759	Mc	Leaves, stems
	<i>Enterolobium schomburgkii</i> (Benth.) Benth.	Forget 4976	Si	Wood, bark
	<i>Inga alba</i> (Sw.) Willd.	Moretti 1129	Si	Wood
	<i>Inga virgultosa</i> (Vahl) Desv.	Odonne 805	Rg	Leaves, stems
	<i>Muelleria frutescens</i> (Aubl.) Standl.	Eparvier 108B	Mo	Leaves
	<i>Macrolobium bifolium</i> (Aubl.) Pers.	Odonne 725	Ko	Leaves, stems
	<i>Macrolobium guianense</i> (Aubl.) Pulle	Odonne 785	Ma	Leaves, wood



	<i>Ormosia coutinhoi</i> Ducke	Odonne 717	Ko	Leaves, stems
	<i>Senna quinquangulata</i> (Rich.) H.S. Irwin & Barneby	Odonne 738	Si	Leaves, stems
	<i>Spirotropis longifolia</i> (DC.) Baill.	Eparvier 137	Si	Wood, bark, roots
	<i>Stylosanthes guianensis</i> (Aubl.) Sw.	Odonne 792	Rg	Aerial parts
	<i>Swartzia guianensis</i> (Aubl.) Urb.	Odonne 715	Ko	Leaves, stems
	<i>Vigna luteola</i> (Jacq.) Benth.	Odonne 764	Mc	Aerial parts
<b>Humiriaceae</b>	<i>Humiria balsamifera</i> Aubl.	Eparvier 101	Mc	Wood
	<i>Humiria balsamifera</i> Aubl.	Odonne 784	Ma	Bark
<b>Lauraceae</b>	<i>Licaria cannella</i> (Meisn.) Kosterm.	Silland 16	Rg	Wood
	<i>Sextonia rubra</i> (Mez) van der Werff	1039 <sup>b</sup>	Si	Bark
	<i>Sextonia rubra</i> (Mez) van der Werff	Rodrigues 12	Rg	Wood
<b>Loranthaceae</b>	<i>Phthirusa</i> sp.	Odonne 720	Ko	Leaves, stems
<b>Lythraceae</b>	<i>Cuphea blackii</i> Lourteig	Odonne 796	Rg	Aerial parts
<b>Malpighiaceae</b>	<i>Byrsonima aerugo</i> Sagot	Odonne 780	Ma	Leaves
	<i>Byrsonima crassifolia</i> (L.) Kunth	Odonne 755	Mc	Leaves, bark
	<i>Byrsonima spicata</i> (Cav.) DC.	Odonne 754	Mc	Leaves, wood, bark
<b>Malvaceae</b>	<i>Eriotheca surinamensis</i> (Uittien) A. Robyns	Odonne 801	Rg	Leaves
	<i>Sterculia pruriens</i> (Aubl.) K. Schum	1058 <sup>b</sup>	Si	Bark
<b>Melastomataceae</b>	<i>Ernestia granvillei</i> Wurdack	Odonne 804	Rg	Aerial parts
<b>Meliaceae</b>	<i>Azadirachta indica</i> A. Juss	Odonne 712	Ko	Leaves
	<i>Guarea guidonia</i> (L.) Sleumer	Odonne 756	Mc	Leaves, stems
<b>Moraceae</b>	<i>Bagassa guianensis</i> Aubl.	n.i. <sup>c</sup>	Si	Bark
<b>Myrtaceae</b>	<i>Myrcia saxatilis</i> (Amshoff) McVaugh	Odonne 799	Rg	Leaves, stems
<b>Orobanchaceae</b>	<i>Anisantherina hispidula</i> (Mart.) Pennell	Odonne 757	Mc	Whole plant

<b>Piperaceae</b>	<i>Piper hispidum</i> Sw.	Odonne 741	Si	Leaves, stems
<b>Polygalaceae</b>	<i>Polygala longicaulis</i> Kunth	Odonne 787	Ma	Whole plant
<b>Rubiaceae</b>	<i>Posoqueria longiflora</i> Aubl.	Odonne 723	Ko	Leaves
	<i>Tocoyena guianensis</i> K. Schum.	Odonne 802	Rg	Aerial parts
	<i>Sipanea pratensis</i> Aubl.	Odonne 803	Rg	Aerial parts
<b>Salicaceae</b>	<i>Banara guianensis</i> Aubl.	Odonne 748	Si	Leaves, stems
	<i>Casearia grandiflora</i> Cambess.	Odonne 777	Ma	Leaves, wood, bark
	<i>Laetia procera</i> (Poepp.) Eichl.	1003 <sup>b</sup>	Si	Bark
	<i>Laetia procera</i> (Poepp.) Eichl.	424 <sup>b</sup>	Si	Bark
	<i>Laetia procera</i> (Poepp.) Eichl.	Odonne 771	Mc	Bark
<b>Sapindaceae</b>	<i>Cupania scrobiculata</i> Rich.	Odonne 778	Ma	Leaves, stems, fruits
	<i>Matayba arborescens</i> (Aubl.) Radlk.	Odonne 776	Ma	Leaves, stems, fruits
	<i>Paullinia</i> sp.	Odonne 713	Si	Leaves, stems
	<i>Paullinia pinnata</i> L.	Odonne 763	Mc	Aerial parts
<b>Sapotaceae</b>	<i>Manilkara huberi</i> (Ducke) A. Chevalier	Riéra 1904	Si	Wood, bark
<b>Simaroubaceae</b>	<i>Quassia amara</i> L..	Odonne 714	Rm	Stems
<b>Siparunaceae</b>	<i>Siparuna guianensis</i> Aubl.	Odonne 747	Si	Leaves, stems
<b>Solanaceae</b>	<i>Cestrum latifolium</i> Lam.	Odonne 761	Mc	Leaves, stems
	<i>Solanum leucocarpon</i> Dunal	Odonne 740	Si	Leaves, stems
	<i>Solanum stramonifolium</i> Jacq.	Odonne 751	Si	Aerial parts
	<i>Solanum subinerme</i> Jacq.	Odonne 752	Si	Aerial parts
<b>Vochysiaceae</b>	<i>Erismia uncinatum</i> Warm.	514 <sup>b</sup>	Si	Bark

133 <sup>a</sup> Legend: Régina (Rg), Roura (Ro), Matoury (Mt), Rémire-Montjoly (Rm), Montsinéry-Tonnegrande (Mo), Macouria (Mc), Kourou (Ko),  
134 Sinnamary (Si), Mana (Ma)

135 <sup>b</sup> Trees from a permanent plot (St Elie) in Sinnamary. This permanent research plot hosts up to 800 identified trees. The systematic  
136 identification of the trees was performed at the IRD herbarium in Cayenne where a voucher sample is deposited

137 <sup>c</sup> Not integrated in Cayenne herbarium. *Bagassa guianensis* was collected in the framework of other research projects and botanical  
138 identification was made in situ by professional forest workers

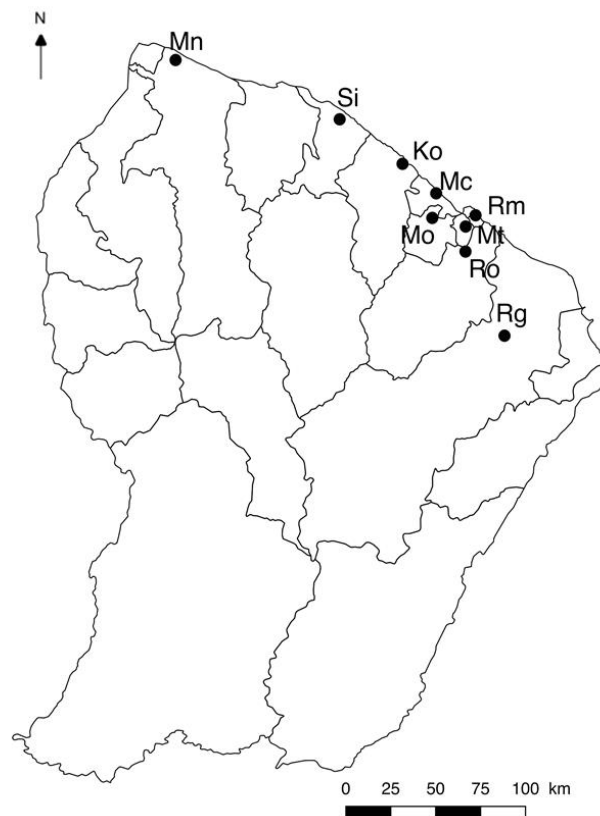
139

140

141 **Table 1** Botanical families, plant species, voucher number (Cayenne herbarium - CAY), location and plant parts collected for testing against 3<sup>rd</sup>-

142 4<sup>th</sup> instar larvae of *Ae. aegypti* L. (Diptera: Culicidae)

143 Plants were collected along an E/W geographical gradient (Figure 1) in the following  
144 locations: Régina (Rg), Roura (Ro), Matoury (Mt), Rémire-Montjoly (Rm), Montsinéry-  
145 Tonnegrande (Mo), Macouria (Mc), Kourou (Ko), Sinnamary (Si), Mana (Mn). The various  
146 environment types were the following: *terra firme* forest, forest edges, white-sand forest, river  
147 bank, dry savannah, coastline, inselberg and ruderal/disturbed areas. To perform multivariate  
148 analysis, these environments were described according to the available light (few light:  
149 forest, to strong light: open environment such as savannah or inselberg) and resources (from  
150 poor environment such as inselbergs to abundant resources environment such as forest or  
151 river bank) at the collection place. The type of vegetation (life-forms) was also characterized  
152 (temporary vegetation, secondary / low or slightly ligneous vegetation, ligneous species,  
153 large trees). Collected plant organs were: bark, wood, stems, roots, leaves, aerial parts,  
154 whole plant, inflorescence and fruits depending on the plant.  
155



156

157 **Fig. 1** Repartition of the collection localities. Legend: Régina (Rg), Roura (Ro), Matoury (Mt),  
158 Rémire-Montjoly (Rm), Montsinéry-Tonnegrande (Mo), Macouria (Mc), Kourou (Ko),  
159 Sinnamary (Si), Mana (Ma)

160

## 161 2.2. *Extraction*

162

163 All plant parts were air-dried (room temperature, 10% air relative humidity) and finely ground  
164 into powder prior to extraction. Plant powders (30 g) were successively extracted at room  
165 temperature by maceration during 24h under stirring, using either ethyl acetate (3 x 150 ml)  
166 followed by methanol (1 x 150 ml), or petroleum ether (3 x 150 ml) followed by boiling water  
167 (1 x 150 ml). After each extraction, the solution was filtered and the solvent removed by  
168 evaporation under reduced pressure with a SpeedVac<sup>TM</sup> concentrator (Savant SPD121P,  
169 Thermo Scientific). The resulting crude extracts (up to 4 extracts for each plant part of each  
170 species) were stored in a freezer at -18°C until assayed.

171

## 172 2.3. *Evaluation of larvicidal activity*

173

174 Insect collection and rearing, cup assay and data analysis were performed as previously  
175 described (Touré et al. 2017). Two *Aedes aegypti* (Diptera: Culicidae) strains were used for  
176 testing the extracts and compounds. The laboratory strain Paea, collected in French  
177 Polynesia, and maintained for a decade in the insectary at the Institut Pasteur de la Guyane,  
178 French Guiana, is susceptible to all insecticides. The Cayenne natural population is resistant  
179 to both pyrethroid and organophosphate insecticides and is a first generation (F1) strain  
180 reared from wild-caught larvae (F0) (Dusfour et al. 2011). The choice to perform a two-step  
181 screening was based on the recommendations made by Cos et al. for antimicrobial  
182 screening to develop a stronger proof of concept (Cos et al. 2006). Indeed LC<sub>50</sub> could  
183 increase 100 times in *Ae. aegypti* resistant populations compared to susceptible ones (Lima  
184 et al. 2011). Late third or early fourth-instar larvae were used in the tests. All extracts were

185 investigated using the WHO procedure for testing of mosquito larvicides (WHO 2005). For  
186 each bioassay, 25 larvae of each strain were transferred to cups containing 99 mL of distilled  
187 water and 1 mL of the tested product diluted in ethanol, at the suitable concentration, and  
188 four cups, representing a total of 100 larvae, were used for each tested concentration. For  
189 the determination of mortality rates, the final concentration was 100 µg/mL and for LC<sub>50</sub>  
190 calculation, concentrations leading from 0 to 100% mortality were tested. Larval mortality  
191 was recorded 24 and 48 h after exposure. Control treatments were performed for each test  
192 with 1 mL of ethanol, and deltamethrin (0.05 µg/mL) was used as a positive control in the  
193 case of the laboratory strain *Paea. Muellera frutescens* (Aubl.) Standl. (Fabaceae), of which  
194 leaves were previously described to contain the rotenoid compounds rotenone, tephrosin and  
195 deguelin, and to be toxic against *Ae. aegypti* mosquito larvae, was included in the screening  
196 to serve as a botanical positive control in order to validate the test protocol (Falkowski et al.  
197 2016; Nirma et al. 2009). Abbott's formula was applied to mortalities if mortality in the control  
198 was between 5% and 20% (Abbott 1925). The test was invalidated if mortality in the control  
199 was greater than 20%. Lethal doses were obtained by a probit regression under a general  
200 linearized model [BioRssay 6.1. script in R environment version 3.2.0 ([https://www.r-](https://www.r-project.org/)  
201 [project.org/](https://www.r-project.org/))].

202

#### 203 2.4. Cytotoxicity assays

204

205 Cytotoxicity assays were conducted with KB (nasopharyngeal epidermoid carcinoma) and  
206 MRC5 (normal lung tissue of a 14-week-old male foetus) cell lines using the procedure  
207 described by Tempête et al. (Tempête et al. 1995). Docetaxel was used as positive control.

208

#### 209 2.5. Ecotoxicological assessment on non-target species, *Daphnia magna* and

210 *Chironomus riparius*

211

212 Ecotoxicity assays were adapted from the guidelines of the “Immediate Immobilization Test”  
213 (OECD No. 202) for *Daphnia magna* (Straus, 1820) and the “Immediate Immobilization Test”  
214 (OECD No. 235) for *Chironomus riparius* (Meigen, 1804). The extracts were tested only at  
215 the LC<sub>50</sub> value defined from the *Ae. aegypti* Paea strain sensitivity for each extract. Three  
216 conditions were tested: control, control/solvent, and LC<sub>50</sub>, with four replicates per condition.  
217 The physicochemical measurements (pH, dissolved oxygen, conductivity) were performed  
218 with measuring devices (sensors). The remaining measures (chlorine, nitrites, nitrates,  
219 phosphates) were performed with aquarium strips. Photoperiod and temperature were  
220 recorded using a “templight” recorder throughout the test period, from clutch incubation until  
221 the end of the exposure.

222

## 223 2.6. *Phytochemical studies*

### 224 2.6.1. *General remarks*

225

226 <sup>1</sup>H NMR spectra were recorded at 400 MHz and <sup>13</sup>C NMR spectra at 100.6 MHz on a Varian  
227 400 MR spectrometer equipped with a 5 mm inverse probe (Auto X PGF 1H/15N-13C).

228 Samples were dissolved in deuterated chloroform (CDCl<sub>3</sub>) in 5 mm tubes as stated. Chemical  
229 shifts are in ppm downfield from tetramethylsilane (TMS), and coupling constants (J) are in  
230 Hz (s stands for singlet, d for doublet, t for triplet, q for quartet, m for merduplet, br for broad).

231 TLC analyses were performed using ALUGRAM®SIL G/UV<sub>254</sub> plates, eluted with petroleum  
232 ether 90:10 and revealed using a solution of 1% KMnO<sub>4</sub> in water.

233 Water (HPLC grade) was obtained from a Milli-Q system (Milli-Q plus, Millipore Bedford, MA).

234 HPLC analyses were performed on a Discovery C18 column (15 cm x 4.6 mm, 5 μm,  
235 Supelco) at 1 mL/min using a Waters HPLC system equipped with a W2996 photodiode  
236 array absorbance detector and a W2424 light-scattering detector. HPLC semi-preparative  
237 chromatography was performed at 15 mL/min on a Discovery C18 column (15 cm x 21.2  
238 mm, 5 μm, Supelco) using a Waters HPLC system equipped with a W600 pump and a  
239 W2487 double wavelength UV detector (Waters).

240

241 2.6.2. *Costus erythrothyrus* Loes. (*Costaceae*) phytochemical study

242

243 *C. erythrothyrus* inflorescence ethyl acetate extract was purified by column chromatography  
244 using a petroleum ether / ethyl acetate gradient from 100:0 to 10:90 and eventually 100%  
245 methanol. Ten fractions were gathered according to their TLC profile. Fraction F4 eluted with  
246 petroleum ether / ethyl acetate 85:15 exhibited 72% larvicidal mortality against *Ae. aegypti*  
247 Paea laboratory strain at 100 µg/mL and 100% larvicidal mortality against Cayenne resistant  
248 strain at the same concentration, and its chemical composition was therefore investigated  
249 using NMR. TLC profiles from the crude extract and fraction F4 were also compared to  
250 standard lipids L13-0521 (VHOSO, Very High Oleic Sunflower Oil fatty acids), L13-0001  
251 (Linseed oil fatty acids including 50% linolenic acid, 21% linoleic acid and 13% oleic acid),  
252 E12-1986 (stearic acid), L14-0146 (hydrogenated VHOSO methylic ester – stearic acid) and  
253 P14-002 (VHOSO methylic ester – oleic acid) kindly provided by ITERG (Institut des Corps  
254 Gras, Pessac, France).

255

256 2.6.3. *Maytenus oblongata* Reissek (*Celastraceae*) phytochemical study

257

258 The thoroughgoing bioguided fractionation as well as isolation and identification of *M.*  
259 *oblongata* extract components were described in Touré et al. (2017).

260

261 2.6.4. *Sextonia rubra* (Mez.) van der Werff (*Lauraceae*) phytochemical study

262

263 Isolation of rubrenolide and rubrynlide was performed using HPLC semi-preparative  
264 chromatography according to previously described procedures (Fu et al. 2019) and  
265 their identification confirmed by NMR.

266



## 267 2.7. *Multivariate analysis*

268

269 The complete set of data used for multivariate analysis is available in Supporting Information  
270 (table S1). Multivariate analysis was conducted in R 3.2.0 environment. Z-scores were  
271 obtained from mortality data. This transformation gives the dataset a mean of 0 and a  
272 standard deviation of 1. A generalized linear model (GLM) using the quasi-Poisson  
273 distribution, logistic link function and a mixture of forwards and backwards selection was  
274 used to relate mortality responses to the technical, chemotaxonomic and environmental  
275 predictor variables. Pairwise comparisons were further performed with TukeyHSD test  
276 between modalities of each factor that were identified to have an effect on mortalities.  
277 Family, solvent, organ, light, resource, type of vegetation and location were thus selected as  
278 explanatory variables in our analyses.

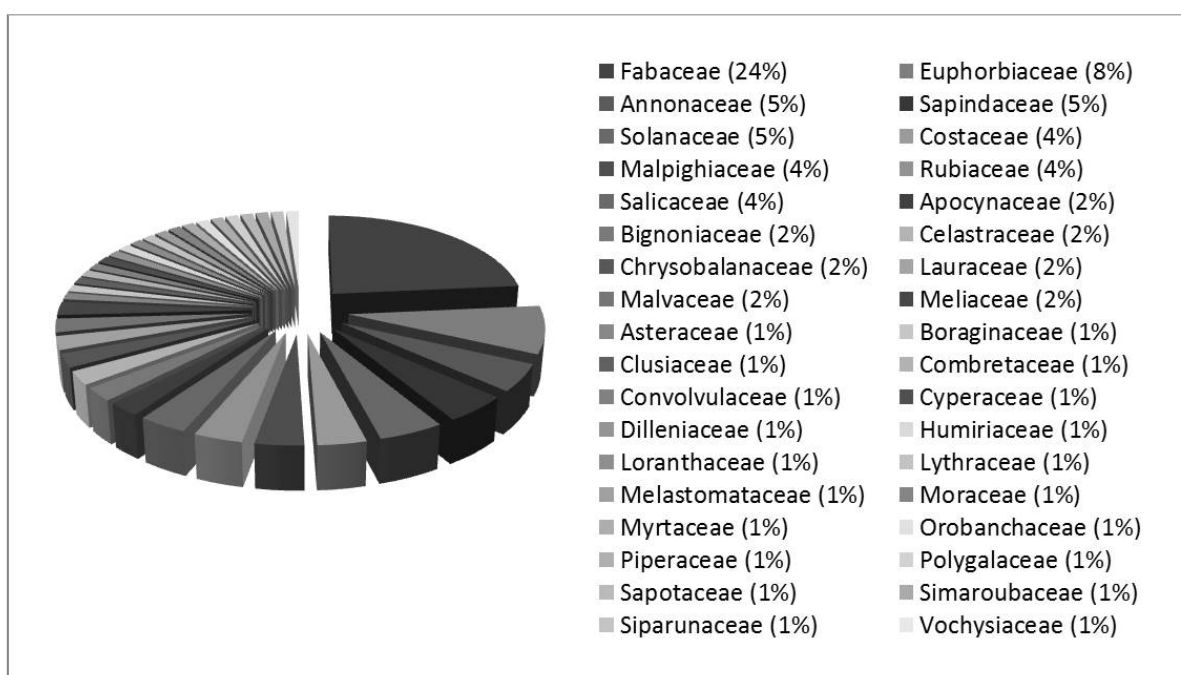
279

## 280 3. Results and discussion

### 281 3.1. *Larvicidal screening on susceptible and resistant Ae. aegypti strains*

282

283 A total of 144 plant parts issued from 85 species belonging to 36 botanical families were  
284 collected during the project (Table 1). Fabaceae (24%) were the most represented, with 17  
285 genera and 20 species. Euphorbiaceae, Annonaceae, Sapindaceae and Solanaceae  
286 represented from 5 to 8% of the collected species (Figure 2). The genera *Byrsonima*, *Croton*  
287 and *Solanum* were the most represented, with 3 to 4 species each. For two species (*Croton*  
288 *nuntians* Croizat, Euphorbiaceae, *Laetia procera* (Poepp.) Eichler, Salicaceae) 2 to 3  
289 different samples of the same plant part were collected at different times and locations. It  
290 should be noticed that the Fabaceae family is one of the most cited in the literature for its  
291 insecticidal activity, being notably a source of rotenoids and in particular rotenone, a well-  
292 known, yet controversial botanical insecticide (Boulogne et al. 2012; Isman 2006; Pavela et  
293 al., 2019).



295

296 **Fig. 2** Diversity of the collected species: the relative importance of the botanical families is  
 297 shown in the pie chart (families are represented clockwise in the pie chart)

298

299 Eventually, 452 extracts were obtained and tested on *Ae. aegypti* Paea strain. The complete  
 300 dataset is available in Supporting Information (Table S1). The extracts exhibiting more than  
 301 50% mortality after 48 h of exposition at 100 µg/mL were considered active, which is  
 302 consistent with the requirements proposed by Pavela (2015). Fifteen botanical species thus  
 303 led to 22 larvicidal extracts listed in Table 2. The active extracts on the Paea strain were then  
 304 tested on a natural population of resistant Cayenne *Ae. aegypti* in order to obtain more  
 305 selective and realistic results, thus improving the probability to highlight promising plant  
 306 extracts for the search of new botanical insecticides.

307

308 The extracts exhibiting larvicidal mortality  $\geq 50\%$  after 48 h of exposition at 100 µg/mL  
 309 against this resistant strain are highlighted in Table 2. Eventually, 8 species led to 11  
 310 larvicidal extracts against the Cayenne strain. Among the botanical families hosting these  
 311 active species Celastraceae (Alvarenga and Ferro 2005; Deepa and Narmatha Bai 2010),

312 Lauraceae (Cuca-Suarez et al. 2012; Dias and Moraes, 2014), Piperaceae (Dorla et al. 2017;  
313 Lija-Escaline and al. 2015; Marques and Kaplan 2015), and Sapindaceae (Diaz and Rossini  
314 2012), are particularly well described for their numerous insecticidal effects. These 8 species  
315 represents 9% of the collected species and 2% of the extracts. By comparison, among 94  
316 extracts from 10 Brazilian plant species selected randomly or according to chemotaxonomic  
317 criteria, 19 were considered to be effective against *Ae. aegypti* larvae, exhibiting  $LC_{50} < 250$   
318  $\mu\text{g/mL}$ , including 6 (6.4%) extracts with  $LC_{50} < 100 \mu\text{g/mL}$  (Oliveira et al. 2010). Another 27  
319 species identified from a screening performed on 83 Asteraceae belonging to 48 genera,  
320 promoted statistically significant mortality of *Ae. fluviatilis* (Lutz, 1904) 4<sup>th</sup> instar larvae, with 8  
321 (9.6%) species leading to 50% or more mortality at  $100 \mu\text{g/mL}$  (Macêdo et al. 1997). In terms  
322 of active extracts, these results are consistent with those observed in our screening, even if  
323 contrary to the example of the Asteraceae family, the selected plants in our case did not all  
324 belong to botanical families well-known for the insecticidal activities of their species. This  
325 could be an indication that selecting species on different criteria, e.g. the ecosystem, could  
326 also lead to interesting results.  
327

Botanical families	Plant species <sup>a</sup>	Plant part	Solvent <sup>c</sup>	Extraction yield (%)	Mortality (% Paea strain) ± SD	LC <sub>50</sub> (µg/ml), Paea strain <sup>d</sup>	Mortality (% Cayenne strain) ± SD <sup>e</sup>	LC <sub>50</sub> (µg/ml), Cayenne strain <sup>d</sup>
Annonaceae	<i>Xylopia frutescens</i> var. <i>ferruginea</i>	Leaves	PE	3.0	54 ± 6.6		4 ± 0.0	
Asteraceae	<i>Bidens cynapiifolia</i>	Whole plant	EA	1.4	97 ± 1.0		5 ± 3.0	
Celastraceae	<b><i>Maytenus oblongata</i></b>	<b>Stems</b>	<b>EA</b>	<b>1.5</b>	<b>98 ± 1.1</b>	<b>74.4 ± 2.5 <sup>f</sup></b>	<b>91 ± 3.0</b>	<b>n.t.</b>
Chrysobalanaceae	<i>Licania affinis</i>	Leaves	PE	0.8	97 ± 1.1		2 ± 1.1	
	<i>Licania affinis</i>	Stems	PE	0.1	100 ± 0.0		n.t.	
Costaceae	<b><i>Costus erythrothyrus</i> (Odonne 742)</b>	<b>Inflorescence</b>	<b>EA</b>	<b>4.8</b>	<b>100 ± 0.0</b>	<b>45.0 (95%CI: 36.6-54.0)</b>	<b>100 ± 0.0</b>	<b>55.7 (95%CI: 49.8-61.2)</b>
	<b><i>Costus erythrothyrus</i> (Odonne 742)</b>	<b>Inflorescence</b>	<b>PE</b>	<b>3.9</b>	<b>97 ± 1.0</b>	<b>n.t.</b>	<b>99 ± 1.0</b>	<b>n.t.</b>
Euphorbiaceae	<i>Croton macradenis</i>	Aerial parts	PE	0.4	54 ± 3.8		5 ± 1.9	
Fabaceae	<i>Alexa wachenheimii</i>	Bark	PE	0.2	56 ± 2.8		2 ± 1.1	
	<i>Muelleria frutescens</i> <sup>b</sup>	Leaves	PE	3.7	100 ± 0.0		n.t.	
	<i>Muelleria frutescens</i>	Leaves	EA	4.3	100 ± 0.0		n.t.	
	<i>Muelleria frutescens</i>	Leaves	M	4.6	97 ± 1.9		n.t.	
Humiriaceae	<b><i>Humiria balsamifera</i> (Odonne 784)</b>	<b>Bark</b>	<b>EA</b>	<b>17.9</b>	<b>84 ± 4.3</b>	<b>49.0 (95%CI 35.8-64.8)</b>	<b>91 ± 1.9</b>	<b>45.0 (CI95% 39.0-51.2)</b>
Lauraceae	<b><i>Sextonia rubra</i> (Rodrigues 12)</b>	<b>Wood</b>	<b>EA</b>	<b>4.2</b>	<b>100.0 ± 0.0</b>	<b>3.1 7 (95%CI 2.7-3.7)</b>	<b>100.0 ± 0.0</b>	<b>n.t.</b>
	<b><i>Sextonia rubra</i> (1039)</b>	<b>Bark</b>	<b>EA</b>	<b>2.4</b>	<b>100.0 ± 0.0</b>	<b>n.t.</b>	<b>85.0 ± 6.0</b>	<b>n.t.</b>
Piperaceae	<b><i>Piper hispidum</i></b>	<b>Leaves</b>	<b>EA</b>	<b>7.0</b>	<b>62 ± 5.3</b>	<b>54.7 (95%CI 46.0-64.0)</b>	<b>84 ± 1.6</b>	<b>n.t.</b>
Salicaceae	<b><i>Laetia procera</i> (1003)</b>	<b>Bark</b>	<b>PE</b>	<b>3.4</b>	<b>94 ± 2.0</b>	<b>33.5 (95%CI 28.0-39.8)</b>	<b>87 ± 3.4</b>	<b>61.0 (95%CI 49.8-77.7)</b>
	<b><i>Laetia procera</i> (1003)</b>	<b>Bark</b>	<b>EA</b>	<b>2.7</b>	<b>63 ± 6.0</b>	<b>43.7 (95%CI: 33.9-57.3)</b>	<b>57 ± 7.2</b>	<b>65.9 (95%CI: 51.7-90.5)</b>
Sapindaceae	<b><i>Matayba arborescens</i></b>	<b>Fruits</b>	<b>EA</b>	<b>11.2</b>	<b>60 ± 2.8</b>	<b>76.9 (95%CI 67.7-86.7)</b>	<b>98 ± 1.1</b>	<b>40.5 (95%CI 34.1-46.2)</b>
	<b><i>Matayba arborescens</i></b>	<b>Fruits</b>	<b>PE</b>	<b>17.4</b>	<b>51 ± 6.6</b>	<b>n.t.</b>	<b>50 ± 6.8</b>	<b>n.t.</b>
	<b><i>Cupania scrobiculata</i></b>	<b>Fruits</b>	<b>EA</b>	<b>2.9</b>	<b>64 ± 1.6</b>	<b>105.3 (95%CI 86.6-136.5)</b>	<b>74 ± 3.8</b>	<b>102.5 (95%CI 80.4-145.4)</b>
Solanaceae	<i>Cestrum latifolium</i>	Stems	EA	0.7	58 ± 10.5		7 ± 1.9	

329 <sup>a</sup> Voucher number at Cayenne Herbarium (CAY) or tree number from a permanent plot in Sinnamary is indicated when several samples were  
330 previously collected

331 <sup>b</sup> *Muelleria frutescens* was used as a botanical insecticide positive control in order to validate the test protocol

332 <sup>c</sup> PE: petroleum ether; EA: ethyl acetate; M: methanol

333 <sup>d</sup> LC<sub>50</sub> values were calculated after 48h of exposition unless otherwise specified

334 <sup>e</sup> n.t.: not tested.

335 <sup>f</sup> LC<sub>50</sub> value was calculated after 24h of exposition using the protocol descrid in Touré et al. (2017)

336

337 **Table 2** Active extracts (mortality  $\geq$  50% after 48 h of exposition at 100  $\mu$ g/mL) against *Ae. aegypti* Paea and Cayenne strains 3<sup>rd</sup>-4<sup>th</sup>

338 instar larvae. Extracts exhibiting larvicidal activities  $\geq$  50% against Cayenne resistant strain are highlighted in bold characters.

### 339 3.2. Selectivity of the active extracts and phytochemical discussion

340

341 In the global perspective of improving our knowledge about the selectivity of the extract in  
342 terms of bioactivity, cytotoxicity of the extracts highlighted as active on the *Ae. aegypti*  
343 Cayenne strain was then evaluated on two human cellular strains (KB cancerous cell line,  
344 MRC5 healthy cell line). Concurrently 3 randomly selected extracts (*Maytenus oblongata*  
345 Reissek, Celastraceae, *Matayba arborescens* (Aubl.) Radlk., Sapindaceae, and *Humiria*  
346 *balsamifera* Aubl., Humiriaceae) were tested for possible ecotoxicity against non-target  
347 species *C. riparius*, an aquatic diptera, and *D. magna*, a small planktonic crustacean. If the  
348 obtained values (inhibition of cellular growth for cytotoxic assay, and mortality for ecotoxicity)  
349 were too high, the extract was abandoned. These bioassays were used at this step of the  
350 screening to prevent further study of active non-selective extracts. Indeed, as stated by  
351 Isman and Grieneisen, studying the effect of botanical insecticides on human health is quite  
352 rare in the existing literature, as most botanicals are renowned for their low acute toxicity  
353 (Isman and Grieneisen 2014). However, plants can be highly toxic too and this parameter  
354 should clearly be taken into account in the context of the search for new insecticides of plant  
355 origin. The cytotoxicity results are presented in Table 3. *Cupania scrobiculata* Rich.  
356 (Sapindaceae) fruits extract was cytotoxic and was dropped. *M. arborescens* fruits extract  
357 was only moderately cytotoxic but was strongly ecotoxic with almost 100% of mortality  
358 against both *C. riparius* and *D. magna* at 100 µg/mL and was therefore dropped as well.

359

360 *H. balsamifera* bark ethyl acetate extract exhibited significant cyto- and ecotoxicity, with  
361 respectively 52±2% and 40±5% of growth inhibition against KB and MRC5 cells at 10 µg/ml,  
362 and leading to almost 100% of mortality against both *C. riparius* and *D. magna* at 80 µg/mL.  
363 The latter value is close to the LC<sub>50</sub> values of 63.6 (CI95% 52.7-77.5) and 49.0 (CI95% 35.8-  
364 64.8) µg/mL measured at 24 and 48 h against the laboratory strain Paea. *H. balsamifera* is a  
365 large tree common in Amazonia and North-East Brazil. Numerous compounds were isolated  
366 from this species, including *trans*-isolongifolenone (Da Silva et al. 2004).<sup>48</sup> Interestingly, a

367 repulsive effect of this compound was described on *Ae. aegypti* and *Anopheles stephensi*,  
368 but also on other insects (Wang et al. 2013; Zhang et al. 2009). Moreover, *trans*-  
369 isolongifolenone is described as odorless, whereas some of its derivatives have a  
370 characteristic woody smell (Zhang et al. 2009). It has to be noted that the sampled bark was  
371 strongly odoriferous, and we noticed in the field that this phenomenon was linked to a  
372 damage caused to the bark, leading to an abundant production of resinous product. It should  
373 therefore be checked if the more frequently encountered non-odoriferous barks also lead to  
374 larvicidal extracts, and if odoriferous isolongifolenone derivatives exhibit larvicidal activity. In  
375 the case of this extract, toxicity could be linked with the plant's response to stress due to  
376 mechanical damage, leading to the production of defensive compounds. If these molecules  
377 led to the discovery of a larvicidal extract, our results also highlight the fact that cyto- and  
378 ecotoxicity bioassays are essential in the evaluation of a potential new insecticidal product,  
379 as *H. balsamifera* bark extract showed to be non-selective against the various targets tested  
380 in our study. It should also be mentioned that *H. balsamifera* wood extract did not exhibit any  
381 larvicidal activity in our hands. It would be interesting to investigate if this difference is linked  
382 to the collected specimen or to a systematic difference in terms of chemical defenses  
383 allocation between the two tissues.

384

385

Botanical families	Plant species <sup>a</sup>	Plant part / Solvent <sup>b</sup>	Growth inhibition of KB cells,		Growth inhibition of MRC5 cells,	
			% ± SD <sup>c</sup>		% ± SD <sup>c</sup>	
			10 µg/ml	1 µg/ml	10 µg/ml	1 µg/ml
Celastraceae	<i>Maytenus oblongata</i>	Stems (EA)	9±1	n.t.	8±6	n.t.
Costaceae	<i>Costus erythrothyrus</i> (Odonne 742)	Inflorescence (EA)	0±1	0±10	0±1	0±1
Humiriaceae	<i>Humiria balsamifera</i> (Odonne 784)	Bark (EA)	52±2	5±2	40±5	18±4
Piperaceae	<i>Piper hispidum</i>	Leaves (EA)	22±5	0±1	0±4	0±1
Salicaceae	<i>Laetia procera</i> (1003)	Bark (PE)	18±2	0±1	45±5	4±1
Sapindaceae	<i>Matayba arborescens</i>	Fruits (EA)	24±6	n.t.	16±2	n.t.
	<i>Cupania scrobiculata</i>	Fruits (EA)	71±1	1±6	67±2	27±2

386

387 <sup>a</sup> Voucher number at Cayenne Herbarium (CAY) or tree number from a permanent plot in Sinnamary is indicated when several samples were  
388 previously collected

389 <sup>b</sup> PE: petroleum ether; EA: ethyl acetate; M: methanol

390 <sup>c</sup> PE: petroleum ether; EA: ethyl acetate; M: methanol

391

392 **Table 3** Growth inhibition of KB (nasopharyngeal epidermoid carcinoma) and MRC5 (normal lung tissue of a 14-week-old male fetus) cell lines.

393 Positive control: docetaxel induced 0.0005% survival at 1 µg/mL.



394 Species from the genus *Costus* are rhizomatous perennial herbs from the Costaceae family  
395 (Specht and Stevenson 2006). In our study, *C. erythrothyrsus* Loes. inflorescence ethyl  
396 acetate extract exhibited no cytotoxicity against human cell lines, which could make this  
397 extract a valuable candidate in the search of new botanical insecticides. The LC<sub>50</sub> at 24 and  
398 48 h were 69.1 (95% CI: 59.4-82.9) and 45.0 (95% CI: 36.6-54.0) µg/mL, respectively,  
399 against the Paea strain. Although the insecticidal activity of several *Costus* species has been  
400 described before in the literature, neither *C. erythrothyrsus* nor *Costus* inflorescences were  
401 described for insecticidal activity (Pipithsangchan and Morallo-Rejesus 2005; Surendra  
402 Kumar et al. 2014). However, although the first extract exhibited strong larvicidal activity, no  
403 other positive result could be observed while testing inflorescences extracts from the same  
404 *C. erythrothyrsus* specimen at a later collection date, or inflorescences collected from other  
405 *Costus* species. Interestingly, we noticed that the first collected inflorescence had been  
406 damaged by some predators. Defense compounds may have been produced by the plant on  
407 this occasion, and further studies to investigate these mechanisms and the compounds  
408 responsible for the biological activity would thus be of great interest. In the case of this  
409 extract, bioguided fractionation allowed us to isolate an active mixture of 3 fatty acids. <sup>1</sup>H  
410 NMR spectrum was consistent with a mixture linolenic, linoleic and oleic acids (Figure S1)  
411 (Sacchi et al. 1997). This type of compounds were already found in a chemical analysis  
412 performed on the inflorescence of *Etilingera elatior* Jack, a plant from the Zingiberaceae  
413 family, which is in close relationship with Costaceae, and are known for their larvicidal activity  
414 (Harada et al. 2000; Jeevani Osadee Wijekoon et al. 2011; Rahuman et al. 2008; Ramsewak  
415 et al. 2001; Santos et al. 2017). Moreover, they were also highlighted for their role in  
416 chemical defense mechanisms, and more particularly induced defense against pathogenous  
417 organisms (Domingues et al. 2007; Rojas et al. 2014; Ryu et al. 2005). Therefore the fact  
418 that a single extract was found active might be correlated with the activation of defense  
419 mechanisms in response to herbivory damage and this observation could be the subject of  
420 complementary studies.

421

422 The case of *L. procera* petroleum ether bark extract also raised interesting questions  
423 concerning the activation of chemical defense mechanisms and the interest of studying  
424 several samples of a same species. *L. procera* is a long-lived pioneer tree, i.e., a fast-  
425 growing light-demanding species, characterized as an early colonizer of the Amazonian  
426 forest (Santos et al. 2012). Petroleum ether bark extract of *L. procera* N°1003 collected in the  
427 Saint Elie permanent investigation plot in Sinnamary (Si) led to a LC<sub>50</sub> value of 33.5 (CI95%  
428 28.0-39.8) µg/mL at 48 h against the laboratory strain *Paea*. However, no larvicidal activity  
429 was discovered while testing two other bark extracts. One inactive tree bark had been  
430 collected in the same mature forest area as the active bark (tree N°424), and the second one  
431 in a secondary forest close to dry savannahs in Macouria (Mc). Therefore, the activity  
432 described for the first sample could be due again to an increased production of toxic  
433 compounds by a single individual rather than an environmental effect of resources  
434 availability. Indeed, Jullian et al. already described the fact that bark extracts from the same  
435 tree N°1003, collected a few years before, led to the isolation of laetiaprocerine A and  
436 laetianolide A as major compounds, whereas casearlucine A and caseamembrol A were the  
437 main components of tree N°424 bark extract, alongside with small amounts of laetiaprocerine  
438 A and laetianolide A (Jullian et al. 2005). Preliminary phytochemical studies were performed  
439 but did not lead to a clear conclusion concerning the pure compounds responsible for the  
440 bioactivity of the extract. It would thus be interesting to pursue the evaluation of the larvicidal  
441 activity of the pure compounds, and correlate *L. procera* bark extracts chemical profiles and  
442 larvicidal activity for example through a metabolomic approach.

443

444 *M. oblongata* extracts were not cytotoxic against KB and MCR5 human cell lines at 10  
445 µg/mL, and exhibited noticeable toxicity against *C. riparius* whereas it did not have any  
446 activity against *D. magna* at 75 µg/mL, as presented in a previously published article (Touré  
447 et al. 2017). This article also reported the isolation in *M. oblongata* extract of two new  
448 sesquiterpene alkaloids with a β-dihydroagrofuran skeleton and exhibiting significant activity  
449 against *Paea* strain *Ae. aegypti* larvae. Whereas published elsewhere, this work was

450 performed by our team in the context of the same project, as bioguided fractionation of active  
451 extracts is indeed a key step to progress towards the development of novel botanical  
452 insecticides (Isman and Grieneisen, 2014; Pavela 2015; Pavela et al. 2019).

453  
454 During the screening, *Piper hispidum* Sw. (Piperaceae) leaves ethyl acetate extract was also  
455 identified as active, with LC<sub>50</sub> values of 70.5 (CI95% 60.4-81.6) and 54.7 (CI95% 45.9-64.0)  
456 µg/mL at 24 and 48 h against the laboratory strain Paea. However, due to the vast amount of  
457 existing literature on insecticidal Piperaceae and compounds isolated from *Piper* species  
458 such as piperine or dillapiole,<sup>42-44</sup> we did not investigate further the chemical composition of  
459 this extract (Dorla et al. 2017; Lija-Escaline and al. 2015; Marques and Kaplan 2015).

460 Moreover, if the potential development of a novel botanical insecticide is logically based on  
461 its biological activity and its selectivity, other criteria such as the availability of the resource  
462 are also fundamental when it comes to valorization (Borges et al. 2019; Pavela et al., 2019).  
463 We therefore chose to concentrate on *S. rubra* extract, the most active extract but also the 4<sup>th</sup>  
464 species exploited in the forest industry in French Guiana, leading to wood wastes that could  
465 represent a source of valuable material and undisclosed as larvicidal product before the work  
466 of our team.

467  
468 *Sextonia rubra* (Mez) Van der Werff (Lauraceae) wood and bark extracts were actually  
469 shown to possess excellent larvicidal activities in the context of this study. *S. rubra* is a  
470 neotropical shade-tolerant rainforest tree species native to South America, and one of the  
471 most commercially exploited wood for construction in French Guiana owing to its excellent  
472 natural durability. Two compounds rubrynolide and rubrenolide were first isolated from its  
473 stem wood in the early '70s, and recently characterized *in situ* and identified in bark extracts,  
474 and their antifungal and termiticidal activities have been described (Franca et al. 1972; Fu et  
475 al. 2018, 2019; Houël et al. 2017; Rodrigues et al. 2010, 2011). As part of the cited work was  
476 performed by member of our team, we were able, following the previously described  
477 protocols, to characterize the chemical composition of the larvicidal extract and confirm the

478 presence of the two  $\gamma$ -lactones rubrenolide and rubrymolide. We also highlighted during this  
 479 project the strong larvicidal activity of these two compounds against *Ae. aegypti*, with  
 480 respective LC<sub>50</sub> of  $3.84 \pm 0.02$  and  $0.60 \pm 0.02$  for rubrymolide and rubrenolide at 24 h, and  
 481  $2.11 \pm 0.04$  and  $0.30 \pm 0.02$   $\mu\text{g/mL}$  at 48 h, alongside with a measured value of  $3.15 \pm 0.02$   
 482  $\mu\text{g/mL}$  for the crude wood extract at 24 h and  $2.06 \pm 0.02$   $\mu\text{g/mL}$  at 48 h (Falkowski et al.  
 483 2016). Following a patent deposit concerning the bioactivity of the wood extract and its  
 484 constituents, a further evaluation of the larvicidal activity and its mechanisms will be  
 485 performed, alongside with the characterization of its ecotoxicity (Falkowski et al. N°  
 486 WO2016046489 A1). Cytotoxicity of *S. rubra* was not evaluated in this study on KB and  
 487 MRC5 cells, however it was demonstrated before that the two major compounds of wood and  
 488 bark extracts, rubrenolide and rubrymolide, displayed low cytotoxicities on NIH-3T3  
 489 mammalian fibroblasts cells with IC<sub>50</sub> values > 100  $\mu\text{g/mL}$  in each case (Rodrigues et al.  
 490 2010). Complementary results have also been published, which highlighted notable toxicity  
 491 for rubrenolide against several human cancer cell lines (Tofoli et al. 2016). This point will  
 492 thus be further evaluated in the context of an ongoing project which aims at deepening the  
 493 above-described results regarding the crude extract and isolated compounds and  
 494 progressing towards the development of a marketable product.

495

### 496 3.3. *Multivariate analysis*

497

498 A generalized linear model (GLM) regression identified that solvents, organs, family and  
 499 location are significantly associated to larvicidal potential of the extracts, while light,  
 500 resources and vegetation type don't (Table 4). A second model was run using only those first  
 501 four factors and a Tukey HSD test was computed on this second model. The significantly  
 502 different comparisons are listed in Table 5 and full data are available in Table S2.

503

Variable	Degree of freedom	Sum of square	Mean of square	F-value	P-value
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Solvent	3	30.79	10.264	13.943	1.19e-08
Botanical family	35	46.97	1.342	1.823	0.00367
Location	8	62.24	7.781	10.569	1.88e-13
Light	2	1.32	0.658	0.894	0.40986
Ressource	2	0.26	0.129	0.175	0.83941
Vegetation type	3	3.48	1.162	1.578	0.19420
Plant organs	9	19.57	2.174	2.953	0.00209
Residuals	389	286.37	0.736		

504

505 **Table 4** Anova analysis on quasi-Poisson generalized linear model (GLM) results

506

CI 95%				
	Differences	Lower	Upper	P-value
<b>Solvent <sup>a</sup></b>				
W / PE	-0.707	-1.046	-0.368	< 0.001
PE / M	0.584	0.283	0.885	< 0.001
W / EA	-0.479	-0.788	-0.171	< 0.001
M / EA	-0.356	-0.622	-0.091	0.003
<b>Organs</b>				
Inflorescence / Aerial parts	1.334	0.229	2.438	0.006
Stems / Inflorescence	-1.234	-2.301	-0.166	0.01
Leaves / Inflorescence	-1.201	-2.259	-0.142	0.013
Fruits / Aerial parts	1.171	0.067	2.276	0.028
Stems / Fruits	-1.072	-2.139	-0.004	0.048
<b>Family</b>				
Lauraceae / Annonaceae	1.704	0.222	3.187	0.006
Lauraceae / Bignoniaceae	1.82	0.021	3.62	0.043
Lauraceae / Costaceae	1.701	0.091	3.31	0.023
Lauraceae / Dilleniaceae	2.411	0.261	4.561	0.009
Lauraceae / Euphorbiaceae	1.8	0.35	3.25	0.001
Lauraceae / Fabaceae	1.697	0.301	3.093	0.002
Loranthaceae / Lauraceae	-1.949	-3.802	-0.096	0.025
Malpighiaceae / Lauraceae	-1.979	-3.513	-0.444	0.001
Malvaceae / Lauraceae	-2.05	-3.973	-0.126	0.02
Meliaceae / Lauraceae	-1.889	-3.645	-0.133	0.018
Sapindaceae / Lauraceae	-1.61	-3.118	-0.101	0.02
Sapotaceae / Lauraceae	-1.93	-3.729	-0.131	0.018

Siparunaceae / Lauraceae	-1.91	-3.709	-0.111	0.022
Solanaceae / Lauraceae	-1.543	-3.064	-0.023	0.041
<b>Location<sup>b</sup></b>				
Si-Mo	-2.353	-3.328	-1.377	< 0.001
Rg-Mo	-2.454	-3.48	-1.428	< 0.001
Mo-Mc	2.414	1.415	3.413	< 0.001
Mo-Ma	2.391	1.389	3.393	< 0.001
Mo-Ko	2.383	1.393	3.373	< 0.001
Mt-Mo	-2.581	-3.924	-1.238	< 0.001
Rm-Mo	-3.126	-5.251	-1.002	< 0.001
Ro-Mo	-3.898	-6.748	-1.048	0.001

507

508 <sup>a</sup> W: water. PE: petroleum ether. M: methanol. EA: ethyl acetate

509 <sup>b</sup> Si: Sinnamary. Mo: Montsinéry-Tonnegrade. Rg: Régina. Mc: Macouria. Ma: Mana. Ko:

510 Kourou. Mt: Matoury. Rm: Rémire-Montjoly. Ro: Roura

511

512 **Table 5** Tukey HSD significant pairwise differences between variables

513

514 Analysis revealed that mortalities observed for methanol and water extracts were significantly  
515 lower than those obtained for petroleum ether and ethyl acetate extracts. Similar results had  
516 been previously reported in structure-activity studies (Carreno Otero et al., 2014; Santos et  
517 al. 2010). It can be assumed that more polar compounds are less prone to penetrate larvae  
518 cuticles, whereas lipophilic compounds have higher affinity for cell membranes and insect  
519 cuticles (Chen et al. 2014; Santos et al. 2010). In a study comparing the larvicidal,  
520 morphological and behavioral response of *Ae. aegypti* to various extracts of *Argemone*  
521 *mexicana* L. (Papaveraceae), apolar extracts were shown to be the most efficient, inducing  
522 modification of larvae cuticles (Warikoo and Kumar, 2013). Our dataset reinforces the  
523 interest of lipophilic extracts and compounds as larvicidal products.

524

525 Among plant organs (bark, wood, stem, leaves, roots, aerial parts, whole plant, inflorescence  
526 and fruits), mortalities induced by the inflorescence extracts were significantly higher than for

527 aerial parts, stems and leaves. Fruits also induced higher mortality than aerial parts and  
528 stems. Inflorescences were only collected from *Costus* species (*C. erythrothyrus*, *C. spiralis*  
529 var. *villosus*, *C. cf. spiralis*) and among the 7 tested extracts, 2 exhibited strong larvicidal  
530 potential (97-100% mortality) whereas the other 5 were inactive (0-2% mortality). Fruits were  
531 collected from 3 species (*Matayba arborescens* and *Cupania scrobiculata*, Sapindaceae,  
532 *Tetracera asperula*, Dilleniaceae) and alongside the leaves of *Maytenus* sp. (Celastraceae).  
533 Over 9 tested extracts 4 were moderately active (32 to 64% larval mortality) whereas the  
534 remaining 5 were inactive (0-1% mortality), including the 2 *Tetracera* extracts (Table S1  
535 Supporting Information). As discussed above, particular cases (damaged *Costus*  
536 inflorescence) and chemotaxonomy (Celastraceae and Sapindaceae being well-known  
537 insecticidal plants) may explain part of these results. However, the fact that reproductive  
538 organs (fruits and inflorescences) exhibit significantly higher larvicidal effect than non-  
539 reproductive organs (aerial parts, stems and leaves) is a point of interest in the light of plant  
540 species defense. In their work, McCall and Fordyce could not conclude on a possible more  
541 intense defense allocation in flowers compared to leaves (McCall and Fordyce 2010). This  
542 result possibly originated either from the fact that flowers are not so more valuable than  
543 leaves, or simply from a lack of power of the analysis due to a reduced dataset. A recent  
544 work for its part demonstrated that wild tobacco flowers accumulate large amounts of  
545 defensive compounds, which expression is specifically regulated by jasmonate  
546 phytohormones signaling (Li et al. 2017). Moreover, reproductive tissues (including anthers,  
547 nectary, ovary, style and stigma) were shown to exhibit higher relative levels of defense-  
548 related compounds than vegetative tissues (leaf, root, stem and seed) in a metabolic  
549 specialization study of the *Nicotiana attenuata* Torr. ex S. Watson (Solanaceae) model  
550 species (Li et al. 2016). Also, the comparison of the natural variation in glucosinolate  
551 between vegetative and reproductive tissues in *Boechera stricta* (Graham) Al-Shehbaz  
552 (Brassicaceae) revealed much higher concentrations of these defense compounds in fruits  
553 compared to leaves (Keith and Mitchell-Olds, 2017). In our case, insecticide activity was  
554 detected in inflorescence and fruits extracts of *Costus* and *Cupania* species while leaves and

555 stem extracts were all inactive. For *Maytenus* and *Matayba* extracts, the observation of the  
556 dataset does not lead to obvious conclusions concerning defense allocation. In our study,  
557 roots or barks were not highlighted as organ leading to higher proportion of larvicidal  
558 extracts. However, these tissues may be of interest in a wider dataset. For example, higher  
559 levels of glucosinolate were detected in roots than in shoots of several species, and a higher  
560 chemical diversity of both monoterpenes and sesquiterpenes were released by barks  
561 compared to leaves immediately after mechanical damage for 178 individual trees belonging  
562 to 55 angiosperm species in French Guiana (Courtois et al. 2012; Tsunoda et al. 2017). This  
563 later finding was attributed to a larger investment in chemical defenses in the bark. Overall,  
564 our data together with the above cited literature suggest that plant organs are differently  
565 protected against pests. More active insecticides are found in reproductive organs, and  
566 recent herbivory/damage can significantly increase the probability to obtain active extracts.  
567 The choice of lipophilic extraction solvent is also critical.

568  
569 Results concerning families and location are difficult to interpret due to the small size of the  
570 dataset. Although expected according to other works, light, resource availability and  
571 vegetation type did not significantly affect insecticide potential (Endara and Coley, 2011; Fine  
572 et al. 2006, 2013; Smilanich et al. 2016). One reason may be that the objective of developing  
573 botanical insecticides prompted us to investigate specifically plant qualitative defense  
574 compounds (small weight highly active molecules). These do not represent the totality of  
575 plant defensive arsenal. Quantitative defense compounds, such as tannins, are not  
576 accessible by these techniques (De Almeida et al. 2005).

577

#### 578 **4. Conclusion**

579 The above discussed examples distinctly point out the fact, highlighted by Isman and  
580 Grieneisen (2014), that collecting a single sample from a single specimen does not allow to  
581 conclude on the interest of a given species as a new source of insecticide, and that chemical  
582 characterization of the studied extracts can clearly add value to this type of study. Moreover,



583 we also exemplified that plant defensive chemistry mechanisms are crucial while trying to  
584 discover insecticidal products, even if the search for toxic compounds only encompasses a  
585 small facet of this highly complex machinery. Multivariate analysis allowed us to identify  
586 lipophilic solvents as the most interesting to yield insecticide extracts, and highlighted the fact  
587 that extending screening to various plant tissues, in particular reproductive organs, could  
588 lead to new promising larvicidal compounds. Analyzing existing dataset and conducting  
589 screening studies inspired by the functional role of secondary metabolites in nature, in the  
590 light of the chemistry of defense and with the understanding of the mechanisms driving  
591 resource allocations as proposed by Berenbaum or Miresmailli and Isman, could therefore  
592 help renewing the old-fashioned field of insecticidal natural products (Berenbaum 1995;  
593 Miresmailli and Isman 2014).

594

#### 595 **Supporting information**

596 Supporting information may be found in the online version of this article.

597

#### 598 **Conflict of interest**

599 On behalf of all authors, the corresponding authors state that there is no conflict of interest.

600

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## Supporting information

### **Towards the optimization of botanical insecticides research: a case study on *Aedes aegypti* larvicidal botanical extracts in French Guiana**

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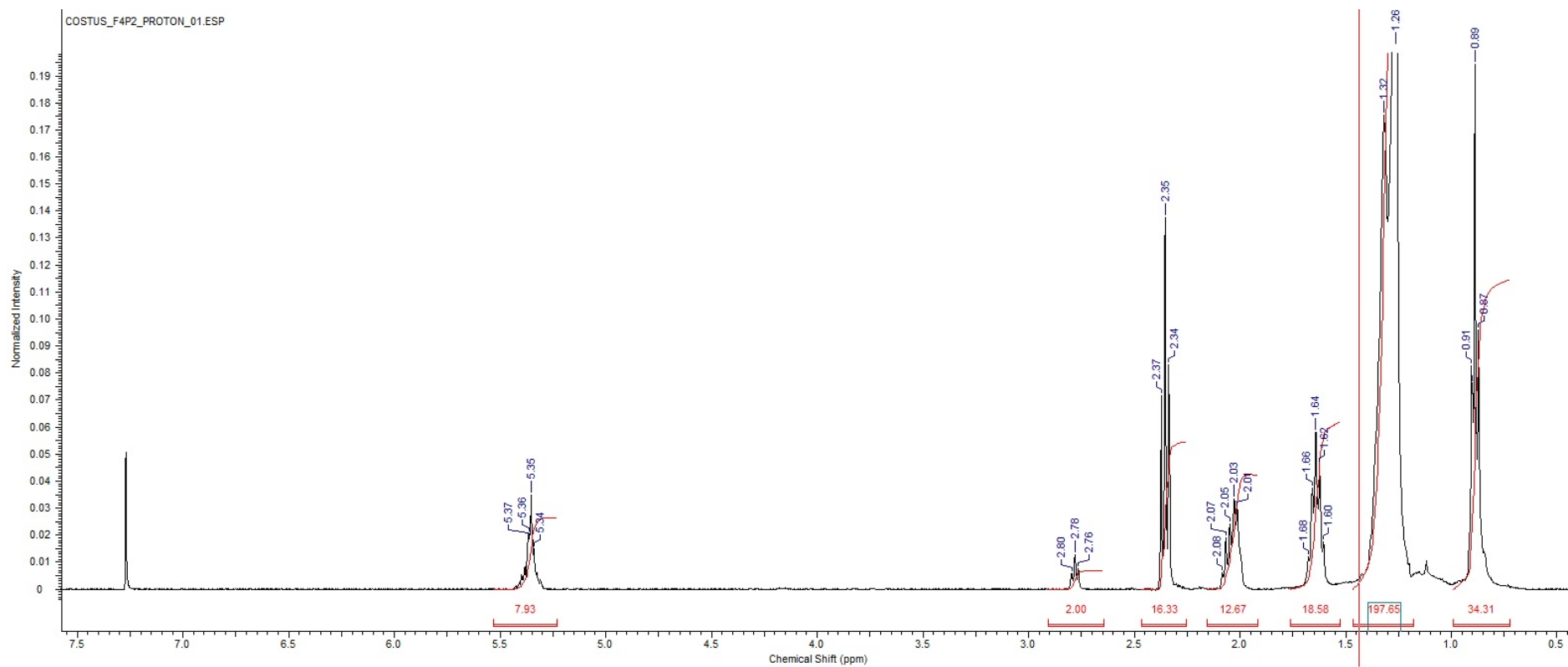
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**Fig. S1**  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) spectrum of the larvicidal fraction obtained from *Costus erythrothyrus* (Costaceae) ethyl acetate extract inflorescence.

**Table S1** Full dataset of the extracts tested against larvae of the susceptible laboratory strain Paea: botanical identification, extraction solvent, absolute mortality (number of dead larvae), geographical origin and environment and vegetation characterization

**Table S2** Full dataset of Tukey HSD pairwise differences between variables

**Fig. S1**  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) spectrum of the larvicidal fraction obtained from *Costus erythrothyrus* (Costaceae) ethyl acetate extract inflorescence.





**Table S1** Full dataset of the extracts tested against larvae of the susceptible laboratory strain *Paea*: botanical identification, extraction solvent, absolute mortality (number of dead larvae), geographical origin and environment and vegetation characterization

Voucher nb. <sup>a</sup>	Botanical family	Genus	Species	Plant organ <sup>b</sup>	Solvent <sup>c</sup>	Mortality	SD <sup>d</sup>	Localization <sup>e</sup>	Light (0= few / 2 = strong)	Resource (0= poor / 2 =rich)	Vegetation <sup>f</sup>
GO721	Annonaceae	<i>Anaxagorea</i>	<i>dolichocarpa</i>	L	EA	1	1	Ko	2	2	2
GO721	Annonaceae	<i>Anaxagorea</i>	<i>dolichocarpa</i>	L	M	1	1	Ko	2	2	2
GO721	Annonaceae	<i>Anaxagorea</i>	<i>dolichocarpa</i>	L	PE	3	2	Ko	2	2	2
GO721	Annonaceae	<i>Anaxagorea</i>	<i>dolichocarpa</i>	L	W	0	0	Ko	2	2	2
GO721	Annonaceae	<i>Anaxagorea</i>	<i>dolichocarpa</i>	St	EA	3	2	Ko	2	2	2
GO721	Annonaceae	<i>Anaxagorea</i>	<i>dolichocarpa</i>	St	M	0	0	Ko	2	2	2
GO721	Annonaceae	<i>Anaxagorea</i>	<i>dolichocarpa</i>	St	PE	5	1	Ko	2	2	2
GO721	Annonaceae	<i>Anaxagorea</i>	<i>dolichocarpa</i>	St	W	0	0	Ko	2	2	2
GO718	Annonaceae	<i>Guatteria</i>	<i>ouregou</i>	L	EA	0	0	Ko	2	2	3
GO718	Annonaceae	<i>Guatteria</i>	<i>ouregou</i>	L	M	0	0	Ko	2	2	3
GO718	Annonaceae	<i>Guatteria</i>	<i>ouregou</i>	L	PE	4	2	Ko	2	2	3
GO718	Annonaceae	<i>Guatteria</i>	<i>ouregou</i>	L	W	1	1	Ko	2	2	3
GO718	Annonaceae	<i>Guatteria</i>	<i>ouregou</i>	St	EA	1	1	Ko	2	2	3
GO718	Annonaceae	<i>Guatteria</i>	<i>ouregou</i>	St	M	2	1	Ko	2	2	3
GO718	Annonaceae	<i>Guatteria</i>	<i>ouregou</i>	St	PE	14	3	Ko	2	2	3
GO718	Annonaceae	<i>Guatteria</i>	<i>ouregou</i>	St	W	0	0	Ko	2	2	3
GO788	Annonaceae	<i>Xylopia</i>	<i>cayennensis</i>	L	EA	4	2	Ma	2	1	3
GO788	Annonaceae	<i>Xylopia</i>	<i>cayennensis</i>	L	M	0	0	Ma	2	1	3
GO788	Annonaceae	<i>Xylopia</i>	<i>cayennensis</i>	B	EA	1	1	Ma	2	1	3
GO788	Annonaceae	<i>Xylopia</i>	<i>cayennensis</i>	B	M	1	1	Ma	2	1	3
GO774	Annonaceae	<i>Xylopia</i>	<i>frutescens</i> var. <i>ferruginea</i>	L	EA	8	2	Ma	2	0	3
GO774	Annonaceae	<i>Xylopia</i>	<i>frutescens</i> var. <i>ferruginea</i>	L	M	1	1	Ma	2	0	3
GO774	Annonaceae	<i>Xylopia</i>	<i>frutescens</i> var. <i>ferruginea</i>	L	PE	54	7	Ma	2	0	3

GO774	Annonaceae	<i>Xylopia</i>	<i>frutescens</i> var. <i>ferruginea</i>	L	W	0	0	Ma	2	0	3
GO774	Annonaceae	<i>Xylopia</i>	<i>frutescens</i> var. <i>ferruginea</i>	B	EA	4	2	Ma	2	0	3
GO774	Annonaceae	<i>Xylopia</i>	<i>frutescens</i> var. <i>ferruginea</i>	B	M	1	1	Ma	2	0	3
GO774	Annonaceae	<i>Xylopia</i>	<i>frutescens</i> var. <i>ferruginea</i>	B	PE	23	5	Ma	2	0	3
GO774	Annonaceae	<i>Xylopia</i>	<i>frutescens</i> var. <i>ferruginea</i>	B	W	0	0	Ma	2	0	3
GO774	Annonaceae	<i>Xylopia</i>	<i>frutescens</i> var. <i>ferruginea</i>	St	EA	1	1	Ma	2	0	3
GO774	Annonaceae	<i>Xylopia</i>	<i>frutescens</i> var. <i>ferruginea</i>	St	M	0	0	Ma	2	0	3
GO774	Annonaceae	<i>Xylopia</i>	<i>frutescens</i> var. <i>ferruginea</i>	St	PE	38	8	Ma	2	0	3
GO774	Annonaceae	<i>Xylopia</i>	<i>frutescens</i> var. <i>ferruginea</i>	St	W	0	0	Ma	2	0	3
GO724	Apocynaceae	<i>Tabernaemontana</i>	<i>siphilitica</i>	AP	EA	0	0	Ko	2	2	1
GO724	Apocynaceae	<i>Tabernaemontana</i>	<i>siphilitica</i>	AP	M	1	1	Ko	2	2	1
GO724	Apocynaceae	<i>Tabernaemontana</i>	<i>siphilitica</i>	AP	PE	10	3	Ko	2	2	1
GO724	Apocynaceae	<i>Tabernaemontana</i>	<i>siphilitica</i>	AP	W	0	0	Ko	2	2	1
GO749	Apocynaceae	<i>Lacmellea</i>	<i>aculeata</i>	L	EA	15	3	Si	1	2	2
GO749	Apocynaceae	<i>Lacmellea</i>	<i>aculeata</i>	L	M	0	0	Si	1	2	2
GO749	Apocynaceae	<i>Lacmellea</i>	<i>aculeata</i>	L	PE	31	3	Si	1	2	2
GO749	Apocynaceae	<i>Lacmellea</i>	<i>aculeata</i>	L	W	0	0	Si	1	2	2
GO749	Apocynaceae	<i>Lacmellea</i>	<i>aculeata</i>	St	EA	0	0	Si	1	2	2
GO749	Apocynaceae	<i>Lacmellea</i>	<i>aculeata</i>	St	M	0	0	Si	1	2	2
GO749	Apocynaceae	<i>Lacmellea</i>	<i>aculeata</i>	St	PE	0	0	Si	1	2	2
GO749	Apocynaceae	<i>Lacmellea</i>	<i>aculeata</i>	St	W	1	1	Si	1	2	2
GO760	Asteraceae	<i>Bidens</i>	<i>cynapiifolia</i>	WP	EA	97	1	Mc	2	0	0
GO760	Asteraceae	<i>Bidens</i>	<i>cynapiifolia</i>	WP	M	2	1	Mc	2	0	0
GO760	Asteraceae	<i>Bidens</i>	<i>cynapiifolia</i>	WP	PE	1	1	Mc	2	0	0
GO795	Bignoniaceae	<i>Handroanthus</i>	<i>capitatus</i>	L	EA	4	2	Rg	2	0	2
GO795	Bignoniaceae	<i>Handroanthus</i>	<i>capitatus</i>	L	M	0	0	Rg	2	0	2
GO795	Bignoniaceae	<i>Handroanthus</i>	<i>capitatus</i>	St	EA	1	1	Rg	2	0	2
GO795	Bignoniaceae	<i>Handroanthus</i>	<i>capitatus</i>	St	M	1	1	Rg	2	0	2
GO727	Bignoniaceae	<i>Adenocalymma</i>	<i>moringifolium</i>	AP	EA	0	0	Ko	0	2	2
GO727	Bignoniaceae	<i>Adenocalymma</i>	<i>moringifolium</i>	AP	M	1	1	Ko	0	2	2

GO727	Bignoniaceae	<i>Adenocalymma</i>	<i>moringifolium</i>	AP	PE	3	2	Ko	0	2	2
GO727	Bignoniaceae	<i>Adenocalymma</i>	<i>moringifolium</i>	AP	W	0	0	Ko	0	2	2
GO789	Boraginaceae	<i>Varronia</i>	<i>schomburgkii</i>	AP	EA	21	3	Ma	1	2	2
GO789	Boraginaceae	<i>Varronia</i>	<i>schomburgkii</i>	AP	M	1	1	Ma	1	2	2
GO726	Celastraceae	<i>Maytenus</i>	<i>oblongata</i>	L	EA	0	0	Ko	2	2	2
GO726	Celastraceae	<i>Maytenus</i>	<i>oblongata</i>	L	M	1	1	Ko	2	2	2
GO726	Celastraceae	<i>Maytenus</i>	<i>oblongata</i>	L	PE	0	0	Ko	2	2	2
GO726	Celastraceae	<i>Maytenus</i>	<i>oblongata</i>	L	W	0	0	Ko	2	2	2
GO726	Celastraceae	<i>Maytenus</i>	<i>oblongata</i>	St	EA	98	1	Ko	2	2	2
GO726	Celastraceae	<i>Maytenus</i>	<i>oblongata</i>	St	M	1	1	Ko	2	2	2
GO726	Celastraceae	<i>Maytenus</i>	<i>oblongata</i>	St	PE	6	3	Ko	2	2	2
GO726	Celastraceae	<i>Maytenus</i>	<i>oblongata</i>	St	W	1	1	Ko	2	2	2
GO797	Celastraceae	<i>Maytenus</i>	sp.	L and F	EA	32	7	Rg	2	0	2
GO797	Celastraceae	<i>Maytenus</i>	sp.	L and F	M	0	0	Rg	2	0	2
GO797	Celastraceae	<i>Maytenus</i>	sp.	St	EA	1	1	Rg	2	0	2
GO797	Celastraceae	<i>Maytenus</i>	sp.	St	M	0	0	Rg	2	0	2
GO716	Chrysobalanaceae	<i>Licania</i>	<i>affinis</i>	L	EA	0	0	Ko	2	2	3
GO775	Chrysobalanaceae	<i>Couepia</i>	<i>bracteosa</i>	L	EA	1	1	Ma	2	0	3
GO775	Chrysobalanaceae	<i>Couepia</i>	<i>bracteosa</i>	L	M	1	1	Ma	2	0	3
GO775	Chrysobalanaceae	<i>Couepia</i>	<i>bracteosa</i>	L	PE	2	1	Ma	2	0	3
GO775	Chrysobalanaceae	<i>Couepia</i>	<i>bracteosa</i>	St	EA	1	1	Ma	2	0	3
GO775	Chrysobalanaceae	<i>Couepia</i>	<i>bracteosa</i>	St	M	2	1	Ma	2	0	3
GO775	Chrysobalanaceae	<i>Couepia</i>	<i>bracteosa</i>	St	PE	3	1	Ma	2	0	3
GO716	Chrysobalanaceae	<i>Licania</i>	<i>affinis</i>	L	M	2	2	Ko	2	2	3
GO716	Chrysobalanaceae	<i>Licania</i>	<i>affinis</i>	L	PE	97	1	Ko	2	2	3
GO716	Chrysobalanaceae	<i>Licania</i>	<i>affinis</i>	L	W	1	1	Ko	2	2	3
GO716	Chrysobalanaceae	<i>Licania</i>	<i>affinis</i>	St	EA	1	1	Ko	2	2	3
GO716	Chrysobalanaceae	<i>Licania</i>	<i>affinis</i>	St	M	2	2	Ko	2	2	3
GO716	Chrysobalanaceae	<i>Licania</i>	<i>affinis</i>	St	PE	100	0	Ko	2	2	3
GO716	Chrysobalanaceae	<i>Licania</i>	<i>affinis</i>	St	W	0	0	Ko	2	2	3

GO798	Clusiaceae	<i>Clusia</i>	<i>palmicida</i>	L	EA	3	2	Rg	2	0	3
GO798	Clusiaceae	<i>Clusia</i>	<i>palmicida</i>	L	M	0	0	Rg	2	0	3
GO798	Clusiaceae	<i>Clusia</i>	<i>palmicida</i>	St	EA	3	2	Rg	2	0	3
GO798	Clusiaceae	<i>Clusia</i>	<i>palmicida</i>	St	M	3	2	Rg	2	0	3
GO783	Combretaceae	<i>Terminalia</i>	<i>amazonia</i>	L	EA	1	1	Ma	2	0	2
GO783	Combretaceae	<i>Terminalia</i>	<i>amazonia</i>	L	M	0	0	Ma	2	0	2
GO783	Combretaceae	<i>Terminalia</i>	<i>amazonia</i>	B	EA	0	0	Ma	2	0	2
GO783	Combretaceae	<i>Terminalia</i>	<i>amazonia</i>	B	M	0	0	Ma	2	0	2
GO791	Convolvulaceae	<i>Ipomea</i>	<i>leprieurii</i>	AP	EA	7	3	Rg	2	0	1
GO791	Convolvulaceae	<i>Ipomea</i>	<i>leprieurii</i>	AP	M	14	4	Rg	2	0	1
GO791	Convolvulaceae	<i>Ipomea</i>	<i>leprieurii</i>	AP	PE	3	2	Rg	2	0	1
GO742	Costaceae	<i>Costus</i>	<i>erythrothyrus</i>	L	EA	3	1	Si	2	2	1
GO742	Costaceae	<i>Costus</i>	<i>erythrothyrus</i>	L	M	3	1	Si	2	2	1
GO742	Costaceae	<i>Costus</i>	<i>erythrothyrus</i>	L	PE	13	3	Si	2	2	1
GO742	Costaceae	<i>Costus</i>	<i>erythrothyrus</i>	L	W	0	0	Si	2	2	1
GO742	Costaceae	<i>Costus</i>	<i>erythrothyrus</i>	St	EA	11	4	Si	2	2	1
GO742	Costaceae	<i>Costus</i>	<i>erythrothyrus</i>	St	M	0	0	Si	2	2	1
GO742	Costaceae	<i>Costus</i>	<i>erythrothyrus</i>	St	PE	4	2	Si	2	2	1
GO742	Costaceae	<i>Costus</i>	<i>erythrothyrus</i>	St	W	0	0	Si	2	2	1
GO742	Costaceae	<i>Costus</i>	<i>erythrothyrus</i>	I	EA	100	0	Si	2	2	1
GO742	Costaceae	<i>Costus</i>	<i>erythrothyrus</i>	I	M	1	1	Si	2	2	1
GO742	Costaceae	<i>Costus</i>	<i>erythrothyrus</i>	I	PE	97	1	Si	2	2	1
GO742	Costaceae	<i>Costus</i>	<i>erythrothyrus</i>	I	W	0	0	Si	2	2	1
EH3	Costaceae	<i>Costus</i>	<i>cf spiralis</i>	I	EA	2	0	Rm	1	2	1
EH4	Costaceae	<i>Costus</i>	<i>spiralis</i> var. <i>villosus</i>	I	EA	0	0	Ko	2	2	1
EH5	Costaceae	<i>Costus</i>	<i>spiralis</i> var. <i>villosus</i>	I	EA	2	0	Ro	1	2	1
GO793	Cyperaceae	<i>Scleria</i>	<i>cyperina</i>	AP	EA	0	0	Rg	2	0	1
GO793	Cyperaceae	<i>Scleria</i>	<i>cyperina</i>	AP	M	4	3	Rg	2	0	1
GO781	Dilleniaceae	<i>Tetracera</i>	<i>asperula</i>	L	EA	2	1	Ma	2	0	1
GO781	Dilleniaceae	<i>Tetracera</i>	<i>asperula</i>	L	M	1	1	Ma	2	0	1

GO781	Dilleniaceae	<i>Tetracera</i>	<i>asperula</i>	F	EA	1	1	Ma	2	0	1
GO781	Dilleniaceae	<i>Tetracera</i>	<i>asperula</i>	F	M	0	0	Ma	2	0	1
GO722	Euphorbiaceae	<i>Conceveiba</i>	<i>guianensis</i>	L	EA	0	0	Ko	2	2	2
GO722	Euphorbiaceae	<i>Conceveiba</i>	<i>guianensis</i>	L	M	0	0	Ko	2	2	2
GO722	Euphorbiaceae	<i>Conceveiba</i>	<i>guianensis</i>	L	PE	12	3	Ko	2	2	2
GO722	Euphorbiaceae	<i>Conceveiba</i>	<i>guianensis</i>	L	W	0	0	Ko	2	2	2
GO722	Euphorbiaceae	<i>Conceveiba</i>	<i>guianensis</i>	St	EA	0	0	Ko	2	2	2
GO722	Euphorbiaceae	<i>Conceveiba</i>	<i>guianensis</i>	St	M	1	1	Ko	2	2	2
GO722	Euphorbiaceae	<i>Conceveiba</i>	<i>guianensis</i>	St	PE	8	2	Ko	2	2	2
GO722	Euphorbiaceae	<i>Conceveiba</i>	<i>guianensis</i>	St	W	0	0	Ko	2	2	2
GO790	Euphorbiaceae	<i>Cnidoscolus</i>	<i>urens</i>	AP	EA	1	1	Mc	2	1	1
GO790	Euphorbiaceae	<i>Cnidoscolus</i>	<i>urens</i>	AP	M	0	0	Mc	2	1	1
GO786	Euphorbiaceae	<i>Croton</i>	<i>guianensis</i>	L	EA	2	1	Ma	2	1	2
GO786	Euphorbiaceae	<i>Croton</i>	<i>guianensis</i>	L	M	3	2	Ma	2	1	2
VE202	Euphorbiaceae	<i>Croton</i>	<i>macradenis</i>	AP	EA	2	2	Mo	2	1	0
VE202	Euphorbiaceae	<i>Croton</i>	<i>macradenis</i>	AP	M	0	0	Mo	2	1	0
VE202	Euphorbiaceae	<i>Croton</i>	<i>macradenis</i>	AP	PE	54	4	Mo	2	1	0
VE202	Euphorbiaceae	<i>Croton</i>	<i>macradenis</i>	AP	W	3	1	Mo	2	1	0
VE167	Euphorbiaceae	<i>Croton</i>	<i>matourensis</i>	L	EA	0	0	Mt	2	1	2
VE167	Euphorbiaceae	<i>Croton</i>	<i>matourensis</i>	L	M	4	2	Mt	2	1	2
VE167	Euphorbiaceae	<i>Croton</i>	<i>matourensis</i>	L	PE	0	0	Mt	2	1	2
VE167	Euphorbiaceae	<i>Croton</i>	<i>matourensis</i>	L	W	0	0	Mt	2	1	2
VE167	Euphorbiaceae	<i>Croton</i>	<i>matourensis</i>	B	EA	1	1	Mt	2	1	2
VE167	Euphorbiaceae	<i>Croton</i>	<i>matourensis</i>	B	M	2	1	Mt	2	1	2
VE167	Euphorbiaceae	<i>Croton</i>	<i>matourensis</i>	B	PE	2	1	Mt	2	1	2
VE167	Euphorbiaceae	<i>Croton</i>	<i>matourensis</i>	B	W	0	0	Mt	2	1	2
GO743	Euphorbiaceae	<i>Croton</i>	<i>nuntians</i>	L	EA	1	1	Si	2	2	1
GO743	Euphorbiaceae	<i>Croton</i>	<i>nuntians</i>	L	M	2	1	Si	2	2	1
GO743	Euphorbiaceae	<i>Croton</i>	<i>nuntians</i>	L	PE	1	1	Si	2	2	1
GO743	Euphorbiaceae	<i>Croton</i>	<i>nuntians</i>	L	W	1	1	Si	2	2	1

GO743	Euphorbiaceae	<i>Croton</i>	<i>nuntians</i>	St	EA	6	1	Si	2	2	1
GO743	Euphorbiaceae	<i>Croton</i>	<i>nuntians</i>	St	M	0	0	Si	2	2	1
GO743	Euphorbiaceae	<i>Croton</i>	<i>nuntians</i>	St	PE	3	1	Si	2	2	1
GO743	Euphorbiaceae	<i>Croton</i>	<i>nuntians</i>	St	W	0	0	Si	2	2	1
VE199	Euphorbiaceae	<i>Croton</i>	<i>nuntians</i>	L	EA	2	1	Si	2	2	1
VE199	Euphorbiaceae	<i>Croton</i>	<i>nuntians</i>	L	M	2	1	Si	2	2	1
VE199	Euphorbiaceae	<i>Croton</i>	<i>nuntians</i>	L	PE	3	2	Si	2	2	1
VE199	Euphorbiaceae	<i>Croton</i>	<i>nuntians</i>	L	W	0	0	Si	2	2	1
VE199	Euphorbiaceae	<i>Croton</i>	<i>nuntians</i>	St	EA	1	1	Si	2	2	1
VE199	Euphorbiaceae	<i>Croton</i>	<i>nuntians</i>	St	M	0	0	Si	2	2	1
VE199	Euphorbiaceae	<i>Croton</i>	<i>nuntians</i>	St	PE	4	2	Si	2	2	1
VE199	Euphorbiaceae	<i>Croton</i>	<i>nuntians</i>	St	W	1	1	Si	2	2	1
GO794	Euphorbiaceae	<i>Sapium</i>	<i>argutum</i>	L	EA	8	4	Rg	2	0	2
GO794	Euphorbiaceae	<i>Sapium</i>	<i>argutum</i>	L	M	0	0	Rg	2	0	2
GO794	Euphorbiaceae	<i>Sapium</i>	<i>argutum</i>	St	EA	0	0	Rg	2	0	2
GO794	Euphorbiaceae	<i>Sapium</i>	<i>argutum</i>	St	M	0	0	Rg	2	0	2
GO719	Fabaceae	<i>Alexa</i>	<i>wachenheimii</i>	L	EA	0	0	Ko	2	2	3
GO719	Fabaceae	<i>Alexa</i>	<i>wachenheimii</i>	L	M	0	0	Ko	2	2	3
GO719	Fabaceae	<i>Alexa</i>	<i>wachenheimii</i>	L	PE	5	1	Ko	2	2	3
GO719	Fabaceae	<i>Alexa</i>	<i>wachenheimii</i>	L	W	0	0	Ko	2	2	3
GO719	Fabaceae	<i>Alexa</i>	<i>wachenheimii</i>	B	EA	6	3	Ko	2	2	3
GO719	Fabaceae	<i>Alexa</i>	<i>wachenheimii</i>	B	M	1	1	Ko	2	2	3
GO719	Fabaceae	<i>Alexa</i>	<i>wachenheimii</i>	B	PE	56	3	Ko	2	2	3
GO719	Fabaceae	<i>Alexa</i>	<i>wachenheimii</i>	B	W	0	0	Ko	2	2	3
238	Fabaceae	<i>Bocoa</i>	<i>prouacensis</i>	B	EA	3	2	Si	0	2	3
238	Fabaceae	<i>Bocoa</i>	<i>prouacensis</i>	B	M	1	1	Si	0	2	3
238	Fabaceae	<i>Bocoa</i>	<i>prouacensis</i>	B	PE	0	0	Si	0	2	3
238	Fabaceae	<i>Bocoa</i>	<i>prouacensis</i>	B	W	0	0	Si	0	2	3
GO806	Fabaceae	<i>Chamaecrista</i>	<i>desvauxii</i> var. <i>saxatilis</i>	AP	EA	4	2	Rg	2	0	1
GO806	Fabaceae	<i>Chamaecrista</i>	<i>desvauxii</i> var. <i>saxatilis</i>	AP	M	0	0	Rg	2	0	1

GO758	Fabaceae	<i>Chamaecrista</i>	<i>diphylla</i>	AP	EA	4	0	Mc	2	1	0
GO758	Fabaceae	<i>Chamaecrista</i>	<i>diphylla</i>	AP	M	0	0	Mc	2	1	0
GO758	Fabaceae	<i>Chamaecrista</i>	<i>diphylla</i>	AP	PE	1	1	Mc	2	1	0
GO758	Fabaceae	<i>Chamaecrista</i>	<i>diphylla</i>	AP	W	0	0	Mc	2	1	0
GO762	Fabaceae	<i>Dalbergia</i>	<i>monetaria</i>	L	EA	0	0	Mc	2	0	0
GO762	Fabaceae	<i>Dalbergia</i>	<i>monetaria</i>	L	M	1	1	Mc	2	0	0
GO762	Fabaceae	<i>Dalbergia</i>	<i>monetaria</i>	L	PE	2	1	Mc	2	0	0
GO762	Fabaceae	<i>Dalbergia</i>	<i>monetaria</i>	L	W	1	1	Mc	2	0	0
GO762	Fabaceae	<i>Dalbergia</i>	<i>monetaria</i>	St	EA	1	1	Mc	2	0	0
GO762	Fabaceae	<i>Dalbergia</i>	<i>monetaria</i>	St	M	0	0	Mc	2	0	0
GO762	Fabaceae	<i>Dalbergia</i>	<i>monetaria</i>	St	PE	2	1	Mc	2	0	0
GO762	Fabaceae	<i>Dalbergia</i>	<i>monetaria</i>	St	W	0	0	Mc	2	0	0
GO746	Fabaceae	<i>Desmodium</i>	<i>barbatum</i>	WP	EA	2	1	Si	2	0	0
GO746	Fabaceae	<i>Desmodium</i>	<i>barbatum</i>	WP	M	0	0	Si	2	0	0
GO746	Fabaceae	<i>Desmodium</i>	<i>barbatum</i>	WP	PE	3	2	Si	2	0	0
GO746	Fabaceae	<i>Desmodium</i>	<i>barbatum</i>	WP	W	0	0	Si	2	0	0
GO779	Fabaceae	<i>Dimorphandra</i>	<i>polyandra</i>	L	EA	5	5	Ma	2	0	3
GO779	Fabaceae	<i>Dimorphandra</i>	<i>polyandra</i>	L	M	1	1	Ma	2	0	3
GO779	Fabaceae	<i>Dimorphandra</i>	<i>polyandra</i>	B	EA	4	2	Ma	2	0	3
GO779	Fabaceae	<i>Dimorphandra</i>	<i>polyandra</i>	B	M	0	0	Ma	2	0	3
GO759	Fabaceae	<i>Entada</i>	<i>polystachya</i>	L	EA	0	0	Mc	2	1	1
GO759	Fabaceae	<i>Entada</i>	<i>polystachya</i>	L	M	0	0	Mc	2	1	1
GO759	Fabaceae	<i>Entada</i>	<i>polystachya</i>	L	PE	2	1	Mc	2	1	1
GO759	Fabaceae	<i>Entada</i>	<i>polystachya</i>	L	W	0	0	Mc	2	1	1
GO759	Fabaceae	<i>Entada</i>	<i>polystachya</i>	St	EA	2	1	Mc	2	1	1
GO759	Fabaceae	<i>Entada</i>	<i>polystachya</i>	St	M	1	1	Mc	2	1	1
GO759	Fabaceae	<i>Entada</i>	<i>polystachya</i>	St	W	0	0	Mc	2	1	1
PMF4976	Fabaceae	<i>Enterolobium</i>	<i>schomburgkii</i>	W	EA	1	1	Si	0	2	3
PMF4976	Fabaceae	<i>Enterolobium</i>	<i>schomburgkii</i>	W	M	13	2	Si	0	2	3
PMF4976	Fabaceae	<i>Enterolobium</i>	<i>schomburgkii</i>	W	W	2	1	Si	0	2	3

PMF4976	Fabaceae	<i>Enterolobium</i>	<i>schomburgkii</i>	B	EA	1	1	Si	0	2	3
PMF4976	Fabaceae	<i>Enterolobium</i>	<i>schomburgkii</i>	B	M	2	2	Si	0	2	3
PMF4976	Fabaceae	<i>Enterolobium</i>	<i>schomburgkii</i>	B	PE	0	0	Si	0	2	3
PMF4976	Fabaceae	<i>Enterolobium</i>	<i>schomburgkii</i>	B	W	2	1	Si	0	2	3
MC1129	Fabaceae	<i>Inga</i>	<i>alba</i>	W	EA	3	1	Si	0	2	3
MC1129	Fabaceae	<i>Inga</i>	<i>alba</i>	W	M	5	1	Si	0	2	3
MC1129	Fabaceae	<i>Inga</i>	<i>alba</i>	W	W	1	1	Si	0	2	3
GO805	Fabaceae	<i>Inga</i>	<i>virgultosa</i>	L	EA	0	0	Rg	2	0	3
GO805	Fabaceae	<i>Inga</i>	<i>virgultosa</i>	L	M	0	0	Rg	2	0	3
GO805	Fabaceae	<i>Inga</i>	<i>virgultosa</i>	St	EA	1	1	Rg	2	0	3
GO805	Fabaceae	<i>Inga</i>	<i>virgultosa</i>	St	M	0	0	Rg	2	0	3
VE108B	Fabaceae	<i>Lonchocarpus</i>	<i>monilis</i>	L	EA	100	0	Mo	2	1	2
VE108B	Fabaceae	<i>Lonchocarpus</i>	<i>monilis</i>	L	M	97	2	Mo	2	1	2
VE108B	Fabaceae	<i>Lonchocarpus</i>	<i>monilis</i>	L	PE	100	0	Mo	2	1	2
VE108B	Fabaceae	<i>Lonchocarpus</i>	<i>monilis</i>	L	W	19	1	Mo	2	1	2
GO725	Fabaceae	<i>Macrolobium</i>	<i>bifolium</i>	L	EA	1	1	Ko	2	2	3
GO725	Fabaceae	<i>Macrolobium</i>	<i>bifolium</i>	L	M	1	1	Ko	2	2	3
GO725	Fabaceae	<i>Macrolobium</i>	<i>bifolium</i>	L	PE	8	2	Ko	2	2	3
GO725	Fabaceae	<i>Macrolobium</i>	<i>bifolium</i>	L	W	0	0	Ko	2	2	3
GO725	Fabaceae	<i>Macrolobium</i>	<i>bifolium</i>	St	EA	0	0	Ko	2	2	3
GO725	Fabaceae	<i>Macrolobium</i>	<i>bifolium</i>	St	M	1	1	Ko	2	2	3
GO725	Fabaceae	<i>Macrolobium</i>	<i>bifolium</i>	St	PE	3	1	Ko	2	2	3
GO725	Fabaceae	<i>Macrolobium</i>	<i>bifolium</i>	St	W	0	0	Ko	2	2	3
GO785	Fabaceae	<i>Macrolobium</i>	<i>guianense</i>	L	EA	0	0	Ma	0	2	3
GO785	Fabaceae	<i>Macrolobium</i>	<i>guianense</i>	L	M	0	0	Ma	0	2	3
GO785	Fabaceae	<i>Macrolobium</i>	<i>guianense</i>	W	EA	1	1	Ma	0	2	3
GO785	Fabaceae	<i>Macrolobium</i>	<i>guianense</i>	W	M	0	0	Ma	0	2	3
GO717	Fabaceae	<i>Ormosia</i>	<i>coutinhoi</i>	L	EA	2	1	Ko	2	2	2
GO717	Fabaceae	<i>Ormosia</i>	<i>coutinhoi</i>	L	M	1	1	Ko	2	2	2
GO717	Fabaceae	<i>Ormosia</i>	<i>coutinhoi</i>	L	PE	14	5	Ko	2	2	2



GO717	Fabaceae	<i>Ormosia</i>	<i>coutinhoi</i>	L	W	0	0	Ko	2	2	2
GO717	Fabaceae	<i>Ormosia</i>	<i>coutinhoi</i>	St	EA	1	1	Ko	2	2	2
GO717	Fabaceae	<i>Ormosia</i>	<i>coutinhoi</i>	St	M	2	1	Ko	2	2	2
GO717	Fabaceae	<i>Ormosia</i>	<i>coutinhoi</i>	St	PE	6	2	Ko	2	2	2
GO717	Fabaceae	<i>Ormosia</i>	<i>coutinhoi</i>	St	W	0	0	Ko	2	2	2
GO738	Fabaceae	<i>Senna</i>	<i>quinguangulata</i>	L	EA	4	2	Si	2	2	1
GO738	Fabaceae	<i>Senna</i>	<i>quinguangulata</i>	L	M	4	3	Si	2	2	1
GO738	Fabaceae	<i>Senna</i>	<i>quinguangulata</i>	L	PE	10	3	Si	2	2	1
GO738	Fabaceae	<i>Senna</i>	<i>quinguangulata</i>	L	W	0	0	Si	2	2	1
GO738	Fabaceae	<i>Senna</i>	<i>quinguangulata</i>	St	EA	2	1	Si	2	2	1
GO738	Fabaceae	<i>Senna</i>	<i>quinguangulata</i>	St	M	0	0	Si	2	2	1
GO738	Fabaceae	<i>Senna</i>	<i>quinguangulata</i>	St	PE	7	3	Si	2	2	1
GO738	Fabaceae	<i>Senna</i>	<i>quinguangulata</i>	St	W	1	1	Si	2	2	1
VE137	Fabaceae	<i>Spirotropis</i>	<i>longifolia</i>	W	EA	3	2	Si	0	2	3
VE137	Fabaceae	<i>Spirotropis</i>	<i>longifolia</i>	W	M	0	0	Si	0	2	3
VE137	Fabaceae	<i>Spirotropis</i>	<i>longifolia</i>	W	PE	16	4	Si	0	2	3
VE137	Fabaceae	<i>Spirotropis</i>	<i>longifolia</i>	W	W	0	0	Si	0	2	3
VE137	Fabaceae	<i>Spirotropis</i>	<i>longifolia</i>	B	EA	0	0	Si	0	2	3
VE137	Fabaceae	<i>Spirotropis</i>	<i>longifolia</i>	B	M	0	0	Si	0	2	3
VE137	Fabaceae	<i>Spirotropis</i>	<i>longifolia</i>	B	PE	3	2	Si	0	2	3
VE137	Fabaceae	<i>Spirotropis</i>	<i>longifolia</i>	B	W	0	0	Si	0	2	3
VE137	Fabaceae	<i>Spirotropis</i>	<i>longifolia</i>	Roots	EA	2	1	Si	0	2	3
VE137	Fabaceae	<i>Spirotropis</i>	<i>longifolia</i>	Roots	M	0	0	Si	0	2	3
VE137	Fabaceae	<i>Spirotropis</i>	<i>longifolia</i>	Roots	PE	13	3	Si	0	2	3
VE137	Fabaceae	<i>Spirotropis</i>	<i>longifolia</i>	Roots	W	3	1	Si	0	2	3
GO792	Fabaceae	<i>Stylosanthes</i>	<i>guianensis</i>	AP	EA	3	2	Rg	2	0	1
GO792	Fabaceae	<i>Stylosanthes</i>	<i>guianensis</i>	AP	M	1	1	Rg	2	0	1
GO715	Fabaceae	<i>Swartzia</i>	<i>guianensis</i>	L	EA	1	1	Ko	2	2	2
GO715	Fabaceae	<i>Swartzia</i>	<i>guianensis</i>	L	M	4	2	Ko	2	2	2
GO715	Fabaceae	<i>Swartzia</i>	<i>guianensis</i>	L	PE	0	0	Ko	2	2	2

GO715	Fabaceae	<i>Swartzia</i>	<i>guianensis</i>	L	W	0	0	Ko	2	2	2
GO715	Fabaceae	<i>Swartzia</i>	<i>guianensis</i>	St	EA	3	1	Ko	2	2	2
GO715	Fabaceae	<i>Swartzia</i>	<i>guianensis</i>	St	M	0	0	Ko	2	2	2
GO715	Fabaceae	<i>Swartzia</i>	<i>guianensis</i>	St	PE	10	2	Ko	2	2	2
GO715	Fabaceae	<i>Swartzia</i>	<i>guianensis</i>	St	W	0	0	Ko	2	2	2
GO764	Fabaceae	<i>Vigna</i>	<i>luteola</i>	AP	EA	0	0	Mc	2	0	1
GO764	Fabaceae	<i>Vigna</i>	<i>luteola</i>	AP	M	5	1	Mc	2	0	1
GO764	Fabaceae	<i>Vigna</i>	<i>luteola</i>	AP	PE	2	1	Mc	2	0	1
GO784	Humiriaceae	<i>Humiria</i>	<i>balsamifera</i>	B	EA	84	4	Ma	1	0	3
GO784	Humiriaceae	<i>Humiria</i>	<i>balsamifera</i>	B	M	16	3	Ma	1	0	3
VE101	Humiriaceae	<i>Humiria</i>	<i>balsamifera</i>	W	EA	0	0	Mc	1	1	2
VE101	Humiriaceae	<i>Humiria</i>	<i>balsamifera</i>	W	M	2	1	Mc	1	1	2
VE101	Humiriaceae	<i>Humiria</i>	<i>balsamifera</i>	W	PE	6	1	Mc	1	1	2
VE101	Humiriaceae	<i>Humiria</i>	<i>balsamifera</i>	W	W	1	1	Mc	1	1	2
PS16	Lauraceae	<i>Licaria</i>	<i>cannella</i>	W	EA	6	3	Rg	0	2	3
PS16	Lauraceae	<i>Licaria</i>	<i>cannella</i>	W	M	0	0	Rg	0	2	3
PS16	Lauraceae	<i>Licaria</i>	<i>cannella</i>	W	PE	20	2	Rg	0	2	3
PS16	Lauraceae	<i>Licaria</i>	<i>cannella</i>	W	W	0	0	Rg	0	2	3
1039	Lauraceae	<i>Sextonia</i>	<i>rubra</i>	B	EA	100	0	Si	0	2	3
AR12	Lauraceae	<i>Sextonia</i>	<i>rubra</i>	W	M	100	0	Rg	0	2	3
GO720	Loranthaceae	<i>Phthirusa</i>	sp.	L	EA	0	0	Ko	2	2	2
GO720	Loranthaceae	<i>Phthirusa</i>	sp.	L	M	0	0	Ko	2	2	2
GO720	Loranthaceae	<i>Phthirusa</i>	sp.	L	PE	5	1	Ko	2	2	2
GO720	Loranthaceae	<i>Phthirusa</i>	sp.	L	W	0	0	Ko	2	2	2
GO720	Loranthaceae	<i>Phthirusa</i>	sp.	St	EA	1	1	Ko	2	2	2
GO720	Loranthaceae	<i>Phthirusa</i>	sp.	St	M	1	1	Ko	2	2	2
GO720	Loranthaceae	<i>Phthirusa</i>	sp.	St	PE	1	1	Ko	2	2	2
GO796	Lythraceae	<i>Cuphea</i>	<i>blackii</i>	AP	EA	0	0	Rg	2	0	1
GO796	Lythraceae	<i>Cuphea</i>	<i>blackii</i>	AP	M	0	0	Rg	2	0	1
GO755	Malpighiaceae	<i>Byrsonima</i>	<i>crassifolia</i>	L	EA	4	0	Mc	2	1	2

GO780	Malpigiaceae	<i>Byrsonima</i>	<i>aerugo</i>	L	EA	2	1	Ma	2	0	2
GO780	Malpigiaceae	<i>Byrsonima</i>	<i>aerugo</i>	L	M	0	0	Ma	2	0	2
GO755	Malpigiaceae	<i>Byrsonima</i>	<i>crassifolia</i>	L	M	1	1	Mc	2	1	2
GO755	Malpigiaceae	<i>Byrsonima</i>	<i>crassifolia</i>	L	PE	1	1	Mc	2	1	2
GO755	Malpigiaceae	<i>Byrsonima</i>	<i>crassifolia</i>	L	W	0	0	Mc	2	1	2
GO755	Malpigiaceae	<i>Byrsonima</i>	<i>crassifolia</i>	B	EA	1	1	Mc	2	1	2
GO755	Malpigiaceae	<i>Byrsonima</i>	<i>crassifolia</i>	B	M	1	1	Mc	2	1	2
GO755	Malpigiaceae	<i>Byrsonima</i>	<i>crassifolia</i>	B	PE	2	2	Mc	2	1	2
GO755	Malpigiaceae	<i>Byrsonima</i>	<i>crassifolia</i>	B	W	0	0	Mc	2	1	2
GO754	Malpigiaceae	<i>Byrsonima</i>	<i>spicata</i>	L	EA	0	0	Mc	1	1	2
GO754	Malpigiaceae	<i>Byrsonima</i>	<i>spicata</i>	L	M	0	0	Mc	1	1	2
GO754	Malpigiaceae	<i>Byrsonima</i>	<i>spicata</i>	L	PE	6	3	Mc	1	1	2
GO754	Malpigiaceae	<i>Byrsonima</i>	<i>spicata</i>	L	W	0	0	Mc	1	1	2
GO754	Malpigiaceae	<i>Byrsonima</i>	<i>spicata</i>	W	EA	3	1	Mc	1	1	2
GO754	Malpigiaceae	<i>Byrsonima</i>	<i>spicata</i>	W	M	0	0	Mc	1	1	2
GO754	Malpigiaceae	<i>Byrsonima</i>	<i>spicata</i>	W	PE	2	1	Mc	1	1	2
GO754	Malpigiaceae	<i>Byrsonima</i>	<i>spicata</i>	W	W	0	0	Mc	1	1	2
GO754	Malpigiaceae	<i>Byrsonima</i>	<i>spicata</i>	B	EA	4	2	Mc	1	1	2
GO754	Malpigiaceae	<i>Byrsonima</i>	<i>spicata</i>	B	M	2	1	Mc	1	1	2
GO754	Malpigiaceae	<i>Byrsonima</i>	<i>spicata</i>	B	PE	1	1	Mc	1	1	2
GO754	Malpigiaceae	<i>Byrsonima</i>	<i>spicata</i>	B	W	1	1	Mc	1	1	2
GO801	Malvaceae	<i>Eriotheca</i>	<i>surinamensis</i>	L	EA	1	1	Rg	2	0	3
GO801	Malvaceae	<i>Eriotheca</i>	<i>surinamensis</i>	L	M	1	1	Rg	2	0	3
1058	Malvaceae	<i>Sterculia</i>	<i>pruriens</i>	B	EA	0	0	Si	0	2	3
1058	Malvaceae	<i>Sterculia</i>	<i>pruriens</i>	B	M	0	0	Si	0	2	3
1058	Malvaceae	<i>Sterculia</i>	<i>pruriens</i>	B	PE	1	1	Si	0	2	3
1058	Malvaceae	<i>Sterculia</i>	<i>pruriens</i>	B	W	1	1	Si	0	2	3
GO804	Melastomataceae	<i>Ernestia</i>	<i>granvillei</i>	AP	EA	2	2	Rg	2	0	1
GO804	Melastomataceae	<i>Ernestia</i>	<i>granvillei</i>	AP	M	0	0	Rg	2	0	1
GO712	Meliaceae	<i>Azadirachta</i>	<i>indica</i>	L	M	2	0	Ko	1	2	2

GO756	Meliaceae	<i>Guarea</i>	<i>guidonia</i>	L	EA	3	1	Mc	2	1	2
GO756	Meliaceae	<i>Guarea</i>	<i>guidonia</i>	L	M	0	0	Mc	2	1	2
GO756	Meliaceae	<i>Guarea</i>	<i>guidonia</i>	L	PE	0	0	Mc	2	1	2
GO756	Meliaceae	<i>Guarea</i>	<i>guidonia</i>	L	W	0	0	Mc	2	1	2
GO756	Meliaceae	<i>Guarea</i>	<i>guidonia</i>	St	EA	2	1	Mc	2	1	2
GO756	Meliaceae	<i>Guarea</i>	<i>guidonia</i>	St	M	1	1	Mc	2	1	2
GO756	Meliaceae	<i>Guarea</i>	<i>guidonia</i>	St	PE	0	0	Mc	2	1	2
GO756	Meliaceae	<i>Guarea</i>	<i>guidonia</i>	St	W	1	1	Mc	2	1	2
BC	Moraceae	<i>Bagassa</i>	<i>guianensis</i>	B	EA	1	1	Si	1	1	3
BC	Moraceae	<i>Bagassa</i>	<i>guianensis</i>	B	M	0	0	Si	1	1	3
GO799	Myrtaceae	<i>Myrcia</i>	<i>saxatilis</i>	L	EA	0	0	Rg	2	0	2
GO799	Myrtaceae	<i>Myrcia</i>	<i>saxatilis</i>	L	M	1	1	Rg	2	0	2
GO799	Myrtaceae	<i>Myrcia</i>	<i>saxatilis</i>	St	EA	3	2	Rg	2	0	2
GO799	Myrtaceae	<i>Myrcia</i>	<i>saxatilis</i>	St	M	2	2	Rg	2	0	2
GO757	Orobanchaceae	<i>Anisantherina</i>	<i>hispidula</i>	WP	EA	2	1	Mc	2	1	2
GO757	Orobanchaceae	<i>Anisantherina</i>	<i>hispidula</i>	WP	M	0	0	Mc	2	1	2
GO757	Orobanchaceae	<i>Anisantherina</i>	<i>hispidula</i>	WP	PE	0	0	Mc	2	1	2
GO757	Orobanchaceae	<i>Anisantherina</i>	<i>hispidula</i>	WP	W	0	0	Mc	2	1	2
GO741	Piperaceae	<i>Piper</i>	<i>hispidum</i>	L	EA	62	5	Si	2	1	1
GO741	Piperaceae	<i>Piper</i>	<i>hispidum</i>	L	M	1	1	Si	2	1	1
GO741	Piperaceae	<i>Piper</i>	<i>hispidum</i>	L	PE	3	2	Si	2	1	1
GO741	Piperaceae	<i>Piper</i>	<i>hispidum</i>	L	W	0	0	Si	2	1	1
GO741	Piperaceae	<i>Piper</i>	<i>hispidum</i>	St	EA	3	1	Si	2	1	1
GO741	Piperaceae	<i>Piper</i>	<i>hispidum</i>	St	M	0	0	Si	2	1	1
GO741	Piperaceae	<i>Piper</i>	<i>hispidum</i>	St	PE	39	10	Si	2	1	1
GO741	Piperaceae	<i>Piper</i>	<i>hispidum</i>	St	W	0	0	Si	2	1	1
GO787	Polygalaceae	<i>Polygala</i>	<i>longicaulis</i>	WP	EA	2	1	Ma	2	0	0
GO787	Polygalaceae	<i>Polygala</i>	<i>longicaulis</i>	WP	M	0	0	Ma	2	0	0
GO723	Rubiaceae	<i>Posoqueria</i>	<i>longifolia</i>	L	EA	0	0	Ko	2	2	2
GO723	Rubiaceae	<i>Posoqueria</i>	<i>longifolia</i>	L	M	0	0	Ko	2	2	2

GO723	Rubiaceae	<i>Posoqueria</i>	<i>longifolia</i>	L	PE	10	2	Ko	2	2	2
GO723	Rubiaceae	<i>Posoqueria</i>	<i>longifolia</i>	L	W	0	0	Ko	2	2	2
GO803	Rubiaceae	<i>Sipanea</i>	<i>pratensis</i>	AP	EA	3	2	Rg	2	0	0
GO803	Rubiaceae	<i>Sipanea</i>	<i>pratensis</i>	AP	M	0	0	Rg	2	0	0
GO802	Rubiaceae	<i>Tocoyena</i>	<i>guianensis</i>	AP	EA	1	1	Rg	2	0	2
GO802	Rubiaceae	<i>Tocoyena</i>	<i>guianensis</i>	AP	M	1	1	Rg	2	0	2
GO748	Salicaceae	<i>Banara</i>	<i>guianensis</i>	L	EA	1	1	Si	2	1	1
GO748	Salicaceae	<i>Banara</i>	<i>guianensis</i>	L	M	0	0	Si	2	1	1
GO748	Salicaceae	<i>Banara</i>	<i>guianensis</i>	L	PE	8	2	Si	2	1	1
GO748	Salicaceae	<i>Banara</i>	<i>guianensis</i>	L	W	0	0	Si	2	1	1
GO748	Salicaceae	<i>Banara</i>	<i>guianensis</i>	St	EA	2	2	Si	2	1	1
GO748	Salicaceae	<i>Banara</i>	<i>guianensis</i>	St	M	0	0	Si	2	1	1
GO748	Salicaceae	<i>Banara</i>	<i>guianensis</i>	St	W	0	0	Si	2	1	1
GO777	Salicaceae	<i>Casearia</i>	<i>grandiflora</i>	L	EA	8	4	Ma	2	0	3
GO777	Salicaceae	<i>Casearia</i>	<i>grandiflora</i>	L	M	0	0	Ma	2	0	3
GO777	Salicaceae	<i>Casearia</i>	<i>grandiflora</i>	L	PE	4	0	Ma	2	0	3
GO777	Salicaceae	<i>Casearia</i>	<i>grandiflora</i>	W	EA	1	1	Ma	2	0	3
GO777	Salicaceae	<i>Casearia</i>	<i>grandiflora</i>	W	M	1	1	Ma	2	0	3
GO777	Salicaceae	<i>Casearia</i>	<i>grandiflora</i>	B	EA	5	3	Ma	2	0	3
GO777	Salicaceae	<i>Casearia</i>	<i>grandiflora</i>	B	M	3	1	Ma	2	0	3
GO777	Salicaceae	<i>Casearia</i>	<i>grandiflora</i>	B	PE	11	2	Ma	2	0	3
GO771	Salicaceae	<i>Laetia</i>	<i>procera</i>	B	EA	14	3	Mc	1	1	3
424	Salicaceae	<i>Laetia</i>	<i>procera</i>	B	EA	28	3	Si	0	2	3
424	Salicaceae	<i>Laetia</i>	<i>procera</i>	B	M	21	4	Si	0	2	3
1003	Salicaceae	<i>Laetia</i>	<i>procera</i>	B	EA	63	6	Si	0	2	3
1003	Salicaceae	<i>Laetia</i>	<i>procera</i>	B	M	0	0	Si	0	2	3
1003	Salicaceae	<i>Laetia</i>	<i>procera</i>	B	PE	94	2	Si	0	2	3
1003	Salicaceae	<i>Laetia</i>	<i>procera</i>	B	W	6	3	Si	0	2	3
GO778	Sapindaceae	<i>Cupania</i>	<i>scrobiculata</i>	L	EA	2	2	Ma	2	0	3
GO778	Sapindaceae	<i>Cupania</i>	<i>scrobiculata</i>	L	M	3	2	Ma	2	0	3

GO778	Sapindaceae	<i>Cupania</i>	<i>scrobiculata</i>	F	EA	64	2	Ma	2	0	3
GO778	Sapindaceae	<i>Cupania</i>	<i>scrobiculata</i>	F	M	0	0	Ma	2	0	3
GO778	Sapindaceae	<i>Cupania</i>	<i>scrobiculata</i>	St	EA	3	2	Ma	2	0	3
GO778	Sapindaceae	<i>Cupania</i>	<i>scrobiculata</i>	St	M	1	1	Ma	2	0	3
GO776	Sapindaceae	<i>Matayba</i>	<i>arborescens</i>	L	EA	14	5	Ma	2	0	3
GO776	Sapindaceae	<i>Matayba</i>	<i>arborescens</i>	L	M	2	1	Ma	2	0	3
GO776	Sapindaceae	<i>Matayba</i>	<i>arborescens</i>	L	PE	4	0	Ma	2	0	3
GO776	Sapindaceae	<i>Matayba</i>	<i>arborescens</i>	F	EA	60	3	Ma	2	0	3
GO776	Sapindaceae	<i>Matayba</i>	<i>arborescens</i>	F	M	1	1	Ma	2	0	3
GO776	Sapindaceae	<i>Matayba</i>	<i>arborescens</i>	F	PE	51	7	Ma	2	0	3
GO776	Sapindaceae	<i>Matayba</i>	<i>arborescens</i>	St	EA	31	6	Ma	2	0	3
GO776	Sapindaceae	<i>Matayba</i>	<i>arborescens</i>	St	M	2	1	Ma	2	0	3
GO776	Sapindaceae	<i>Matayba</i>	<i>arborescens</i>	St	PE	24	5	Ma	2	0	3
GO713	Sapindaceae	<i>Paullinia</i>	sp.	L	EA	0	0	Si	2	2	2
GO713	Sapindaceae	<i>Paullinia</i>	sp.	L	M	0	0	Si	2	2	2
GO713	Sapindaceae	<i>Paullinia</i>	sp.	L	PE	3	1	Si	2	2	2
GO713	Sapindaceae	<i>Paullinia</i>	sp.	L	W	1	1	Si	2	2	2
GO713	Sapindaceae	<i>Paullinia</i>	sp.	St	EA	0	0	Si	2	2	2
GO713	Sapindaceae	<i>Paullinia</i>	sp.	St	M	0	0	Si	2	2	2
GO713	Sapindaceae	<i>Paullinia</i>	sp.	St	PE	1	1	Si	2	2	2
GO713	Sapindaceae	<i>Paullinia</i>	sp.	St	W	0	0	Si	2	2	2
GO763	Sapindaceae	<i>Paullinia</i>	<i>pinnata</i>	AP	EA	9	3	Mc	2	0	1
GO763	Sapindaceae	<i>Paullinia</i>	<i>pinnata</i>	AP	M	0	0	Mc	2	0	1
GO763	Sapindaceae	<i>Paullinia</i>	<i>pinnata</i>	AP	PE	2	1	Mc	2	0	1
RB1904	Sapotaceae	<i>Manilkara</i>	<i>huberi</i>	W	EA	2	1	Si	0	2	3
RB1904	Sapotaceae	<i>Manilkara</i>	<i>huberi</i>	W	M	2	1	Si	0	2	3
RB1904	Sapotaceae	<i>Manilkara</i>	<i>huberi</i>	W	PE	11	1	Si	0	2	3
RB1904	Sapotaceae	<i>Manilkara</i>	<i>huberi</i>	W	W	0	0	Si	0	2	3
RB1904	Sapotaceae	<i>Manilkara</i>	<i>huberi</i>	B	EA	2	2	Si	0	2	3
RB1904	Sapotaceae	<i>Manilkara</i>	<i>huberi</i>	B	M	1	1	Si	0	2	3

RB1904	Sapotaceae	<i>Manilkara</i>	<i>huberi</i>	B	PE	7	2	Si	0	2	3
RB1904	Sapotaceae	<i>Manilkara</i>	<i>huberi</i>	B	W	1	1	Si	0	2	3
GO714	Simaroubaceae	<i>Quassia</i>	<i>amara</i>	St	EA	8	1	Rm	0	2	2
GO747	Siparunaceae	<i>Siparuna</i>	<i>guianensis</i>	L	EA	0	0	Si	2	1	1
GO747	Siparunaceae	<i>Siparuna</i>	<i>guianensis</i>	L	M	0	0	Si	2	1	1
GO747	Siparunaceae	<i>Siparuna</i>	<i>guianensis</i>	L	PE	1	1	Si	2	1	1
GO747	Siparunaceae	<i>Siparuna</i>	<i>guianensis</i>	L	W	0	0	Si	2	1	1
GO747	Siparunaceae	<i>Siparuna</i>	<i>guianensis</i>	St	EA	5	2	Si	2	1	1
GO747	Siparunaceae	<i>Siparuna</i>	<i>guianensis</i>	St	M	0	0	Si	2	1	1
GO747	Siparunaceae	<i>Siparuna</i>	<i>guianensis</i>	St	PE	2	1	Si	2	1	1
GO747	Siparunaceae	<i>Siparuna</i>	<i>guianensis</i>	St	W	0	0	Si	2	1	1
GO761	Solanaceae	<i>Cestrum</i>	<i>latifolium</i>	L	EA	39	3	Mc	2	0	1
GO761	Solanaceae	<i>Cestrum</i>	<i>latifolium</i>	L	M	20	3	Mc	2	0	1
GO761	Solanaceae	<i>Cestrum</i>	<i>latifolium</i>	L	PE	1	1	Mc	2	0	1
GO761	Solanaceae	<i>Cestrum</i>	<i>latifolium</i>	L	W	0	0	Mc	2	0	1
GO761	Solanaceae	<i>Cestrum</i>	<i>latifolium</i>	St	EA	58	11	Mc	2	0	1
GO761	Solanaceae	<i>Cestrum</i>	<i>latifolium</i>	St	M	0	0	Mc	2	0	1
GO761	Solanaceae	<i>Cestrum</i>	<i>latifolium</i>	St	PE	15	2	Mc	2	0	1
GO761	Solanaceae	<i>Cestrum</i>	<i>latifolium</i>	St	W	0	0	Mc	2	0	1
GO740	Solanaceae	<i>Solanum</i>	<i>leucocarpon</i>	L	EA	0	0	Si	2	1	2
GO740	Solanaceae	<i>Solanum</i>	<i>leucocarpon</i>	L	M	1	1	Si	2	1	2
GO740	Solanaceae	<i>Solanum</i>	<i>leucocarpon</i>	L	PE	11	4	Si	2	1	2
GO740	Solanaceae	<i>Solanum</i>	<i>leucocarpon</i>	L	W	0	0	Si	2	1	2
GO740	Solanaceae	<i>Solanum</i>	<i>leucocarpon</i>	St	EA	0	0	Si	2	1	2
GO740	Solanaceae	<i>Solanum</i>	<i>leucocarpon</i>	St	M	5	1	Si	2	1	2
GO740	Solanaceae	<i>Solanum</i>	<i>leucocarpon</i>	St	PE	3	2	Si	2	1	2
GO740	Solanaceae	<i>Solanum</i>	<i>leucocarpon</i>	St	W	0	0	Si	2	1	2
GO751	Solanaceae	<i>Solanum</i>	<i>stramoniifolium</i>	AP	EA	3	2	Si	2	1	0
GO751	Solanaceae	<i>Solanum</i>	<i>stramoniifolium</i>	AP	M	0	0	Si	2	1	0
GO751	Solanaceae	<i>Solanum</i>	<i>stramoniifolium</i>	AP	PE	4	2	Si	2	1	0

GO751	Solanaceae	<i>Solanum</i>	<i>stramonifolium</i>	AP	W	1	1	Si	2	1	0
GO752	Solanaceae	<i>Solanum</i>	<i>subinerme</i>	AP	EA	6	1	Si	2	1	0
GO752	Solanaceae	<i>Solanum</i>	<i>subinerme</i>	AP	M	0	0	Si	2	1	0
GO752	Solanaceae	<i>Solanum</i>	<i>subinerme</i>	AP	PE	1	1	Si	2	1	0
GO752	Solanaceae	<i>Solanum</i>	<i>subinerme</i>	AP	W	0	0	Si	2	1	0
514	Vochysiaceae	<i>Erismia</i>	<i>uncinatum</i>	B	EA	0	0	Si	0	2	3
514	Vochysiaceae	<i>Erismia</i>	<i>uncinatum</i>	B	M	0	0	Si	0	2	3
514	Vochysiaceae	<i>Erismia</i>	<i>uncinatum</i>	B	PE	2	1	Si	0	2	3
514	Vochysiaceae	<i>Erismia</i>	<i>uncinatum</i>	B	W	0	0	Si	0	2	3

<sup>a</sup> Voucher number at Cayenne Herbarium (CAY) or tree number from a permanent plot in Sinnamary or tree identifies by forest prospectors (BC)

<sup>b</sup> B: bark, W: wood, St: stems, R: roots, L: leaves, AP: aerial parts, WP: whole plant, I: inflorescence, F: fruits

<sup>c</sup> W: water. PE: petroleum ether. M: methanol. EA: ethyl acetate

<sup>d</sup> Standard deviation

<sup>e</sup> Si: Sinnamary. Mo: Montsinéry-Tonnegrande. Rg: Régina. Mc: Macouria, Ma: Mana. Ko: Kourou. Mt: Matoury. Rm: Rémire-Montjoly. Ro: Roura

<sup>f</sup> Temporary vegetation: 0, secondary / low or slightly ligneous vegetation: 1, ligneous species: 2, large trees: 3



**Table S2** Full dataset of Tukey HSD pairwise differences between variables

	CI 95%			
	Differences	Lower	Upper	P-value
<b>Solvents <sup>a</sup></b>				
M - EA	-0.3564242	-0.6220793	-0.09076897	0.0033256
PE - EA	0.2273556	-0.0720787	0.52678993	0.2054870
W - EA	-0.4794681	-0.7877130	-0.17122314	0.0004155
PE - M	0.5837798	0.2826667	0.88489285	0.0000051
W -M	-0.1230439	-0.4329198	0.18683205	0.7352206
W -PE	-0.7068237	-1.0461043	-0.36754305	0.0000008
<b>Organs</b>				
Bark-Aerial parts	0.30846280	-0.20425632	0.821181914	0.6593495
Fruits-Aerial parts	1.17136950	0.06659874	2.276140254	0.0277396
Inflorescence-Aerial parts	1.33354457	0.22877381	2.438315322	0.0055035
Leaves-Aerial parts	0.13294164	-0.30847814	0.574361423	0.9942709
Leaves and fruits-Aerial parts	0.72096847	-1.25477307	2.696710000	0.9776100
Roots-Aerial parts	0.06533190	-1.35784387	1.488507670	1.0000000
Stems-Aerial parts	0.09981891	-0.36192028	0.561558101	0.9995720
Whole plant-Aerial parts	0.25682463	-0.59475547	1.108404731	0.9942117
Wood-Aerial parts	0.21014143	-0.41407223	0.834355098	0.9871663
Fruits-Bark	0.86290670	-0.22741042	1.953223818	0.2619128
Inflorescence-Bark	1.02508177	-0.06523535	2.115398886	0.0856270
Leaves-Bark	-0.17552116	-0.57940780	0.228365484	0.9319896
Leaves and fruits-Bark	0.41250567	-1.55519035	2.380201681	0.9996671
Roots-Bark	-0.24313090	-1.65511612	1.168854323	0.9999355
Stems-Bark	-0.20864389	-0.63464398	0.217356201	0.8671013
Whole plant-Bark	-0.05163817	-0.88438162	0.781105288	1.0000000
Wood-Bark	-0.09832137	-0.69658192	0.499939193	0.9999566

Inflorescence-Fruits	0.16217507	-1.30289454	1.627244673	0.9999986
Leaves-Fruits	-1.03842786	-2.09708831	0.020232593	0.0596834
Leaves and fruits-Fruits	-0.45040103	-2.64800544	1.747203375	0.9997236
Roots-Fruits	-1.10603760	-2.82398399	0.611908790	0.5651381
Stems-Fruits	-1.07155059	-2.13884324	-0.004257937	0.0481570
Whole plant-Fruits	-0.91454487	-2.19949591	0.370406179	0.4146034
Wood-Fruits	-0.96122807	-2.10820375	0.185747621	0.1911146
Leaves-Inflorescence	-1.20060293	-2.25926338	-0.141942476	0.0126912
Leaves and fruits-Inflorescence	-0.61257610	-2.81018051	1.585028307	0.9967995
Roots-Inflorescence	-1.26821267	-2.98615906	0.449733722	0.3599797
Stems-Inflorescence	-1.23372566	-2.30101831	-0.166433005	0.0099442
Whole plant-Inflorescence	-1.07671993	-2.36167098	0.208231111	0.1912617
Wood-Inflorescence	-1.12340313	-2.27037882	0.023572553	0.0604733
Leaves and fruits-Leaves	0.58802683	-1.36230600	2.538359653	0.9942238
Roots-Leaves	-0.06760974	-1.45529588	1.320076391	1.0000000
Stems-Leaves	-0.03312273	-0.36994110	0.303695633	0.9999995
Whole plant-Leaves	0.12388299	-0.66695972	0.914725703	0.9999712
Wood-Leaves	0.07719979	-0.46121104	0.615610629	0.9999865
Roots-Leaves and fruits	-0.65563657	-3.02932062	1.718047485	0.9970155
Stems-Leaves and fruits	-0.62114956	-2.57618147	1.333882358	0.9915177
Whole plant-Leaves and fruits	-0.46414383	-2.54600247	1.617714801	0.9994500
Wood-Leaves and fruits	-0.51082703	-2.51047435	1.488820288	0.9983706
Stems-Roots	0.03448701	-1.35979577	1.428769788	1.0000000
Whole plant-Roots	0.19149273	-1.37567351	1.758658981	0.9999966
Wood-Roots	0.14480954	-1.31137180	1.600990871	0.9999994
Whole plant-Stems	0.15700572	-0.64535570	0.959367146	0.9998116
Wood-Stems	0.11032252	-0.44486923	0.665514281	0.9997859
Wood-Whole plant	-0.04668320	-0.95234509	0.858978696	1.0000000

## Families

Malpighiaceae-Lauraceae	-1,978693751	-3,51302532	-0,444362181	0,0005192
Lauraceae-Euphorbiaceae	1,800228841	0,350421784	3,250035899	0,0012218
Lauraceae-Fabaceae	1,697098501	0,301104545	3,093092457	0,0019153
Lauraceae-Annonaceae	1,704489447	0,222420681	3,186558213	0,0056639
Lauraceae-Dilleniaceae	2,411053704	0,260642323	4,561465085	0,0089106
Meliaceae-Lauraceae	-1,889082147	-3,644885687	-0,133278606	0,0175804
Sapotaceae-Lauraceae	-1,929862138	-3,729025382	-0,130698895	0,0184339
Sapindaceae-Lauraceae	-1,609596436	-3,118424873	-0,100767998	0,0200608
Malvaceae-Lauraceae	-2,04962174	-3,973008151	-0,126235329	0,020396
Siparunaceae-Lauraceae	-1,909791167	-3,708954411	-0,110627924	0,021642
Lauraceae-Costaceae	1,700601821	0,091381295	3,309822347	0,0231388
Loranthaceae-Lauraceae	-1,949016743	-3,802438265	-0,095595221	0,0249045
Solanaceae-Lauraceae	-1,543442125	-3,064012595	-0,022871655	0,0410494
Lauraceae-Bignoniaceae	1,820373311	0,021210068	3,619536554	0,0428566
Lauraceae-Apocynaceae	1,662054623	-0,003646871	3,327756116	0,0514344
Rubiaceae-Lauraceae	-1,794476669	-3,593639912	0,004686575	0,0517106
Vochysiaceae-Lauraceae	-2,130124826	-4,280536208	0,020286555	0,0564364
Orobanchaceae-Lauraceae	-2,07826572	-4,228677101	0,072145661	0,0761888
Lauraceae-Combretaceae	2,01783601	-0,132575371	4,168247391	0,1061758
Salicaceae-Lauraceae	-1,40160285	-2,935934419	0,132728719	0,1400313
Myrtaceae-Lauraceae	-1,844606449	-3,995017831	0,305804932	0,2449298
Lauraceae-Celastraceae	1,412817163	-0,252884331	3,078518656	0,2673108
Lauraceae-Clusiaceae	1,803548277	-0,346863104	3,953959659	0,2906057
Dilleniaceae-Asteraceae	-2,025994766	-4,570395826	0,518406293	0,4082505
Malpighiaceae-Asteraceae	-1,593634813	-3,643971616	0,456701991	0,4665869
Moraceae-Lauraceae	-2,092312224	-4,812391372	0,627766925	0,4919833
Polygalaceae-Lauraceae	-2,013081002	-4,733160151	0,706998146	0,5855017
Lauraceae-Chrysobalanaceae	1,176310514	-0,449247696	2,801868722	0,6379844

Euphorbiaceae-Asteraceae	-1,415169904	-3,403045188	0,572705381	0,6745907
Malvaceae-Asteraceae	-1,664562802	-4,020220445	0,691094841	0,6907166
Malpighiaceae-Chrysobalanaceae	-0,802383237	-1,941329051	0,336562577	0,6971459
Vochysiaceae-Asteraceae	-1,745065889	-4,289466948	0,799335171	0,7514566
Sapotaceae-Asteraceae	-1,5448032	-3,800173684	0,710567284	0,7539743
Piperaceae-Lauraceae	-1,225488299	-3,024651542	0,573674945	0,7644735
Loranthaceae-Asteraceae	-1,563957806	-3,862844271	0,73492866	0,7667464
Meliaceae-Asteraceae	-1,504023209	-3,724958534	0,716912116	0,7751465
Siparunaceae-Asteraceae	-1,524732229	-3,780102713	0,730638255	0,7782387
Fabaceae-Asteraceae	-1,312039563	-3,261015388	0,636936262	0,7857696
Lythraceae-Lauraceae	-1,813071799	-4,533150947	0,90700735	0,8028346
Orobanchaceae-Asteraceae	-1,693206782	-4,237607842	0,851194278	0,8055611
Asteraceae-Annonaceae	1,319430509	-0,692095148	3,330956167	0,8286167
Dilleniaceae-Chrysobalanaceae	-1,234743191	-3,123471152	0,653984771	0,8337017
Melastomataceae-Lauraceae	-1,758327569	-4,478406718	0,961751579	0,8500662
Lauraceae-Convolvulaceae	1,517159319	-0,838498324	3,872816962	0,855173
Combretaceae-Asteraceae	-1,632777072	-4,177178132	0,911623988	0,8600927
Bignoniaceae-Asteraceae	-1,435314373	-3,690684857	0,820056111	0,8709165
Lauraceae-Cyperaceae	1,70358334	-1,016495809	4,423662488	0,8900398
Rubiaceae-Asteraceae	-1,409417731	-3,664788215	0,845952753	0,8925103
Costaceae-Asteraceae	-1,315542883	-3,422507131	0,791421366	0,8934617
Humiriaceae-Dilleniaceae	1,32696921	-0,823442172	3,477380591	0,9058423
Euphorbiaceae-Chrysobalanaceae	-0,623918328	-1,646153481	0,398316825	0,9163799
Sapindaceae-Asteraceae	-1,224537498	-3,255859948	0,806784952	0,9271787
Asteraceae-Apocynaceae	1,276995685	-0,873415697	3,427407066	0,9387737
Malpighiaceae-Humiriaceae	-0,894609256	-2,428940825	0,639722313	0,9508666
Piperaceae-Dilleniaceae	1,185565406	-0,854493956	3,225624767	0,9528219
Salicaceae-Malpighiaceae	0,577090901	-0,427364893	1,581546694	0,9591225
Myrtaceae-Asteraceae	-1,459547512	-4,003948571	1,084853548	0,9599289

Solanaceae-Asteraceae	-1,158383187	-3,198442549	0,881676174	0,9648541
Lauraceae-Humiriaceae	1,084084495	-0,839301917	3,007470906	0,968106
Moraceae-Asteraceae	-1,707253286	-4,748394226	1,333887654	0,9697546
Clusiaceae-Asteraceae	-1,41848934	-3,962890399	1,12591172	0,9724534
Salicaceae-Dilleniaceae	1,009450854	-0,80135758	2,820259289	0,9724773
Fabaceae-Chrysobalanaceae	-0,520787987	-1,465151968	0,423575993	0,9762597
Piperaceae-Malpighiaceae	0,753205452	-0,622202289	2,128613193	0,9784656
Malvaceae-Chrysobalanaceae	-0,873311227	-2,498869436	0,752246982	0,9836223
Polygalaceae-Asteraceae	-1,628022064	-4,669163005	1,413118876	0,9844506
Dilleniaceae-Celastraceae	-0,998236541	-2,921622953	0,92514987	0,9902553
Sapotaceae-Chrysobalanaceae	-0,753551625	-2,230038191	0,722934941	0,9925146
Vochysiaceae-Chrysobalanaceae	-0,953814313	-2,842542274	0,934913649	0,9936852
Malvaceae-Humiriaceae	-0,965537246	-2,888923657	0,957849166	0,9942711
Loranthaceae-Chrysobalanaceae	-0,77270623	-2,314846153	0,769433693	0,9944442
Meliaceae-Chrysobalanaceae	-0,712771633	-2,136102332	0,710559065	0,9944957
Siparunaceae-Chrysobalanaceae	-0,733480654	-2,20996722	0,743005912	0,9951809
Salicaceae-Asteraceae	-1,016543912	-3,066880716	1,033792892	0,9953372
Chrysobalanaceae-Annonaceae	0,528178934	-0,53931909	1,595676957	0,995494
Humiriaceae-Euphorbiaceae	0,716144347	-0,733662711	2,165951404	0,9956184
Vochysiaceae-Humiriaceae	-1,046040332	-3,196451713	1,104371049	0,9966252
Solanaceae-Dilleniaceae	0,867611579	-0,931551665	2,666774822	0,9970968
Celastraceae-Asteraceae	-1,027758225	-3,178169606	1,122653157	0,9975187
Orobanchaceae-Chrysobalanaceae	-0,901955207	-2,790683168	0,986772755	0,9975542
Malpighiaceae-Celastraceae	-0,565876588	-1,761418115	0,629664939	0,997912
Sapotaceae-Humiriaceae	-0,845777644	-2,644940887	0,9533856	0,998154
Lythraceae-Asteraceae	-1,428012861	-4,469153801	1,613128079	0,9981913
Loranthaceae-Humiriaceae	-0,864932249	-2,718353771	0,988489273	0,9983839
Orobanchaceae-Humiriaceae	-0,994181226	-3,144592607	1,156230156	0,9986393
Siparunaceae-Humiriaceae	-0,825706673	-2,624869916	0,973456571	0,998813

Meliaceae-Humiriaceae	-0,804997652	-2,560801193	0,950805888	0,9988351
Salicaceae-Euphorbiaceae	0,398625991	-0,471258243	1,268510226	0,9988458
Piperaceae-Malvaceae	0,824133442	-0,975029802	2,623296685	0,9988546
Simaroubaceae-Lauraceae	-1,637337537	-5,235664024	1,96098895	0,9989893
Melastomataceae-Asteraceae	-1,373268631	-4,414409571	1,667872309	0,9991258
Piperaceae-Euphorbiaceae	0,574740543	-0,705694381	1,855175466	0,9992207
Sapindaceae-Dilleniaceae	0,801457268	-0,987793155	2,590707691	0,9992514
Combretaceae-Chrysobalanaceae	-0,841525496	-2,730253458	1,047202465	0,9993246
Lauraceae-Boraginaceae	1,210885275	-1,509193874	3,930964423	0,9993358
Vochysiaceae-Piperaceae	-0,904636528	-2,944695889	1,135422834	0,9993843
Solanaceae-Malpighiaceae	0,435251625	-0,548055362	1,418558613	0,9994055
Humiriaceae-Fabaceae	0,613014006	-0,782979949	2,009007962	0,9994918
Chrysobalanaceae-Bignoniaceae	0,644062798	-0,832423769	2,120549364	0,9995546
Humiriaceae-Combretaceae	0,933751515	-1,216659866	3,084162897	0,9995935
Cyperaceae-Asteraceae	-1,318524402	-4,359665342	1,722616538	0,9996056
Costaceae-Chrysobalanaceae	-0,524291307	-1,762279556	0,713696942	0,9997552
Sapotaceae-Piperaceae	-0,70437384	-2,370075333	0,961327654	0,9997627
Salicaceae-Malvaceae	0,64801889	-0,886312679	2,18235046	0,9997687
Fabaceae-Dilleniaceae	0,713955203	-0,981230022	2,409140428	0,9997817
Piperaceae-Loranthaceae	0,723528445	-1,000636404	2,447693294	0,9997975
Rubiaceae-Chrysobalanaceae	-0,618166155	-2,094652721	0,858320411	0,999807
Humiriaceae-Annonaceae	0,620404953	-0,861663813	2,102473719	0,9998076
Piperaceae-Orobanchaceae	0,852777422	-1,18728194	2,892836783	0,9998132
Convolvulaceae-Asteraceae	-1,132100381	-3,85217953	1,587978767	0,9998295
Dilleniaceae-Boraginaceae	-1,20016843	-4,085248046	1,684911188	0,9998313
Siparunaceae-Piperaceae	-0,684302869	-2,350004362	0,981398625	0,9998705
Piperaceae-Meliaceae	0,663593848	-0,955177032	2,282364728	0,9998763
Humiriaceae-Bignoniaceae	0,736288817	-1,062874427	2,53545206	0,9998807
Vochysiaceae-Salicaceae	-0,728521977	-2,539330411	1,082286458	0,9999174

Dilleniaceae-Annonaceae	-0,706564257	-2,473307489	1,060178975	0,9999274
Rubiaceae-Humiriaceae	-0,710392174	-2,509555418	1,088771069	0,9999452
Sapindaceae-Chrysobalanaceae	-0,433285922	-1,537635259	0,671063414	0,9999524
Dilleniaceae-Apocynaceae	-0,748999082	-2,672385493	1,17438733	0,9999597
Piperaceae-Combretaceae	0,792347711	-1,24771165	2,832407073	0,999962
Piperaceae-Fabaceae	0,471610202	-0,747558454	1,690778859	0,9999653
Sapotaceae-Salicaceae	-0,528259288	-1,903667029	0,847148453	0,9999705
Humiriaceae-Costaceae	0,616517326	-0,9927032	2,225737852	0,9999721
Sapindaceae-Malpighiaceae	0,369097315	-0,595952597	1,334147226	0,9999732
Malvaceae-Celastraceae	-0,636804578	-2,302506071	1,028896916	0,9999735
Salicaceae-Fabaceae	0,295495651	-0,481393789	1,072385091	0,9999764
Dilleniaceae-Costaceae	-0,710451883	-2,585137063	1,164233296	0,9999783
Salicaceae-Loranthaceae	0,547413894	-0,898244924	1,993072711	0,9999787
Salicaceae-Orobanchaceae	0,67666287	-1,134145564	2,487471305	0,9999843
Chrysobalanaceae-Asteraceae	-0,791251576	-2,910720173	1,328217022	0,9999846
Vochysiaceae-Celastraceae	-0,717307664	-2,640694075	1,206078748	0,999985
Piperaceae-Asteraceae	-0,840429361	-3,095799845	1,414941123	0,9999853
Chrysobalanaceae-Apocynaceae	0,485744109	-0,824822818	1,796311036	0,999987
Moraceae-Humiriaceae	-1,008227729	-3,728306878	1,711851419	0,999987
Salicaceae-Meliaceae	0,487479297	-0,830702841	1,805661435	0,9999877
Siparunaceae-Salicaceae	-0,508188317	-1,883596058	0,867219424	0,9999879
Piperaceae-Annonaceae	0,479001149	-0,837851507	1,795853804	0,9999917
Moraceae-Chrysobalanaceae	-0,91600171	-3,434305659	1,602302239	0,9999917
Malpighiaceae-Fabaceae	-0,28159525	-1,05848469	0,49529419	0,9999923
Piperaceae-Bignoniaceae	0,594885012	-1,070816481	2,260586506	0,9999946
Euphorbiaceae-Celastraceae	-0,387411679	-1,472347936	0,697524579	0,9999946
Myrtaceae-Chrysobalanaceae	-0,668295936	-2,557023898	1,220432026	0,9999957
Myrtaceae-Humiriaceae	-0,760521955	-2,910933336	1,389889426	0,9999958
Dilleniaceae-Convolvulaceae	-0,893894385	-3,438295445	1,650506675	0,9999964

Euphorbiaceae-Dilleniaceae	0,610824863	-1,128943606	2,350593332	0,9999964
Sapindaceae-Humiriaceae	-0,525511941	-2,034340379	0,983316496	0,9999971
Humiriaceae-Apocynaceae	0,577970128	-1,087731365	2,243671622	0,9999973
Orobanchaceae-Celastraceae	-0,665448557	-2,588834969	1,257937854	0,9999975
Polygalaceae-Humiriaceae	-0,928996508	-3,649075656	1,791082641	0,9999982
Rubiaceae-Piperaceae	-0,56898837	-2,234689864	1,096713123	0,9999982
Sapotaceae-Celastraceae	-0,517044975	-2,037615446	1,003525495	0,9999984
Salicaceae-Combretaceae	0,61623316	-1,194575275	2,427041594	0,9999984
Loranthaceae-Celastraceae	-0,536199581	-2,120597737	1,048198575	0,9999986
Humiriaceae-Clusiaceae	0,719463783	-1,430947598	2,869875164	0,9999989
Clusiaceae-Chrysobalanaceae	-0,627237764	-2,515965726	1,261490198	0,9999991
Polygalaceae-Chrysobalanaceae	-0,836770489	-3,355074437	1,68153346	0,9999991
Solanaceae-Malvaceae	0,506179615	-1,014390855	2,026750085	0,9999991
Salicaceae-Annonaceae	0,302886597	-0,619764964	1,225538159	0,9999993
Piperaceae-Moraceae	0,866823925	-1,766881386	3,500529236	0,9999993
Siparunaceae-Celastraceae	-0,496974004	-2,017544475	1,023596466	0,9999994
Solanaceae-Chrysobalanaceae	-0,367131612	-1,487470292	0,753207068	0,9999994
Vochysiaceae-Solanaceae	-0,586682701	-2,385845944	1,212480542	0,9999994
Simaroubaceae-Asteraceae	-1,252278599	-5,099051422	2,594494224	0,9999995
Meliaceae-Celastraceae	-0,476264984	-1,945275621	0,992745653	0,9999995
Piperaceae-Costaceae	0,475113522	-0,983366437	1,933593481	0,9999995
Vochysiaceae-Boraginaceae	-0,919239552	-3,804319169	1,965840065	0,9999997
Malpighiaceae-Boraginaceae	-0,767808476	-3,22821264	1,692595689	0,9999998
Combretaceae-Celastraceae	-0,605018847	-2,528405259	1,318367564	0,9999998
Salicaceae-Bignoniaceae	0,418770461	-0,95663728	1,794178202	0,9999999
Malvaceae-Boraginaceae	-0,838736466	-3,558815614	1,881342683	0,9999999
Orobanchaceae-Boraginaceae	-0,867380445	-3,752460062	2,017699172	0,9999999
Rubiaceae-Dilleniaceae	0,616577035	-1,423482326	2,656636397	0,9999999
Solanaceae-Euphorbiaceae	0,256786716	-0,588588805	1,102162237	0,9999999



Solanaceae-Humiriaceae	-0,459357631	-1,979928101	1,061212839	0,9999999
Piperaceae-Myrtaceae	0,619118151	-1,42094121	2,659177512	0,9999999
Polygalaceae-Piperaceae	-0,787592704	-3,421298014	1,846112607	0,9999999
Apocynaceae-Annonaceae	0,042434825	-1,085250417	1,170120067	1
Bignoniaceae-Annonaceae	-0,115883864	-1,432736519	1,200968792	1
Boraginaceae-Annonaceae	0,493604173	-1,934552147	2,921760493	1
Celastraceae-Annonaceae	0,291672285	-0,836012957	1,419357527	1
Clusiaceae-Annonaceae	-0,09905883	-1,865802062	1,667684402	1
Combretaceae-Annonaceae	-0,313346563	-2,080089795	1,45339667	1
Convolvulaceae-Annonaceae	0,187330128	-1,824195529	2,198855786	1
Costaceae-Annonaceae	0,003887626	-1,038562967	1,04633822	1
Cyperaceae-Annonaceae	0,000906108	-2,427250212	2,429062428	1
Euphorbiaceae-Annonaceae	-0,095739394	-0,869724564	0,678245776	1
Fabaceae-Annonaceae	0,007390946	-0,660375228	0,675157121	1
Loranthaceae-Annonaceae	-0,244527296	-1,634593438	1,145538845	1
Lythraceae-Annonaceae	-0,108582351	-2,536738671	2,319573969	1
Malpighiaceae-Annonaceae	-0,274204303	-1,196855865	0,648447258	1
Malvaceae-Annonaceae	-0,345132293	-1,827201059	1,136936473	1
Melastomataceae-Annonaceae	-0,053838122	-2,481994442	2,374318198	1
Meliaceae-Annonaceae	-0,1845927	-1,441556745	1,072371346	1
Moraceae-Annonaceae	-0,387822776	-2,815979096	2,040333544	1
Myrtaceae-Annonaceae	-0,140117002	-1,906860234	1,62662623	1
Orobanchaceae-Annonaceae	-0,373776273	-2,140519505	1,392966959	1
Polygalaceae-Annonaceae	-0,308591555	-2,736747875	2,119564765	1
Rubiaceae-Annonaceae	-0,089987222	-1,406839877	1,226865434	1
Sapindaceae-Annonaceae	0,094893011	-0,784695411	0,974481434	1
Sapotaceae-Annonaceae	-0,225372691	-1,542225346	1,091479964	1
Simaroubaceae-Annonaceae	0,067151911	-3,315903816	3,450207636	1
Siparunaceae-Annonaceae	-0,20530172	-1,522154375	1,111550935	1

Solanaceae-Annonaceae	0,161047322	-0,7385343	1,060628944	1
Vochysiaceae-Annonaceae	-0,425635379	-2,192378611	1,341107853	1
Bignoniaceae-Apocynaceae	-0,158318689	-1,678889159	1,362251782	1
Boraginaceae-Apocynaceae	0,451169348	-2,093231712	2,995570408	1
Celastraceae-Apocynaceae	0,24923746	-1,110802115	1,609277034	1
Clusiaceae-Apocynaceae	-0,141493655	-2,064880066	1,781892756	1
Combretaceae-Apocynaceae	-0,355781387	-2,279167799	1,567605024	1
Convolvulaceae-Apocynaceae	0,144895303	-2,005516078	2,295306685	1
Costaceae-Apocynaceae	-0,038547198	-1,328794027	1,251699631	1
Cyperaceae-Apocynaceae	-0,041528717	-2,585929777	2,502872343	1
Euphorbiaceae-Apocynaceae	-0,138174219	-1,223110476	0,946762038	1
Fabaceae-Apocynaceae	-0,035043878	-1,046945703	0,976857946	1
Loranthaceae-Apocynaceae	-0,286962121	-1,871360277	1,297436035	1
Lythraceae-Apocynaceae	-0,151017176	-2,695418236	2,393383884	1
Malpighiaceae-Apocynaceae	-0,316639128	-1,512180655	0,878902399	1
Malvaceae-Apocynaceae	-0,387567118	-2,053268611	1,278134376	1
Melastomataceae-Apocynaceae	-0,096272947	-2,640674006	2,448128113	1
Meliaceae-Apocynaceae	-0,227027524	-1,696038161	1,241983112	1
Moraceae-Apocynaceae	-0,430257601	-2,974658661	2,114143459	1
Myrtaceae-Apocynaceae	-0,182551827	-2,105938238	1,740834584	1
Orobanchaceae-Apocynaceae	-0,416211098	-2,339597509	1,507175314	1
Piperaceae-Apocynaceae	0,436566324	-1,084004146	1,957136794	1
Polygalaceae-Apocynaceae	-0,35102638	-2,895427439	2,19337468	1
Rubiaceae-Apocynaceae	-0,132422046	-1,652992516	1,388148424	1
Salicaceae-Apocynaceae	0,260451773	-0,935089754	1,4559933	1
Sapindaceae-Apocynaceae	0,052458187	-1,110172207	1,21508858	1
Sapotaceae-Apocynaceae	-0,267807516	-1,788377986	1,252762954	1
Simaroubaceae-Apocynaceae	0,024717086	-3,442717079	3,49215125	1
Siparunaceae-Apocynaceae	-0,247736545	-1,768307015	1,272833925	1

Solanaceae-Apocynaceae	0,118612497	-1,059216324	1,296441319	1
Vochysiaceae-Apocynaceae	-0,468070204	-2,391456615	1,455316207	1
Boraginaceae-Asteraceae	-0,825826337	-3,866967277	2,215314603	1
Humiriaceae-Asteraceae	-0,699025557	-3,0546832	1,656632086	1
Lauraceae-Asteraceae	0,385058938	-1,970598705	2,740716581	1
Boraginaceae-Bignoniaceae	0,609488036	-2,024217274	3,243193347	1
Celastraceae-Bignoniaceae	0,407556148	-1,113014322	1,928126618	1
Clusiaceae-Bignoniaceae	0,016825034	-2,023234328	2,056884395	1
Combretaceae-Bignoniaceae	-0,197462699	-2,23752206	1,842596662	1
Convolvulaceae-Bignoniaceae	0,303213992	-1,952156492	2,558584476	1
Costaceae-Bignoniaceae	0,11977149	-1,338708469	1,578251449	1
Cyperaceae-Bignoniaceae	0,116789971	-2,516915339	2,750495282	1
Dilleniaceae-Bignoniaceae	-0,590680393	-2,630739755	1,449378968	1
Euphorbiaceae-Bignoniaceae	0,02014447	-1,260290454	1,300579393	1
Fabaceae-Bignoniaceae	0,12327481	-1,095893847	1,342443467	1
Loranthaceae-Bignoniaceae	-0,128643432	-1,852808282	1,595521417	1
Lythraceae-Bignoniaceae	0,007301512	-2,626403798	2,641006823	1
Malpighiaceae-Bignoniaceae	-0,15832044	-1,53372818	1,217087301	1
Malvaceae-Bignoniaceae	-0,229248429	-2,028411673	1,569914814	1
Melastomataceae-Bignoniaceae	0,062045742	-2,571659569	2,695751053	1
Meliaceae-Bignoniaceae	-0,068708836	-1,687479716	1,550062044	1
Moraceae-Bignoniaceae	-0,271938913	-2,905644223	2,361766398	1
Myrtaceae-Bignoniaceae	-0,024233139	-2,0642925	2,015826223	1
Orobanchaceae-Bignoniaceae	-0,257892409	-2,29795177	1,782166952	1
Polygalaceae-Bignoniaceae	-0,192707691	-2,826413002	2,440997619	1
Rubiaceae-Bignoniaceae	0,025896642	-1,639804851	1,691598136	1
Sapindaceae-Bignoniaceae	0,210776875	-1,136121912	1,557675662	1
Sapotaceae-Bignoniaceae	-0,109488827	-1,775190321	1,556212666	1
Simaroubaceae-Bignoniaceae	0,183035774	-3,35045069	3,716522239	1

Siparunaceae-Bignoniaceae	-0,089417856	-1,75511935	1,576283637	1
Solanaceae-Bignoniaceae	0,276931186	-1,083108389	1,63697076	1
Vochysiaceae-Bignoniaceae	-0,309751515	-2,349810877	1,730307846	1
Celastraceae-Boraginaceae	-0,201931888	-2,746332948	2,342469172	1
Chrysobalanaceae-Boraginaceae	0,034574761	-2,483729188	2,55287871	1
Clusiaceae-Boraginaceae	-0,592663003	-3,47774262	2,292416614	1
Combretaceae-Boraginaceae	-0,806950735	-3,692030352	2,078128882	1
Convolvulaceae-Boraginaceae	-0,306274045	-3,347414985	2,734866896	1
Costaceae-Boraginaceae	-0,489716546	-2,99750561	2,018072518	1
Cyperaceae-Boraginaceae	-0,492698065	-3,824101052	2,838704922	1
Euphorbiaceae-Boraginaceae	-0,589343567	-2,997943947	1,819256813	1
Fabaceae-Boraginaceae	-0,486213226	-2,86281046	1,890384008	1
Humiriaceae-Boraginaceae	0,12680078	-2,593278368	2,846879929	1
Loranthaceae-Boraginaceae	-0,738131469	-3,409196168	1,93293323	1
Lythraceae-Boraginaceae	-0,602186524	-3,933589511	2,729216463	1
Melastomataceae-Boraginaceae	-0,547442295	-3,878845282	2,783960693	1
Meliaceae-Boraginaceae	-0,678196872	-3,282474384	1,92608064	1
Moraceae-Boraginaceae	-0,881426949	-4,212829936	2,449976038	1
Myrtaceae-Boraginaceae	-0,633721175	-3,518800792	2,251358442	1
Piperaceae-Boraginaceae	-0,014603024	-2,648308335	2,619102287	1
Polygalaceae-Boraginaceae	-0,802195728	-4,133598715	2,529207259	1
Rubiaceae-Boraginaceae	-0,583591394	-3,217296705	2,050113917	1
Salicaceae-Boraginaceae	-0,190717575	-2,65112174	2,269686589	1
Sapindaceae-Boraginaceae	-0,398711161	-2,843292627	2,045870304	1
Sapotaceae-Boraginaceae	-0,718976864	-3,352682174	1,914728447	1
Simaroubaceae-Boraginaceae	-0,426452262	-4,506570985	3,653666461	1
Siparunaceae-Boraginaceae	-0,698905893	-3,332611203	1,934799418	1
Solanaceae-Boraginaceae	-0,332556851	-2,784403062	2,11928936	1
Chrysobalanaceae-Celastraceae	0,236506649	-1,074060277	1,547073576	1

Clusiaceae-Celastraceae	-0,390731115	-2,314117526	1,532655297	1
Convolvulaceae-Celastraceae	-0,104342156	-2,254753538	2,046069225	1
Costaceae-Celastraceae	-0,287784658	-1,578031487	1,002462171	1
Cyperaceae-Celastraceae	-0,290766177	-2,835167237	2,253634883	1
Fabaceae-Celastraceae	-0,284281338	-1,296183163	0,727620486	1
Humiriaceae-Celastraceae	0,328732668	-1,336968825	1,994434162	1
Lythraceae-Celastraceae	-0,400254636	-2,944655696	2,144146424	1
Melastomataceae-Celastraceae	-0,345510406	-2,889911466	2,198890653	1
Moraceae-Celastraceae	-0,679495061	-3,223896121	1,864905999	1
Myrtaceae-Celastraceae	-0,431789287	-2,355175698	1,491597125	1
Piperaceae-Celastraceae	0,187328864	-1,333241606	1,707899334	1
Polygalaceae-Celastraceae	-0,60026384	-3,144664899	1,94413722	1
Rubiaceae-Celastraceae	-0,381659506	-1,902229976	1,138910964	1
Salicaceae-Celastraceae	0,011214313	-1,184327214	1,20675584	1
Sapindaceae-Celastraceae	-0,196779273	-1,359409667	0,96585112	1
Simaroubaceae-Celastraceae	-0,224520374	-3,691954538	3,24291379	1
Solanaceae-Celastraceae	-0,130624963	-1,308453784	1,047203859	1
Convolvulaceae-Chrysobalanaceae	-0,340848806	-2,460317403	1,778619792	1
Cyperaceae-Chrysobalanaceae	-0,527272826	-3,045576775	1,991031123	1
Humiriaceae-Chrysobalanaceae	0,092226019	-1,53333219	1,717784228	1
Lythraceae-Chrysobalanaceae	-0,636761285	-3,155065234	1,881542664	1
Melastomataceae-Chrysobalanaceae	-0,582017056	-3,100321004	1,936286893	1
Piperaceae-Chrysobalanaceae	-0,049177785	-1,525664351	1,427308781	1
Salicaceae-Chrysobalanaceae	-0,225292336	-1,364238151	0,913653478	1
Simaroubaceae-Chrysobalanaceae	-0,461027023	-3,909356722	2,987302675	1
Combretaceae-Clusiaceae	-0,214287732	-2,569945375	2,141369911	1
Convolvulaceae-Clusiaceae	0,286388958	-2,258012101	2,830790018	1
Costaceae-Clusiaceae	0,102946457	-1,771738723	1,977631636	1
Cyperaceae-Clusiaceae	0,099964938	-2,785114679	2,985044555	1

Dilleniaceae-Clusiaceae	-0,607505427	-2,96316307	1,748152216	1
Euphorbiaceae-Clusiaceae	0,003319436	-1,736449033	1,743087905	1
Fabaceae-Clusiaceae	0,106449777	-1,588735448	1,801635001	1
Loranthaceae-Clusiaceae	-0,145468466	-2,233535792	1,942598861	1
Lythraceae-Clusiaceae	-0,009523521	-2,894603138	2,875556096	1
Malpighiaceae-Clusiaceae	-0,175145473	-1,985953908	1,635662961	1
Malvaceae-Clusiaceae	-0,246073463	-2,396484844	1,904337919	1
Melastomataceae-Clusiaceae	0,045220708	-2,839858909	2,930300325	1
Meliaceae-Clusiaceae	-0,085533869	-2,087457918	1,916390179	1
Moraceae-Clusiaceae	-0,288763946	-3,173843563	2,596315671	1
Myrtaceae-Clusiaceae	-0,041058172	-2,396715815	2,314599471	1
Orobanchaceae-Clusiaceae	-0,274717443	-2,630375086	2,0809402	1
Piperaceae-Clusiaceae	0,578059979	-1,461999382	2,61811934	1
Polygalaceae-Clusiaceae	-0,209532725	-3,094612342	2,675546892	1
Rubiaceae-Clusiaceae	0,009071609	-2,030987753	2,04913097	1
Salicaceae-Clusiaceae	0,401945428	-1,408863007	2,212753862	1
Sapindaceae-Clusiaceae	0,193951842	-1,595298581	1,983202264	1
Sapotaceae-Clusiaceae	-0,126313861	-2,166373222	1,913745501	1
Simaroubaceae-Clusiaceae	0,166210741	-3,558411029	3,89083251	1
Siparunaceae-Clusiaceae	-0,10624289	-2,146302251	1,933816472	1
Solanaceae-Clusiaceae	0,260106152	-1,539057091	2,059269396	1
Vochysiaceae-Clusiaceae	-0,326576549	-2,682234192	2,029081094	1
Convolvulaceae-Combretaceae	0,500676691	-2,043724369	3,045077751	1
Costaceae-Combretaceae	0,317234189	-1,557450991	2,191919369	1
Cyperaceae-Combretaceae	0,31425267	-2,570826947	3,199332287	1
Dilleniaceae-Combretaceae	-0,393217694	-2,748875337	1,962439949	1
Euphorbiaceae-Combretaceae	0,217607169	-1,5221613	1,957375638	1
Fabaceae-Combretaceae	0,320737509	-1,374447716	2,015922734	1
Loranthaceae-Combretaceae	0,068819267	-2,01924806	2,156886593	1

Lythraceae-Combretaceae	0,204764211	-2,680315406	3,089843828	1
Malpighiaceae-Combretaceae	0,039142259	-1,771666175	1,849950694	1
Malvaceae-Combretaceae	-0,03178573	-2,182197112	2,118625651	1
Melastomataceae-Combretaceae	0,259508441	-2,625571176	3,144588058	1
Meliaceae-Combretaceae	0,128753863	-1,873170185	2,130677911	1
Moraceae-Combretaceae	-0,074476214	-2,959555831	2,810603403	1
Myrtaceae-Combretaceae	0,17322956	-2,182428083	2,528887203	1
Orobanchaceae-Combretaceae	-0,06042971	-2,416087353	2,295227933	1
Polygalaceae-Combretaceae	0,004755008	-2,880324609	2,889834625	1
Rubiaceae-Combretaceae	0,223359341	-1,81670002	2,263418703	1
Sapindaceae-Combretaceae	0,408239574	-1,381010849	2,197489997	1
Sapotaceae-Combretaceae	0,087973872	-1,95208549	2,128033233	1
Simaroubaceae-Combretaceae	0,380498473	-3,344123297	4,105120243	1
Siparunaceae-Combretaceae	0,108044843	-1,932014519	2,148104204	1
Solanaceae-Combretaceae	0,474393885	-1,324769359	2,273557128	1
Vochysiaceae-Combretaceae	-0,112288817	-2,467946459	2,243368827	1
Costaceae-Convolvulaceae	-0,183442502	-2,29040675	1,923521747	1
Cyperaceae-Convolvulaceae	-0,186424021	-3,227564961	2,85471692	1
Euphorbiaceae-Convolvulaceae	-0,283069522	-2,270944807	1,704805763	1
Fabaceae-Convolvulaceae	-0,179939182	-2,128915007	1,769036644	1
Humiriaceae-Convolvulaceae	0,433074825	-1,922582818	2,788732468	1
Loranthaceae-Convolvulaceae	-0,431857424	-2,73074389	1,867029041	1
Lythraceae-Convolvulaceae	-0,29591248	-3,33705342	2,745228461	1
Malpighiaceae-Convolvulaceae	-0,461534431	-2,511871235	1,588802372	1
Malvaceae-Convolvulaceae	-0,532462421	-2,888120064	1,823195222	1
Melastomataceae-Convolvulaceae	-0,24116825	-3,28230919	2,79997269	1
Meliaceae-Convolvulaceae	-0,371922828	-2,592858152	1,849012497	1
Moraceae-Convolvulaceae	-0,575152905	-3,616293845	2,465988036	1
Myrtaceae-Convolvulaceae	-0,32744713	-2,87184819	2,216953929	1

Orobanchaceae-Convolvulaceae	-0,561106401	-3,105507461	1,983294659	1
Piperaceae-Convolvulaceae	0,291671021	-1,963699463	2,547041505	1
Polygalaceae-Convolvulaceae	-0,495921683	-3,537062623	2,545219257	1
Rubiaceae-Convolvulaceae	-0,27731735	-2,532687834	1,978053134	1
Salicaceae-Convolvulaceae	0,115556469	-1,934780334	2,165893273	1
Sapindaceae-Convolvulaceae	-0,092437117	-2,123759567	1,938885334	1
Sapotaceae-Convolvulaceae	-0,412702819	-2,668073303	1,842667665	1
Simaroubaceae-Convolvulaceae	-0,120178218	-3,96695104	3,726594605	1
Siparunaceae-Convolvulaceae	-0,392631848	-2,648002332	1,862738636	1
Solanaceae-Convolvulaceae	-0,026282806	-2,066342168	2,013776555	1
Vochysiaceae-Convolvulaceae	-0,612965507	-3,157366567	1,931435552	1
Cyperaceae-Costaceae	-0,002981519	-2,510770583	2,504807545	1
Euphorbiaceae-Costaceae	-0,099627021	-1,095677179	0,896423138	1
Fabaceae-Costaceae	0,00350332	-0,912452213	0,919458853	1
Loranthaceae-Costaceae	-0,248414923	-1,773323691	1,276493846	1
Lythraceae-Costaceae	-0,112469978	-2,620259042	2,395319086	1
Malpighiaceae-Costaceae	-0,27809193	-1,393595752	0,837411893	1
Malvaceae-Costaceae	-0,349019919	-1,958240445	1,260200607	1
Melastomataceae-Costaceae	-0,057725748	-2,565514812	2,450063315	1
Meliaceae-Costaceae	-0,188480326	-1,593123159	1,216162506	1
Moraceae-Costaceae	-0,391710403	-2,899499467	2,116078661	1
Myrtaceae-Costaceae	-0,144004629	-2,018689808	1,730680551	1
Orobanchaceae-Costaceae	-0,377663899	-2,252349079	1,49702128	1
Polygalaceae-Costaceae	-0,312479181	-2,820268245	2,195309882	1
Rubiaceae-Costaceae	-0,093874848	-1,552354807	1,364605111	1
Salicaceae-Costaceae	0,298998971	-0,816504852	1,414502794	1
Sapindaceae-Costaceae	0,091005385	-0,989151394	1,171162164	1
Sapotaceae-Costaceae	-0,229260317	-1,687740276	1,229219641	1
Simaroubaceae-Costaceae	0,063264284	-3,377393926	3,503922494	1



Siparunaceae-Costaceae	-0,209189346	-1,667669305	1,249290612	1
Solanaceae-Costaceae	0,157159696	-0,939339264	1,253658655	1
Vochysiaceae-Costaceae	-0,429523006	-2,304208185	1,445162174	1
Dilleniaceae-Cyperaceae	-0,707470365	-3,592549981	2,177609253	1
Euphorbiaceae-Cyperaceae	-0,096645502	-2,505245882	2,311954878	1
Fabaceae-Cyperaceae	0,006484839	-2,370112395	2,383082073	1
Humiriaceae-Cyperaceae	0,619498845	-2,100580303	3,339577994	1
Loranthaceae-Cyperaceae	-0,245433404	-2,916498103	2,425631295	1
Lythraceae-Cyperaceae	-0,109488459	-3,440891446	3,221914528	1
Malpighiaceae-Cyperaceae	-0,275110411	-2,735514575	2,185293754	1
Malvaceae-Cyperaceae	-0,346038401	-3,066117549	2,374040748	1
Melastomataceae-Cyperaceae	-0,05474423	-3,386147217	3,276658758	1
Meliaceae-Cyperaceae	-0,185498807	-2,789776319	2,418778705	1
Moraceae-Cyperaceae	-0,388728884	-3,720131871	2,942674103	1
Myrtaceae-Cyperaceae	-0,14102311	-3,026102727	2,744056507	1
Orobanchaceae-Cyperaceae	-0,37468238	-3,259761997	2,510397237	1
Piperaceae-Cyperaceae	0,478095041	-2,15561027	3,111800352	1
Polygalaceae-Cyperaceae	-0,309497663	-3,64090065	3,021905324	1
Rubiaceae-Cyperaceae	-0,090893329	-2,72459864	2,542811982	1
Salicaceae-Cyperaceae	0,30198049	-2,158423675	2,762384654	1
Sapindaceae-Cyperaceae	0,093986904	-2,350594562	2,538568369	1
Sapotaceae-Cyperaceae	-0,226278799	-2,859984109	2,407426512	1
Simaroubaceae-Cyperaceae	0,066245803	-4,01387292	4,146364526	1
Siparunaceae-Cyperaceae	-0,206207828	-2,839913138	2,427497483	1
Solanaceae-Cyperaceae	0,160141214	-2,291704997	2,611987425	1
Vochysiaceae-Cyperaceae	-0,426541487	-3,311621104	2,45853813	1
Loranthaceae-Dilleniaceae	0,462036961	-1,626030366	2,550104287	1
Lythraceae-Dilleniaceae	0,597981906	-2,287097712	3,483061522	1
Malpighiaceae-Dilleniaceae	0,432359954	-1,378448481	2,243168388	1

Malvaceae-Dilleniaceae	0,361431964	-1,788979417	2,511843345	1
Melastomataceae-Dilleniaceae	0,652726135	-2,232353482	3,537805752	1
Meliaceae-Dilleniaceae	0,521971557	-1,479952491	2,523895605	1
Moraceae-Dilleniaceae	0,318741481	-2,566338136	3,203821097	1
Myrtaceae-Dilleniaceae	0,566447255	-1,789210388	2,922104898	1
Orobanchaceae-Dilleniaceae	0,332787984	-2,022869659	2,688445627	1
Polygalaceae-Dilleniaceae	0,397972702	-2,487106915	3,283052319	1
Sapotaceae-Dilleniaceae	0,481191566	-1,558867795	2,521250927	1
Simaroubaceae-Dilleniaceae	0,773716167	-2,950905602	4,498337937	1
Siparunaceae-Dilleniaceae	0,501262537	-1,538796824	2,541321898	1
Vochysiaceae-Dilleniaceae	0,280928878	-2,074728765	2,636586521	1
Fabaceae-Euphorbiaceae	0,103130341	-0,489595854	0,695856535	1
Loranthaceae-Euphorbiaceae	-0,148787902	-1,504404572	1,206828768	1
Lythraceae-Euphorbiaceae	-0,012842957	-2,421443337	2,395757423	1
Malpighiaceae-Euphorbiaceae	-0,178464909	-1,048349144	0,691419325	1
Malvaceae-Euphorbiaceae	-0,249392899	-1,699199956	1,200414159	1
Melastomataceae-Euphorbiaceae	0,041901272	-2,366699108	2,450501652	1
Meliaceae-Euphorbiaceae	-0,088853306	-1,307611399	1,129904788	1
Moraceae-Euphorbiaceae	-0,292083382	-2,700683762	2,116516998	1
Myrtaceae-Euphorbiaceae	-0,044377608	-1,784146077	1,695390861	1
Orobanchaceae-Euphorbiaceae	-0,278036879	-2,017805348	1,46173159	1
Polygalaceae-Euphorbiaceae	-0,212852161	-2,621452541	2,195748219	1
Rubiaceae-Euphorbiaceae	0,005752173	-1,274682751	1,286187096	1
Sapindaceae-Euphorbiaceae	0,190632406	-0,633435838	1,014700649	1
Sapotaceae-Euphorbiaceae	-0,129633297	-1,41006822	1,150801627	1
Simaroubaceae-Euphorbiaceae	0,162891305	-3,206155849	3,531938458	1
Siparunaceae-Euphorbiaceae	-0,109562326	-1,389997249	1,170872598	1
Vochysiaceae-Euphorbiaceae	-0,329895985	-2,069664454	1,409872484	1
Loranthaceae-Fabaceae	-0,251918243	-1,54982239	1,045985905	1

Lythraceae-Fabaceae	-0,115973298	-2,492570532	2,260623936	1
Malvaceae-Fabaceae	-0,352523239	-1,748517195	1,043470716	1
Melastomataceae-Fabaceae	-0,061229068	-2,437826302	2,315368166	1
Meliaceae-Fabaceae	-0,191983646	-1,346206289	0,962238997	1
Moraceae-Fabaceae	-0,395213723	-2,771810957	1,981383511	1
Myrtaceae-Fabaceae	-0,147507949	-1,842693173	1,547677276	1
Orobanchaceae-Fabaceae	-0,381167219	-2,076352444	1,314018006	1
Polygalaceae-Fabaceae	-0,315982501	-2,692579735	2,060614732	1
Rubiaceae-Fabaceae	-0,097378168	-1,316546825	1,121790489	1
Sapindaceae-Fabaceae	0,087502065	-0,637720033	0,812724163	1
Sapotaceae-Fabaceae	-0,232763637	-1,451932294	0,986405019	1
Simaroubaceae-Fabaceae	0,059760964	-3,286481308	3,406003236	1
Siparunaceae-Fabaceae	-0,212692666	-1,431861323	1,00647599	1
Solanaceae-Fabaceae	0,153656376	-0,595688933	0,903001684	1
Vochysiaceae-Fabaceae	-0,433026326	-2,12821155	1,262158899	1
Lythraceae-Humiriaceae	-0,728987304	-3,449066453	1,991091844	1
Melastomataceae-Humiriaceae	-0,674243075	-3,394322223	2,045836074	1
Piperaceae-Humiriaceae	-0,141403804	-1,940567047	1,657759439	1
Salicaceae-Humiriaceae	-0,317518356	-1,851849925	1,216813214	1
Simaroubaceae-Humiriaceae	-0,553253042	-4,151579529	3,045073444	1
Lythraceae-Loranthaceae	0,135944945	-2,535119754	2,807009644	1
Malpighiaceae-Loranthaceae	-0,029677007	-1,475335824	1,41598181	1
Malvaceae-Loranthaceae	-0,100604997	-1,954026519	1,752816525	1
Melastomataceae-Loranthaceae	0,190689174	-2,480375525	2,861753873	1
Meliaceae-Loranthaceae	0,059934597	-1,618934703	1,738803896	1
Moraceae-Loranthaceae	-0,14329548	-2,814360179	2,527769219	1
Myrtaceae-Loranthaceae	0,104410294	-1,983657033	2,19247762	1
Orobanchaceae-Loranthaceae	-0,129248977	-2,217316303	1,95881835	1
Polygalaceae-Loranthaceae	-0,064064259	-2,735128958	2,60700044	1

Rubiaceae-Loranthaceae	0,154540075	-1,569624775	1,878704924	1
Sapindaceae-Loranthaceae	0,339420308	-1,0791421	1,757982715	1
Sapotaceae-Loranthaceae	0,019154605	-1,705010244	1,743319454	1
Simaroubaceae-Loranthaceae	0,311679207	-3,249740392	3,873098805	1
Siparunaceae-Loranthaceae	0,039225576	-1,684939273	1,763390425	1
Solanaceae-Loranthaceae	0,405574618	-1,025470666	1,836619902	1
Vochysiaceae-Loranthaceae	-0,181108083	-2,269175409	1,906959244	1
Malpighiaceae-Lythraceae	-0,165621952	-2,626026116	2,294782213	1
Malvaceae-Lythraceae	-0,236549942	-2,95662909	2,483529207	1
Melastomataceae-Lythraceae	0,05474423	-3,276658758	3,386147217	1
Meliaceae-Lythraceae	-0,076010348	-2,68028786	2,528267164	1
Moraceae-Lythraceae	-0,279240425	-3,610643412	3,052162562	1
Myrtaceae-Lythraceae	-0,031534651	-2,916614268	2,853544966	1
Orobanchaceae-Lythraceae	-0,265193921	-3,150273538	2,619885696	1
Piperaceae-Lythraceae	0,5875835	-2,046121811	3,221288811	1
Polygalaceae-Lythraceae	-0,200009204	-3,531412191	3,131393783	1
Rubiaceae-Lythraceae	0,01859513	-2,615110181	2,652300441	1
Salicaceae-Lythraceae	0,411468949	-2,048935216	2,871873113	1
Sapindaceae-Lythraceae	0,203475363	-2,241106103	2,648056828	1
Sapotaceae-Lythraceae	-0,11679034	-2,75049565	2,516914971	1
Simaroubaceae-Lythraceae	0,175734262	-3,904384461	4,255852985	1
Siparunaceae-Lythraceae	-0,096719369	-2,730424679	2,536985942	1
Solanaceae-Lythraceae	0,269629673	-2,182216538	2,721475884	1
Vochysiaceae-Lythraceae	-0,317053028	-3,202132645	2,568026589	1
Malvaceae-Malpighiaceae	-0,07092799	-1,605259559	1,46340358	1
Melastomataceae-Malpighiaceae	0,220366181	-2,240037983	2,680770346	1
Meliaceae-Malpighiaceae	0,089611604	-1,228570535	1,407793742	1
Moraceae-Malpighiaceae	-0,113618473	-2,574022637	2,346785691	1
Myrtaceae-Malpighiaceae	0,134087301	-1,676721133	1,944895736	1

Orobanchaceae-Malpighiaceae	-0,09957197	-1,910380404	1,711236465	1
Polygalaceae-Malpighiaceae	-0,034387252	-2,494791416	2,426016913	1
Rubiaceae-Malpighiaceae	0,184217082	-1,191190659	1,559624823	1
Sapotaceae-Malpighiaceae	0,048831612	-1,326576129	1,424239353	1
Simaroubaceae-Malpighiaceae	0,341356214	-3,06491911	3,747631538	1
Siparunaceae-Malpighiaceae	0,068902583	-1,306505158	1,444310324	1
Vochysiaceae-Malpighiaceae	-0,151431076	-1,96223951	1,659377359	1
Melastomataceae-Malvaceae	0,291294171	-2,428784978	3,01137332	1
Meliaceae-Malvaceae	0,160539593	-1,595263947	1,916343134	1
Moraceae-Malvaceae	-0,042690483	-2,762769632	2,677388665	1
Myrtaceae-Malvaceae	0,205015291	-1,945396091	2,355426672	1
Orobanchaceae-Malvaceae	-0,02864398	-2,179055361	2,121767402	1
Polygalaceae-Malvaceae	0,036540738	-2,683538411	2,756619887	1
Rubiaceae-Malvaceae	0,255145071	-1,544018172	2,054308315	1
Sapindaceae-Malvaceae	0,440025304	-1,068803133	1,948853742	1
Sapotaceae-Malvaceae	0,119759602	-1,679403641	1,918922845	1
Simaroubaceae-Malvaceae	0,412284203	-3,186042283	4,01061069	1
Siparunaceae-Malvaceae	0,139830573	-1,65933267	1,938993816	1
Vochysiaceae-Malvaceae	-0,080503086	-2,230914468	2,069908295	1
Meliaceae-Melastomataceae	-0,130754578	-2,73503209	2,473522934	1
Moraceae-Melastomataceae	-0,333984655	-3,665387641	2,997418333	1
Myrtaceae-Melastomataceae	-0,08627888	-2,971358497	2,798800737	1
Orobanchaceae-Melastomataceae	-0,319938151	-3,205017768	2,565141466	1
Piperaceae-Melastomataceae	0,532839271	-2,10086604	3,166544581	1
Polygalaceae-Melastomataceae	-0,254753433	-3,58615642	3,076649554	1
Rubiaceae-Melastomataceae	-0,0361491	-2,66985441	2,597556211	1
Salicaceae-Melastomataceae	0,356724719	-2,103679445	2,817128884	1
Sapindaceae-Melastomataceae	0,148731133	-2,295850332	2,593312599	1
Sapotaceae-Melastomataceae	-0,171534569	-2,80523988	2,462170742	1

Simaroubaceae-Melastomataceae	0,120990032	-3,959128691	4,201108755	1
Siparunaceae-Melastomataceae	-0,151463598	-2,785168909	2,482241713	1
Solanaceae-Melastomataceae	0,214885444	-2,236960767	2,666731655	1
Vochysiaceae-Melastomataceae	-0,371797257	-3,256876874	2,51328236	1
Moraceae-Meliaceae	-0,203230077	-2,807507589	2,401047435	1
Myrtaceae-Meliaceae	0,044475697	-1,957448351	2,046399746	1
Orobanchaceae-Meliaceae	-0,189183573	-2,191107621	1,812740475	1
Polygalaceae-Meliaceae	-0,123998855	-2,728276367	2,480278657	1
Rubiaceae-Meliaceae	0,094605478	-1,524165402	1,713376358	1
Sapindaceae-Meliaceae	0,279485711	-1,008921848	1,56789327	1
Sapotaceae-Meliaceae	-0,040779991	-1,659550871	1,577990889	1
Simaroubaceae-Meliaceae	0,25174461	-3,259862471	3,763351691	1
Siparunaceae-Meliaceae	-0,02070902	-1,6394799	1,59806186	1
Solanaceae-Meliaceae	0,345640022	-0,956498734	1,647778778	1
Vochysiaceae-Meliaceae	-0,24104268	-2,242966728	1,760881369	1
Myrtaceae-Moraceae	0,247705774	-2,637373843	3,132785391	1
Orobanchaceae-Moraceae	0,014046504	-2,871033113	2,899126121	1
Polygalaceae-Moraceae	0,079231221	-3,252171766	3,410634208	1
Rubiaceae-Moraceae	0,297835555	-2,335869756	2,931540865	1
Salicaceae-Moraceae	0,690709374	-1,769694791	3,151113538	1
Sapindaceae-Moraceae	0,482715788	-1,961865678	2,927297253	1
Sapotaceae-Moraceae	0,162450085	-2,471255225	2,796155396	1
Simaroubaceae-Moraceae	0,454974687	-3,625144036	4,53509341	1
Siparunaceae-Moraceae	0,182521057	-2,451184254	2,816226367	1
Solanaceae-Moraceae	0,548870098	-1,902976113	3,000716309	1
Vochysiaceae-Moraceae	-0,037812603	-2,92289222	2,847267014	1
Orobanchaceae-Myrtaceae	-0,233659271	-2,589316914	2,121998372	1
Polygalaceae-Myrtaceae	-0,168474553	-3,05355417	2,716605064	1
Rubiaceae-Myrtaceae	0,050129781	-1,989929581	2,090189142	1

Salicaceae-Myrtaceae	0,4430036	-1,367804835	2,253812034	1
Sapindaceae-Myrtaceae	0,235010014	-1,554240409	2,024260436	1
Sapotaceae-Myrtaceae	-0,085255689	-2,12531505	1,954803673	1
Simaroubaceae-Myrtaceae	0,207268913	-3,517352857	3,931890682	1
Siparunaceae-Myrtaceae	-0,065184718	-2,105244079	1,974874644	1
Solanaceae-Myrtaceae	0,301164324	-1,497998919	2,100327568	1
Vochysiaceae-Myrtaceae	-0,285518377	-2,64117602	2,070139266	1
Polygalaceae-Orobanchaceae	0,065184718	-2,819894899	2,950264335	1
Rubiaceae-Orobanchaceae	0,283789051	-1,75627031	2,323848413	1
Sapindaceae-Orobanchaceae	0,468669284	-1,320581139	2,257919707	1
Sapotaceae-Orobanchaceae	0,148403582	-1,89165578	2,188462943	1
Simaroubaceae-Orobanchaceae	0,440928183	-3,283693586	4,165549953	1
Siparunaceae-Orobanchaceae	0,168474553	-1,871584809	2,208533914	1
Solanaceae-Orobanchaceae	0,534823595	-1,264339649	2,333986838	1
Vochysiaceae-Orobanchaceae	-0,051859106	-2,407516749	2,303798537	1
Salicaceae-Piperaceae	-0,176114551	-1,551522292	1,199293189	1
Sapindaceae-Piperaceae	-0,384108137	-1,731006924	0,96279065	1
Simaroubaceae-Piperaceae	-0,411849238	-3,945335703	3,121637226	1
Solanaceae-Piperaceae	-0,317953827	-1,677993401	1,042085748	1
Rubiaceae-Polygalaceae	0,218604333	-2,415100977	2,852309644	1
Salicaceae-Polygalaceae	0,611478152	-1,848926012	3,071882317	1
Sapindaceae-Polygalaceae	0,403484566	-2,041096899	2,848066032	1
Sapotaceae-Polygalaceae	0,083218864	-2,550486447	2,716924175	1
Simaroubaceae-Polygalaceae	0,375743465	-3,704375257	4,455862188	1
Siparunaceae-Polygalaceae	0,103289835	-2,530415476	2,736995146	1
Solanaceae-Polygalaceae	0,469638877	-1,982207334	2,921485088	1
Vochysiaceae-Polygalaceae	-0,117043824	-3,002123441	2,768035793	1
Salicaceae-Rubiaceae	0,392873819	-0,982533922	1,76828156	1
Sapindaceae-Rubiaceae	0,184880233	-1,162018554	1,53177902	1

Sapotaceae-Rubiaceae	-0,135385469	-1,801086963	1,530316024	1
Simaroubaceae-Rubiaceae	0,157139132	-3,376347332	3,690625597	1
Siparunaceae-Rubiaceae	-0,115314498	-1,781015992	1,550386995	1
Solanaceae-Rubiaceae	0,251034544	-1,109005031	1,611074118	1
Vochysiaceae-Rubiaceae	-0,335648158	-2,375707519	1,704411204	1
Sapindaceae-Salicaceae	-0,207993586	-1,173043497	0,757056325	1
Simaroubaceae-Salicaceae	-0,235734687	-3,642010011	3,170540637	1
Solanaceae-Salicaceae	-0,141839275	-1,125146263	0,841467712	1
Sapotaceae-Sapindaceae	-0,320265702	-1,667164489	1,026633085	1
Simaroubaceae-Sapindaceae	-0,027741101	-3,422605085	3,367122883	1
Siparunaceae-Sapindaceae	-0,300194731	-1,647093518	1,046704056	1
Solanaceae-Sapindaceae	0,066154311	-0,876863463	1,009172084	1
Vochysiaceae-Sapindaceae	-0,520528391	-2,309778813	1,268722032	1
Simaroubaceae-Sapotaceae	0,292524601	-3,240961863	3,826011066	1
Siparunaceae-Sapotaceae	0,020070971	-1,645630522	1,685772465	1
Solanaceae-Sapotaceae	0,386420013	-0,973619561	1,746459587	1
Vochysiaceae-Sapotaceae	-0,200262688	-2,24032205	1,839796673	1
Siparunaceae-Simaroubaceae	-0,27245363	-3,805940095	3,261032834	1
Solanaceae-Simaroubaceae	0,093895412	-3,306203524	3,493994347	1
Vochysiaceae-Simaroubaceae	-0,49278729	-4,217409059	3,23183448	1
Solanaceae-Siparunaceae	0,366349042	-0,993690532	1,726388616	1
Vochysiaceae-Siparunaceae	-0,220333659	-2,260393021	1,819725702	1

#### Locations <sup>b</sup>

Ma-Ko	-0.00801175	-0.4314406	0.4154171	1.0000000
Mc-Ko	-0.03089504	-0.4478716	0.3860816	0.9999998
Mo-Ko	2.38300425	1.3930768	3.3729317	0.0000000
Mt-Ko	-0.19788885	-1.1878163	0.7920386	0.9994729
Rg-Ko	-0.07121689	-0.5487204	0.4062867	0.9999418



Rm-Ko	-0.74348137	-2.6636283	1.1766656	0.9545730
Ro-Ko	-1.51482916	-4.2159971	1.1863388	0.7154648
Si-Ko	0.03027990	-0.3261796	0.3867394	0.9999993
Mc-Ma	-0.02288329	-0.4677662	0.4219997	1.0000000
Mo-Ma	2.39101600	1.3890142	3.3930178	0.0000000
Mt-Ma	-0.18987709	-1.1918789	0.8121247	0.9996452
Rg-Ma	-0.06320514	-0.5652619	0.4388516	0.9999842
Rm-Ma	-0.73546962	-2.6618693	1.1909301	0.9581631
Ro-Ma	-1.50681741	-4.2124338	1.1987989	0.7231976
Si-Ma	0.03829165	-0.3504431	0.4270264	0.9999977
Mo-Mc	2.41389929	1.4146069	3.4131916	0.0000000
Mt-Mc	-0.16699381	-1.1662862	0.8322985	0.9998617
Rg-Mc	-0.04032185	-0.5369490	0.4563053	0.9999995
Rm-Mc	-0.71258633	-2.6375781	1.2124054	0.9651629
Ro-Mc	-1.48393412	-4.1885482	1.2206800	0.7393738
Si-Mc	0.06117493	-0.3205216	0.4428715	0.9998993
Mt-Mo	-2.58089310	-3.9242739	-1.2375123	0.0000002
Rg-Mo	-2.45422114	-3.4802452	-1.4281971	0.0000000
Rm-Mo	-3.12648562	-5.2505572	-1.0024140	0.0002034
Ro-Mo	-3.89783341	-6.7475745	-1.0480923	0.0008297
Si-Mo	-2.35272436	-3.3283160	-1.3771327	0.0000000
Rg-Mt	0.12667196	-0.8993521	1.1526960	0.9999864
Rm-Mt	-0.54559252	-2.6696641	1.5784791	0.9968021
Ro-Mt	-1.31694031	-4.1666814	1.5328008	0.8810614
Si-Mt	0.22816874	-0.7474229	1.2037604	0.9983512
Rm-Rg	-0.67226448	-2.6112677	1.2667387	0.9766404
Ro-Rg	-1.44361227	-4.1582168	1.2709922	0.7712175
Si-Rg	0.10149678	-0.3455294	0.5485230	0.9986669
Ro-Rm	-0.77134779	-4.0619454	2.5192498	0.9983242

Si-Rm	0.77376126	-1.1390344	2.6865569	0.9416272
Si-Ro	1.54510905	-1.1508381	4.2410562	0.6904639

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<sup>a</sup> W: water. PE: petroleum ether. M: methanol. EA: ethyl acetate

<sup>b</sup> Si: Sinnamary. Mo: Montsinéry-Tonnegrade. Rg: Régina. Mc: Macouria. Ma: Mana. Ko: Kourou. Mt: Matoury. Rm: Rémire-Montjoly. Ro: Roura

## Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: