Phylogenomics of New Guinean *Begonia*

Evolution of a mega-diverse genus on a mega-diverse island

Begonia Expedition to Telefomin, Papua New Guinea 2018

The Royal Botanic Garden Edinburgh

&

The University of Glasgow

Contents

1. Introduction

Diversity is not evenly distributed, spatially, or across the tree of life. Comprising 1869 species, *Begonia* is the 6th largest genus of flowering plants, with centres of diversity in the Neotropics and South-East Asia. With this staggering species diversity, exceptionally high levels of micro-endemism, and a pantropical distribution, *Begonia* is ideal for researching the origins of tropical mega-biodiversity and reconstructing historical biogeography. To better understand the processes driving the evolution of biodiversity this project focuses on the diversification of the mega-diverse genus *Begonia* on the mega-diverse island New Guinea, aiming to identify the key factors driving the rapid evolution of the genus in the region by conducting a species radiation study.

The Royal Botanic Garden Edinburgh (RBGE) has a strong history of *Begonia* research, largely due to our extensive collection of herbarium specimens, and diverse living collections. However, despite excellent collecting effort in recent years, there remain large geographical gaps in our collections. New Guinea is one such region which, despite being fantastically biodiverse and attracting the admiration of explorers for centuries, remains significantly under-studied and poorly understood. We estimate that there may be as many as 350 species of *Begonia* from New Guinea, equating to 20% of the genus; though only 100 species are currently reliably recorded from the island.

Location description

New Guinea is the last great tropical wilderness. Extreme diversity is the theme common to all studies both on and of the island; necessitating an excessive use of superlatives in it's description. It is the largest tropical island, the highest island (with Puncak Jaya reaching 4884m), and one of only three tropical areas with glaciers. It boasts a complicated array of climate zones, land forms and geologies. The complex relationships between these varied factors have resulted in a remarkable number of different ecological niches existing on New Guinea in a broad range of ecosystems, including alpine meadows, cloud forests, tropical forests, mangroves and savannahs. It is hardly surprising then that despite making up less than 1% of the world's landmass, it harbours at least 5% of all animal and plant species (Gressit, 1982). The island is home to a staggering 15,000 endemic species (Myers *et al.*, 2000), including the world's largest and smallest parrots, largest rat, smallest frog, tallest tropical trees and smallest Rhododendron L..

New Guinea is a humid, tropical island with moderate to high rainfall, minimal seasonality, and characteristically high cloudiness; an equatorial island situated at the convergent boundary of the Pacific and Australian plates. To the north of the island, lies the vast Western Pacific Warm Pool; formed of the warmest surface waters in the world. This is the largest single heat source driving global atmospheric circulation (Prentice and Hope, 2007). To the south of the island lies the Arafura Sea, a shallow epicontinental sea separating New Guinea from Australia, which also has high surface temperatures.

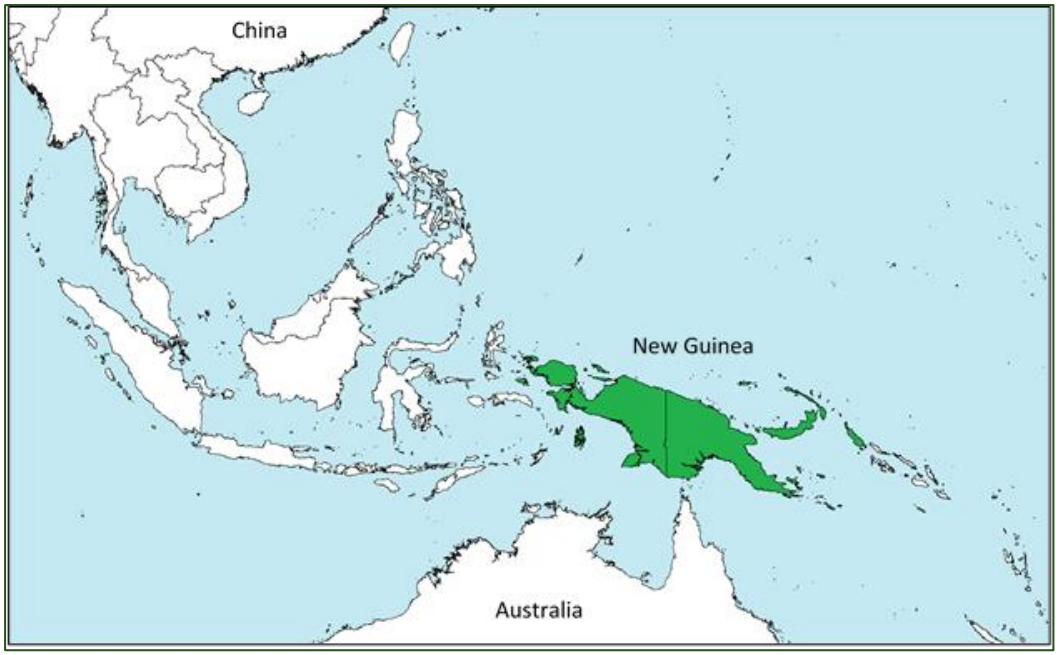


Figure 1: Map of countries in Southeast Asia, showing the location of New Guinea (green)

Although the island of New Guinea is long and narrow, with no point being more than 250km from the sea, it is effectively divided in two by a great central spine of mountain ranges with very few areas in which the peaks do not exceed 2,000m asl, (Gressit, 1982).

New Guinea has been described as a "keystone in Pacific botany" (van Steenis, 1950), due to its position at the critical junction between Asia and Australia. This unique location is responsible for the islands heterogeneous vegetation, containing both Laurasian and Gondwanan elements, as well as numerous neo-endemics. Much of the remarkable botanical diversity (Table 1) on the island today is underpinned by the complex relationships between these biogeographically distinct components (Takeuchi, 2007).

Region	Collections/100km²	Endemic genera	Spermatophyte species	% Species endemic
Borneo	35	59	10,000-15,000	37%
Java	199	10	4,500	5%
Malay Peninsular	>175	20	7,500	14%
New Guinea	30	ca. 80	**20,000-25,000**	**54%**
Phillipines	85	26	8,000	27-28%
Sumatra	21-22	17	8,000-10,000	11%
Sulawesi	24	7	5,000	13-14%

Table 1: Floristic summary of major Malesian areas. Adapted from (Takeuchi, 2007)

Early studies attempting to understand and explain the complexity of the New Guinea flora (Lam, 1934), were severely hindered by a poor understanding of the exceedingly complex geological history of the island. Whilst the true number and accurate timings of accretion events are still subjects of much debate, the biotic connections to these geological processes are becoming clearer with an increasing number of biogeographical studies employing molecular phylogenetic methods demonstrating clear links to the geological history (Heads, 2002; Deiner *et al.*, 2011; Crayn, Costion and Harrington, 2015).

2. Aims and Objectives

The aim of my PhD project is to address the question of why the tropics are so diverse, by determining the key factors driving species radiation on New Guinea. The main objective of the expedition was to improve sampling for this project by targeting one of the most underexplored yet likely species-rich areas of Papua New Guinea.

The specific scientific objectives of this expedition were:

- Fill in a sampling black-hole by collecting in a botanically underexplored region. Focussing on *Begonia* collections, but also collecting other RBGE key research taxa (*Gesneriaceae, Zingiberaceae*).
- Collect DNA samples and herbarium specimens, of all *Begonia* species found in the region, particularly targeting the extensive limestone karst: a known favourite habitat of *Begonia*.
- Observe and document morphological variation within wild populations of species in *B.* sect. *oligandrae* and *B.* sect. *symbegonia* known to be present in the area.
- Collect seed and/or living material of each *Begonia* species encountered for cultivation at LAE National Botanic Gardens, RBGE. These new collections will significantly enhance the research collections at both institutions.
- Establish new collaborations with staff at Papua New Guinea Forestry Research Institute and LAE herbarium.

3. Study Sites

Specimen coverage of Papua New Guinea is reasonable in more accessible parts, but there remain considerable geographic and taxonomic gaps. This expedition targeted such a sampling blackhole for *Begonia*; Telefomin District in Sandaun Province.

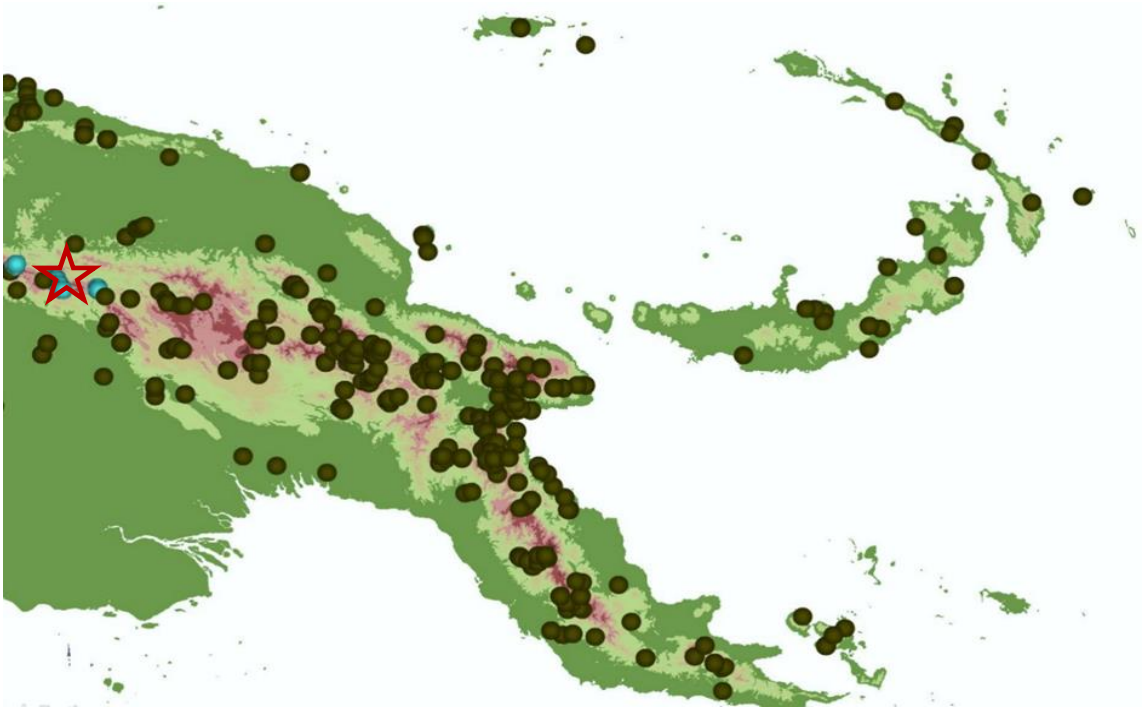


Figure 2: Map of Papua New Guinea with georeferenced *Begonia* specimens; green are existing, historical collections, and turquoise are collections made during this expedition. ☆ = Telefomin

We explored the immediate area surrounding the town of Telefomin on foot as well as taking MAF flights to visit three other villages in the district; Feranmin, Tekin and Busilmin.

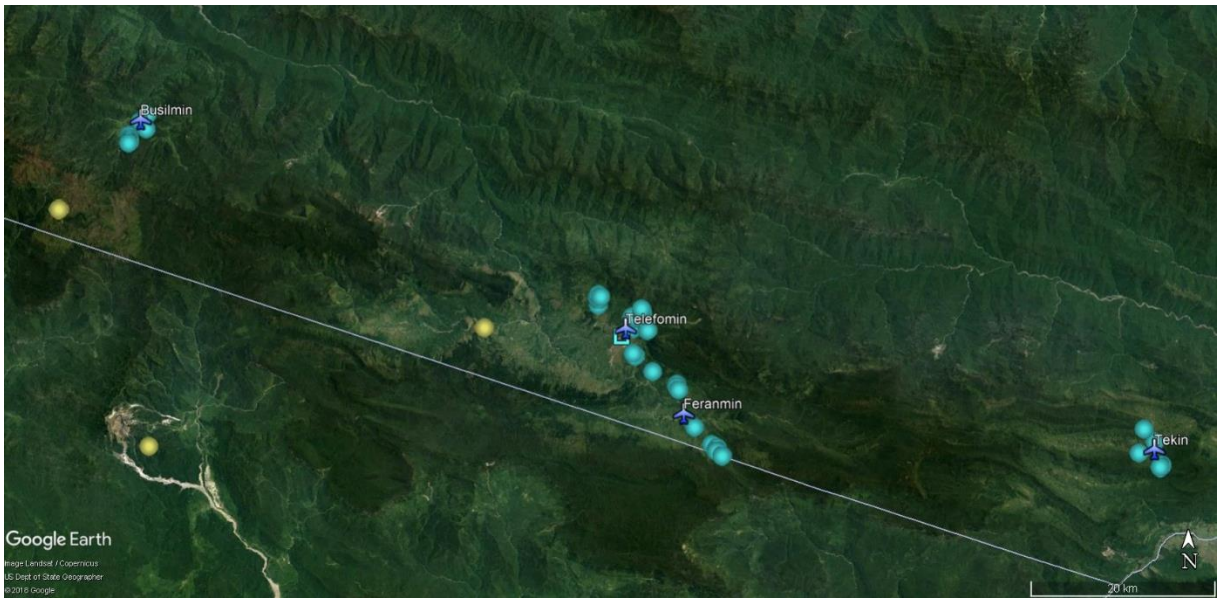


Figure 3 Satellite imagery of Telefomin region. All four sites: Telefomin, Feranmin, Busilmin and Tekin are indicated. Turquoise dots are collections made during this expedition, yellow dots show historical herbarium specimens from this region.

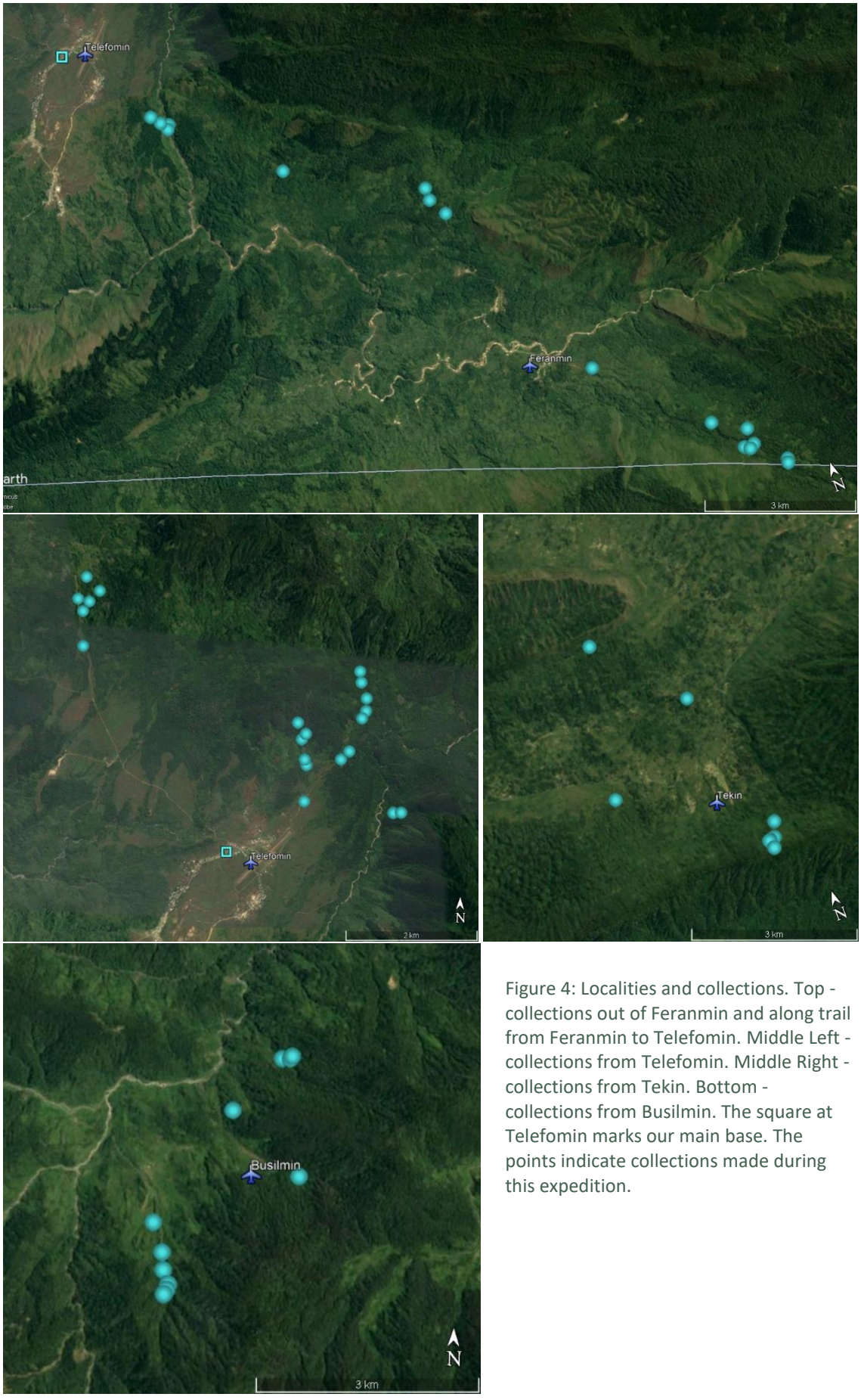


Figure 4: Localities and collections. Top - collections out of Feranmin and along trail from Feranmin to Telefomin. Middle Left - collections from Telefomin. Middle Right - collections from Tekin. Bottom - collections from Busilmin. The square at Telefomin marks our main base. The points indicate collections made during this expedition.

4. Participants

Hannah Wilson: PhD student at University of Glasgow/RBGE

Dr. Mark Hughes: Begonia Researcher at the Royal botanic Garden Edinburgh

Oliver Paul: Botanist at Lae Herbarium

Local Guides:

Lucas and Rosalia: Telefomin area

Mr Ungip: Feranmin

Gideon: Tekin

Patrick Charles and Jaffen: Busilmin

5. Methods

We made 42 collections of *Begonia,* the target taxa of this expedition, representing 14 different species. General collecting was also carried out, bringing the total number of collections made to 116 (see Appendix).

Preserved Material

Wherever possible duplicate herbarium specimens were made for each collection number, and the 1st set of specimens (including any unicate collections) was deposited at Lae herbarium before our return to Edinburgh with the duplicates. We recorded GPS coordinates for each collection and for future molecular work we dried a leaf sample in silica gel for all *Begonia*, *Gesneriaceae* and *Zingiberaceae* collections. Fleshy specimens were preserved using medical isopropyl alcohol until they could be dried at Lae. Non-fleshy specimens were dried by frequently changing the newspaper sheets, replacing the wet sheets with dry ones on rest days.

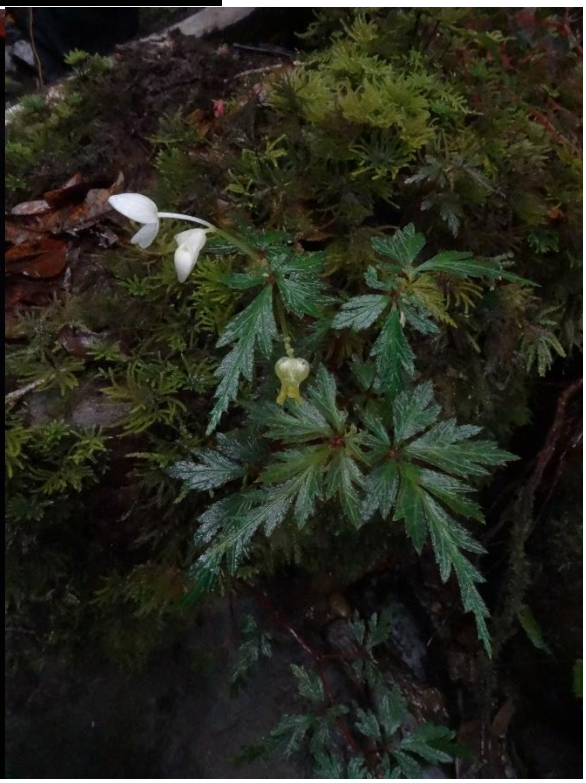
Living Material

Cutting material was collected for many of the *Begonia* species, and given to Lae Botanic Garden.

Seeds were collected for10 of *Begonia* collections, and for the Hoya species, for cultivation at the Royal Botanic Garden Edinburgh.

Top three images: *Begonia vinkii* at Telefomin

Bottom two images: *B.* sp. nov. at Telefomin



Top two images: *Begonia oligandrae* at Telefomin

Bottom two images: *B.sandsiana* at Telefomin

Top left: *B. brachybotrys*. Top right: *B. pentandra*

Lower two images: *B. kaniensis*

Three different (possibly new) species in *Begonia* Section *Petermannia*

Top left: *Begonia brassii,* top right *B. chambersiae*

Bottom: *B. kaniensis*, a climbing species

6. Logistics

Itinerary

Dates	Locality	Activity
18th June:	Singapore to Port Moresby	Arrived PNG. Met counterpart Oliver Paul
19th June:	Port Moresby	Met with Ms. Georgia Kaipu from Papua New Guinea National Research Centre, processed paperwork and permits, finalised itinerary with Papuan counterpart, confirmed bookings with MAF.
20th June:	Port Moresby to Tabubil (Air Niugini)	Arrived Tabubil. Purchased supplies.
21st June:	Tabubil to Telefomin (MAF).	Arrived Telefomin. Established base camp at MAF spare pilot house. Finalised flights with MAF contact Siobhain Cole. Met guides Lucas and Roselia.
22nd - 24th June	Telefomin	Collecting in vicinity of Telefomin on foot with Lucas and Rosalia.
25th June	Telefomin to Feranmin (MAF)	Collected in valley southwest of Feranmin
26th June	Feranmin to Telefomin (on foot)	Hiked from Feranmin to Telefomin, collecting enroute
27th June – 1st July	Telefomin	Collecting in vicinity of Telefomin with Lucas and Rosalia.
2nd July	Telefomin to Tekin (MAF)	Arrived Tekin, arranged to stay at old missionary rest house. Collecting west of Tekin.
3rd – 5th July	Tekin	Collecting in vicinity of Tekin with Gideon
6th July	Tekin to Telefomin (MAF)	Returned to Telefomin. Rest day; sort specimens, prepare for trip to Busilmin
7th July	Telefomin to Busilmin (MAF)	Arrived Busilmin, arranged a place to stay, sought meeting with village elders
8th – 9th July	Busilmin	Collected in vicinity of village with Patrick, Charles and Jaffen
10th July	Busilmin to Telefomin (MAF)	Returned to Telefomin. Rest day. Organised collections and belongings for departure
12th July	Telefomin to Wewak (MAF)	
13th July	Wewak to Lae (PNG Air)	Arrived Lae, visited Lae National Botanic Gardens & LAE Herbarium, put specimens in dryers
14th – 16th July	Lae	Worked in herbarium, imaged all *Begonia* specimens, dried ELAE collections, sorted duplicates, deposited 1st set at LAE. Arranged export permit.
17th July	Lae to Port Moresby (PNG Air)	Visited Port Moresby Nature Park
17th June:	Return to Edinburgh	Returned home

7. Funding

This expedition cost £15,338. I would like to express my gratitude to the Davis Expedition Fund Committee for their generous support of this project.

Expenditure	Cost
Return flights Edinburgh-Singapore × 2	£1,200
Return flights Singapore-Port Moresby × 2	£1,700
Internal flights Port Moresby-Tabubil × 3	£976
Internal chartered flight Tabubil-Telefomin ×1	£650
Internal flight Telefomin-Tabubil × 3	£233
Internal return flights Telefomin-Tekin × 3	£356
Internal return flights Telefomin-Feranmin × 3	£311
Internal return flights Telefomin-Busilmin × 3	£530
Internal flights Telefomin to Wewak x 3	£740
Internal flights Wewak to Lae x 3	£720
Internal flights Lae to Port Moresby × 3	£375
Driver + vehicle hire in Port Moresby (3 days)	£150
Per diem £24/day × 35 days × 2	£1,680
Counterpart honorarium £45/day × 35 days	£1,575
Local guides £10/day x 28 days	£280
Visa application fees + postage	£100
Research Project Facilitation and Management Fee	£72
Vaccinations: Hannah	£200
Freeze-dried food	£62
Satellite Phone top up	£80
Vaccinations: Mark	£300
Sawyer water filter	£109
Medical kit + malaria tablets	£250
Lightweight expedition hammock	£340
Port Moresby accommodation (2 nights × 2 people)	£600
Tabubil accommodation	£350
Lae accommodation (5 nights)	£950
Specimen freight PNG to Edinburgh	£450
Total:	£15,338

Expedition Funds	Amount
Davis expedition fund	£4,000
Merlin Trust	£1,500
RBGE expedition fund	£6,000
James and Eve Bennett Trust	£1,645
Friends of RBGE	£1,500
Total:	£14,645

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