Distribution and Ecology of Malaysian Rhododendrons in Papua New Guinea*

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INTRODUCTION

This is the second report from the expedition of the Kagoshima University team to Papua New Guinea (PNG) from Oct. 16 to Dec. 6, 1979. The purpose of the expedition was to study the intra- and interspecific variations of the ornamental characteristics such as shoot development, flowering, size of cluster, color, etc., distribution and ecology of Malaysian (*Vireya*) rhododenronons.

The places where we conducted field observations have already been described in TAGAWA *et al* (1980) in detail. As they have a close relation to the explanations in the text, we would like to reproduce only the outlines of the route we traversed.

Port Moresby ⇨ Wapenamanda → Wabag → Mount Kaiap (Sirunki, Kakas, Pumas) → Tomba → Mount Hagen → Baiyer River → Mount Hagen → Goroka (Dauro Pass, Lufa, Frigano, Marafunga, Pine Plantation, Kassam Pass) → Lae → Wau (Mt. Kainki, Bulolo, Aseki) → Bulldog Road → Wau (Kaisinik) → Lae (Buso, Wagan, Nadzab) ⇨ Port Moresby (Fig. 1).

The places in parenthesis are those we visited from a base written before the parenthesis.

Our research team for Malaysian rhododendrons obtained the hearty co-operation of Mrs. ANDRÉE MILLAR, the Director of National Capital Botanic Gardens in PNG, who kindly gave us helpful suggestions and a plan for our researches in the field and gave us every facility. Mr. MICHAEL GALORE, the Director of National Herbarium at Lae offered every facility for us and gave us a chance to identify the collected plants. Mr. KARL KERENGA, Junior Botanist at the Herbarium, helped us while we were at Lae and Wau. Mr. DIKE KALI, Chief Officer, Mr. ATAIA ANDREW, Officer,

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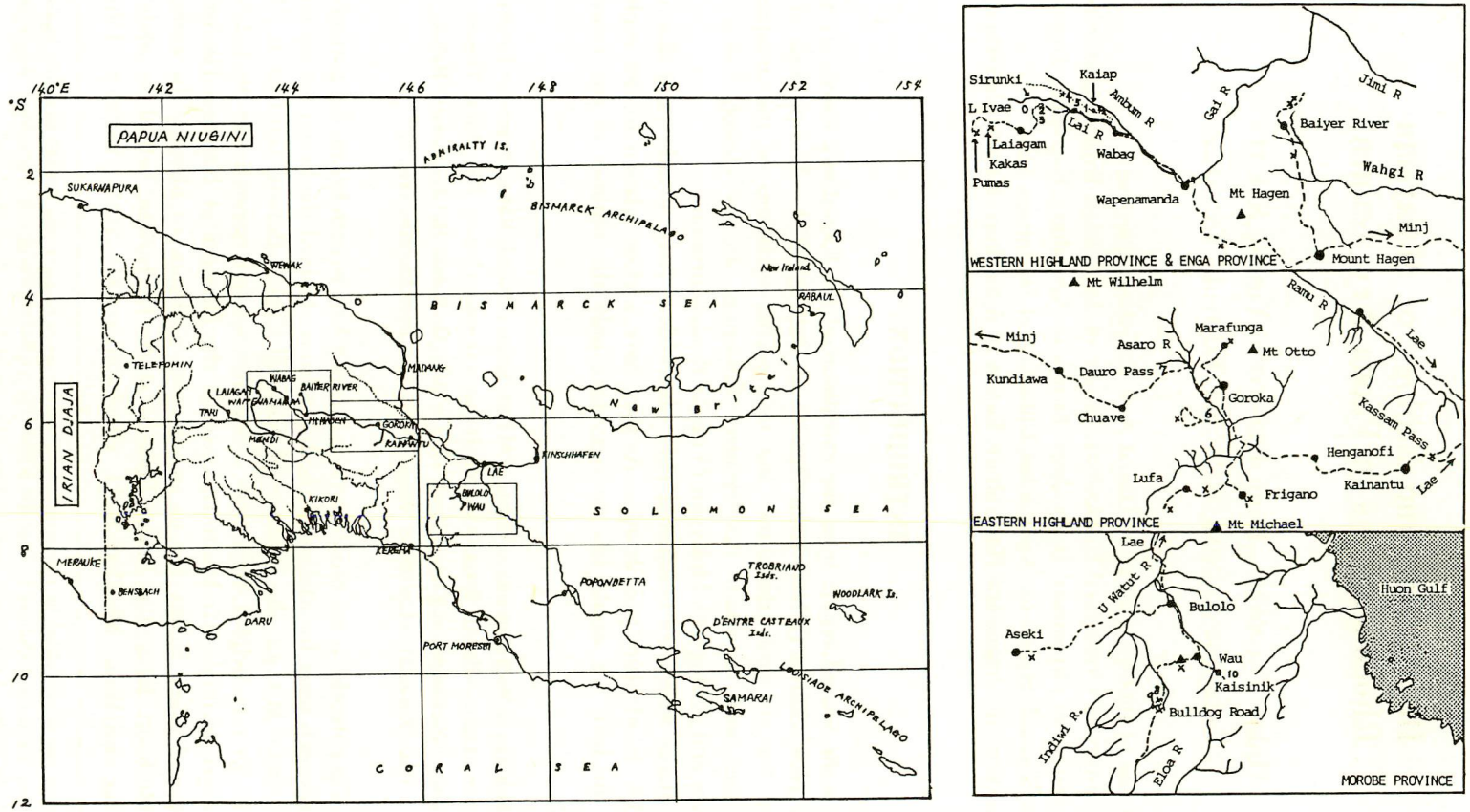

Fig. 1. A map of Papua New Guinea showing the location of the quadrats placed and the stations for rhododendron observation.

and the staff of the Provincial Office of Forestry, EHP, gave us precise information on rhododenrons and guided us every day in Goroka. Dr. J. L. GLESSITT, Director, and Dr. A. ALLISON, Vice-director of Wau Ecology Institute, kindly offered lodge facilities for us and showed us a good field to collect rhododendrons. Prof. Dr. T. SHIN, Kagoshima University helped us to identify bryophyte, and Prof. Dr. K. IWATSUKI, Kyoto University, kindly identified pteridophyte for us. Groups of farmers, who were led by Mr. PETER PIAOEN, helped us in the field works on Mt. Kaiap. Our research in PNG would not have succeeded but for their invaluable help.

CLIMATE AND VEGETATION OF PNG

Climate PNG lies between about 2°S and 12°S, and the climate is tropical in the lowland area. Temperature decreases with increasing altitude, and it is so cold sometimes as to necessitate a fire in the fireplaces of hotels in Mount Hagen (1500 m alt.) in the night. Frost and snow fall on the alpine area higher than 4000 m above sea level.

Rainfall is distributed unevenly over PNG. Trade winds blow from the southeast between May and October, and bring much rain to the southern slopes of the central mountain ranges. About 5000 mm of rain falls on the southern area from Kikori to Kiunga, and more than 4000 mm at Lae. The monsoon season is from December to March, and the northern lowland has heavy rain which fills up the Sepik and Ramu Rivers. The amount of rain varies with the topography of the region. The regions of little rain are Port Moresby and south; the area connecting Menyamya, Aseki and Edie Creek; Tabibuga east of Baiyer River with 1200 mm per year; south-west of a line from Morehead to Weam, with 1600 mm (PNG Nat. Met. Service, 1975).

Geology According to the Bureau of Mineral Resources, Geology and Geophysics (1972), a large area southwest of PNG covering the Fly River basin has thick sedimentary rock and alluvium. Active or dormant volcanoes which have eruptive history with lava flow are Bosavi, Sisa, Kerewa, Doma Peaks, Giluwe, Hagen, Ialibu, Suaru, Kaimui, Mountain, Duau, Murray, Lamington and small volcanic islands in the Bismarck Sea. As one approaches the central mountain ranges from the south, alluvium becomes thin and disappears to be replaced with limestone in places.

The Kubor Range and Mt. Wilhelm, the highest mountain in PNG, were made by an uprising of granite with or without sedimentary rock on it. The bed of the northern side of the central mountain range is igneous rock which is covered by a thick layer of sedimentary rock or alluvium on the Sepik.

Vegetation The vegetation of PNG has been studied intensively by Australian ecologists and an instructive book on the vegetation and vegetation maps have already been published (Paijmans, 1975 and 1976). The nature and the distribution of vegetation types are of general reference to the study on the habitat of Malaysian rhododendrons. We recognize the following eleven types based on many papers and a book, and our own observations.

1. Mangrove. The estuaries of the Fly, Sepik and other rivers, and the delta of Deception Bay are covered with dense stands of mangrove which are composed of the species of *Rhizophora, Bruguiera, Avicennia, Sonneratia, Ceriops* and *Lumnitzera.*

Mangrove trees grow up above 30 m, and the forest floor is open because the submerged floor carries no herb, grass and fern. In such a mangrove habitat rhododendrons may grow only as epiphytes, but epiphytic rhododendron has never been reported from PNG and Irian Jaya, except on Bornean mangroves.

2. **Lowland rain forest.** Lowland rain forest covers the northern shore, west of Speik River, Mt. Victory and in places in the lowland areas. Paijmans (1976) defined several types based on the size of tree crown. It develops in areas which have a rainfall of more than 2000 mm and where there is no distinction between the wet and dry seasons. Trees in the forest reach about 60 m, form buttresses and cauriflories, and are dressed up with many epiphytes and lianes. The forest floor is very seldom inundated with water. There is a great mixture of species such as *Pometia, Octomeles, Alstonia, Terminalia* and so on. Species composition is quite different from the SE Asian tropical rain forest dominated by Dipterocarpaceae, and there are a few species of *Anisoptera, Vatica, Hopea,* and *Vateria* of the genus in Dipterocarpaceae.

3. **Swamp forest.** Parts of the area north of the Fly River are submerged throughout the year, other parts only when it rains heavily. The continually submerged type of swamp forest is represented by *Campnosperma* forest with the following common species in the first layer, *Terminalia, Syzygium,* and *Myristica* with prop roots. The intermittently inundated swamp forest is dominated by *Melaleuca* spp. and it has an affinity with the Australian swamp forest. *Podocarpus, Dacrycarpus* and *Dacrydium* of Podocarpaceae make a swamp forest in altitudes over 1700 m. These swamp forests are gradually being replaced by *Phragmites* grassland as a result of human interference.

4. **Montane forest zone.** Montane forest is seen in the mountain area below about 1400 m, and it coincides with the hill forest of Paijmans' classification. Trees in the forest are as low as 40 m, and buttress is rare. The species composition is greatly affected by topography, edaphic condition and rainfall. A canopy is made of *Pometia, Canarium, Anisoptera, Cryptocarya, Terminalia, Syzygium, Ficus, Celtis,* etc. In Bulolo and Watut Valley there is a mixed coniferous forest whose dominants are *Araucaria hunsteinii* and *A. cunninghamii.* These conifers have been successfully afforested in a large area of Bulolo Valley. The natural *Araucaria* forest is preserved in McAdam National Park near Bulolo. The Wildlife and Bird of Paradise Sanctuary at Baiyer River which our party visited is on the upper limit of the montane forest.

5. **Castanopsis forest zone.** As one goes higher the dominant of vegetation converges into a small nunber of species. *Castanopsis acuminatissima* zone appears between 1400 m and 2300 m (the altitude is different from place to place). In this forest zone trees grow to at most 40 m. The forest floor is characterized by the growth of Zingiberaceae and climbers of Hymenophyllaceae are abundant on the tree surface. Accumulation of litter on the forest floor becomes thick, and a dense shrub layer develops.

The climate is similar to that of warm temperate zones which have no winter, and the human population has increased in the *Castanopsis* and *Nothofagus* forest zones with the introduction of sweet potato as food. A vast area of *Castanopsis* forest has been turned into grassland by human interference, and pigs domesticated by the local people disturb the forest floor.

The upper part of this zone and the lower part of the *Nothofagus* forest zone are

enveloped in dense cloud and mist every afternoon and the surfaces of plants, dead matter and rocks are thickly covered in bryophytes which creates a mossy forest.

6. Nothofagus forest zone. Between 2300 m and 3400 m alt. *Nothofagus grandis, N. pullei* and *N. rubra* dominate in the forest where many species of Lauraceae and Elaeocarpaceae, *Pandanus papuana* and climbing bomboos grow. The hight limit of cultivation is on about 2800 m where it is cold at night, and above this the mountain becomes so steep as to make land-slides frequent. Rhododendrons pay an important role for revegetation on the land-slide site. Ericaceae and Podocarpaceae increase their importance in the forest in the upper part of this zone. The quadrats placed along the Bulldog Road were near the upper limit of this zone.

7. Coniferous forest zone. Up to 3900 m where the timber line runs, the forests are of conifers such as *Dacrycarpus, Phyllocladus* and *Papuacedrus,* and as the forest goes up near the timber line the trees become stunted to make scrub with their branches stretching horizontally.

8. Alpine scrub. Above the timber line there are many types of scrub dominated by Ericaceae. We did not visit this alpine zone because our main purpose was to introduce genes resistant to high temperature into the Japanese rhododendrons.

9. Savanna forest. The vegetation hitherto described is that of rainy areas, but there are much drier places in PNG. Dry climate with a long dry season and annual rainfall lower than 2600mm makes savanna vegetation. Eucalypt savanna has a sparse distribution of evergreen *Eucalyptus alba, E. papuana, E. confertiflora* and *E. tereticornis* with an undergrowth of *Themeda australis.* This grass is dried up in the dry season, and green in the rainy season. Eucalypt savanna is seen in Port Moresby and adjacent areas.

Cajuputi savanna comes into existence in the southwest of PNG, where there is a long dry season and which is shortly inundated in the wet season. The dominants are *Melaleuca cajuputi, M. leucadendron* and *M. viridiflora,* and undergrowth is mainly *Themeda* spp. Cajuputi savanna is said to be originated from the artificial fire. Tree-fern savanna develops on the well-drained slope between 2700 m and 3300 m in alt., and tree-fern *(Cyathea)* is resistant to fire.

On the south shore of the central region there is a small area of rain green forest between savanna and grassland which is refered to in the next section. Deciduous trees are *Garuga floribunda, Brachychiton carruthersii, Intsia bijuga, Protium macgregorii, Gyrocarpus americanus, Bombax ceiba, Albizzia* sp., etc.

10. Grassland. This is the vegetation of the dry continental climate, and the natural grassland in PNG is observed as savanna with or without trees described in the preceding section. Kunai, a local name of *Imperata cylindrica* grassland, occupies a large area of the irregularly inundated terrace of Mahkam River and the newly abandoned gardens, but it is thought to be a seral stage changing into a forest, or alternatively, a disclimax due to intermittent flood.

As described before, *Castanopsis* and *Nothofagus* forest zones have been heavily deforested by the people in a long history of shifting cultivation, and there are vast areas of several types of grassland between about 1000 m and 3000 m a.s.l. These grasslands have been maintained by making fires for the last hundred years. The people who have managed the grassland are uncertain of the frequency of the fires

they make.

Short grassland dominated by *Themeda australis* and the other grasses comes shortly after the burning, and it is gradually replaced by the tall grassland where *Miscanthus floridulus* dominates. *Phragmites karka* on the wet soils and *Sacharum spontaneum* on the humid soils mediate between the pioneer vegetations and forests. *Rhododendron* species prefer to invade the short grassland and disappear from the ground as it changes into tall grassland and forest. In our expedition grasslands were the main subject of study.

11. Cultivated land. People make round mounds in their gardens in the montane region and ridges near the developed colonies and cities to plant sweet potatoes; they do not use a hoe but a rod to dig the ground and to remove the weeds. Coffee production in the Highland Provinces and in New Britain ranks second in the world. For the cultivation of coffee, tea and coconut, the fields are constantly managed and planted, but the gardens surrounding the straw huts of the people are used cyclically in the following pattern,

Cultivation → abandonment → short grassland → tall grassland → scrub → burning → cultivation.

They do not use nutrients such as compost. No attention as described by RAPPAPORT (1971) is payed to soil conservation in the civilized communities and no terraced fields were found.

In general, land is owned by the people, and the wild plants in their own land belong to them. Weed communities in the gardens will described in the future.

METHODS

Ecological observations were carried out by placing quadrats arbitrarily on the habitat where rhododendrons were growing. As we had to devote much labour to the study of ornamental observations such as size, branching, and phyllotaxis of the shrubs of rhododendron, flowering, size of flowers and cluster, colour of flower, size of leaves, and to the collection of cuttings to send and bring back to Japan, we set up only 10 quadrats of various sizes. They were; 1 in *Nothofagus* forest, 3 in *Miscanthus* grassland with shrubs in places, 2 in *Themeda* grassland with scattered shrubs, 3 on the cliffs made by the road excavation and 1 on the site of a landslide. Altitudes were measured directly with an altimeter. In these equatorial region the variation of atmospheric pressure in a day was slight at a few millibars.

Besides the botanists who were described in the introduction some other botanists helped us in the troublesome identification based on the flowerless herbarium from the quadrats. They were Dr. J.L. RAUSE, University of Melbourne, and Dr. D.G. FLODIN, University of Papua New Guinea.

Collected specimens were kept in the Institute of Biology, College of Liberal Arts, Kagoshima University, and a list of the specimens was published in the previous edition of this report (TAGAWA et al. 1980).

RESULTS

Three quadrats, PNG-1, PNG-4 and PNG-5 were placed on the gentle slope of Kaiap in the NW from Wabag and between Ambum and Lai River. PNG-1 was in *Miscanthus floridulus* grassland along a pathway, PNG-4 was on the excavated surface of a road made in 5 or 6 years before, and PNG-5 was in a typically well developed *Nothofagus grandis* forest. All these places were in the *Nothofagus* zone.

PNG-1 The results are shown in Figs. 2 and 18 and Table 1. It is obvious from the figure that trees such as *Weimannia* sp., *Finschia* sp. and *Rhododendron macgregoriae* were extended from the grassland taller than 2 m. It is noted that *Rh. macgregoriae* grew both on the ground and on the stem of *Finschia* sp., and that there were no rhododendron seedlings. This may be because of the darkness on the floor in the tall grassland. In the afternoon in these mountain region between 1500 m and 3000 m a.s.l. it rains for a few hours everyday. If there is enough medium to

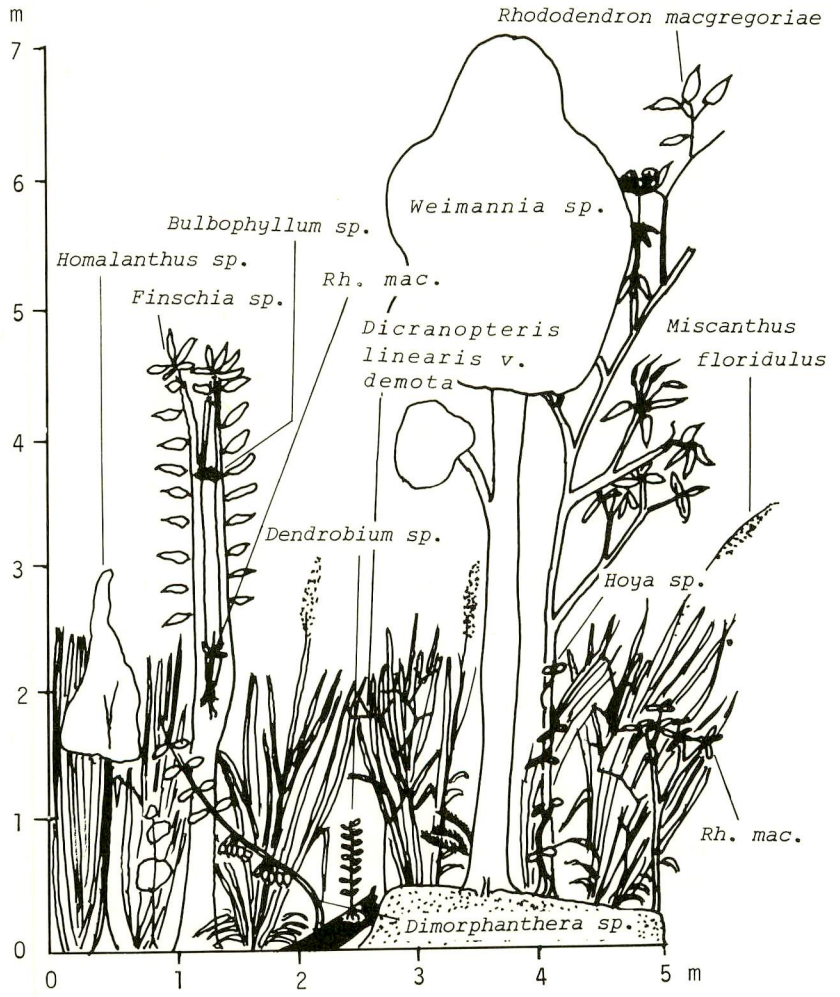

Fig. 2. Profile diagram of PNG-1.

Table 1. Species composition of PNG-1. Numerical figures in parenthesis show the number of seedlings.

Quadrat no.		PNG-1	
Locality		Kaiap, EP.	
Date		22 Oct 1979	
Altitude (m)		2550	
Exposure		Flat place	
Inclination (°)		0	
Quadrat size (m^2)		5 × 5	
Vegetation		*Miscanthus* grassland	
Habitat		Ridge near village	
Tree layer (H > 2 m)		No. ind.	$(DBH)^2$ cm^2
Weimannia sp.		3	340
Rhododendron macgregoriae		3	41
Nothofagus grandis		2	25
Eurya tigang	〔017〕	1	25
Finschia sp.	〔131〕	5	168
Carpodetus sp.	〔133〕	2	10
Polyscias sp.	〔144〕	2	8
Cordyline sp.	〔049〕	1	1
Schefflera sp.	〔141〕	1	4
Homaranthus sp.		1	16
Shrub layer (2 > H > 1.2 m)			
Rhododendron macgregoriae		6	10
Dimorphanthera sp.	〔090〕	6	23
Psychotria dolichosepala		1	1
Schefflera sp.	〔049〕	1	1
Herb layer			Cover %
Miscanthus floridulus			90
Pteridium aquilinum			80
Dicranopteris linearis	〔138〕	50	20
Alpinia sp.		20	10
Rhododendron macgregoiae		(25) 5	10
Calanthe sp.	〔143〕	1	+
C. sp.	〔024〕	10	+
Agrostophyllum sp.	〔083〕	4	+
Climber			
Hoya sp.	〔105〕	1	
Freycinetia sp.	〔023〕	1	
Pleomele (Dracaena) sp.	〔137〕	1	
Epiphyte			
Bulbophyllum sp.	〔139〕	3	
Ctenopteris alata	〔136〕	1	
Ctenopteris contigua	〔134〕	2	
Dendrobium sp.	〔135〕	3	
Rhododendron macgregoriae		1	

〔 〕 Means the collection number of TAGAWA et al (1980)

sustain roots of rhododendron, epiphytic life may be possible in humid air at the branching of the trunk.

The vegetation in this quadrat was on a seral stage where shrubs and trees were prominent from the tall grassland and an initial stage for regeneration of forest. Terrestrial and epiphytic orchids were remarkable.

PNG-4 The results are shown in Figs. 3 and 21 and Table 2. The surface where the quadrat was placed was densely covered by bryophytes. Woody species were the seedlings and saplings of *Rh. macgregoriae, Rh. inconspicuum,* and *Rh. phaeochitum,* and *Cordyline* sp. Soil beneath bryophytes was wet and humid enough to maintain the rhododendron seedlings. Capsules were kept even on *Rh. macgregoriae* not taller than 70 cm in height.

PNG-5 Only one quadrat was placed in the forest. There was no trace of using stone axes on the trees. The forest has never been cut down simultaneously in a large area, but pigs on the prowl for their food in the forest disturb the undergrowth heavily. We never saw earthworms, frogs, snakes or small lizards in the forests in the highland provinces, so their densities might have been decreased by pigs.

The results are shown in Figs. 4 and 22 and Table 3. The first layer was dominated by *Nothofagus grandis* and it reached about 40 m in height. Many acorns were found on the forest floor, but there were no seedlings on the floor except for the side of the path in the sun. Total coverage of this layer was 50%. The second

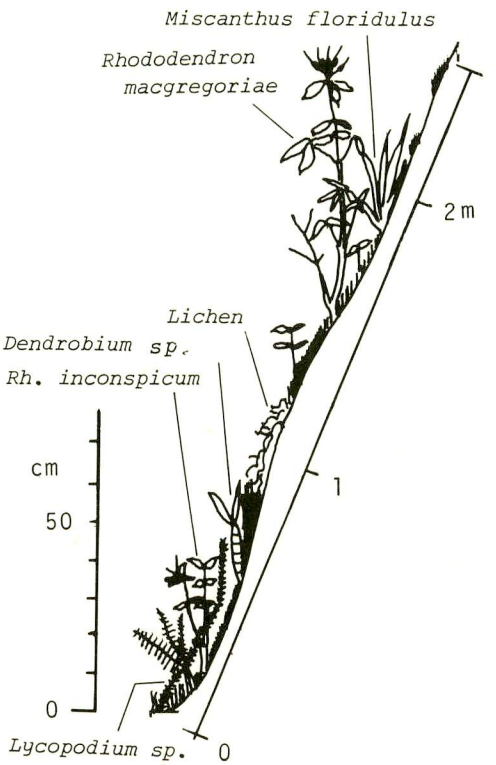

Fig. 3. Profile diagram of PNG-4.

layer was made up of a mixed growth of *Streblus* sp., *Polyosma* sp., *Timonius* sp., *Pandanus papuanus* and so on. The third layer had several common species such as *Ascarina* sp., *Psychotria valetonii, Finschia* sp., and *Syzygium* sp. In this layer there were many climbing bamboos. *Macaranga* spp. which is the characteristic species in the subseral communities of montane vegetations in PNG, were growing only in the layer lower than the third. The shrub layer was characterized by *Psychotria valetonii* and *Dimorphanthera* sp., a few species of ferns and Zingiberaceae grew on the floor.

It is noticeable that four seedlings of *Rh. phaeochitum* were growing simultaneously on the sunny floor and on the trunks of old *Nothofagus grandis*. *Rh. dielsianum* and *Rh.* sp. were also found as epiphytes. The epiphytic position of rhododendrons on the trunk of *Nothofagus grandis* is shown in Table 4, and there is not a clear difference in the epiphytic position among 3 species of rhododenrons.

Table 2. Species composition of PNG-4.

Quadrat no.		PNG-4	
Locality		Kaiap, EP.	
Date		22 Oct. 1979	
Altitude (m)		2620	
Exposure		S 41° W	
Inclination (°)		65	
Quadrat size (m^2)		2.5 × 10	
Vegetation		Mossy carpet	
Habitat		Road cutting	
Herb layer		No. ind.	Cover %
Rhododendron macgregoriae		188	
Rh. inconspicuum		39	
Rh. phaeochitum		1	
Cordyline sp.	[144]	1	
Dendrobium papuana		8	
Lycopodium sp.		3	
Miscanthus floridulus		7	5
Gleicheniaceae		2	5
Dipteris conjugata	[042]	2	
Crypsinus sp.		2	
Lycopodium clavatum	[254]	3	
Hypericaceae	[275]	2	
Compositae	[258]	1	
Rabiaceae		1	
Habenaria sp.		1	
Crypsinus sp.	[162]	2	
Grammitis frigida	[256]	1	
Lycopodium cernuum	[110]	1	+
Jackiella sp.	[257]		50
Frullania sp.	[257]		60
Polytrichum sp.	[253]		
Lichen			60

PNG-2 and 3 were placed in the *Miscanthus floridulus* grassland which is near Lake Ivae and a small community, Sirunki, on the upper reaches of Lai River. The underground water-table was high, and there were a number of small patches dominated by *Juncus* sp. Domesticated pigs have created in the floor of the grassland canals in whichi no vegetation grows (Figs. 5 and 6).

PNG-2 The results are shown in Fig. 5 and Table 5. The height of the grassland was about 2 m, and *Rh. macgregoriae, Saurauia* sp., *Cordyline* sp., *Dodonaea viscosa* were taller than the other grasses, so this might be a younger stand than PNG-1. *Miscanthus* grasses were replaced by *Imperata* grasses in places and vice versa. Saplings of *Rh. macgregoriae* were abundant, but seedligs were never found.

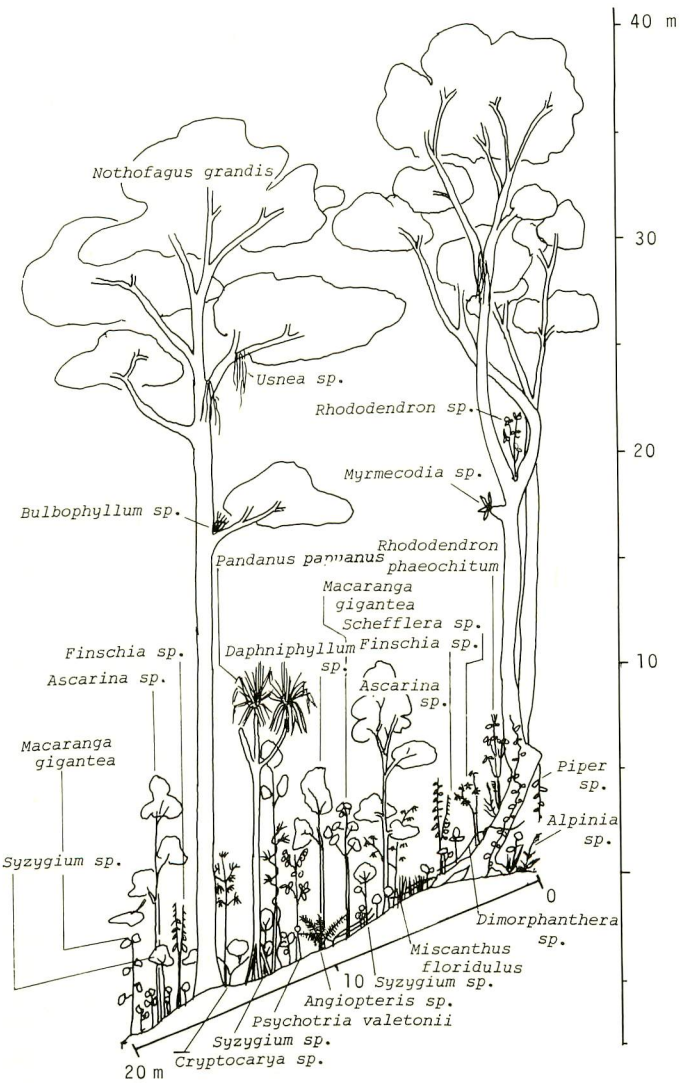

Fig. 4. Profile diagram of PNG-5.

Table 3. Species composition of PNG-5.

Quadrat no.	PNG-5	
Locality	Kaiap, EP.	
Data	26 Oct. 1979	
Altitude (m)	2475	
Exposure	S 45° W	
Inclination (°)	23	
Quadrat size (m^2)	20 × 20	
Vegetation	*Nothofagus* forest	
Habitat	Slope, medium moist	
1st tree layer (H>20 m)	No. ind.	(DBH)^2 cm^2
Nothofagus grandis	3	26902
2nd tree layer (20>H>10 m)		
Nothofagus grandis	1	225
Streblus sp. (190)	2	1341
Eurya tigang	1	36
Dodonaea viscosa (132)	1	1369
Pandanus papuanus	1	400
Polyosma sp. (212)	4	857
Timonius sp. (215)	4	990
Sphenostemon sp. (220)	1	144
Daphniphyllum sp. (223)	1	196
Pittosporum sp. (226)	1	81
P. sp. (238)	2	244
Trimenia sp. (236)	1	196
Schizomeria sp. (235)	1	196
Ascarina sp. (202)	2	458
A. sp. (198)	1	100
3rd tree layer (10>H>2 m)		
Psychotria valetonii	27	115
Helicia sp. (188)		38
Saurauia sp. (189)		151
Streblus sp. (190)	11	132
Prunus sp. (191)		57
Syzygium sp. (192)	16	99
Daphniphyllum sp. (123)		43
Schefflera sp.	11	96
Finschia sp. (017)	21	185
Ascarina sp. (198)	13	256
Eurya tigang		95
Macaranga sp. (203)	10	46
M. sp. (221)	10	21
Mischocarpus sp. (242)	4	7
Polyosma sp. (212)	2	6
Timonius sp. (215)	7	100
Rapanaea sp. (214)	5	253
Memecylon sp. (217)	8	20
(218)	3	3
Sphenostemon sp. (220)	4	18
Eurya sp. (225)	4	26
Schefflera sp.	1	4 21
Sloania sp. (331)		3 34
Cryptocarya sp. (231)		3 35
C. sp. (195)		1 1
Levieria sp. (194)		1 1
Ficus sp. (219)		2 60
Mischocarpus sp. (196)		2 2
Dodonaea viscosa (132)		2 8
Nothofagus grandis		3 73
Ascarina sp. (233) (202)		2 101
Planchonella sp. (205)		1 25
Saurauia sp. (230) (206)		4 8
S. sp. (207)		1 6
Xanthomyrtus sp. (211)		1 64
Cryptocarya sp. (210)		1 2
Sloanea sp. (224)		1 16
Saurauia sp. (229)		1 36
Trimenia sp. (236)		1 18
Vaccinium sp. (237)		2 21
Pittosporum sp. (238)		1 1
Planchonella sp. (241)		1 16
Ficus sp. (243)		1 1
Dimorphanthera sp. (red) (052)		4 59
D. sp. (yel)		3 29
Elaeocarpus sp.	①	1 ⑩ 2
Unknown 1		2 3
Unknown 2		1 1
Shrub layer (2>H>1.2 m)		
Nothofagus grandis		1 2
Psychotria valetonii		32 46
Leviera sp. (187)		1 1
Helicia sp. (188)		3 4
Streblus sp. (190)		5 9
Syzygium sp. (192)		2 2
Daphniphyllum sp. (223)		1 1
Finschia sp. (017)		1 1
Acacia sp.		1 1
Sloania sp. (331)		1 1
Eurya tigang		1 1
Planchonella sp. (205)		1 1
Alstonia sp. (208)		1 1
Olearia sp. (209)		1 1
Cryptocarya sp. (210)		1 2
Timonius sp. (215)		1 1
Cypholophus sp. (216)		1 1
Rapanaea sp. (214)		2 3
R. sp. (109)		3 6
Macaranga sp. (221)		1 1
Medinilla sp. (222)		1 1

Symplocos sp.	(227)	1	1
Saurauia sp.		1	1
S. sp.	(230)	2	2
Cryptocarya sp.	(231)	1	2
Pittosporum sp.	(232)	1	1
Trimenia sp.	(236)	1	1
Pittosporum sp.	(238)	1	1
Polyosma sp.	(239)	2	5
Schefflera sp.		1	1
Dimorphanthera sp. (red)	(052)	28	99
D. sp. (yel)		2	2
Pandanus papuana		2	+
Climber			
Climbing bamboo	(010)	48	48
Freicinetia sp.	(023)	8	27
Piper sp.	(025)	1	1
Palmeria sp.	(197)	1	1
Ficus sp.		2	10
Meringium ovatum	(317)	5	+
Mecodium polyanthos	(327)	5	+
Herb layer			Cover %
Phododendron phaeochitum		(4)	+
Ctenopteris celebica	(251)	22	20
Angiopteris sp.	(245)	7	10
Alpinia sp.		12	10
Rubus sp.		1	+
Cyperus sp.	(246)	4	+
Pilea sp.	(249)	5	+
Cyathea sp.	(244)	2	+
Coleus sp.	(250)	17	+
Begonia sp.	(247)	4	+
Calanthe sp.	(024)	2	+
Liparis sp.	(306)	2	+
Nertera granadense	(324)	1	+
Crypsinus albidosquamatus	(118)	1	+
Ctenopteris contigua	(282)	1	+
Athyrium sp.	(292)	1	+
Thelypteris obtusata	(291)	1	+
Dryopteris sparsa	(305)	1	+
Thelypteris sp.	(293)	1	+
Cyathea sp.	(312)	1	+
Crypsinus sp.	(128)	1	+
Thelypteris sp.	(294)	1	+
Plagiogyria sp.	(288)	1	+
Dryopteris sparsa	(284)	1	+
Grammitis frigida	(325)	1	+
Selliguea feei	(127)	1	+
Thelypteris beddomei	(283)	1	+
Cyathea sp.	(313)	1	+
Pteridophyte	(315)	1	+
Pteridophyte	(316)	1	+
Polypodium subauriculatum	(329)	1	+
Pteridophyte	(318)	1	+
〃	(309)	1	+
Selaginella sp.	(289)	1	+
Viola sp.	(290)	1	+
Phaius sp.	(304)	1	+
Epiphyte			No. of species
Agrostophyllum sp.	(278)		1
Bulbophyllum	(280) (298) (299) (300) (306) (319)		6
Dendrobium	(281) (285) (286) (301) (302) (307) (308) (310) (311) (302) (321) (322) (323) (326)		14
Diplocaulobium	(296) (303)		2
Eria javanica	(277)		1
Epiblastus sp.	(279)		1
Oberonia	(295) (328)		2
Thelasis sp.	(297)		1
Myrmecodia sp.			1
Epiphyte H>2m			No. ind. $(DBH)^2$ cm^2
Rhododendron phaeochitum			6 81
Rh. dielsianum			1 9
Rh. sp.			2 4
Epiphyte 2>H>1.2m			
Rh. phaeochitum			(273) 2 9
Rh. sp.			3 11
Epiphyte H>1.2m			
Rh. phaeochitum			(273) 10
Rh. sp.			(230) 17

PNG-3 This was close to PNG-2, and the vegetation was quite similar to that of PNG-2. Figure 6 and Table 6 show the profile diagram and species composition in the quadrat. *Rh. macgregoriae* and *Dodonaea viscosa* reached about 3 m in height. Seedlings and saplings of both species of rhododendron were generated commonly on the floor. Species diversity was higher than PNG-2.

Table 4. Distribution of epiphytic rhododendrons.

Hight of epiphytic position (m)		0	0.5	1	2	3	4	5	8	9	10	20	Total
Rhododendron phaeochitum	H > 2 m				1			2	2				5
	2 > H > 0.03 m		8	5			5						18
	Seedling	4				270			3				277
Rh. sp.	H > 2 m					1						1	2
	2 > H > 0.03 m		1	2	1	2	1	1	6	1	2		17
	Seedling		1			215			3			3	222
Rh. dielsianum	H > 2 m								1				1
	2 > H > 0.03 m												
	Seedling												

Table 5. Species composition of PNG-2.

Quadrat no.		PNG-2	
Locality		Sirunki, Ep.	
Date		23 Oct 1979	
Altitude (m)		2580	
Exposure		N 35° E	
Inclination (°)		8	
Quadrat size (m^2)		5 × 5	
Vegetation		*Miscanthus* grassland	
Habitat		Gentle slope with bad drainage	
Shrub layer (2 > H > 1.2 m)		No. ind.	$(DBH)^2$ cm^2
Rhododendron macgregoriae		18	52
Breynia sp.	〔153〕	1	1
Herb layer			
Miscanthus floridulus			90
Imperata cylindrica			30
Weimannia sp.	〔003〕	1	+
Viola sp.	〔154〕	7	+
Bidens parviflora	〔155〕	7	+
Spathoglotis sp.	〔047〕	2	+
Anaphalis sp.	〔149〕	2	+
Erigeron sumatrensis		1	+
	〔156〕	1	+
Rhododendron macgregoriae		53	10
Rabiatae	〔152〕	5	+
Rubus sp.	〔147〕	1	+
Carex sp.	〔151〕	2	

PNG-6 The results are shown in Figs. 7 and 23 and Table 7. This quadrat was placed on the abandoned garden on a rather steep slope on the way to the silvicultural spot where a big project of afforestation was being carried out. The surface of the ground was completely covered by *Themeda australis* and a leafless parasitic liane, *Cassytha filiformis* leaving a narrow space between the dead leaves of *Themeda* with a network of *Cassytha* and the ground surface for the seedlings of *Rh. zoelleri.*

On the ground under the shrubs of *Vaccinium* sp. and *Wendrandia* sp., *Themeda* grass disappeared but ferns grew up. *Miscanthus floridulus* was seldom in the quadrat. Vegetation in the quadrat is thought to be in the process of changing from short grassland to scrub without changing into tall grassland.

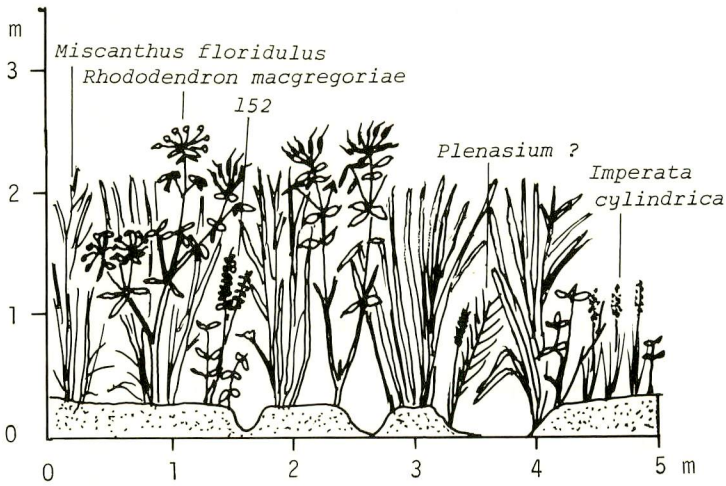

Fig. 5. Profile diagram of PNG-2.

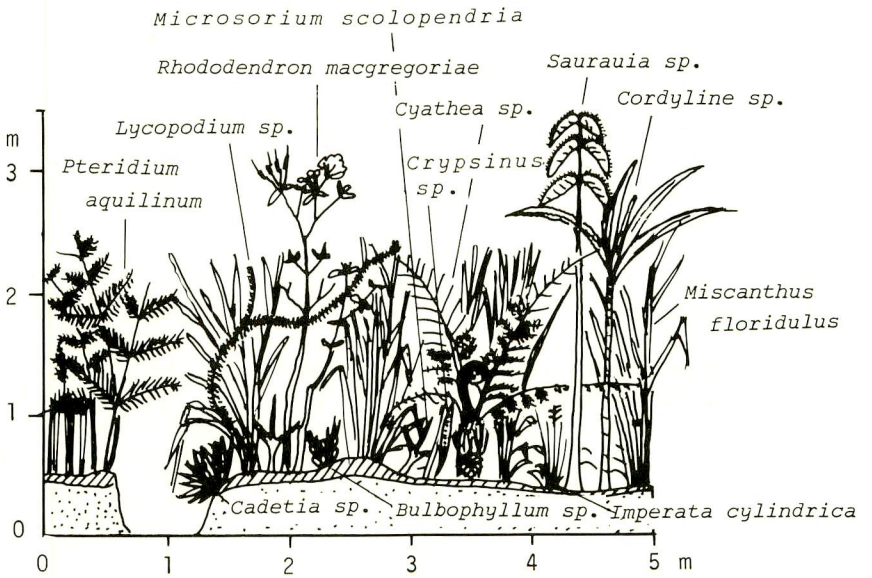

Fig. 6. Profile diagram of PNG-3.

Table 6. Species composition of PNG-3.

Quadrat no.		PNG-3	
Locality		Sirunki, EP.	
Date		24 Oct. 1979	
Altitude (m)		2580	
Exposure		E	
Inclination (°)		8	
Quadrat size (m^2)		5 × 5	
Vegetation		*Miscanthus* grassland	
Habitat		Gentle slope with bad drainage	
		No. ind.	$(DBH)^2$ cm^2
Tree layer (H > 2 m)	〔165〕	2	2
Dodonaea viscosa	〔160〕	2	6
Rhododendron macgregoriae		3	23
Rh. inconspicuum		1	10
Shrub layer (2 > H > 1.2 m)			
Dodonaea viscosa	〔160〕	3	3
Rhododendron macgregoriae		19	91
Rh. inconspicuum		2	7
Saurauia sp.	〔157〕	4	5
Vaccinium sp.	〔159〕	2	11
Cordyline sp.		1	1
Zanthoxylum sp.		1	1
Herb layer			Cover %
Miscanthus floridulus			60
Lycopodium sp.			30
Pteridium aquilinum		12	10
Poaceae	〔164〕		+
Dendrobium sp.	〔170〕		+
Bulbophyllum sp.	〔168〕		+
Spathoglottis sp.	〔169〕		+
Microsorium scolopendria	〔161〕		+
Crypsinus sp.	〔162〕		+
Unknown 1		2	+
Unknown 2		1	+
Cadetia sp.	〔166〕		+
Imperata cylindrica			+
Cyperaceae	〔167〕		+
Carex sp.	〔151〕		+
Rubiaceae	〔152〕		+
Cyathea sp.		2	+
Rhododendron macgregoriae		(90) 144	10
Rh. inconspicuum		(8) 13	+

Table 7. Species composition of PNG-6.

Quadrat no.		PNG-6	
Locality		Goroka	
Date		5 Nov. 1979	
Altitude (m)		1900	
Exposare		E	
Inclination (°)		28	
Quadrat size (m^2)		5 × 5	
Vegetation		*Themeda* grassland with shrubs	
Habitat		Slope of abandoned field	
Tree layer (H > 2 m)		No. ind.	$(DBH)^2$ cm^2
Vaccinium sp.	〔747〕	2	149
Wendrandia sp.	〔735~6〕	1	9
Rhododendron zoelleri		8	247
Pittosporum sp.	〔743〕	2	10
Shrub layer (2 > H > 1.2 m)			
Vaccinium sp.	〔747〕	3	18
Wendrandia sp.	〔735~6〕	(4) 1	1
Rhododendron zoelleri		2	6
Rh. leptanthum		2	13
Pittosporum sp.	〔743〕	(2) 1	2
Herb layer			Cover %
Rhododendron zoelleri		(142) 6	10
Rhododendron leptanthum		1	+
Themeda australis	〔746〕		50
Cassytha filiformis	〔737〕		50
Selliguea feei	〔127〕		10
Do	〔752〕		10
Acalypha sp.	〔751〕	(1)	+
Wendrandia sp.	〔735~6〕	(4)	+
Leucosyke sp.	〔738〕	3	+
Thelypteris sp.	〔739〕	3	+
Ilex sp.	〔740〕	1	+
Glochidion sp.	〔742〕	1	+
Pteridium aquilinum		1	+
Imperata cylindrica		1	+
Coelogyne sp.	〔750〕	1	+
Dendrobium sp.	〔741〕	1	+
Spathoglottis sp.		1	+
Schefflera sp.		(1)	+
Unknown (Poaceae)		1	5

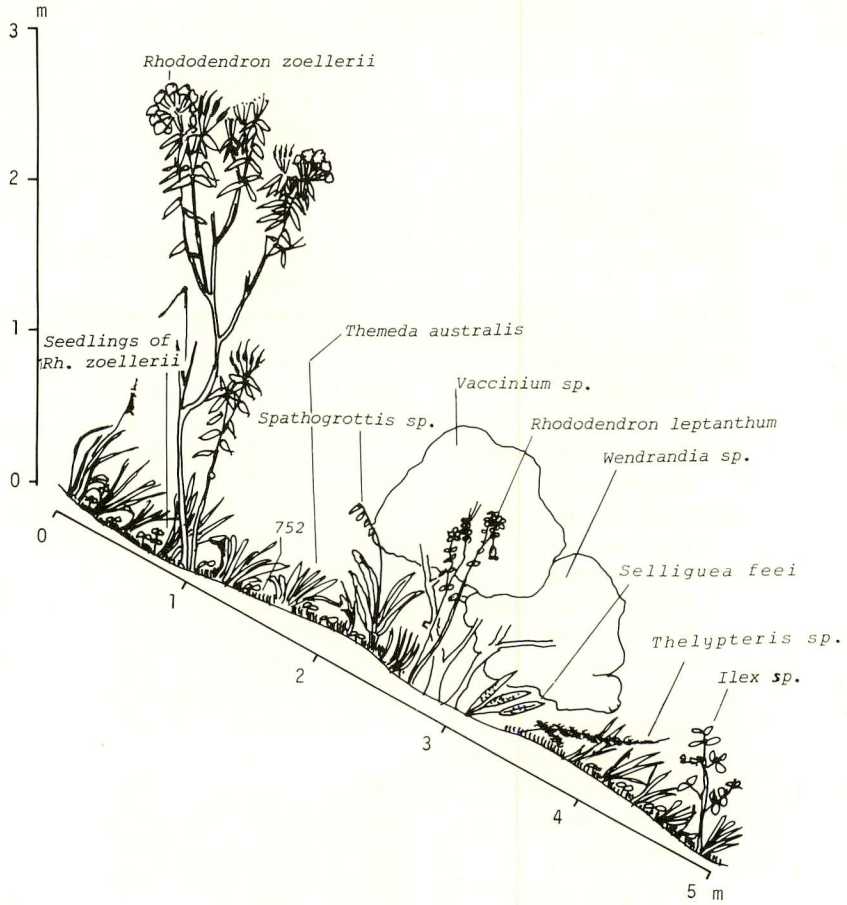

Fig. 7. Profile diagram of PNG-6.

PNG-7 This was placed on the fresh steep slope excavated along the road at Dauro Pass between Mount Hagen and Goroka (Figs. 8 and 24). There was no bryophyte carpet but much exposed gravel on the surface. Many seedlings of *Rh. macgregoriae, Rh. inconspicuum* and *Rh. leptanthum* were commonly found in the quadrat. *Erigeron sumatrensis* known as the world-wide weed was frequently found but a few individuals of *Miscanthus floridulus* (Table 8).

PNG-8 and 9 were set up near the highest places on the Bulldog Road made by the Australian army to connect Port Moresby to Wau in the World War II. It has become ruined because it has only been used for tracking and hunting since the war. It extends from Wau to the Owen-Stanley Mountains through Mt. Kaindi, Eddie Creek and a gold mine, and goes down southwarbs along Eroa River. It takes about 8 hours to go up from Eddie Creek to the highest place (3200 m a.s.l.) on foot. The place where quadrats were placed was in the range of the *Nothofagus* forest zone, and in the upper part of this zone the density increases of such coniferous trees as *Dacrycarpus* and *Dacrydium* of Podocarpaceae and *Papuacedrus of* Cupressaceae

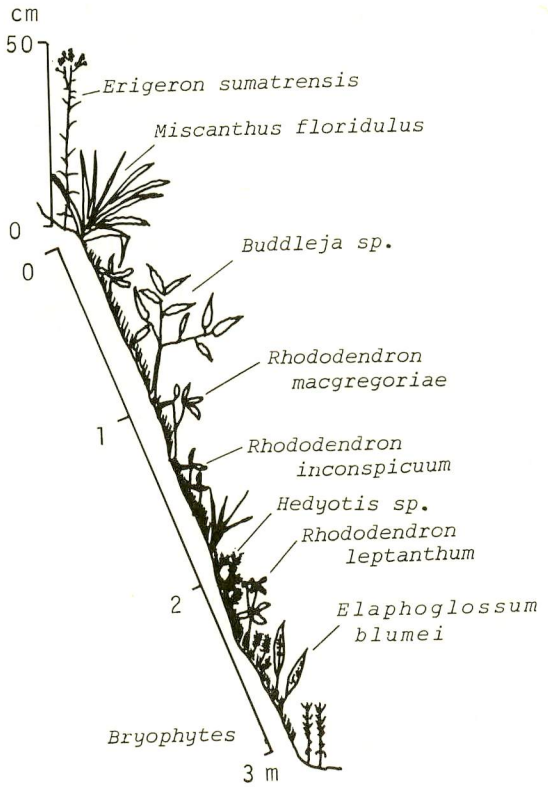

Fig. 8. Profile diagram of PNG-7.

The trees became low, and all exposed matters was covered densely by bryophyte mat to make a mossy forest,

Near the ridge and peak the slope becomes very steep, and there were signs of landslide showing various stages of vegetation recovery. The recovery of the vegetation has been seriously delayed on the exposed rocks in comparison with exposed red soil, where bryophytes easily invade and make a dense mat to help the germination of rhododendrons and the growth thereafter. PNG-9 was placed in the nearly pure scrub of *Rh. inconspicuum* grown on this type of landslide. On the steep slope along the Bulldog Road PNG-8 was placed. Soils in the two quadrats were brownish-yellow forest soil type.

PNG-8. In this quadrat 6 species of rhododendron were found (Table 9 and Figs. 9 and 25); they were *Rh. inconspicuum, Rh. culminicolum, Rh. scabridibracteum, Rh. vitis-ideaea, Rh. gracilentum,* and *Rh. nummatum. Rh. culminicolum* and *Rh. scabridibracteum* did not have seedling and sapling on the floor, but *Rh. vitis-idaea, Rh. gracilentum* and *Rh. nummatum* were found only as seedling and sapling. This may indicate that there is a time series of invasion of rhododendrons onto the newly made habitat.

In the herb layer several species of *Vaccinium* occupied 70% of the area, and the open places without woody species were covered by many species of bryophyte, *Rhacomitrium, Sphagnum,* etc. One individual of *Dacrydium imbricatus* was found.

Table 8. Species composition of PNG-7.

Quadrat no.		PNG-7.	
Locality		Dauro Pass	
Date		9 Nov. 1979	
Altitude (m)		2380	
Exposure		N 45°E	
Inclination (°)		75	
Quadrat size (m^2)		3 × 10	
Vegetation		Almost bare ground	
Habitat		Road cutting	
Herb layer		No. ind.	Cover %
Rhododendron macgregoriae		(40)	10
Rh. incospicuum		(16)	+
Rh. leptanthum		(5)	+
Buddleya sp.		5	+
Hedyotis sp.	〔056〕	1	+
	〔376〕	1	+
Thelypteris obtusata	〔291〕	2	+
Crypsinus albidosquamatus	〔118〕	1	+
Athyrium	〔292〕	1	+
Miscanthus floridulus		9	10
Erigeron sumatrensis		17	+
Polygonum sp.		1	+
Crassocephalum sp.		1	+

PNG-9. This quadrat was placed in the U-shaped depression made by landslide as shown in Figs. 10 and 26. Table 10 shows that it was a almost pure stand of *Rh. inconspicuum* with its canopy at 3.5 m in height, and all the individuals of this species in the stand seem to be a cohort population which originated from the completion of habitat for their simultaneous germination after the landslide. Seedlings of neither rhododendron were found in and outside of the quadrat. *Gaultheria, Dimorphanthera* and *Vaccinium*, woody species other than rhododendron, all belong to Ericaceae. According to our general observation in the stand much older than this, *Dipteris* and a tall sedge species invade the floor of the rhododendron scrub to make the floor very dark. This condition may invite the ecesis of arbour species to make a forest.

The last quadrat, PNG-10, was placed on *Themda australis* grassland in the outskirts of Kaisinik at 20 km east from Wau. This grassland has long been managed by irregular fire, and the fire left half-burned *Banksia dentata, Rh. aurigeranum* and *Ficus damalopsis* standing on the black ash. It is quite strange that there was no cattle in the grassland.

PNG-10. Soil in the quadrat was rather dry, and we could not find bryophyte on the floor. Instead of the bryophyte there were abundant seedlinbs of *Rh. aurigeranum* (Table 11) in a small gap on the ground beneath the dead leaves of the grass as well as those in PNG-6. A big orchid, *Coelogyne asperata* was characteristic on the steep

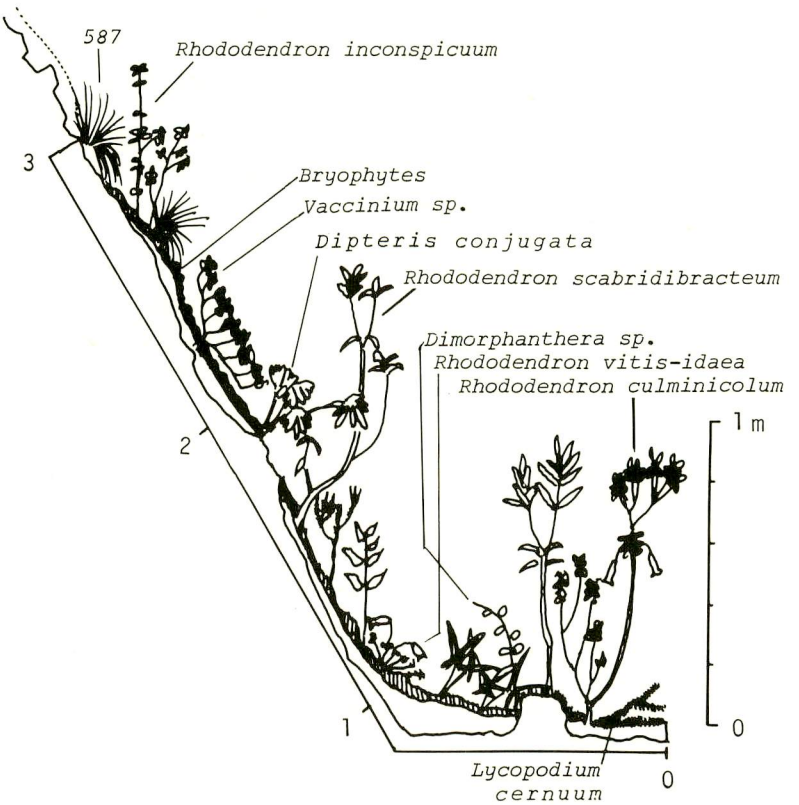

Fig. 9. Profile diagram of PNG-8.

slope in the grassland (Figs. 11 and 27).

DISCUSSION ON THE ECOLOGY OF MALAYSIAN RHODODENDRONS

The western end of the distribution of the *Rhododendron* is the Himalayas and the eastern falls on the Island of New Guinea. According to NUMATA (1965 a and b, 1966) who conducted extensive observations on the vegetation in Central Nepal, *Rhododendron* grows in laurel-leaved forests (*Quercus semecarpifolia* forest, *Q. lanuginosa* forest, *Q. lamellosa* forest, *Machilus duthiei* forest) between 1700 m and 2700 m in alt., mixed conifer forests (*Abies spectabilis* forest, *Tsuga dumosa* forest, *Juniperus recurva* forest) higher than 2700 m in alt. and the summer green *Betula utilis* forest as a member of the second layer and underlayers. On dry south-facing steep slopes where there is little mesophytic forest, there are many types of stunted forest or scrubs dominated by *Rhododendron arboreum* (10 m in height at most), *Rh. arboreum* var. *campbelliae,* and *Rh. campanulatum* (2 to 3 m in height) near the timber-line. There is no description of the epiphytic rhododendron in the Himalayas in any paper refered, and rhododendrons are all terrestrial. Several epiphytic rhododendrons (*Rh. marlipoense,* etc.) were reported from Yunnan, China (FENG, 1981).

Table 9. Species composition of PNG-8.

Quadrate no.		PNG-8	
Locality		Bulldog Rd., MP.	
Date		18 Nov. 1979	
Altitude (m)		2620	
Exposure		S 60° E	
Inclination (°)		75	
Quadrat size (m^2)		3 × 8.3	
Vegetation		*Rhododendron* scrub	
Habitat		Road cutting	
Shrub layer		No. ind.	$(DBH)^2$ cm^2
Rhododendron inconspicuum			
	〔613〕	3	9
Rh. culminicolum	〔618〕	1	4
Rh. scabridibracteum	〔615〕	1	4
Dimorphanthera sp.		8	58
Fagraea sp.	〔595〕	1	4
	〔592〕	1	4
Vaccinium sp.	〔586〕	1	25
Herb layer			Cover %
Rh. inconspicuum	〔613〕	(12) 3	+
Rh. vitis-idaea	〔614〕	(4) 1	+
Rh. gracilentum	〔616〕	(27)	+
Rh. nummatum	〔616〕	2	+
Dimorphanthera sp.		4	+
Fagraea sp.	〔595〕	3	+
Mallotus sp.			+
	〔592〕	1	+
Dacrydium imbricatus	〔563〕	(1) 3	+
Dimorphanthera sp.		4	+
Vaccinium sp.	〔594〕	5	+
	〔588〕		70
Poaceae	〔587〕		+
Alpinia sp.	〔569〕	13	+
Liparis sp.	〔596〕	2	+
Dendrobium phlox	〔589〕	9	+
Melastoma sp.	〔568〕	4	+
Syzygium sp.	〔590〕		+
Lycopodium cernuum	〔584〕		5
L. sp.	〔585〕		5
L. angustiramosum	〔583〕		+
Crypsinus sp.	〔570〕		+
Bryophyte layer			
Campylopus sp.	〔580〕		20
Mastigophora diclados	〔572〕		10
Campylopus sp.	〔574〕		10
Anastrophyllum sp.	〔581〕		+
Plagiochila sp.	〔573〕		+

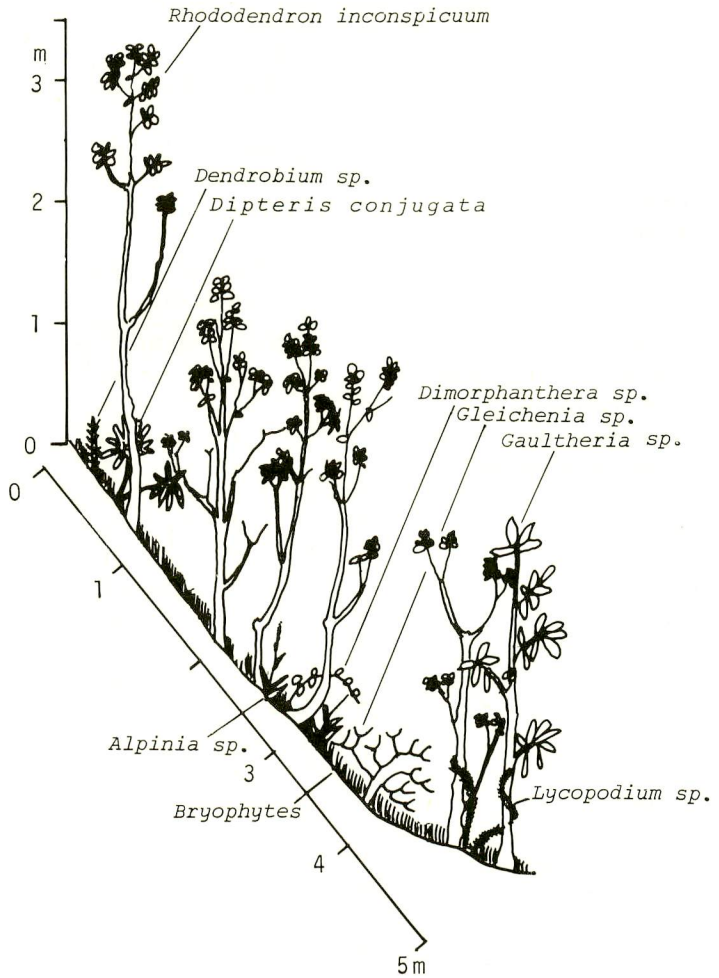

Fig. 10. Profile diagram of PNG-9.

OHSAWA *et al* (1975) reported on the vegetation in East Nepal, and wrote that in the sub-tree and shrub layers *Rh. hodgsonii* and *Rh. barbatum* dominated in *Acer campbellii* forest zone (2500 m to 2900 m in alt.), and the *Rhododendron* layer became a scrub by loosing its overstory, alpine heath, as it went up near the timber line.

NUMATA thought that the natural forests have long been damaged by introducing yak *(Bos grunniens)* into the forests, and gradually replaced by the *Rhododendron* forest or scrub. Thus, Himalayan rhododendron has extended its habitat under human interference.

Malaysian rhododendrons were descried well in the monograph by SLEUMER (1966). In this monograph there were 135 species and 21 varieties of rhododendron collected in New Guinea. The distribution of these species and varieties was illustrated in Fig. 12 which was based on SLEUMER's monograph. Open circles and broken lines in the figure show our collection at the illustrated altitudes and the distribution range extended according to our observation. If we exclude the rhododendron species which are growing only on alpine heath and those collected once, we have 52

Teble 10. Species composition of PNG-9.

Quadrat No.		PNG-9.	
Locality		Bulldog Rd., MP.	
Date		18 Nov. 1979	
Altitude (m)		2600	
Exposure		S 30° E	
Inclination (°)		47	
Quadrat size (m^2)		5 × 5	
Vegetation		*Rhododendron* scrub	
Habitat		Landslide site	
Shrub layer		No. ind.	(OBH)^2 cm^2
Rhododendron inconspicuum		35	268
Rh. nummatum	〔619〕	1	1
Gaultheria sp.	〔594〕	4	10
Dimorphanthera sp.		1	1
Vaccinium sp.	〔583〕	2	2
	〔603〕	2	9
Eurya sp.		1	1
Herb layer			Cover %
Vaccinium sp.	〔583〕		30
Dipteris sp.	〔602〕		10
Gleicheniaceae			10
Lycopodium sp.	〔585〕		+
	〔583〕		+
Alpinia sp.	〔569〕	8	+
Mediocarcha sp.		12	+
Plagiogyria sp.		20	+
Agrostophyllum sp.	〔599〕	1	+
Dendrobium sp.	〔605〕	1	+
D. sp.	〔600〕	1	+
D. sp.	〔604〕	1	+
Poaceae	〔587〕	1	+
Phreatia sp.	〔601〕	2	+
Liparis sp.	〔596〕	1	+
Crypsinus sp.	〔606〕	1	+
Cyathea sp.	〔598〕	1	+
Bryophyte layer			70
Hypnum sp.	〔573〕		10
Mastigophora diclados	〔572〕		
Frullania subdentata	〔608〕		+
Schistochila sciurea	〔609〕		+
Campylopus sp.	〔580〕		+
Jackiella sp.	〔610〕		+
Kurzia sp.	〔611〕		+
Plagiochilon oppositus	〔612〕		+

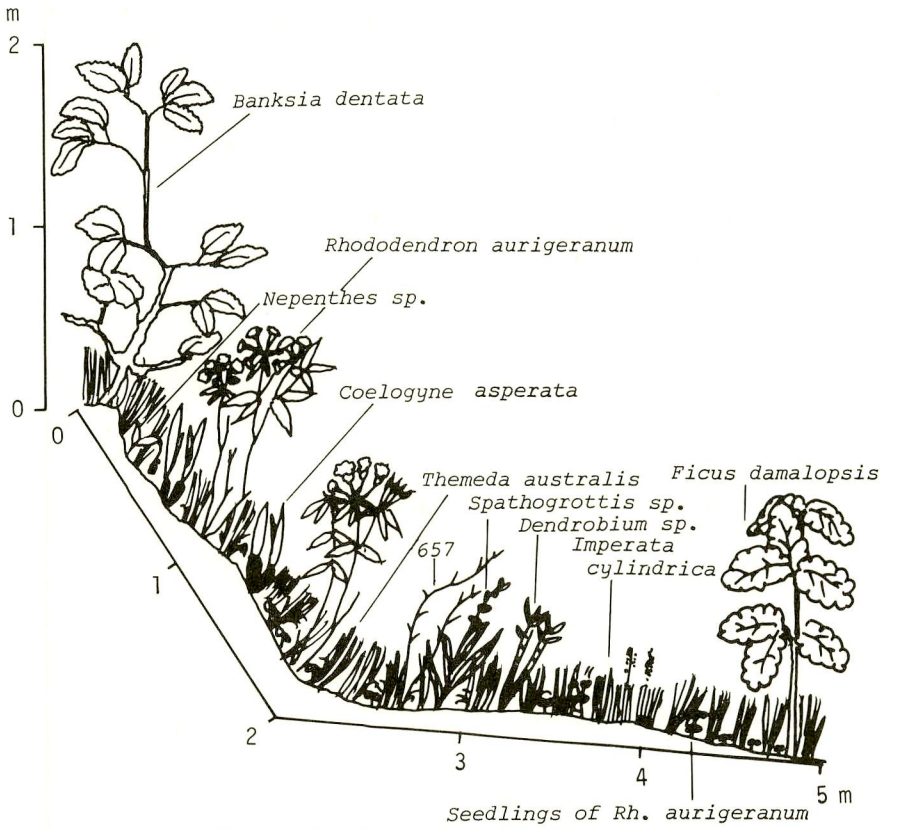

Fig. 11. Profile diagram of PNG-10.

species and 2 varieties. Half of these are facultative species which can be grown on the ground and on the surface of tree trunk, and the another half is known as terrestrial.

Those recorded as terrestrial were common in sunny places such as forest margins, scrub with scattered shrubs, grassland, crevices on limestone, cliff alnog the road, river bank, sites of landslides, bracken, forest gap, peaty swamp, and so on, but not in the dark forest. The species which has collected in the tropical rain forest was always highly epiphytic. Before human beings had evolved on the earth the island of New Guinea was covered with forest apart from savanna areas. The way of survival of heliophylous rhododendron might have been epiphytic on the trunk of trees which exceeded out of the canopy as shown in Fig. 4. Facultative species can grow in the lighter places like the lava flow, sites of land-slides, river banks and gaps made in the forest, as well as on the trunks of trees.

Quadrats, PNG-4, 7, and 8, were placed on the wet slopes made by the excavation of the road, and the slopes bear many seedlings, saplings and even adult trees with flowers and capsules. At Dauro Pass *Rh. macgregoriae, Rh. inconspicuum* and *Rh. leptanthum* grew on the slope, but there were never available seed sources near the slope except for the forest hung over it. The dust seeds of rhododendron are easily blown to remote places, but it is rational to think that the seeds were supplied by the epiphytic examples on the trees. The circumstances were the same as the slope

Table 11. Species composition of PNG-10.

Quadrat no.		PNG-10	
Locality		Vele-Vele V., MP	
Date		22 Nov. 1979	
Altitude (m)		1440	
Exposure		N 20° W	
Inclination (°)		32	
Quadrat size (m^2)		5 × 5	
Vegetation		*Themeda* grassland	
Habitat		Gentle slope with intermittent fire	
Woody species		No. ind.	$(DBH)^2$ cm^2
Banksia dentata		3	27
Ficus damalopsis		1	2
Rhododendron aurigeranum		(495) 22	42
Ochnaceae	[658]	3	8
Vaccinium sp.		(3) 1	+
Herbaceous species			Cover %
Themeda australis			70
Coelogyne asperata		12	20
Graminae	[657]		10
Crypsinus sp.	[570]		10
Dipteris novoguineensis	[602]	1	5
Nepenthes sp.		2	+
Lycopodium cernuus	[654]		+
Imperata cylindrica			+
			5
Gleicheniaceae			10
Dendrobium sp.	[656]		+
Spathoglottis sp.	[653]	3	+
Elaphoglossum blumei	[661]		+
Rubiaceae	[661]		+

observed at Jimi-Wahgi divide near Baiyer River. It is noteworthy that those facing north in the sun and which had little water supply did not carry rhododendron seedlings. Naked surfaces were observed even on the slope facing south near PNG-10 placed on dry grassland.

Bryophyte carpet developed commonly on the wet soil and slope. The rhododendron seedlings easily germinated in the cushion of bryophyte, and grew up to be saplings. New seedlings, however, were never found on the floor of *Rhododendron* forest itself as seen in PNG-9.

In PNG-5 *Rh. phaeochitum* and *Rh.* sp. had several shrubs, saplings and many seedlings on the trunk, but on the floor only four seedlings of *Rh. phaeochitum* were found restricted on the forest edge. As seen in Fig. 4 the canopy of the secondary layer was at about 10 m from the ground, while *Nothofagus grandis* had its stature reaching 40 m in height. *Rhododendron* species germinated as epiphyte on the branching place of a stem at 10 m in height or so may survive and to grow so well because they receive so much light. It is not always necessary to be epiphytic on

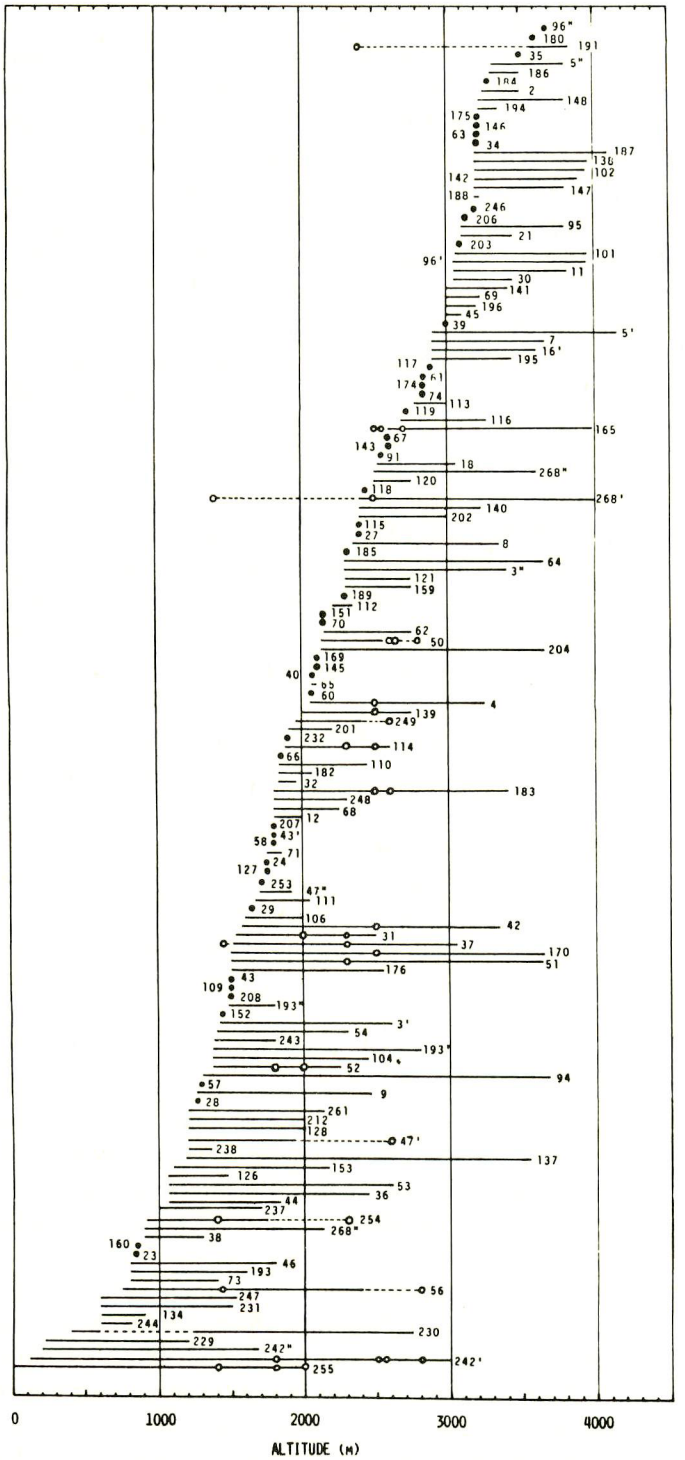

Fig. 12. Vertical distribution of rhododendrons in New Guinea Island. The number attached to the line shows the species number given in SLEUMER (1966) and that with a dash or dashes the variety of species. The single dark circle shows the species once collected, and the open circle refers to our collection.

the stem much higher than the secondary canopy.

On our expeditionary tour we found many species of rhododendrons in the short and tall grasslands dominated by *Themeda australis* and *Miscanthus floridulus* respectively except in Kunai grassland which was mainly composed of *Imperata cylindrica*. Quadrats of PNG-6 and 10 were on a transitional stage from short grassland to scrub, and those of PNG-1, 2 and 3 were examples of tall grassland where several shrubs were invading. The rhododendron seedlings were found abundantly on the floor of short grasslands, for example, those of *Rh. zoelleri* in PNG-6 and of *Rh. aurigeranum* in PNG-10. In the quadrats of PNG-1, 2 and 3 in the tall grassland, adults and saplings of *Rh. macgregoriae* were found, but seedlings were not always found there. It grew in places where the tall grass was absent.

Short grass left its dead leaves to make a layer above the ground with a little space between the layer and the floor. It is natural to think that this affects the loss of water from the soil, and that this space enables the production of many rhododendron seedlings. As the succession proceeds from the short grassland to the tall grassland, the production of seedlings is hard because of the darkness on the floor in the tall grassland. On the other hand seedlings produced in the short grassland grow up into shrubs in the tall grassland, but they have to disappear from the floor again as the tall grassland develops into forest. The seeds discharged from the rhododendrons surviving on the ground in these circumstances can germinate and grow on the surface of tree trunks.

In the present expedition a terrestrial species *Rh. cruttwellii* was found in *Sphagnum* bog at Pumas (Fig. 1), but another terrestrial *Rh. commonae* was an epiphyte which grew on *Nothofagus* tree which had been cut down by the people of Kakas. One individual of terrestrial *Rh. dielsianum* was found as an epiphyte on *Nothofagus grandis* tree (Fig. 4). These facts show that terrestrial rhododendrons may be found as epiphytes in future. The following three species, *Rh. herzogii, Rh. aurigeranum* and *Rh. inconspicuum,* were found only on the ground throughout our tour of PNG.

SUMMARY

1. For the study on the distribution and ecology of rhododendrons growing in Papua New Guinea, ten quadrats of various sizes were placed on diverse habitats; 3 on the cliffs made by the road excavation, 1 in the *Nothofagus* forest, 3 in the *Miscanthus* grassland with shrubs in places, 2 in the *Themeda* grassland with scattered shrubs, and 1 on the site of a landslide.

2. Plenty of rhododendron seedlings were found on the wet excavated faces along the road. The wet faces were almost covered with bryophytes, and there was no bryophyte carpet on the dry faces and no rhododendron seedling. It is uncertain where the source of seed supply of these rhododendrons was, but it is quite natural to think that they come from the adjacent forest epiphyte rhododendrons if there is no terrestrial seed source near by. On the landslide site there was a dense mat of bryophytes on the floor in the open *Rh. inconspicuum* scrub, but rhododendron seedlings were never found.

3. In the *Nothofagus* forest on Mt. Kaiap the following three species of rhodo-

dendrons were found as epiphyte ; *Rh. phaeochitum, Rh. dielsianum* and *Rh.* sp. The height of epiphyte position on the trunk was from the ground level to 20 m. Epiphyte seedlings and adults were frequently found below 10 m on the trunk where they can receive radiation much better than on the floor. We never found the terrestrial rhododendron in the midst of forests but at forest edges.

4. On the ground in the low grassland dominated by *Themeda australis* there were many seedlings of rhododendrons ; *Rh. zoelleri* in the quadrat PNG-6 and *Rh. aurigeranum* in PNG-10. In the tall grassland of *Miscanthus floridulus,* however, the seedlings of predominant rhododendrons were seldom found on the ground. This may be because the tall grassland suffers from intermittent fires made by the local people, and adult rhododendrons except the fire-resistant species are burnt.

5. No rhododendron species has ever been found in kunai *(Imperata cylindrica)* grassland. This is because the kunai is a pioneer stage in a subsere originating directly from the abandonment of gardens.

6. Discussion was given on the origin of terrestrial rhododendrons from epiphytic ones through the facultative species whose growth habit is changeable between terrestrial and epiphytic growth in the woodland environment like New Guinea.

7. We suggest that the growth pattern of rhododendrons in relation to the plant succession is as follows : Seedlings produced in the short grassland grow up to become shrub as the grassland develops into tall grassland, but the shrubby rhododendrons disappear from the floor as this tall grassland develops into a forest. In the forest rhododendrons can grow only on the trunks of trees.

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▲Fig. 13. A lumbering spot of tropical rain forest. A big trees cut down is *Celtis salicifolia*.

◀Fig. 14. Montane forest at Baiyer River.

▲Fig. 15. *Castanopsis acuminatissima* forest at Bulolo.

◀Fig. 16. *Nothofagus grandis* forest at Kakas.

Fig. 17. Mossy forest at Dauro Pass

Fig. 18. PNG-1

Fig. 19. Garden for sweet potato.

Fig. 20. A garden showing various parts just planted and just abandoned.

▲Fig. 21. PNG-4

◀Fig. 22. PNG-5

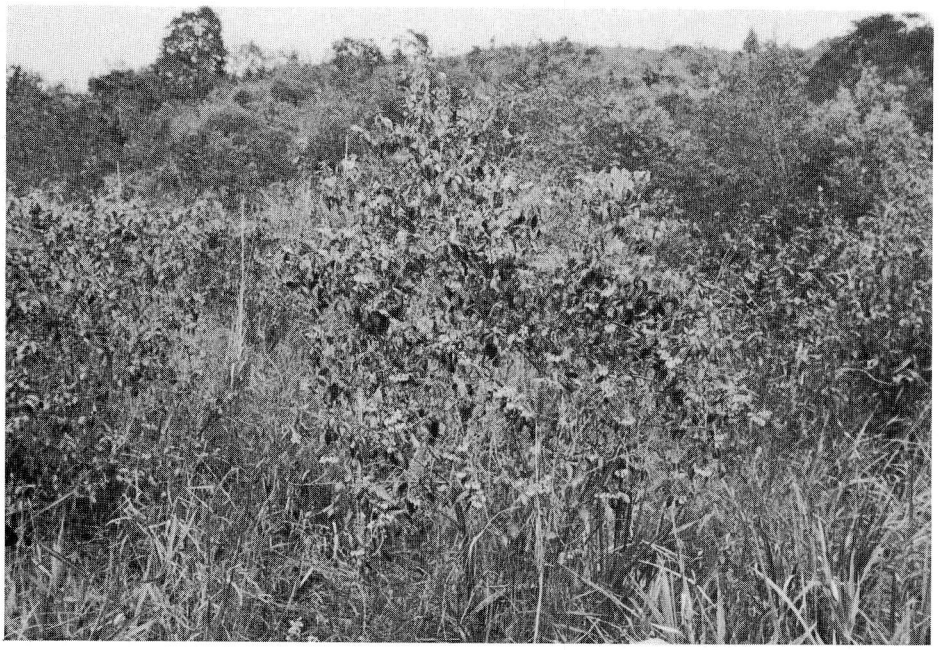

Fig. 23. PNG-6

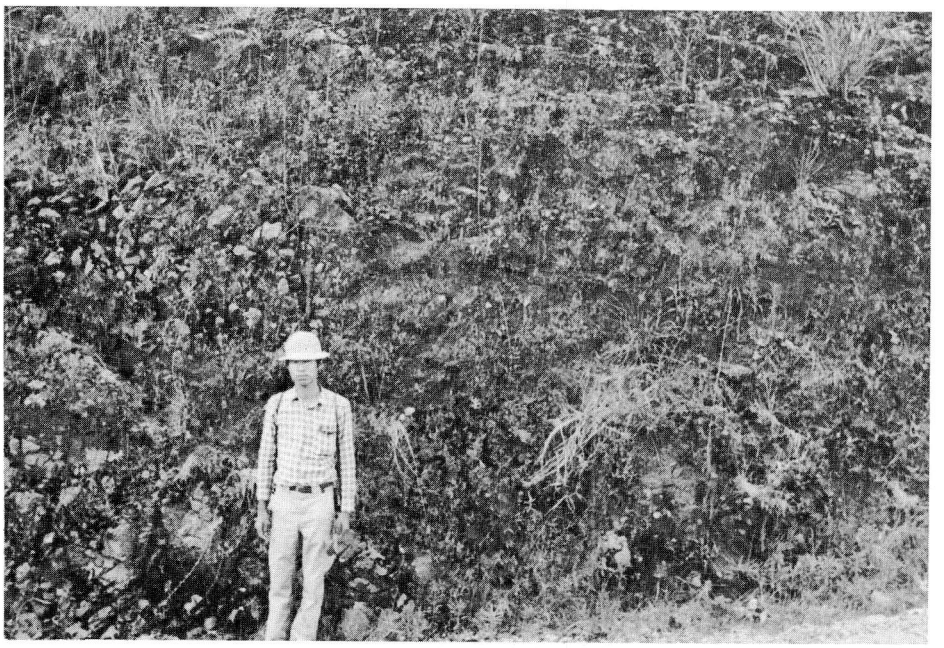

Fig. 24. PNG-7

Fig. 25. PNG-8

Fig. 26. PNG-9

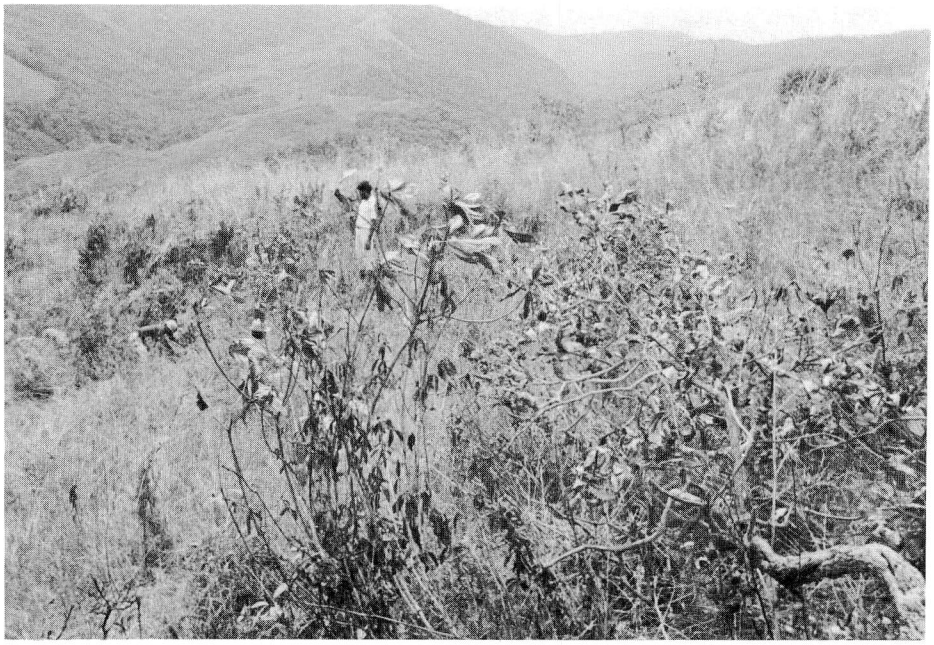

Fig. 27. PNG-10