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Forest Ecological Studies of the Montane Forest of Mt. Pangrango, West Java

II. Stratification and Floristic Composition of the Forest Vegetation of the Higher Part of Mt. Pangrango

by

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Introduction

The present report deals with the results of the forest ecological survey of the higher part of Mt. Pangrango. Methodology of this work is almost identical with the first paper of this series, in which the stratification and floristic composition of the lower part of this mountain were described.[1]

Sample sites and research methods

Two sample plots were chosen, at points 2400 m and 3000 m in alt. One is the Kandang Badak plot (KBP), which is situated a few minutes walk from Kandang Badak mountain hut (2400 m in alt.) and the other one is the Summit plot (SP), which is located a few minutes from the top of Mt. Pangrango (3019 m in alt.).

Along the mountain path from Cibodas to the summit, tree height decreases with altitude and stratification becomes more simple. After passing the *Podocarpus* zone, the tree trunks become more slender and the moss surrounding these trunks becomes thicker.

KBP is located on a rather moderate incline at the foot of a long, steep slope climbing to the summit. The height of the trees rarely exceeds 20 m. The trunks of almost all the trees were covered by moss, but this is not as thick as on the trees in the summit plot. Trunks were slender and straight. Ground vegetation was quite abundant and tree ferns appeared sporadically, though much smaller in height than the ones found at the lower site. Woody climbers and epiphytic plants were small in number. Soil was not as rich as at the lower site and was stony in the deeper layers. Mother rock was found about 70 cm from the surface. Gradient of the slope was 20° directly to the north.

From the KBP, there is a very steep slope up to the summit. Trees on this slope mostly bent close to the ground and the trunks are sometimes twisted. This is caused mainly by the wind. After ascending this slope, one reaches the flat area of the summit.

Trees in the SP generally stand upright as it is a level plot. All the trunks are covered by a very thick mat of moss and diameter of the trunk is very slender. Tree density was very high and tree height did not reach 10 m. The soil was very shallow and lapilli were abundant at 30 cm from the surface. Gradient of the slope was 7° to N 55° W.

In each plot, the following investigations were carried out. A 20 m × 20 m plot, which was subdivided into four 10 m × 10 m subplots, was chosen. Diameter at breast height (1.3 m from the ground) (DBH) of all identified trees larger than 4.5 cm in DBH was measured by the diameter tape. Tree height (H) and the height of the lowest living branch (H_B) were measured for trees larger than 4.5 cm DBH in a 10 m × 10 m subplot. DBH, H and Diameter at 30 cm from the ground of trees less than 4.5 cm DBH and more than 1.3 m in height were also measured in the 10 m × 10 m subplot. Ground vegetation (plants less than 1.3 m in height) was studied by marking off five 1 m × 1 m quadrats, and species name, number, height and fresh weight were recorded. Mapping of the exact position of trees more than 4.5 cm in DBH was also carried out.

Climate

Annual precipitation in the KBP is 3603 mm, which is slightly greater than the SP (3286 mm). Annual temperature is 11.0 °C in the KBP and 9.3 °C in the SP. As temperature data was not available for the KBP, Braak's formula[2)] was used for the estimation of temperature in the KBP.

Using these figures, the Walter's climatic diagram[3)] in Fig. 1 was drawn, in which both plots show minimum rainfall during July-August, and temperature is very steady throughout the year with no fluctuation.

The climatic factor which has most impact on the physiognomy of the SP may well be the humidity of the air through the year. Although the Walter's diagram shows a drier period during July-August, the average number of rainy days is not small, even in the dry month, as mentioned by Steenis *et al.* (1972).[4)] Furthermore, the climatological data from the summit indicates a shortage of sunshine hours, which means that the summit is almost always covered by cloud. These two factors may cause the growth of the mossy forest of the summit area.

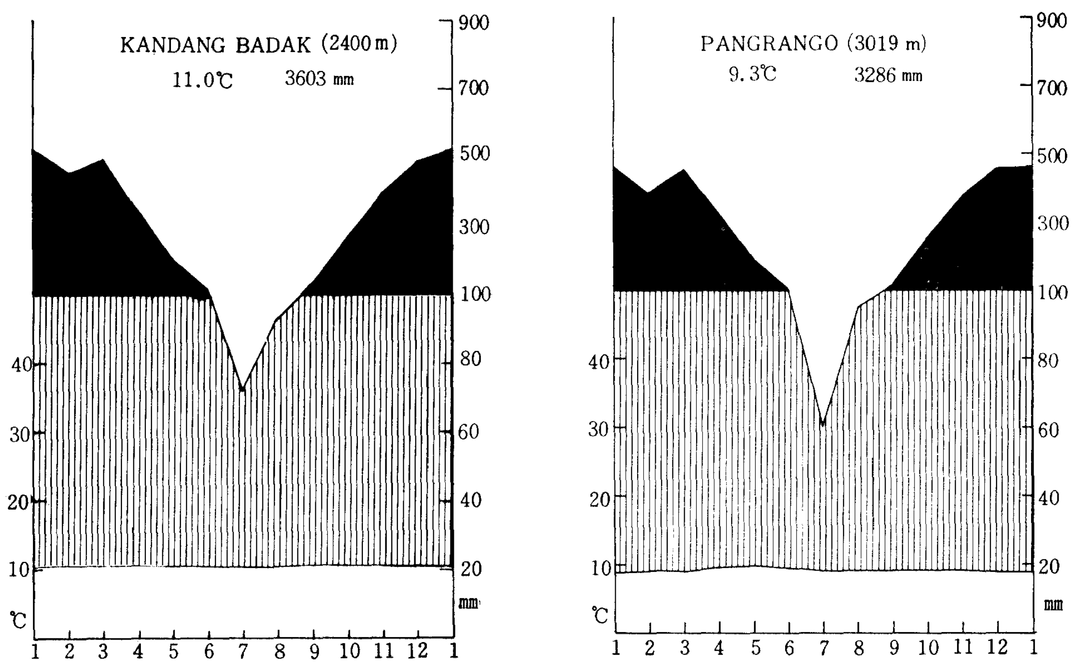

Fig. 1 Comparison of Walter's climatic diagram of Kandang Badak (near KBP, 2400 m in alt.) and of the summit of Mt. Pangrango (near SP, 3019 m in alt.)

Table 1 Climatic conditions of Mt. Pangrango[5)]

	Average air temperature ℃	Average relative humidity %	Monthly rainfall mm	Number of rain days >0.1 mm	Duration of sunshine hr.	Rate of sunshine
1	8.9	91	461	29	80	27
2	9.0	91	386	26	51	28
3	9.0	91	451	30	88	22
4	9.6	88	329	28	99	33
5	9.9	82	191	25	161	41
6	9.5	78	109	20	172	50
7	9.1	70	60	16	219	69
8	9.1	72	95	17	186	67
9	9.1	76	114	20	172	53
10	9.2	84	259	26	131	39
11	9.2	88	376	27	110	30
12	8.9	88	455	28	73	29
year	9.3	83	3,286	291	1,522	41
statistical periods	12～38 (27)	12～38 (27)	12～36 (16)	12～36 (16)	12～36 (16)	12～36 (10)

Results

Basic statistics

Some of the important statistics for the KBP and SP are summarized in Table 2. The number of trees larger than 10 cm DBH in the SP is almost three times that of the KBP. Moreover, the number of trees whose diameter is between 4.5 to 10 cm in the SP is seven times higher than in the KBP. These facts indicates the very high density of trees in the SP.

Considering basal area, there is a comparatively high percentage of trees with DBH from 4.5 to 10 cm in the SP. Scarcity of larger sized trees is evident from this figure.

The number of species of trees above 4.5 cm DBH is 13 in the KBP and 10 in the SP. This is far fewer than for the lower site which had almost 60 species in a 1 ha. plot at 155.0 m in alt., as mentioned in the previous paper. Fisher's index of diversity α is as expected very small.

Diameter distribution histogram for the KBP shows a peak at between 8 and 9 cm DBH, whereas in the SP, the maximum is found at between 6 and 7 cm DBH. The largest diameter in the KBP and the SP is 41 cm and 39 cm DBH respectively. (Fig. 2 a, b).

Table 2 Summary of basic statistics of KBP and SP

		KBP (20 m × 20 m)	KBP–SUBP–I (10 m × 10 m)	SP (20 m × 20 m)	SP–SUBP–I (10 m × 10 m)
DBH ≧ 10cm	No. of trees	57		152	
	Tree density no/ha	1516.45		3828.55	
	No. of species	10		9	
	Fisher's index of diversity α	3.5064		2.1346	
	Basal area %	0.569		0.364	
4.5cm ≦ DBH < 10cm	No. of trees	33		234	
	Tree density no/ha	877.92		5893.93	
	No. of species	12		10	
	Fisher's index of diversity α	6.7730		2.1972	
	Basal area %	0.0427		0.233	
DBH < 4.5cm H > 1.3m	No. of trees		49		22
	Tree density no/ha		5214.43		2216.50
	No. of species		10		5
	Fisher's index of diversity α		3.7911		2.0143
	Basal area %		0.0086		0.0179

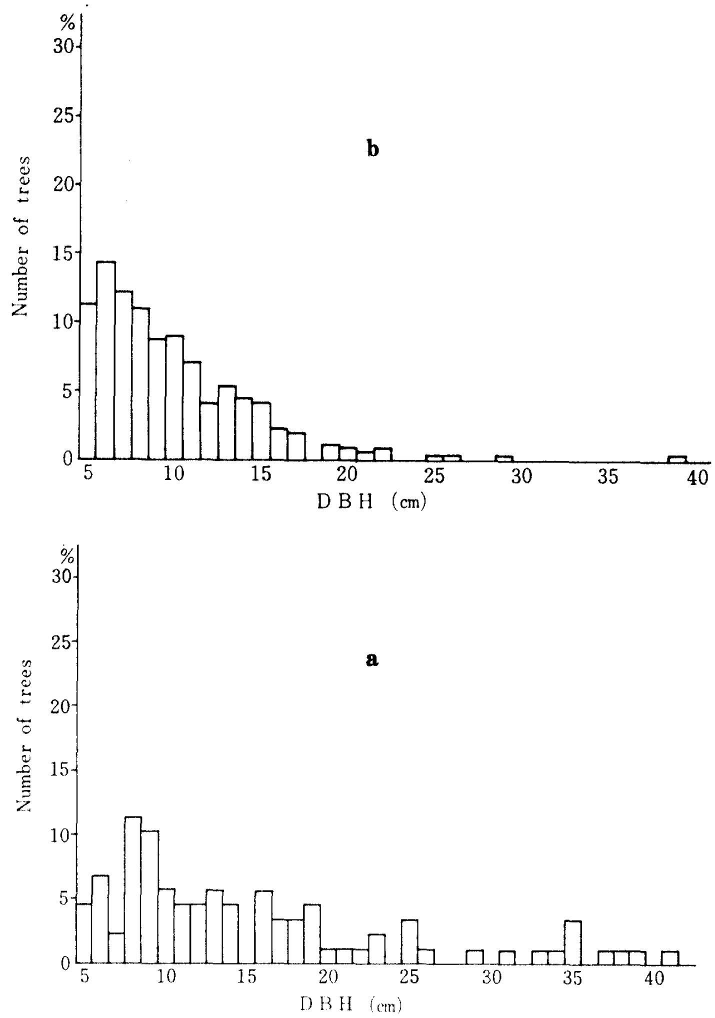

Fig. 2 Frequency histogram of diameter distribution in KBP (a) and SP (b). Only trees larger than 4.5 cm in DBH are shown.

Stratification

The stratification described below is based mainly on data taken from a 10 m × 10 m subplot at each sample site. In both plots, stratification of trees larger than 4.5 cm DBH was analyzed by drawing a crown depth diagram and the height curve (Ogawa *et al.* 1965)[6] as in the previous paper. The ground vegetation was included in stratification.

KBP

The highest tree in this plot is 22 m and as shown in Fig. 3, the height curve indicates discontinuity at the 15 m and 5 m levels. This figure also shows one more layer below 5 m. Most of the species in the ground vegetation was lower than 1 m in height. To summarize, the stand comprises four layers including ground vegetation as follows: lst layer; 22–15 m, 2nd layer; 15–5 m, 3rd layer; 5–1 m and 4th layer; below 1 m (ground vegetation).

As indicated in Fig. 3, trees belonging to the 1st layer are scarce. Twenty one trees of 8 species are found in this layer. These species are not dense and the crown layer is very open.

On the other hand, the density of trees belonging to the 2nd layer is high. There are 81 trees of 13 species. The crown layer is more dense than that of the 1st layer.

Fourty seven plants of 10 species were found in the 3rd layer. Its distinctive feature, compared to the two upper layers, is that indigenous species appear in this layer. Tree ferns also occur here.

Even though the 2nd and 3rd layers are more dense than the 1st layer, this plot shows a rather open forest type of stratification compared with the lower plot. Accordingly, the ground vegetation is comparatively luxuriant under this open canopy. In particular, species of trees, shrubs and ferns were abundant.

In general, the stratification of this plot is not very clear for the higher trees, but is more distinct for the lower trees, shrubs and ground vegetation. The number

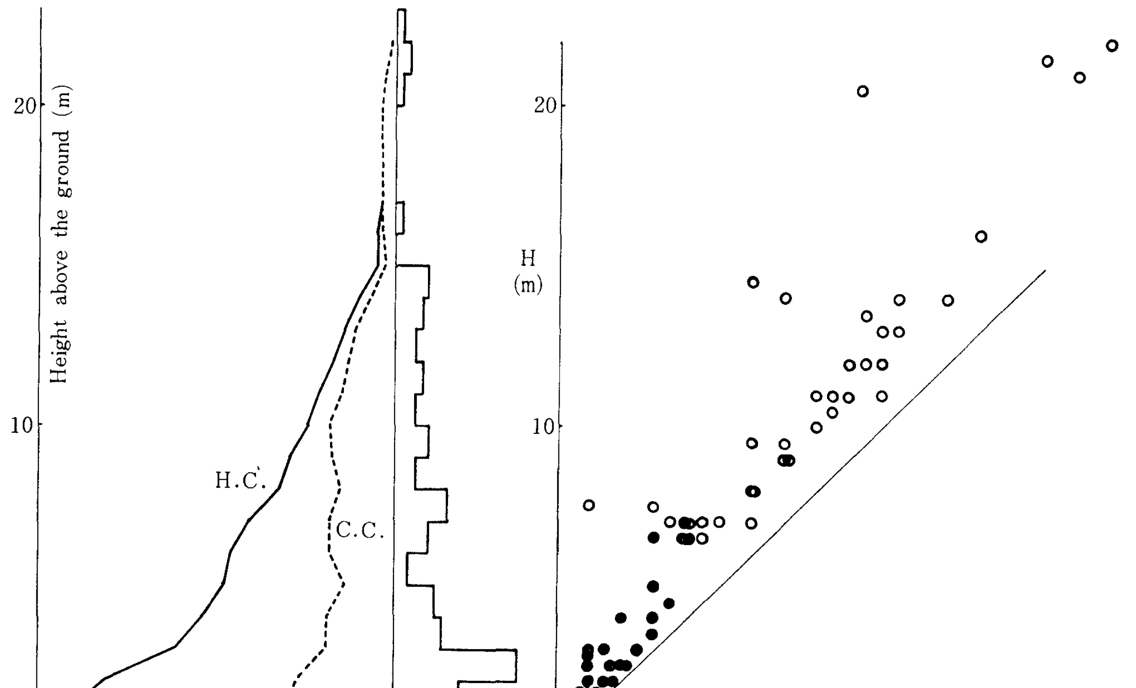

Fig. 3 Crown depth diagram and H–H_B relation in KBP
Open circles: trees over 4.5 cm DBH
Solid circles: trees under 4.5 cm DBH and taller than 1.3 m

of species common to each layer is 3, and species belongs to upper layer occur frequently in the lower layers.

SP

Externally this plot appeared to have a very complicated stratification, because the slender and knotty stems and trunks overlapped and intertwined in an extremely high density. Fig. 4, however, shows a very simple diagram. The highest tree is 9.5 m and one stratum could be recognized between 4 to 9.5 m. The lower layer below 4 m is negligible owing to the paucity of trees. Most of the ground vegetation species were smaller than 50 cm. Accordingly, this plot has two layers as follows: 1st layer; 9.5 to 4 m, and 2nd layer; below 50 cm (ground vegetation).

In the 1st layer, 436 trees of 10 species appeared. Their stems were so dense that the forest crown was very closely packed. From below 4 m to the ground vegetation, there was almost no vegetation. The ground vegetation is much poorer than that of the KBP. This is probably due to the infertility of the soil and climatological influences, and another possible cause is the high density of the canopy. As light reaching the forest floor is smaller, the ground vegetation is less luxuriant than in the KBP. There were more species of herbs than in the KBP, and three species appeared common in each layer.

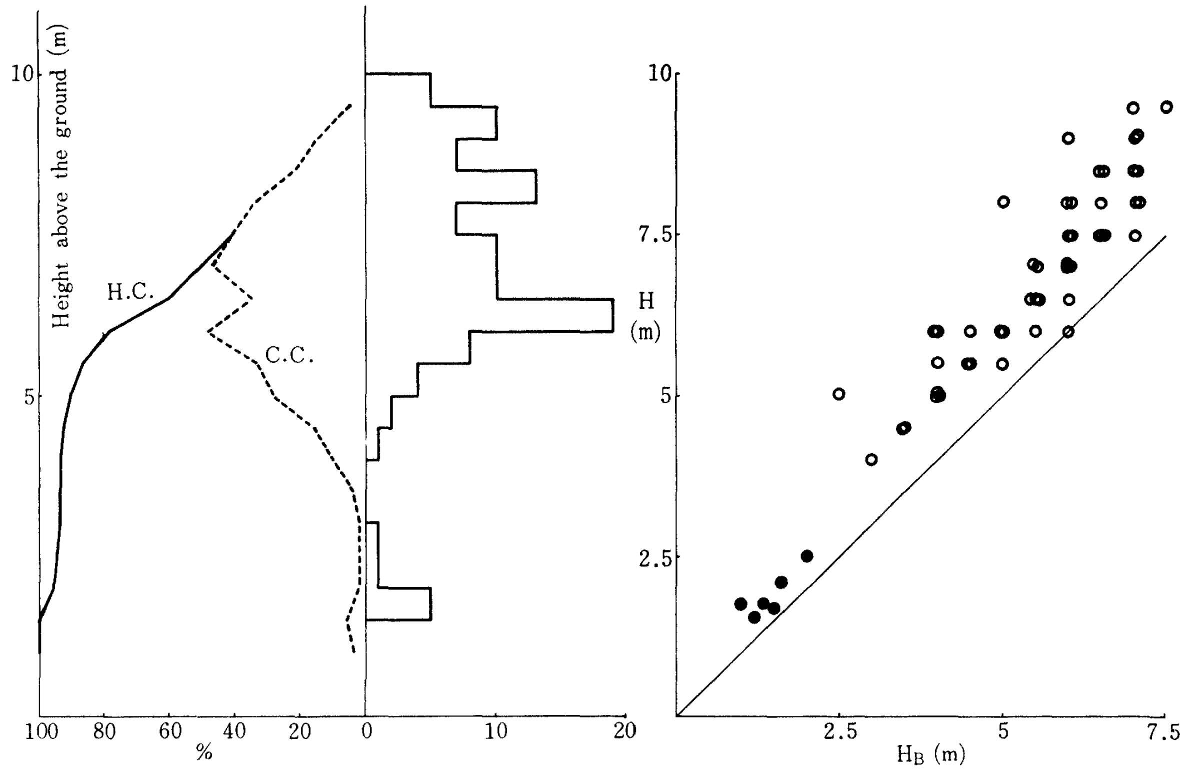

Fig. 4 Crown depth diagram and H–H_B relation in SP
Open circles: trees over 4.5 cm DBH
Solid circles: trees under 4.5 cm DBH and taller than 1.3 m

Floristic composition

KBP

The total number of species found in this plot is 33. Of those, there are 21 species of trees and shrubs, 1 each of tree ferns, lianas, creeping herbs and orchids, 6 of ferns and 2 of herbs.

In the 1st layer, *Myrsine affinis*, *Acronodia punctata*, *Polyosma ilicifolia* and *Symplocos sessilifolia* are more or less evenly distributed, although *Myrsine affinis* is the largest in number and *Acronodia punctata* is the most abundant species in relative dominance. Compared with the next layer, individual numbers of each species were very small. *Schima wallichii* was found as a complete dominance in 1 ha.plot (1550 m in alt.) and *Polyosma ilicifolia* and *Acronodia punctata* were the lower layered components in the 1 ha.plot. Total number of species of trees taller than 15 m was 8.

Polyosma ilicifolia is largest in both number and relative dominance of trees in the 5 to 15 m class, and together with *Acronodia punctata* and then *Myrsine affinis*, they cover 73 % of number and 83 % of relative dominance. Other species are much smaller in both number and relative dominance. Indigenous species in this layer are *Vaccinium laurifolium*, *Viburnum coriaceum* and *Vaccinium laurifolium var. ellipticum* and the total number of the species in this layer is largest as 13.

Table 3 Floristic composition of KBP
(a) ; trees taller than 5 m

Species	H ≧ 15 m		15 m < H ≦ 5 m	
	No. per plot	Relative % dominance	No. per plot	Relative % dominance
Myrsine affinis DC.	5	19.77	13	25.13
Polyosma ilicifolia Bl.	3	12.42	24	32.73
Acronodia punctata Bl.	4	22.74	22	24.77
Symplocos sessilifolia (Bl.) Gürke.	3	22.22	—	—
Eurya obovata (Bl.) Korth.	1	2.76	3	7.14
Daphniphyllum glaucescens Bl.	2	9.91	1	0.32
Schima wallichii (DC.) Korth. ssp. noronhae (Reinw. ex Bl.) Bloembergen	2	8.22	1	0.54
Geniostoma arboreum (Reinw.) O. K.	—		5	4.06
Photinia notoniana W. & A.	1	1.95	1	0.25
Vaccinium laurifolium (Bl.) Miq.	—		3	2.60
Albizia lophantha (Willd.) Bth.	—		2	0.76
Viburnum coriaceum Bl.	—		1	0.64
Vaccinium laurifolium var. ellipticum	—		1	0.42
(Bl.) Sleum.	—		4	0.64
Total	21	100.00	81	100.00

Table 3 Floristic composition of KBP
(b) ; plants smaller than 5 m and taller than 1 m. Tree height was estimated by D–H relations of sample trees in a 10 m × 10 m subplot whose height and DBH had been measured.

Species	1.0 m ≦ H < 5 m	
	No. per plot	Relative dominance %
Ardisia javanica DC.	17	45.54
Acronodia punctata Bl.	5	18.74
Symplocos sp.	6	11.68
Cuphea sp.	4	14.41
Eurya obovata (Bl.) Korth.	3	1.63
Symplocos sessilifolia (Bl.) Gürke	1	3.03
Albizia lophantha (Willd.) Bth.	2	2.11
Geniostoma arboreum (Reinw.) O. K.	2	1.52
Daphniphyllum glaucescens Bl.	1	1.34
Cyathea crenulata Bl.	6	—
Total	47	100.00

Ardisia javanica is most conspicuous in the layer of plants smaller than 5 m and taller than 1.0 m in height. *Symplocos* sp., *Cuphea* sp. and *Cyathea crenulata* are the indigenous species in this layer and *Cyathea crenulata* is abundant. The number of species in this layer is 10.

The number of species found in five 1 m × 1 m quadrats was as follows ; 6 trees, 10 shrubs, 1 each of lianas, creeping herbs and orchids, 6 ferns and 2 herbs.

In cases where the dominant species was not clear, a combination of several measurement is desirable for determining dominance. The SDR[7)]* (summed dominance ratio) is used for analysis of ground vegetation, as in the previous paper.

As shown in Fig. 5 and Table 4, *Polyosma ilicifolia* is the most dominant on the F′N′H′ diagram and the fern *Blechnum patersonii* and the shrub *Dichroa sylvatica* dominate the ground vegetation. On the W′ diagram, *Cyperus* sp. is the most dominant and *Blechnum patersonii* the second. In general, the number of shrubs and trees is small. On the life form diagram, trees, shrubs and ferns all show a similar trend for both F′N′H′ and W′ lines, but the W′ line for herbs is different of the F′N′H′ line. This means that the contribution of *Cyperus* sp. is far bigger than that of other species.

* SDR is calculated according to the following formula :

$$\mathrm{SDR}=\frac{\text{Density ratio}(D')+\text{Frequency ratio}(F')+\text{Cover ratio}(C')}{3}\%$$

Density ratio (Frequency and Cover ratio) is the ratio in terms of percentage of numbers (frequency and cover) of each species to the numbers of the most abundant species. If the height ratio is added, the denominator changes to 4.

Table 4 Floristic composition of ground vegetation (plants less than 1.3 m in height) in KBP. Based on five 1 m × 1 m quadrats. Life forms are classified according to Backer (1963–1968)[9] and the author's observation.

	F	N	W	$\overline{H}$	SDR (F'N'H')
Trees					
Daphniphyllum glaucescens Bl.	3	6	59	30	40.00
Schima wallichii ssp. noronhae	3	7	8.5	10	34.17
Podocarpus imbricatus Bl.	2	3	10.5	15	24.17
Polyosma integrifolia Bl.	2	6	251	55	40.00
Myrsine affinis DC.	1	9	8	20	22.50
Neolitsea javanica (Bl.) Back.	1	1	1	10	12.50
Shrubs					
Polyosma ilicifolia Bl.	4	40	210	20	73.33
Acronodia punctata Bl.	3	6	36	30	40.00
Ardisia javanica DC.	2	2	16	23	26.00
Eurya obovata (Bl.) Korth.	2	3	13.5	21	26.17
Symplocos sessilifolia (Bl.) Gürke	2	3	18	24	27.17
Dichroa sylvatica (Reinw. ex Bl.) Merr.	1	2	195	100	43.33
Symplocos sp.	1	1	60	80	35.83
Vaccinium laurifolium (Bl.) Miq. var. laurifolium.	1	2	1	7	12.33
Vaccinium laurifolium var. ellipticum (Bl.) Sleum.	1	1	34	1	9.50
Viburnum coriaceum Bl.	1	1	0.3	6	11.17
Lianas					
Lonicera javanica (Bl.) DC.	1	1	0.5	10	12.50
Creeping herbs					
Nertera granadensis (Mutis ex L. f.) Druce	2	2	4	8	21.00
Orchids					
One species of Orchidaceae	1	1	0.5	10	12.50
Ferns					
Blechnum patersonii (R. Br.) Mett.	4	5	565	47	53.17
Davallia sp.	1	1	1	15	14.17
Dryopteris sp.	1	1	112	30	19.17
Lycopodium serratum Thunb.	1	1	9	15	14.17
Plagiogyria glauca (Bl.) Mett.	1	1	205	80	35.83
Polypodium feei (Bory) Mett.	1	5	40	15	17.50
Herbs					
Cyperus sp.	3	5	755	39	42.17
Viola pilosa Bl.	1	7	14	10	17.50

Species found in all layers are *Acronodia punctata*, *Eurya obovata* and *Daphniphyllum glaucescens*. Of these, *Acronodia punctata* appears in a dominant position in every tree layer. The dominant species in each layer judging from number, relative dominance and the SDR is as follows:

H ≧ 15 m

Acronodia punctata, *Symplocos sessilifolia*, *Myrsine affinis* and *Polyosma ilicifolia*.

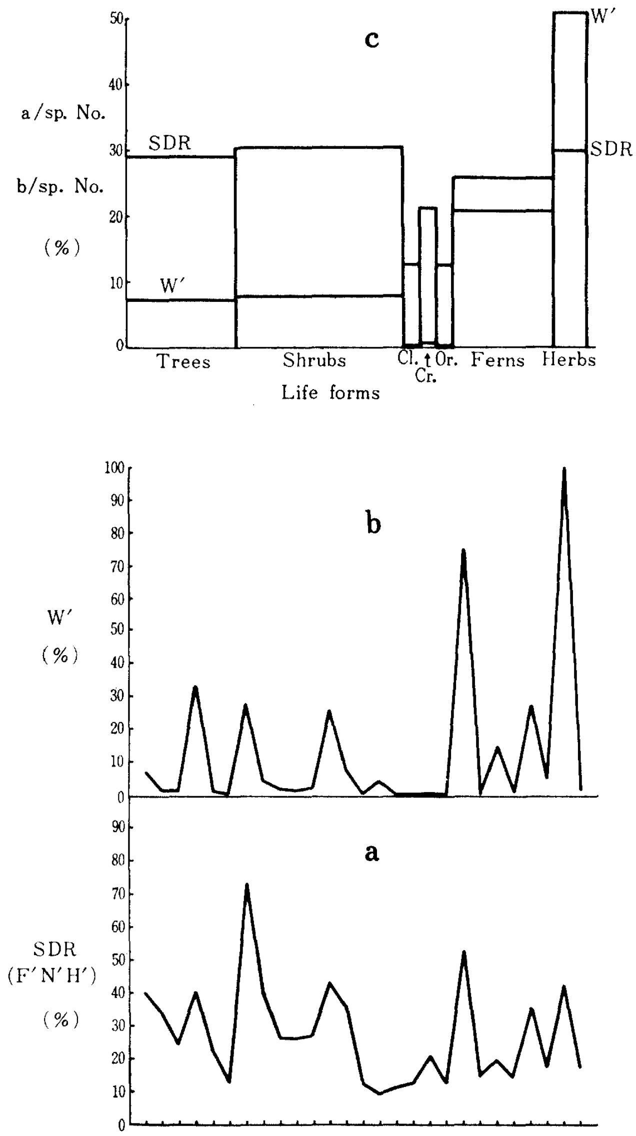

Fig. 5 Composition curve of ground vegetation (plants less than 1.3 m in height) in KBP. a–SDR by F′, N′ and H′, b–W′, c–a/species No., b/species No. Species order is the same as Table 4.

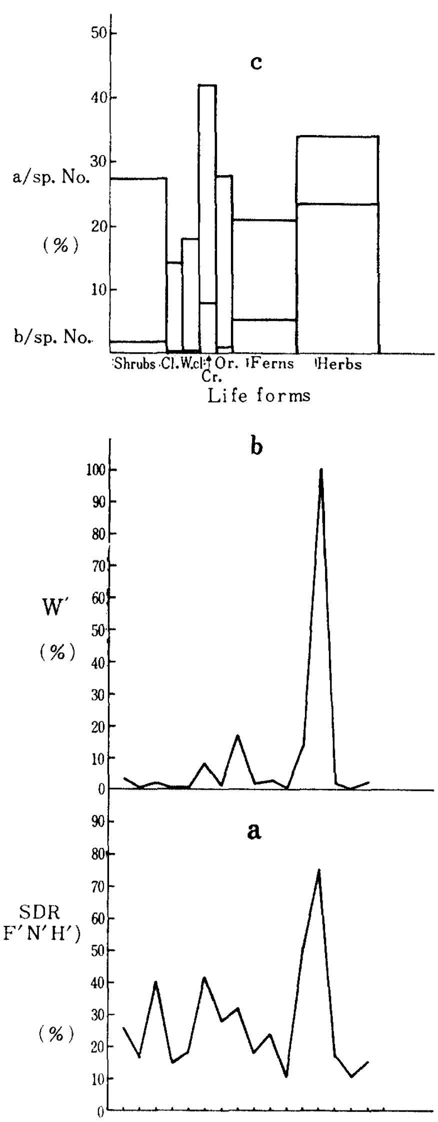

Fig. 6 Composition curve of the ground vegetation (plants less than 1.3 m in height) in SP. a–SDR by F′, N′ and H′, b–W′, c–a/species No., b/species No. Species order is the same as Table 6

15 m > H ≧ 5 m

Polyosma ilicifolia, *Acronodia punctata* and *Myrsine affinis*.

5 m > H ≧ 1 m

Ardisia javanica, *Acronodia punctata*, *Symplocos* sp. *Cuphea* sp. and *Cyathea crenulata*.

H < 1 m

Polyosma ilicifolia, *Dichroa sylvatica*, *Blechnum patersonii* and *Cyperus* sp.

Within these species, *Acronodia punctata*, *Polyosma ilicifolia*, *Myrsine affinis* and *Symplocos* sp. frequently appear as the dominant species in each layer. This means that they are also dominant in the plot as a whole. Some explanation of this is necessary. There are two possibilities; one is that the KBP is in the transition zone from montane to subalpine forest. And the other is that this plot has suffered some destruction, for example, volcanic activity or human invasion. It is possible that, if the original vegetation was once damaged, many kind of species would grow at the same time and the tree strata would be ill-defined even after some decades. So the same species would be found in each layer and, as a whole, would be a dominant.

The first possibility, however, is not so easy to dismiss. As the KBP is in the transition zone from montane to subalpine zone, many of the species from each zone may be mixed at this altitude. Classified as the herbaceous subzone from 7000–8000 ft. by Seifriz[8], the forest physiognomy of the KBP is rather different from both upper and lower zones. No distinct dominance occurs here and the crown is rather open.

The most reasonable explanation may be that the KBP was originally a forest located in the transition zone from montane to subalpine zone, and once suffered damage by volcanic or human activities. Even if this is old secondary forest, however, sufficient time may have passed for the original vegetation to recover, because in the layers below 5 m, indigenous species are mixing in to form strata, although the upper layers are more or less arbitrary. So this plot may be typical of this altitude.

SP

As this plot has been divided at the 4 m level, trees taller than 4 m are listed in Table 5. Of these, *Myrsine affinis* has the greatest number (50 %) followed by *Vaccinium varingiaefolium* and *Eurya obovata*. These three species contribute 75 % to the numbers and 86 % to relative dominance. Other species are much smaller in both number and relative dominance. Four species, that is *Myrsine affinis*, *Symplocos sessilifolia*, *Eurya obovata* and *Photinia notoniana*, are also found in the KBP. Total species number is 10.

Trees smaller than 4 m and taller than 50 cm are very few, that is, *Symplocos* sp. and *Vaccinium laurifolium var. ellipticum*.

Other numbers based on diameter class indicate that *Vaccinium varingiaefolium*

Table 5 Floristic composition of SP

(a) left ; trees taller than 4 m. right ; trees larger than 4.5 cm DBH

Species	10m > H ≧ 4 m (20m×20m)		D ≧ 10 cm (20m×20m)		4.5 cm ≦ D < 10 cm (20m×20m)	
	No. per plot	Relative dominance %	No. per plot	Relative dominance %	No. per plot	Relative dominance %
Myrsine affinis DC.	218	32.69	46	20.99	143	63.04
Photinia notoniana W. & A.	35	3.13	2	1.03	23	7.85
Eurya obovata (Bl.) Korth.	46	17.82	32	22.47	14	6.21
Rhododendron retusum (Bl.) Benn.	2	0.15	—	—	2	0.58
Schefflera rugosa (Bl.) Harms	4	0.90	2	1.00	1	0.54
Schefflera sp.	22	2.06	2	0.74	16	5.28
Symplocos sessilifolia (Bl.) Gürke	17	4.61	8	4.54	9	5.08
Symplocos sp.	16	2.20	2	1.36	10	4.22
Vaccinium varingiaefolium (Bl.) Miq.	64	35.33	57	47.56	7	4.11
Vaccinium laurifolium (Bl.) Miq.	12	1.10	1	0.31	9	3.08
Total	436	100.00	152	100.00	234	100.00

(b) trees smaller than 4.5 cm and taller than 1.3 m

Species	4 m < H ≦ 1.3 m (10m×10m)	
	No. per plot	Relative dominance %
Symplocos sp.	6	89.40
Myrsine affinis DC.	—	—
Photinia notoniana W. & A.	—	—
Schefflera sp.	—	—
Vaccinium laurifolium var. ellipticum (Bl.) Sleum.	1	10.60
Total	7	100.00

and *Eurya obovata* appear frequently in the larger class and in contrast, *Myrsine affinis* is very frequent in the smaller class (DBH from 4.5 to 10 cm).

The number of species of ground vegetation is as follows : one trees, 2 shrubs, 1 each of climbing shrubs, lianas, creeping herbs and orchids, 4 ferns and 5 herbs. The composition curve of the ground vegetation shows that *Ranunclus javanicus* of the herbs is the largest in both F′N′H′ and W′. The life form diagram also indicates the greater percentage of plants in herbs, and it is noteworthy that *Nertera granadensis* is comparatively dominant despite being the only species in creeping ascending herbs. *Carex* sp. also shows dominant pattern. (Fig. 6)

The total number of species in this plot is 24 ; that is 11 shrubs, 1 each of climbing shrubs, lianas, creeping herbs and orchid, 4 ferns and 5 herbs. The dominant species are *Myrsine affinis*, *Vaccinium varingiaefolium* and *Eurya obovata* in the shrub layer and those dominant in ground vegetation appear to be *Nertera granadensis*, *Carex* sp.

Table 6 Floristic composition of ground vegetation (plants smaller than 1.3 m in height) in SP. Based on five 1 m × 1 m quadrats. Life forms are classified according to Backer (1963–1968)[9] and the author's observations.

	F	N	W	$\bar{H}$	SDR (F'N'H')
Trees and Shrubs					
Symplocos sp.	2	10	204	30	25.49
Symplocos sessilifolia (Bl.) Gürke	1	4	17	25	16.34
Myrsine affinis DC.	1	1	126	90	40.10
Climbing shrubs					
Rubus lineatus Reinw. ex Bl.	1	1	2	20	14.18
Lianas					
Lonicera javanica (Bl.) DC.	1	2	24	30	17.99
Creeping herbs					
Nertera granadensis (Mutis ex L. f.) Druce	4	109	519	10	41.76
Orchids					
One species of Orchidaceae	3	23	64	14	27.59
Ferns					
Plagiogyria glauca (Bl.) Mett.	2	3	1075	48	31.42
Athyrium sp.	1	1	99	30	17.88
Dryopteris adnata (Bl.) v. A. v. R.	1	1	170	45	23.44
Elaphoglossum callifolium(Bl.) Moore	1	2	11	10	10.58
Herbs					
Carex sp.	5	20	881	42	50.98
Ranunculus javanicus Bl.	5	319	6520	23	75.19
Myriactis javanica (Bl.) DC.	1	16	96	20	17.17
Swertia javanica Bl.	1	1	1	11	10.34
Viola pilosa Bl.	1	29	140	15	15.25

and *Ranunculus javanicus*.

One important plant not appearing in the sample plot is *Anaphalis javanica*. Near the top of this mountain, there is a spring which is possibly the source of the river Cikuripan and surrounding is an aloon aloon. About the middle of this aloon aloon, *Anaphalis javanica* appears at first small but extending radially to the outer part of the aloon aloon with increasing height and density, and finally mixing with the surrounding forest. In the surrounding forest, this species is abundant where the former dwellers on this area built huts some 20 or more years ago. This species has been called Edelweiss. This is one of the well known secondary species which appear after the burning of subalpine vegetation. Autoecological studies focussing on this species will increase knowledgess of the regeneration process of the tropical subalpine vegetation of Javanese mountains.

One notable feature of the SP is the moss. Almost all the trees have very thick green or sometimes in dry periods brownish-green moss around slender trunks. So the real trunk diameter is much smaller than it appears. Compared with the 1 ha.plot and the KBP, this plot has far more moss. Mossy forest on this mountain starts from 2500 m according to Steenis *et al.*[4] But, from this author's observation, the most dense and beautiful mossy forest is found only very near the summit.

Discussion

Zonal vegetation and floristic composition of the Javanese high mountains have been described by various authors.

Seifriz (1923)[8] divided the upper *Podocarpus* subzone of this mountain into the herbaceous subzone (7000–8000 ft.), the *Vaccinium* subzone (8000–9000 ft.) and the Edelweiss subzone (9400 ft.). According to this classification, the KBP is situated between the herbaceous and the vaccinium subzone and the SP belongs to the Edelweiss subzone.

The climatic zonation of Java can be classified as below (Steenis *et al.* 1972).[4]

0–1000 m Tropical zone
(500–1000 m Colline zone)
1000–2400 m Montane zone
(1000–1500 m Submontane zone)
2400 m above Subalpine zone.

The physiognomy of the forest below 2400 m is characterized by closed high-stemmed forest, with decreasing stem-diameter and increasing quantity of moss above 2000 m. And above 2400 m, there is dense low forest with single higher trees, often mossy or conifers. Of course these are the general aspects of botanical zonation and local factors may cause local deviation as mentioned in their book.[4]

However, floristic observations are not sufficient for a satisfactory study of zonal vegetation. From the ecological forest data already enumerated, the zonal structure of the forest of the higher part of Mt. Pangrango can be described as follows:

The main point is that both stratification and floristic composition become more simple with increasing altitude. As shown in a previous paper, forest at about 1550 m alt. has five strata and the number of tree species found in 1 ha.plot was nearly 60. Ascending the mountain path from this 1 ha.plot, the vegetation changes gradually, species belonging to *Fagaceae* and *Lauraceae* disappeared and *Podocarpus* appeared as the dominant species. The vegetation changes little by little as one ascends the slope, and then one comes to Kandang Badak (2400 m).

Here, the highest tree is 22 m and trees higher than 15 m in height are not very many, and there are 4 strata. Trunks are slender but still upright. Moss become much thicker, and woody climbers and epiphytes are scarce. Tree species dominant in the 1 ha.plot, such as *Schima wallichii* are very few, and decrease in height and diameter, whereas the lower strata components of the 1 ha.plot come to dominates the KBP (*Polyosma ilicifolia* and *Acronodia punctata*). But this plot still has lower altitudinal components in its ground vegetation, such as *Schima wallichii*, *Podocarpus imbricatus*, *Polyosma integrifolia* and *Neolitsea javanicus*.

From this plot, there are bent and crooked trees on the steep slope leading to the summit. At the summit plot, stratification and floristic composition are very much simplified with 2 strata and few species in each of these. In this plot, the species found in the 1 ha.plot did not appear and purely subalpine species were dominant.

With changing altitude, some species appear and the others disappear. The relationship of altitude and species occurrence are shown in Fig. 7a–c. In all figures, the

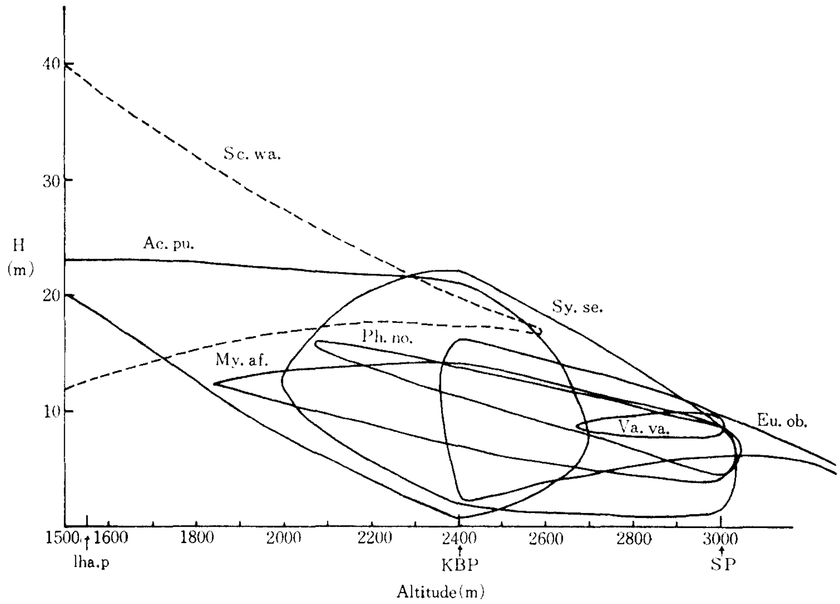

Fig. 7a Schematic sketch of the distribution of the main species occur in KBP and SP. Some of the connected species in the 1 ha.plot are also included.

Distribution pattern of the species of category 1 is indicated by a dotted line and category 2 by a black line. Key to symbols for Fig. 7a–c.

Sc. wa., *Schima wallichii*; Ac. pu., *Acronodia punctata*; Po. il., *Polyosma ilicifolia*; Sy. se., *Symplocos sessilifolia*; Eu. ob., *Eurya obovata*; Va. va., *Vaccinium varingiaefolium*; My. af., *Myrsine affinis*; Ph. no., *Photinia notoniana*. Vi. co., *Viburnum coriaceum*; Sc. ru., *Schefflera rugosa*; Ar. ja., *Ardisia javanica*; Va, la., *Vaccinium laurifolium*,

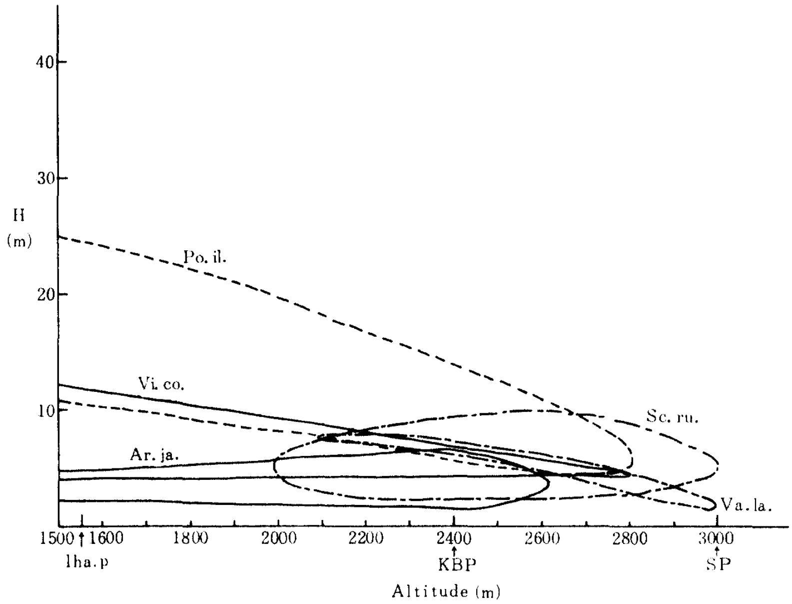

Fig. 7 b Distribution pattern of the species which always form the lower layer (Category 3).

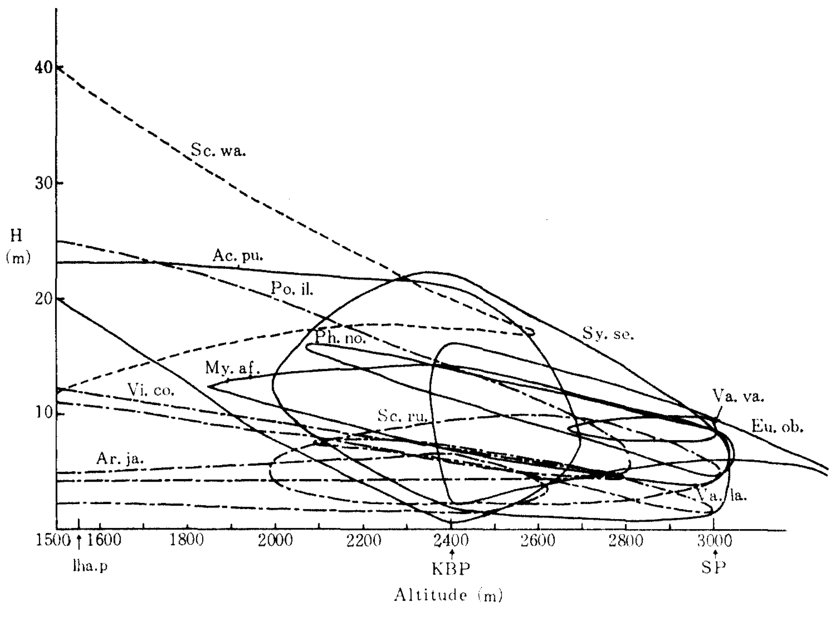

Fig. 7 c Distribution pattern of the species which occur mainly around the KBP and the SP. Dotted line indicates species in category 1. A black line indicates species in category2 and a dot-dash line indicates species in category 3.

ordinates indicates crown layer based on height measurements in each plot and the scope of altitudinal distribution is decided according to Backer *et al.*[9] and by the author's observation. The distribution pattern could be categorized as follows:

C-1. Species inherent to the upper-most strata irrespective of altitude.

C-2. Species which are components of the lower strata in lower altitudes, and which form the upper strata at higher altitudes.

C-3. Species which always occur in lower strata.

Of upper strata species at a lower altitudes in this mountain, the most dominant species appears to be *Rasamala* (*Altingia excelsa*), the next *Schima wallichii*, and these are followed by *Podocarpus imbricatus*. Of these, *Schima wallichii* is a typical example of category 1, which was dominant in the 1st layer of the 1 ha.plot at 1550 m alt. and is still part of the 1st layer in the KBP.

In the KBP, the situation is very different from the lower site, that is, species of category 2 appeared. A typical example is *Acronodia punctata*, which was a component of the 2nd layer in the 1 ha.plot and is part of the 1st layer in the KBP. *Symplocos sessilifolia* is also of this type, and appears in the 1st layer both in the KBP and SP. *Eurya obovata* mainly appears as a 2nd layer species in the KBP and is dominant in the 1st layer of the SP. *Vaccinium varingiaefolium*, *Myrsine affinis* and *Photinia notoniana* also show a similar pattern. Fig. 7a shows the distribution pattern of the species in categories 1 and 2.

A typical species of category 3 is *Viburnum coriaceum*, which formed the lower layer in the 1 ha.plot and appears in the lower layer in the KBP. A similar pattern was found for *Vaccinium laurifolium*, *Schefflera rugosa* and *Ardisia javanica*. *Polyosma ilicifolia* formed the 2nd and 3rd layers in the 1 ha.plot and appears in the 1st and 2nd layers at the KBP. As it is a little lower layer than the main part of the 1st layer, this species included in category 3. (Fig. 7b)

Of the 3 categories, C-2 is noteworthy. With changing altitude, a species which was a component of the lower strata at lower altitude, is found in the upper layer in higher altitudes. Whether this occurs only on this mountain or universally remains to be studied. Not only is there a shift of maximum frequency of certain species, but these species seemed to have a wider adaptability than others.

The characteristics of a species could be determined sufficiently only by extensive study of its growth in connection with other species in the strata, in various environments.

The combination of species could be classified into 10 types as shown in Fig. 8, and Table 7 is the list of the combination types of all the species. The combination type of each species divided into 3 categoris have the following trends:

C-1 × C-2 and C-1 × C-3; showing separate stratification (A. or J.)

C-2×C-2 and C-3×C-3 ; horizontal overlapping combination is frequent.

C-2×C-3 ; there are various types combination, but, horizontal and vertical overlapping types are rather common.

Of the species belonging to category 2, type C (separate strata at low altitudes and becoming the same at higher altitudes) is found in the combination of *Sc. wa.-Ac. pu.*, *Va. va.-Ph. no.*, *My. af.-Sc. ru.*, *Ph. no.-Sc. ru.* and *Sy. se.-Sc. ru.* The ratio of this type to all combinations is 9 %.

Generally, the most common is type E (18 %), followed by type G (15 %) and type J (14 %).

These combinations may be divided roughly into the following broad classification. Types A, B, C, D and J may be regarded as one group which have a common strata relationship. This group consisted of 49.2 % of all combination. The second group is types E and F, which indicate horizontal overlap or segregation. This group accounted for 21.1 %. The third group is type G, which is the

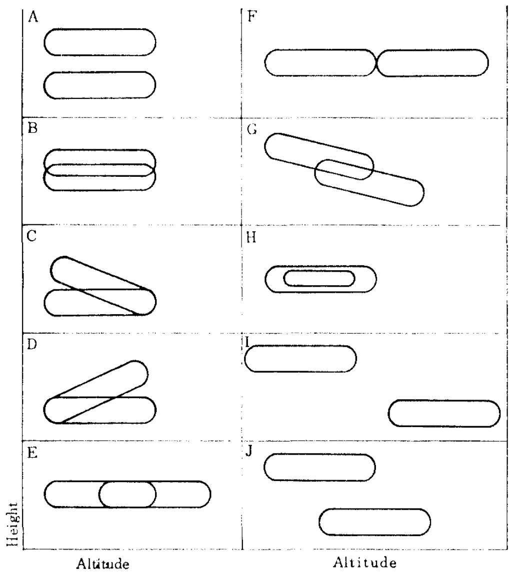

Fig. 8 Types of combination of species distribution.

A. Parallel in strata relationship
B. Parallel overlap in strata relationship
C. Separate strata at low altitudes, becoming the same at high altitudes.
D. The reverse of C.
E. Horizontal overlap.
F. Horizontal segregation
G. Combination of B. and E.
H. Identical.
I. Independent.
J. Sliding type of A.

Table 7 Combinations of main species occurring in the KBP and the SP. A to J are the same as in Fig. 8

	Sc. wa.	Ac. pu.	My. af.	Ph. no.	Sy. se.	Va. va.	Eu. ob.	Sc. ru.	Va. la.	Vi. co.	Po. il.	Ar. ja.
Sc. wa.	＼	C	J	J	F	I	J	J	J	A	A	A
Ac. pu.	C	＼	E	E	E	F	E	G	G	A	B	B
My. af.	J	E	＼	B	H	H	E	C	A	A	E	J
Ph. no.	J	E	B	＼	H	C	E	C	A	J	G	J
Sy. se.	F	E	H	H	＼	H	H	C	B	G	E	G
Va. va.	I	F	H	C	H	＼	H	D	J	J	G	I
Eu. ob.	J	F	E	F	H	H	＼	B	H	G	E	G
Sc. ru.	J	G	C	C	C	D	B	＼	D	E	C	E
Va. la.	J	G	A	A	B	J	H	D	＼	E	G	G
Vi. co.	A	A	A	J	G	J	G	E	E	＼	B	C
Po. il.	A	B	E	G	E	G	E	C	G	B	＼	A
Ar. ja.	A	B	J	J	G	I	G	E	G	C	A	＼

combination of types B and E (15.2 %). The fourth is type H, that is identical strata (10.6 %) and the last is the independent type I (3.8 %).

Schima wallichii or *Ardisia javanica* combine with other species to form strata but do not overlap much. The former occurs in the upper-most layer and the latter in the lowest layer both in the 1 ha. plot and KBP.

Horizontal overlapping is rather rare. But this combination is very important, especially in deciding altitudinal distribution. The combination of *Acronodia punctata* or *Polyosma ilicifolia* with *Myrsine affinis, Symplocos sessilifolia* and *Eurya obovata* is an example. The segregation pattern is very rare, found only in the combination of *Schima wallichi-Symplocos sessilifolia* and *Acronodia punctata-Vaccinium varingiae-folium.* Probably this type occurs more frequently at lower altitudes. *Vaccinium varingiaefolium,* which is a subalpine species, is the example of independent type, being completely separate from *Schima wallichii, Viburnum coriaceum* and *Ardisia javanica,* which are the components of the montane zone.

As shown in Fig. 7c, species overlap very densely in the lower strata (below 10 m) of the KBP and the upper strata (over 5 m) of the SP. These facts coincide with the results already mentioned.

The altitudinal limits of the species from the 1 ha.plot are as follows : *Schima wallichii* and *Ardisia javanica* end at approx. 2600 m, *Acronodia punctata* approx. 2700 m, *Polyosma ilicifolia* and *Viburnum coriacium* approx. 2800 m. These species are the main components of the montane zone.

The species which are the main components of the subalpine zone generally first appear below the KBP. *Myrsine affinis* appears from approx. 1900 m, *Schefflera rugosa* and *Symplocos sessilifolia* from approx. 2000 m, *Photinia notoniana* and *Vaccinium laurifolium* from approx. 2100 m and *Eurya obovata* from 2400 m.

Combining these species' boundaries, Fig. 9 is obtained. This shows the zonal change of the higher part of this mountain based on the stratification and floristic composition. The main components of the montane zone are : *Schima wallichii, Acronodia punctata, Polyosma ilicifolia, Viburnum coriaceum* and *Ardisia javanica,* from upper to lower strata. Other species which do not extend to the KBP are not mentioned here. The main components of the subalpine zone are : *Symplocos sessilifolia, Myrsine affinis, Schefflera rugosa, Photinia notoniana, Vaccinium laurifolium, Eurya obovata* and *Vaccinium varingiaefolium.* And the main components of the transition zone are a mixture of the species of both montane and subalpine zones. The forest of the KBP located in this transition zone has a very mixed floristic composition and ill-defined stratification, whereas the SP is pure subalpine forest with clear stratification and indigenous species.

These figures are limited mainly to the higher part of this mountain and so do not show the distribution pattern of all the main species of the mountain. Because

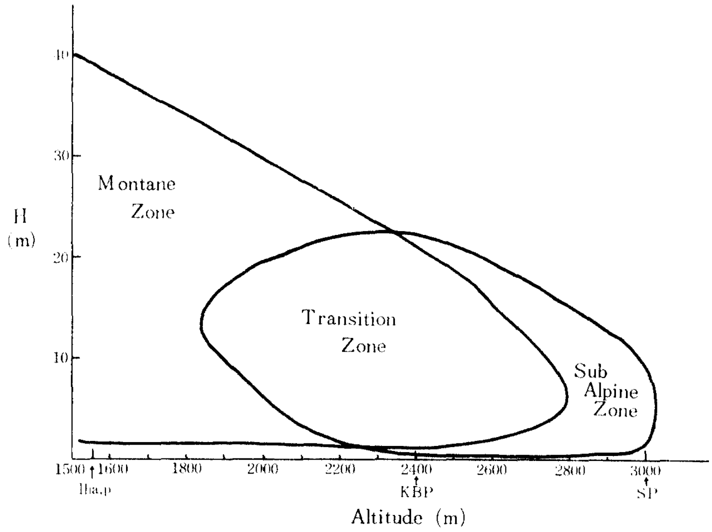

Fig. 9 Zonal classification of the higher part of Mt. Pangrango

some important species such as ***Podocarpus imbricatus***, ***Castanopsis javanica***, ***Persia rimosa***, ***Saurauia pendula***, etç. are not included in this paper. It may be necessary to alter the distribution range after more intensive survey.

The ecological data thus collected are probably useful for illustrating the character of the species, in the sense of the dynamics of the plant community. For example, species belonging to category 2 may have wider adaptability than other species. This adaptability could be discerned more intensively in relation to some environmental factors, such as temperature, air humidity, light intenisty, soil conditions, etc. As a result of such integration, the character of each species conld be clearly determined, e. g. differences in shade tolerance with altitude, whether it is a heliophyta, etc. If the status of a species could be described by such approach, its accuracy and practical use in other field could be greatly extended.

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References

1) Yamada, I. 1975. "Forest ecological studies of the montane forest of Mt. Pangrango, West Java. I. Stratification and floristic composition of the montane rain forest near Cibodas," ***Tonan Ajia Kenkyu*** (South East Asian Studies), Vol. 13. pp. 402-426.

2) Hosokawa, T. 1943. ***Nanpo Nettai no Syokubutsu Gaikan.*** Asahi Shinbunsha. (in Japanese.)

3) Walter, H. 1955. "Klimagramme als Mittel zur Beurteilung der Klimarerhältnisse für ökologische, vegetationskundliche und landwirtschaftliche Zwecke," ***Ber. d. deutch. bot. Ges.***, 68, pp.331–344.

4) Steenis, C. G. G. J. van, A. Hamzah and M. Toha. 1972. ***The mountain flora of Java.*** Leiden.

5) Hatakeyama, H. ed. 1964. *Ajia no Kiko*(The Climate of Asia). Kokin Shoin, Tokyo. (in Japanese)

6) Ogawa, H., K. Yoda, T. Kira, K. Ogino, T. Shidei, D. Ratanawongse and C. Apasutaya, 1965. "Comparative ecological study on three main types of forest vegetation in Thailand I. Structure and floristic composition," ***Nature and Life in Southeast Asia,*** Vol. IV, pp. 13–48.

7) Numata, M. and K. Suzuki. 1958. "Experimental studies on early stages of secondary succession III," *Jap. J. Ecol.* Vol. 8, No. 2, pp. 68–75. (in Japanese)

8) Seifriz, W. 1923. "The altitudinal distribution of plants on Mt. Gedeh, Java," ***Bull. Torrey Bot. Cl.***, Vol. 50, pp. 283–305.

9) Backer, C. A. and R. C. Bakhuizen Van den Brink Jr. 1963–1968. ***Flora of Java.*** 3 Vols. Groningen.