OPEN AIR HOTHOUSES IN THE TROPICS AT 3100 METRES ALTITUDE.

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In this article I discuss the ecological and morphological reponse of some plant species to the action of fumaroles in the highlands of Java and Bali. I also discuss briefly the dispersal of some of these plants.

In June of this year I climbed Mt. Ardjoeno[1] in East Java. This lofty volcanic mountain complex, attaining more than 10,000 feet above sea level, is built upon a fault running north and south.[2] It consists of 5 separate peaks, the northernmost of which is called Mt. Welirang. Welirang is the Javanese name for sulphur, and this peak is so called because of the occurrence of several enormous solfatara, which have been commercialised for centuries, probably even in Hindu times. Numerous Hindu monuments are found on Mt. Ardjoeno at nearly 10,000 feet altitude in the form of remains of well built rooms. Even today on several Javan mountain peaks priests live a poor life and offerings are regularly made by the people.

The southernmost peak of the mountain complex is Mt. Ardjoeno itself in a restricted sense. This peak, the highest of all, is practically extinct. It does not possess such huge craters and solfatara as Welirang. Between Ardjoeno and Welirang there are three other peaks of lesser altitude. The southernmost and lowest is Mt. Bakal, a rough and rocky, extinct lava-stop. The two others are both called Kembar; we shall distinguish them as Kembar S. and Kembar N. Both are characterised by the occurrence of numerous fumaroles near their summits. They are reached easily along the road from Trètès to Lalidjiwo; in the latter place there is a resthouse at about 2500 m. altitude, situated within the pure *Casuarina Junghuhniana* forests, which cover the entire northern side of the mountain. From Lalidjiwo one reaches the pass between the Kembars, 2900 m. altitude, in about one hour and a half. Near the pass I observed the first small and hitherto unrecorded fumaroles in the northern of the two blowholes. The soil, consisting of weathered volcanic rock, is hot, and steam—which condenses immediately at this altitude—is continuously produced.

1 *Oe* in Dutch is pronounced as *ou* in *would*
2 Cf. N. J. M. Taverne, Vulkaanstudien op Java (Vulkan. Med. Ned. Ind. 7, 1926, p. 109, seq.)

It is a well known fact that the local distribution of mountain plants is often very curious. So for instance *Lycopodium clavatum*, L. and *Gaultheria fragrantissima*, Wall. have only been found on the Kembar peaks, but never on the much loftier Welirang or on Ardjoeno itself.

From the pass I climbed Kembar S., which is 3100 m. high, in about half an hour, over the gently sloping northern ridge, which is covered by a very short vegetation of small herbs such as *Styphelia pungens*, Koord., grasses such as *Danthonia pilosa*, R. Br., *Festuca nubigena*, Jungh., *Tripogon exiguus*, Buese, and especially *Imperata (lalang)*, and several orchids such as *Thelymitra javanica*, Bl., and *Microtis unifolia*, Rchb. Remains of charcoal from burned shrubs confirm our idea, derived from the occurrence of lalang, that the absence of forest is due to fire and to the grazing of deer. Deer are very common here, as shown by their numerous droppings, especially towards the summit. I had very bad weather, and made my way upwards first in a cold drizzle, then under heavy rain. Whereas all the slopes, except the ridge towards the pass, are covered by fairly tall tjemara forest, the top region proper is devoid of forest. It consists of a horseshoe-shaped ridge in the centre of which a so-called *sawahan* is situated, that is a cup-shaped basin covered entirely with the tuft grass *Festuca nubigena* Jungh. Everywhere on the summit steam escapes from cracks in the hot rock; the peak may be said to be more or less crowned by numerous steam clouds. It was a very agreeable sensation to sit on the hot soil within reach of the steam, which escapes under pressure with a dull droning sound. Less agreeable is the smell which is halfway between that of a rotten egg and that of a phalloid. However, no SO_2 was observed. The natives told me that deer came here at night to sleep.

A very peculiar vegetation is developed round these fumaroles, and it shows a distinct zonation. Some metres from the centre, where the steam loses its heat, *Lycopodiums* (*L. cernuum*. L. and *L. clavatum*, L.) thrive in a rather dense thicket along with *Gleichenia linearis*, Clarke and some poor tjemara, only one metre tall, densely clad with *Usnea*. Still nearer to the steam-holes the vegetation is much lower and consists of a carpet of very small herbs. Here *Lycopodium cernuum*, L. shows a very peculiar modification, becoming a flat plaited mat of hardly 1 dm. thickness, covering several square metres. It has just the appearance of a moss (Pl. 1). Other weeds are also able to approach the hot steam, namely a common lowland Rubiacea, *Oldenlandia herbacea*, L., which I was very astonished to find in such a peculiar locality, forming

a very low dense mat. Still other weeds show the stunted dwarf habit. These are *Fimbristylis capillaris,* A. Gray, and also, though less typical, *Lindernia crustacea,* F. v. M., *Senecio sonchifolius,* Moench, and a *Blumea.* All of them, however, do not form mats. Moreover, *Lindernia* and *Fimbristylis* are found elsewhere in Java in dwarf forms, notably on poor soil, *e.g.* on gravel round houses. It must be noted that *Lycopodium cernuum* and *Oldenlandia* are found thriving more luxuriantly some metres away from the steam spouts. Hence the **fumarole modification is effected by the tolerance of these plants.** All the plants mentioned live in continuously humid and warm surroundings, which I call an open-air hothouse in a temperate mountain zone. The wind often alters its direction and sways the steam clouds all over the summit ridge and on account of this several of the plants mentioned occur scattered amongst the lalang. In some places swollen semiglobular white cushions of the moss *Racomitrium* lie loosely on the hot wet rocks.

After I had made these observations I unexpectedly received confirmation of the phenomena described when my friend C. N. A. de Voogd, chief forester of Bali, etc., sent me a collection of plants from the Lesser Soenda Islands and gave me permission to publish concerning them. He collected in 1934 on Mt. Agoeng, the highest peak of Bali island, 3100 m. altitude. It is thus of the same height as Mt. Kembar. Agoeng also has fumaroles on the top ridge and there De Voogd collected some other plants which show the same steam habit as the Kembar plants. He too collected the stunted form of *Oldenlandia herbacea,* L. (Pl. 1) and also found some lowland plants in the Bali open air hothouse, *viz. Mitrasacme nudicaulis,* R. Br., *Bidens pilosus,* L. and *Senecio sonchifolius,* Moench. His best finds were, however, the steam-modifications of two species which I did not get on Kembar—of *Dicrocephala chrysanthemifolia,* DC. and of *Hyptis brevipes,* Poit., the former a mountain plant, the latter a typical lowland plant (Pl. 1). Mr. de Voogd informed me that the fumaroles of Mt. Agoeng also produce steam without any smell of SO_2. He camped on the summit ridge and his coolies pitched a tent above one of the fumaroles to keep warm. The condensation of the steam during the night, however, caused "rainfall" in the tent, so that this idea turned out to be less practical than it was ingenious.

It is definitely shown that steam, at least that of fumaroles at high altitudes in the tropics, has a very uniform effect on plants which are not in the least allied to one another. It is of interest to note, too, that the steam does not diminish fertility, as both *Oldenlandia* and *Fimbristylis* were in flower.

The sketches given above lead to another general consideration. The question arises how these lowland plants were dispersed to this high altitude. *Dicrocephala chrysanthemifolia* and *Lycopodium cernuum* are of general occurrence in the Javan high mountain zones, but what about *Oldenlandia* and the others? Of these common weeds (only *Mitrasacme nudicaulis* being decidedly rare) we have abundant herbarium material at Buitenzorg, and on the labels of most specimens the altitude is noted. From this material, collected throughout the Malaysian region, I made the following table of the greatest altitudes:—

In Malaysia from sealevel up to:	Malaysia	Kembar	Agoeng
Bidens pilosus, L. ...	c. 2100 m.	—	3100 m.
Hyptis brevipes, Poit. ...	c. 1200 m.	—	3100 m.
Lindernia crustacea, F. v. M.	c. 1450 m.	3100 m.	—
Mitrasacme nudicaulis, R. Br.	c. 1700 m.	—	3100 m.
Oldenlandia herbacea, L. ...	c. 1450 m.	3100 m.	3100 m.
Senecio sonchifolia, Moench.	c. 2000 m.	3100 m.	3100 m.

This table shows distinctly that there is a distinct gap between the common occurrence in the lowlands and the hills and that near the fumaroles on the mountain tops. This cannot be attributed to the absence of waste ground, where these pantropic weeds generally grow, in the mountains. On the contrary, waste ground is very common on the mountain slopes, where natives burn the vegetation, cut paths, build houses and try to cultivate crops such as maize and potatos. I am of the opinion that the plants concerned cannot stand the cold of the higher mountain zones above 2000 m. This would fit in with their occurrence in local hotter spots, such as the fumaroles.

The question of vertical dispersal still remains. In the case of the only Composite, *Senecio sonchifolius*, Moench., the pappus is no doubt responsible for dispersal by ascending winds, which, as I observed frequently, may be very strong. But the other plants do not possess any special means for wind dispersal. Neither their seeds or their fruits are fleshy and *endozoic dispersal* seems out of the question. **Exozoic dispersal must be held responsible.** Their seeds or fruits are all small and inconspicuous, as are the plants themselves. The only notes on their methods of dispersal that I could find in Ridley's well-known work "Dispersal of Plants throughout the World" are that *Lindernia* may possibly be dispersed by mud on birds' feet,

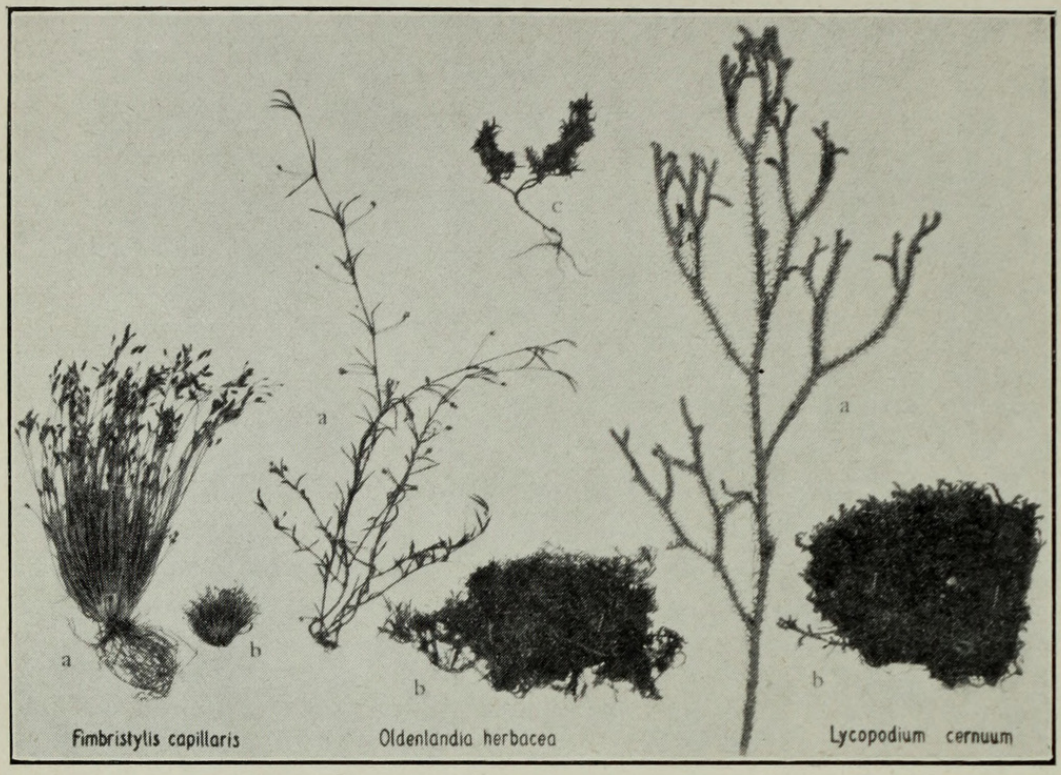
Oldenlandia washed away by rain, and that it might further be possible that the adhesive calyces of *Hyptis* and the pappus of *Senecio sonchifolius* and of *Bidens* could become entangled in the hair and feathers of animals.

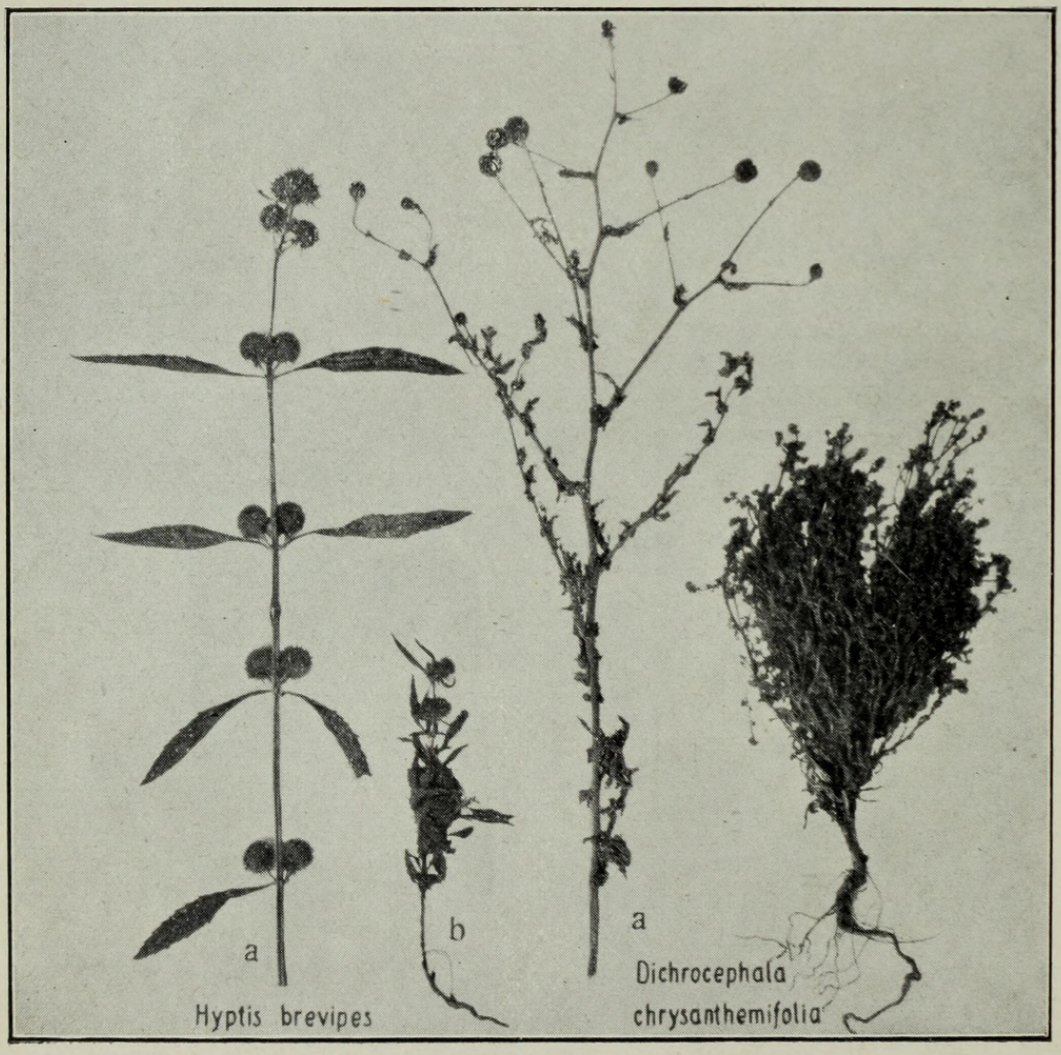
I prefer to put forward the following hypothesis. It is common knowledge that deer migrate through the forests not only in a horizontal but also a vertical direction. Mr. W. H. de Kramer[1] wrote on migration of tiger, python, bear and pig during the fruiting season of the durian (*Durio*) in South Sumatra. The then prevailing western winds bring the smell of durian towards the interior, attracting the pig, and with the latter comes the whole fauna living on them. Migration of elephant and of rhinoceros from sea level to high up the mountains is well known. In January 1935, it was observed that on the north slope of Mt. Slamat in Central Java a continuous migration downwards of the fauna, including deer, was taking place. The natives attributed this to a future eruption, which the animals knew by instinct was coming.[2] That their instinct proved to be at fault does not matter here. It might be that the grazing on higher levels was poor at that time. It is a fact that several animals when old migrate to mountain tops to die in solitude, the reason for which is unknown. Several notes on this phenomenon have been published in our semi-popular naturalists' journal "De Tropische Natuur".[3] I may mention here of the animals found on high mountain tops—often dead—the flying squirrel (at 3675 m. on the summit of Mt. Smeru and at 3800 m. on the summit of Mt. Kerintji), the *kambing utan* (the Sumatran mountain goat) and a rat on the top of Mt. Kerintji, 3800 m., several birds, black monkeys (*Semnopithecus maurus*) on Mt. Smeru and so on. It seems to me that exozoic dispersal by migrating animals, either ascending or descending for food supplies, for dying or for other reasons is the most reasonable explanation of the occurrence of lowland plants near fumaroles. The seeds may adhere with mud to hair or feathers, or, as seems more probable to me, to the hooves and feet of animals, and be occasionally dispersed in that way. They may adhere in no less degree to the master of all animals, man, who frequently visits mountain tops and may unintentionally carry with him seeds from lower down. I refer especially to the statement made above of priests living and people making offerings on mountain summits, a practice which dates back to

1 De Tropische Natuur 23, 1934, p. 119-120.

2 Verslag Ned. Ind. Ver. tot Natuurbescherming 1933-1934, p. 33, 1935.

3 Cf. volumes 19, 1920, p. 197, and 20, 1931, p. 57.


a
b
Fimbristylis capillaris
a
c
b
Oldenlandia herbacea
a
b
Lycopodium cernuum


a
Hyptis brevipes
b
a
Dichrocephala
chrysanthemifolia

Hindu times. De Voogd informed me that the Balinese regularly make offerings on the summit of Mt. Agoeng, and that many monkeys live there, feeding partly on these offerings. These grey monkeys seem to be more or less accustomed to the presence of man, as they took small pieces of bread without hesitation. De Voogd also found a skeleton of a monkey on the summit of Mt. Agoeng.

The gap in altitudinal distribution I believe to be due to the fact that these plants are not able to thrive, or at least to settle, between the highest border of distribution and the abnormal high altitude of the fumaroles, of which the hot soil and atmosphere offer lowland conditions. It would be of great interest to make field experiments on this matter. It would be interesting, too, to make experiments in the laboratory to discover the physiological effect of steam on plants. I do not know of any such experiments. Can the tufted fumarole habit of plants be brought about artificially in the laboratory by the continuous action of pure steam? And in all plants? I much regret that I cannot give any exact data regarding the temperature of the fumarole steam. All I can say is that even near its point of escape it was quite bearable on the human skin.

Plate 1. Modifications of plants by fumaroles, the left figures of each species with the normal, the right with the abnormal habit. *Fimbristylis capillaris,* A. Gray, *a,* from Mt. Tengger, *b.* from Kembar S., x ¼; *Oldenlandia herbacea,* L., *a.* and *b.* from Kembar S., *c.* from Agoeng, x ¼; *Lycopodium cernuum,* L., *a.* and *b.* from Kembar S., x ¼; *Hyptis brevipes,* Poit., *a.* from medium altitude, *b.* from Agoeng, x ⅓; *Dicrocephala chrysanthemifolia,* DC., *a.* and *b* from Agoeng, x ⅓.