Pioneer Plants Found One Year After the 1963 Eruption of Agung in Bali

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AGUNG, THE VOLCANO on the Indonesian island of Bali (Fig. 1), erupted in 1843 and caused the death of thousands of people and animals. No complete report has been written about this catastrophe; however, Zollinger (1845) does mention it briefly.

The first indications of the volcano's being active in 1963 were the frequent and recurrent feeble earthquake tremors and shocks felt by some people living in Jehkuri, a village on the southern slope of the volcano at an elevation of 928 m above sea level and at a distance of about 6 km from the summit. The exact times of these earthquake tremors and shocks were not recorded, but they were felt in the afternoon of February 16. The next day weak earthquakes were again felt, this time at Kubu, a seashore village at the northern foot of the volcano. This event caused a slow swinging of hanging lamps.

On the following day, February 18, at about 11 P.M., weak but distinct rumblings were heard for the first time. At 3 A.M. on the 19th some people who were alarmed and had stayed awake all night noticed the first ascent of a thin smoke column which rose vertically upwards. From this moment the activity continued intermittently, with the period of activity lasting for about 1 hr followed by a rest period of 1 hr. On the night of the 19th glows were visible on the northern crater rim.

The periodic volcanic activity continued with increasing intensity until February 20, on which day lava started to flow along the northern slope and nuées ardentes came down along the same direction, causing the death of the first victims at Siligading. The outpouring of lava continued until the middle of March. The length of the stream grew to 7 km and its tongue stopped at an altitude of about 500 m. Day by day the volcano's activity increased in intensity.

The first paroxysmal eruption started on March 17 at sunrise and lasted for about 7 hr. It was preceded early in the morning two days before by a strong local earthquake. As a consequence of the explosions new breaches appeared in the southern and northern slopes, with the resulting destructive forces reaching a maximum distance of 14 km.

Explosions from the cavity of the crater on March 17 brought an end to the outflow of lava. The characteristics of the andesito-basalt lava, the fact that it began its outpouring in the earliest phase of the eruption, and the fact that its outpouring stopped just before the paroxysmal explosions on March 17, support the theory that this lava was a remainder from the previous eruption of 1843 jammed in the volcano and heated and liquefied in the present eruption.

The number of deaths caused during the first cycle of the 1963 eruption was about 1,100, and about 150 during the second outburst.

Mr. Kusumadinata (1964) of the Geological Survey of Indonesia estimated the volume of the volcanic material energy (Table 1). The total volume of ejected material is about 280×10^6 cubic meters. From this estimated volume of ejected material the released thermal and kinetic energy are computed.

Thus the total kinetic and thermal energy, as estimated, amounts to 8.2×10^{24} ergs.

The lava, streams of mud, glowing clouds, nuées ardentes, lapilli, sand and ash killed not only people and animals but also the plants. In May 1963 we made a trip to the Besakih shrine near the resthouse of the Forest Service, on the northern slope of Agung, more than 900 m above sea level. Here we saw nothing but dead plants—trees, shrubs, herbs, and grasses, fungi, ferns, mosses, and lichens. It was very quiet in the neighborhood of the Besakih shrine.

[1] Herbarium Bogoriense of the National Biological Institute, Bogor, Indonesia. Manuscript received June 30, 1964.

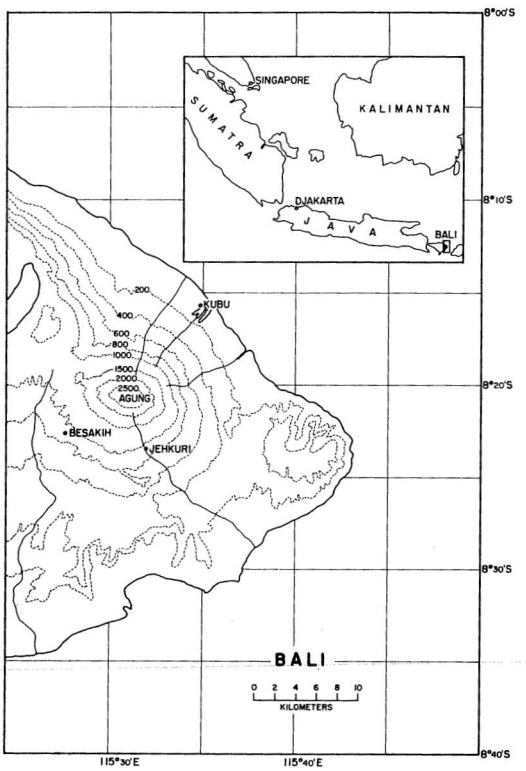

FIG. 1. The part of eastern Bali surrounding the active volcano, Agung, with an inset to show the relationship of this area (in black) to the major islands of western Indonesia.

When the author visited Bali again in October 1963, with Dr. Tarnavschi from Rumania and Prof. Jacovlev from Soviet Russia, we still found in the vicinity of Besakih naught but dead plants with the exception of three species which had begun to grow. These exceptions were the Javanese elder, *Sambucus javanica,* the grass *Eleusine indica,* and the herb *Ageratum conyzoides.* As far as we could see, all other plants were dead.

The third survey during March 1964, was very easy because 90% of the area was still barren. When there were trees at all most of them were dead. Plants were found only near small rivers and on moist sites. With eight helpers we collected the plants and prepared herbarium materials. We could name 75% of the plants in the field; the rest were determined in the herbarium at Bogor.

Circumstances during the survey of March 1964 and its results

The circumstances were very different from those in October. Although there was an outpouring of clouds from the volcano every day, no lapilli, sand, or ash were being ejected anymore, so that after the rains started the plants began to grow again. Although the houses were still in ruins and only one or two were occupied, 10% of the ground surrounding the Besakih shrine had a greenish cover of grasses, herbs, shrubs, and trees which had begun to grow, along with several specimens that had sprouted leaves and were growing normally again.

Between the heights of 900 and 1250 m above sea level, 83 species of grasses, herbs, shrubs, and trees were growing (see list below). All the trees planted by the village people, such as *Erythrina,* were still dead, but 90% of the bamboo *Gigantochloa* sp., and of the legume *Leucaena* sp. in the vicinity had begun to grow again. The condition of *Cordia oblique,* which had been propagated by the Agricultural Extension Service years ago, differed from that observed six months previ-

TABLE 1

MATERIAL AND ENERGY BUDGET FOR THE 1963 ERUPTION OF AGUNG

EJECTED MATERIAL	VOLUME (m^3)	KINETIC ENERGY (ergs)	THERMAL ENERGY (ergs)
Lava flow	110×10^6	.....	4.2×10^{24}
Nuées ardentes, 1st cycle	50×10^6	1.6×10^{22}	1.9×10^{24}
Nuées ardentes, 2nd cycle	20×10^6	0.67×10^{22}	0.7×10^{24}
Pyroclastics, 1st cycle	70×10^6	2.3×10^{22}	0.9×10^{24}
Pyroclastics, 2nd cycle	30×10^6	1.01×10^{22}	0.4×10^{24}

ously: 50% of the trees had begun to bloom again. Of the big trees, several figs and breadfruit trees were now obviously alive, and 50% of the *Albizzia montana* and *A. procera* had already bloomed.

All the plants mentioned above covered only 10% of the area; the rest of the soil surface was still barren, as if the area had been cemented. No plants of any kind were growing there.

As we reached a height of 1250 m, we found the pine forest of *Pinus merkussii* Yunghuhn and de Vr. all dead and the soil in the vicinity hardened as if cemented. We made three holes in this hardened surface and found the hardening extended to a depth of 10–15 cm. Under this layer we found the needles of the pine trees, which were still undamaged, and directly under this layer of needles the original soil.

There are 316 hectares of pine forest surrounding Besakih, all the trees of which are dead because of the hot clouds, lava, lapilli, or sand and ash from the volcano. This lava mixed with lapilli, sand, and ash formed the cemented upper layer of 10–15 cm.

At an elevation of 1250 m, here and there though still very rare, we discovered nine species of plants: a small *Albizzia montana* tree, a small fig, the bamboo *Gigantochloa apus* Kurz., the grass species *Cynodon dactylon* Pers., *Imperata cylindrica* Beau., *Pennisetum purpureum* Schumacher & Thonn., and *Themeda gigantea* Hack., the herb *Plantago major* Linn., and a small tree of *Sesbania grandiflora* Pers. Of these plants we saw only one or two specimens each. Ninety % of the area was still barren, the surface cemented, and the leafless standing trunks of the pine trees looked like abandoned soldiers. We saw three butterflies but no other living animal.

The following list is of the plants found growing on the northern slope of the volcano, from a height of 900 m above sea level (where the area of the Besakih shrine begins at the resthouse of the Forest Service) up to the 1250 m level, where 90 % of the soil surface one year after the eruption of Agung is still barren. The plants were found along dikes and watercourses.

Ageratum conyzoides Linn.
Albizzia montana Benth.
Albizzia procera Benth.
Aleurites montana Wilson
Amaranthus spinosus Linn.
Anaphalis viscida DC.
Areca catechu Linn.
Arenga pinnata Merr.
Artocarpus communis Forst.
Artocarpus elastica Reinw.
Averrhoa carambola Linn.
Boehmeria nivea Gaud.
Caesalpinia pulcherrima Sw.
Callicarpa longifolia Lamk.
Centella asiatica Urb.
Centotheca latifolia Trin.
Ceratopteris thalictroides Brongn.
Cheilanthus tenuifolia Swartz
Citrus maxima Merr.
Citrus sp.
Clerodendron serratum Spreng.
Coffea arabica Linn.
Cordia oblique Willd.
Cynodon dactylon Pers.
Cyperus cyperoides O. K.
Cyperus rotundus Linn.
Davallia trichomonoides Bl.
Digitaria sanguinalis Scop.
Drymaria hirsuta Barttl.
Elaeagnus latifolius Linn.
Eleusine indica Gaertn.
Engelhardia spicata Bl.
Equisetum debile Roxb.
Erechtites valerianifolia Rafin.
Erythrina variegata Linn.
Eugenia cumini Druce
Eugenia polyantha Wight.
Euphorbia rothiana Spreng.
Ficus ampelas Burm.
Ficus benjamina Linn.
Ficus septica Burm.
Fimbristylis miliacea Vah.
Flacourtia rukam Zoll. and Mor.
Gigantochloa apus Kurz.
Goniophlebium subauriculatum DC.
Gynoglossum javanicum Thunb.
Hibiscus rosa-sinensis Linn.
Homalomena sp.
Imperata cylindrica Beauv.
Ipomoea batatas Lamk. (planted)
Jatropha curcas Linn.
Kyllinga monocephala Rottb.
Leucaena sp.
Litsea sp.
Lygodium japonicum Sw.
Melia azedarach Linn.
Michelia sp.
Mirabilis jalapa Linn.
Musa sp.
Nephelium sp.
Paederia fortida Linn.

Paspalum conjugatum Berg.
Pennisetum purpureum Schumacher and Thonn.
Plantago major Linn.
Pleomele elliptica N. E. Br.
Polygonum chinense Linn.
Pteridium aquilinum L. var. *Wightianum*
Ricinus communis Linn.
Saccharum spontaneum Linn.
Sambucus javanica Bl.
Sesbania grandiflora Pers.
Smilax leucophylla Bl.
Solanum torvum Sw.
Spilanthes nodiflora Geschn.
Terminalia bellirica Roxb.
Themeda gigantea Hack.
Toona sinensis Roem.
Vernonia arborea Ham.
Veronia javanica Bl.
Viburnum lutescens Bl.
Viburnum sambucinum Bl.
Vitex trifolia var. *heterophylla* Mol.
Wedelia montana Boerl.

Above 1250 m only nine species of plants have been found: *Albizzia montana* Benth., *Cynodon dactylon* Pers., *Ficus* sp., *Gigantochloa apus* Kurz., *Imperata cylindrica* Beauv., *Pennisetum purpureum* Schumacher and Thonn., *Plantago major* Linn., *Sesbania grandiflora* Pers., and *Themeda gigantea* Hack.

At a height of 1400 m the dead pine trees were left standing, while far down in valleys one or two specimens of the following species were observed: *Phragmites karka* Trin., *Sambucus javanica* Reinw., *Pennisetum purpureum* Schum. and Swarz., *Themeda gigantea* Hack., *Engelhardia* sp., *Schima wallichii* var. *noronhae* Bl.

On the slopes of the valleys we discovered: *Polygonum sinensis* Linn., *Cordia oblique* Willd., *Dryopteris campestris* Rumph., *Cheilanthes tenuifolia* Swarz., *Coffea* sp., and *Gigantochloa apus* Kurz.

According to these observations upon the pioneer plants in the valleys, the Forest Service should be advised to mix in this forest such pioneer trees as *Engelhardia* sp. and *Schima wallichii* var. *noronhae,* whatever the main species in this forest may be. A monoculture of *Pinus merkussii* is not preferable; experience in Western Europe with monocultures and with the dead forests on the northern and southern slopes of Agung volcano, described above, leads us to believe that a mixed forest, following the example of Nature, is the best reforestation.

It would appear that this devastated area near the 1250 m elevation could be reforested rather readily by digging through the cemented material (to a maximum of 20 cm) and planting seeds or seedlings in the original soil beneath. Though *Casuarina yunghuhniana* Bl. is popular, it does not seem wise to plant it at this high altitude because the needles cover the soil giving other plant species little chance of growing. As a result there would be a good chance, then, that the surface of the soil would suffer serious damage by erosion.

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