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# Arthropod Galls Found on the Krakatau Islands and in Adjacent Areas of Indonesia, with Reference to Faunistic Disharmony between the Islands and the Whole of Indonesia

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**Abstract.** Up to 2000, a total of 147 sorts of arthropod gall were found on the Krakatau Islands and in adjacent areas since the world famous volcanic eruption in 1883. They were induced on at least 109 plant species belonging to 81 genera of 42 families and are listed in alphabetical order of host plant families, except one belonging to Pteridophyta. On the Krakataus, Docters van Leeuwen recorded 63 sorts of arthropod gall in 1919-1922. Thereafter, Yukawa and Partomihardjo collected 15 sorts in 1982 and 45 in 1991-1993, and Partomihardjo, Uechi, and Abe collected 22 in 2000. The cumulative number of different gall sorts found on the islands from 1982 to 2000 was 52, consisting of 31 insect and 21 eriophyoid galls, which is equivalent to 3.4% of 1536 sorts of arthropod galls recorded from Indonesia. We also refer to disharmony between galling-arthropod fauna of the Krakataus and that of the whole of Indonesia. During the surveys in 1991-1993 and 2000, we found 16 sorts of arthropod gall that are new to Indonesia. They are briefly described together with photographs and illustrations.

**Key words:** The Krakatau Islands, Indonesia, gall-inducing arthropod, new galls, recolonization, disharmony, island biogeography, Cecidomyiidae, Eriophyoidea.

## Introduction

The Krakatau Islands are situated in the Sunda Strait between Java and Sumatra, Indonesia and now consist of four islets, Rakata, Panjang, Sertung and Anak Krakatau (Fig. 1). In 1883, the world famous eruption of Krakatau Island almost certainly completely sterilized the Krakatau Islands, except Anak Krakatau that appeared above sea level in the 1930s due to submarine volcanic activity. Successive activities of Anak Krakatau have been damaging biota on the Krakataus (Thornton *et al*., 1994). After the 1883 eruption, recolonization of the Krakatau Islands by invertebrates has been studied on many occasions (e.g., Jacobson, 1909; Docters van Leeuwen, 1920, 1922; Dammerman, 1922, 1948; Yamane, 1983; Yukawa, 1984a, 1984b; Kanmiya & Yukawa, 1985; Yukawa & Yamane, 1985; Evenhuis & Yukawa, 1986; Yamane & Tomiyama, 1986; New & Sudarman, 1988; New *et al*., 1988; Thornton & New, 1988; Thornton & Rosengren, 1988; Tsukaguchi & Yukawa, 1988; Bush & Whittaker, 1991; Yamane *et al*., 1992; Thornton, 1996; Yukawa *et al*., 2000; Yukawa *et al*., 2001; Thornton *et al*., 2002).

In order to search for insect and eriophyoid mite galls (arthropod galls, hereafter), Docters van Leeuwen (1920, 1922) visited the Krakataus and adjacent islands several times during the period from 1919 to 1922 and compiled his collecting data in Docters van Leeuwen-Reijnvaan & Docters van Leeuwen (1926). Then, Dammerman (1948) listed 60 sorts of arthropod galls on 44 plant species based on the collecting records of Docters van Leeuwen

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**Fig 1.** Map of the Krakatau Islands and adjacent islands and areas.

(1920, 1936). Because three sorts of gall were omitted from the list in Dammerman (1948), the total number should be 63 in 1919-1922. In 1982, Yukawa & Partomihardjo (1997) surveyed arthropod galls on Peucang Island, Panaitan Island and the Krakatau Islands, and found 15 sorts on the Krakataus. Thereafter, we visited the Krakataus and adjacent areas on many occasions to search for galls during the period from 1991 to 2000.

The aim of this paper is to enumerate all arthropod galls that were found on the Krakatau Islands and in adjacent areas after the 1883 eruption until 2000. This enumeration is essential for further faunistic studies. In this paper, we refer to the existence of faunistic disharmony by comparing galling-arthropod fauna of the Krakataus with that of Indonesia provided by Docters van Leeuwen-Reijnvaan & Docters van Leeuwen (1926). We also describe, together with photographs or illustrations, galls that were newly detected in Indonesia during the 1991 to 2000 field surveys.

## Materials and Methods

### Areas and periods of field surveys

Arthropod galls were surveyed on the Krakatau Islands and in adjacent areas such as Sebesi Island, Sebuku Island, South Sumatra, Carita, Peucang Island, Panaitan Island and Ujung Kulon (Fig. 1). These areas were less influenced by the 1883 eruption than the Krakataus.

Surveys were divided into four periods: the first period in the 1920s (Docters van Leeuwen, 1920, 1922), the second in 1982 (Yukawa & Partomihardjo, 1997), the third in 1991-1993 (current data), and the fourth in 2000 (current data) (Table 1). We gathered collection records in the first period through literature survey (e.g., Docters van Leeuwen, 1920, 1922, 1936; Docters van Leeuwen-Reijnvaan & Docters van Leeuwen, 1926; Dammerman, 1948). We devoted a total of at least 77 days to the field surveys from 1982 to 2000 (Table 1), but surveys in 1982 and 2000 were less intensive than in 1991-1993. Collection records from 1982 to 2000 were, then, summed to

**Table 1**. Field survey of galling arthropods on the Krakatau Islands and in surrounding areas in West Java and South Sumatra.

| Period | Year (Month) | Days | Island or Location | Collector |
|---|---|---|---|---|
| 2nd | 1982 (Oct.-Nov.) | 22 | Krakataus, Carita, Peucang, and Panaitan | Yukawa & Partomihardjo |
| 3rd | 1991 (Jul.) | 13 | Krakataus and Carita | Yukawa & Partomihardjo |
| 3rd | 1992 (Sep.) | 20 | Krakataus, Ujung Kulon, and Peucang | Partomihardjo |
| 3rd | 1993 (Jul.) | 10 | Krakataus, Sebesi, Sebuku and Lampung | Yukawa & Partomihardjo |
| 4th | 2000 (Oct.) | 12 | Krakataus and Ujung Kulon | Partomihardjo, Uechi & Abe |

compare with those in the first periods.

**Field survey and identification of gall-inducing arthropods and their host plants**

In the field, we searched for galls randomly and collected from various plant species. Fortunately, the flora of the Krakataus and the succession of vegetation have been relatively intensively surveyed by plant taxonomists and ecologists (e.g., Whittaker & Flenly, 1982; Partomihardjo *et al*., 1985; Whittaker *et al*., 1989, 1992). Relying on the results of their surveys, most host plants were identified by us in the field. Plants that could not be identified in the field were compared with the herbarium collection in the Herbarium Bogoriense for species identification.

Galls and gall-bearing plants collected were brought back to the Herbarium Bogoriense, Bogor. Gall size was measured and their shape, coloration and position were recorded. The galls were dissected under a binocular microscope to identify the gall-inducing species to the family or order level. In some cases, the gall material was kept in 70-75% ethanol for later dissection. All gall-bearing plants collected from the Krakatau Islands and adjacent areas are kept in the collection of the Herbarium Bogoriense, Bogor (now in Cibinong), Indonesia.

We identified galls relying upon descriptions of galls by Docters van Leeuwen (1920, 1922), Docters van Leeuwen-Reijnvaan & Docters van Leeuwen (1926), and Yukawa & Partomihardjo (1997). To distinguish identified galls from each other, gall numbers were quoted from Docters van Leeuwen-Reijnvaan & Docters van Leeuwen (1926), and they are referred to in Table 2. Galls that had been newly found in the second, third and fourth periods were numbered with "PY" for convenience of gall identification in the future. Some of the newly found galls are shown in this paper as photographs (Figs. 2-7) or illustrations (Figs. 8-17).

## Results

**Accumulated number of sorts of arthropod gall found on the Krakataus and in adjacent areas since the 1883 eruption up until 2000**

A total of 147 sorts of arthropod gall were found on the Krakataus and in adjacent areas since the 1883 eruption up until 2000 (Table 2). They were induced on at least 109 plant species belonging to 81 genera of 42 families including one species of Pteridophyta.

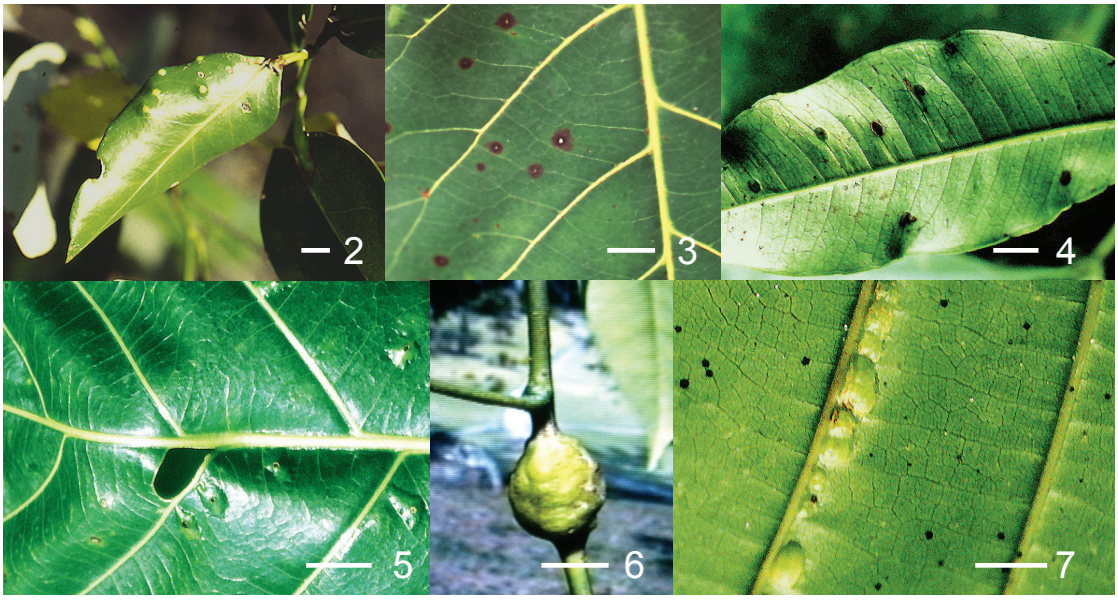
**Collection of galls from the Krakataus in 1991-1993 and 2000**

The 1991-1993 survey was the most intensive in recent years, and 45 different sorts of arthropod gall were collected from the islands (Table 2). Among them, eriophyoid and cecidomyiid galls were dominant, and psylloid, thysanopteran, coccoid, hymenopteran, and lepidopteran galls were in a minority (Table 3).

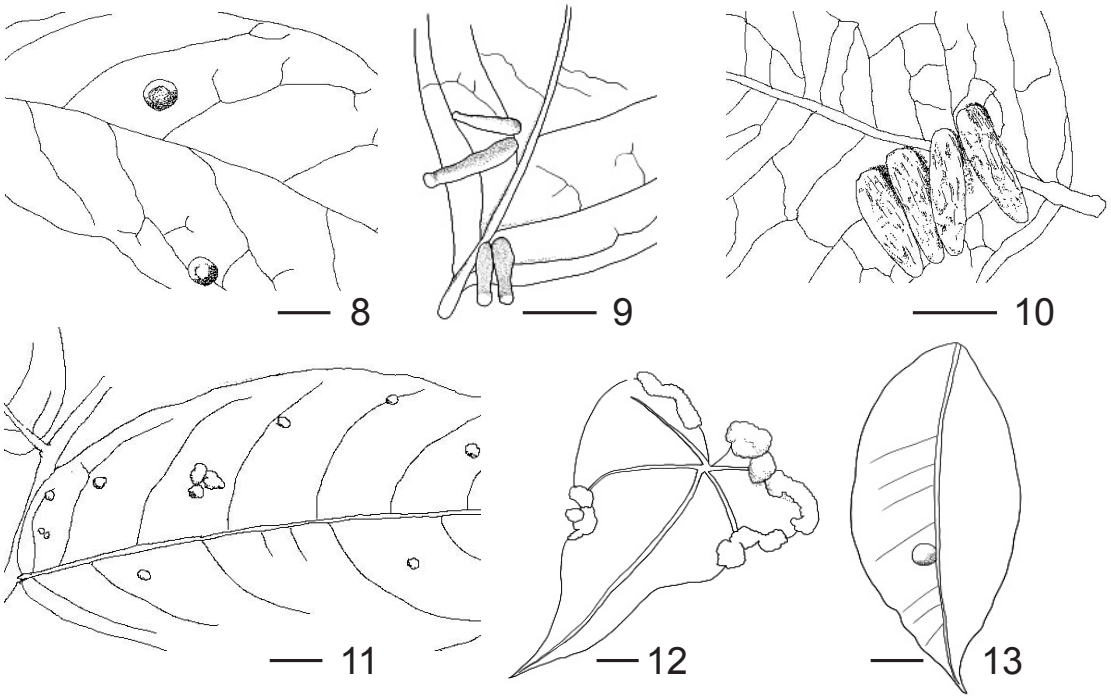
In the 2000 survey, 22 sorts of gall were collected from the islands (Table 3). Among them, two were not collected in 1991-1993 but had been recorded in the 1920s, and another was found, for the first time, in Indonesia (Table 2). In total, 52 different sorts of gall were collected from the islands during the period from 1982-2000 (Table 3).

**Collection of galls from Carita**

In the 1982 survey, only three cecidomyiid, three eriophyoid, and one dipteran galls were collected from beach vegetation in Carita (West Coast of Java) (Fig. 1; Table 2). In the 1991-93 field survey, 21 different sorts of gall were found mainly in the inland forest and partly in the beach vegetation near Carita. These included 11 cecidomyiid, five eriophyoid, two thysanopteran, two lepidopteran, and one coccoid galls (Table 2). Among them, 12 sorts (57.1%) were common to the Krakatau Islands




**Figs. 2-7.** Arthropod galls new to Indonesia. 2, Eriophyoid galls on *Garcinia dioica* (Clusiaceae), Gall no. PY003; 3, Cecidomyiid galls on *Terminalia catappa* (Combretaceae), Gall no. PY004; 4, Eriophyoid galls on *Syzygium polyanthum* (Myrtaceae), Gall no. PY021; 5, Cecidomyiid galls on *Anthocephalus chinensis* (Rubiaceae), Gall no. PY023; 6, Cecidomyiid gall on *Luvunga* sp. (Rutaceae), Gall no. PY025; 7, Cecidomyiid galls on *Poikilospermum suaveolens* (Urticaceae), Gall no. PY028. Scale bar: 10mm.




**Figs. 8-13.** Arthropod galls new to Indonesia. 8, Eriophyoid galls on *Antidesma montanum* (Euphorbiaceae), Gall no. PY005; 9, Cecidomyiid galls on *Antidesma* sp. (Euphorbiaceae), Gall no. PY006; 10, Cecidomyiid galls on *Breynia cernua* (Euphorbiaceae), Gall no. PY007; 11, Eriophyoid galls on *Glochidion borneensis* (Euphorbiaceae), Gall no. PY009; 12, Eriophyoid galls on *Hernandia peltata* (Hernandiaceae), Gall no. PY011; 13, Cecidomyiid galls on *Intsia bijuga* (Fabaceae), Gall no. PY013. Scale bar: 10mm.

**Table 2.** Arthropod galls collected from the Krakatau Islands and adjacent areas in the first, second, third, and fourth periods of field surveys.

| Family and species of host plant | Gall inducer | Gall No. | Rakata | Sertung | Panjang | Anak | Sebesi & Sebuku | South Sumatra | Carita | Panaitan & Peucang | Ujung Kulon |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OLEANDRACEAE | | | | | | | | | | | |
| *Nephrolepis bisserata* | Eriophyoid | 20604 | - | - | - | - | 1,3 | 3 | 2 | - | - |
| *Nephrolepis hirsutula* | Eriophyoid | 20605 | 1,2,3,4 | 2,3,4 | 1,2,3,4 | - | 1,3 | 1,3 | 2 | - | - |
| *Nephrolepis hirsutula* | Cecidomyiid | 21412 | 1 | 1 | - | - | - | 1 | - | - | - |
| ACANTHACEAE | | | | | | | | | | | |
| *Acanthus ilicifolius* | Cecidomyiid | 20006 | - | - | - | - | - | - | - | - | 3,4 |
| ACTINIDIACEAE | | | | | | | | | | | |
| *Saurauia nudiflora* | Eriophyoid | 21090 | 1D | - | - | - | - | 1 | - | - | - |
| ALANGIACEAE | | | | | | | | | | | |
| *Alangium densiflorum* | Cecidomyiid | 21185 | - | - | - | - | 3 | 1 | - | - | - |
| ANACARDIACEAE | | | | | | | | | | | |
| *Buchanania arborescens* | Cecidomyiid | 20097 | 2,3,4 | 2 | 3,4 | - | 3 | - | 2 | 2 | 3,4 |
| *Mangifera indica* | Cecidomyiid | 21005 | - | - | - | - | 1,3 | 1 | - | - | - |
| *Mangifera indica* | Cecidomyiid | 20617 | - | - | - | - | 1,3 | 3 | 2 | - | - |
| ANNONACEAE | | | | | | | | | | | |
| *Pseuduvaria reticulata* | Cecidomyiid | PY001 | - | - | - | - | - | - | - | 2N | 3R |
| APOCYNACEAE | | | | | | | | | | | |
| *Alstonia scholaris* | Psylloid | 20025 | - | - | - | - | 1,3 | 1,3 | - | 3 | - |
| ARISTOLOCHIACEAE | | | | | | | | | | | |
| *Aristolochia tagala* | Cecidomyiid | (1924) | 1 | - | - | - | - | - | - | - | - |
| ASTERACEAE | | | | | | | | | | | |
| *Chromolaena odorata* | Eriophyoid | PY002 | - | 2N | - | 3 | 3 | 3 | - | - | 3 |
| *Mikania cordata* | Eriophyoid | 21043 | 1 | 1 | - | 4R | 1,3 | 1 | 2 | - | - |
| *Pluchea indica* | Eriophyoid | 21406 | - | 1 | - | - | 1,3 | 1 | - | - | - |
| *Vernonia arborea* | Eriophyoid | 20210 | 1 | - | - | - | - | - | - | - | - |
| *Vernonia cinerea* | Psylloid | 20217 | 1 | 1 | - | - | - | - | - | - | - |
| *Wollastonia biflora* | Diptera | 20201 | 1 | - | - | 4R | 3 | 3 | 2 | - | - |
| *Wollastonia biflora* | Eriophyoid | 20200 | 1,2 | 1,2 | - | - | 3 | 3 | - | - | - |
| *Wollastonia biflora* | Cecidomyiid | 20198 | 1 | 1 | - | - | 3 | - | 2 | - | - |
| *Wollastonia biflora* | Aphidoid | 21408 | 1D | 1 | - | - | 3 | 1,3 | - | - | - |
| BORAGINACEAE | | | | | | | | | | | |
| *Cordia mixa* | Eriophyoid | 20282 | - | 1 | - | - | - | 1 | - | - | - |
| CLUSIACEAE | | | | | | | | | | | |
| *Calophyllum inophyllum* | Lepidoptera | 21104 | 2,3,4 | 2,3,4 | 1,2,3,4 | 3,4 | 3 | 3 | 3 | 3 | 3 |
| *Garcinia dioica* | Eriophyoid | PY003 (Fig.2) | - | - | - | - | 3N | - | - | - | - |
| COMBRETACEAE | | | | | | | | | | | |
| *Terminalia catappa* | Cecidomyiid | 21122 | 1,2,3,4 | 3,4 | 3,4 | 3,4 | 1,3 | 1,3 | 3 | 3 | 3 |
| *Terminalia catappa* | Eriophyoid | 21123 | 1,2,3,4 | - | - | - | 1,3 | 1,3 | - | - | - |
| *Terminalia catappa* | Cecidomyiid | PY004 (Fig.3) | 3,4 | 3N | 3,4 | 3N | 3N | 3N | 3N | - | 3N |
| CONVOLVULACEAE | | | | | | | | | | | |
| *Ipomoea gracilis* | Aphidoid | 21244 | - | 1 | - | - | - | - | - | - | - |
| CUCURBITACEAE | | | | | | | | | | | |
| *Coccinia cordifolia* | Cecidomyiid | 20255 | - | - | 1 | - | - | - | - | - | - |
| *Trichosanthes bracteata* | Cecidomyiid | 21401 | 1,3 | 1D | - | 3 | 1,3 | 3 | 3 | - | - |
| ELAEOCARPACEAE | | | | | | | | | | | |
| *Elaeocarpus glabra* | Eriophyoid | 21058 | 1,3 | - | - | - | - | - | - | - | 3 |
| *Elaeocarpus glabra* | Thysanoptera | PY029 | - | - | - | - | - | - | - | 2 | - |
| EUPHORBIACEAE | | | | | | | | | | | |
| *Antidesma bunius* | Cecidomyiid | 20048 | - | - | - | - | 1 | 1 | - | - | - |
| *Antidesma montanum* | Eriophyoid | PY005 (Fig.8) | 3N | - | 3N,4 | - | - | - | - | - | - |
| *Antidesma sp.* | Cecidomyiid | PY006 (Fig.9) | - | - | - | - | - | - | 3N | - | - |
| *Breynia cernua* | Cecidomyiid | PY007 (Fig.10) | 3N | - | - | - | - | - | - | - | - |
| *Bridelia monoica* | Cecidomyiid | 20094 | 1,3 | 4R | 4R | - | 3 | 3 | - | - | - |
| *Croton caudatus* | Eriophyoid | 21060 | - | - | - | - | - | 1,3 | 3 | - | - |
| *Drypetes macrophylla* | Cecidomyiid | PY008 | - | - | - | - | - | - | - | 2N | - |
| *Glochidion borneensis* | Eriophyoid | PY009 (Fig.11) | 3N | - | - | - | - | - | - | - | - |
| *Glochidion microcarpum* | Eriophyoid | PY010 | - | - | - | - | - | - | - | 2N | 3R |
| *Glochidion phillipicum* | Cecidomyiid | 20475 | - | - | - | - | 3 | 1,3 | - | - | - |
| *Glochidion phillipicum* | Eriophyoid | 20474 | - | - | - | - | 3 | 1,3 | - | - | - |
| *Glochidion phillipicum* | Eriophyoid | 20964 | - | - | - | - | 3 | 1,3 | - | - | - |
| *Glochidion phillipicum* | Lepidoptera | 20963 | - | - | - | - | 3 | 1,3 | - | - | - |
| *Macaranga tanarius* | Eriophyoid | 20972 | 1,2,3,4 | 1,2,3,4 | - | - | 1,3 | 1,3 | - | - | - |

**Table 2.** Continued

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Macaranga tanarius* | Eriophyoid | 20973 | 1 | 1D | 1D | - | 3 | 1,3 | - | - | - |
| *Mallotus richinoides* | Cecidomyiid | 20990 | - | - | - | - | 3 | 3 | - | - | - |
| *Melanolepis multiglandulosa* | Cecidomyiid | 20981 | - | - | - | - | - | - | 3 | - | - |
| *Omalanthus populneus* | Psylloid | 20553 | 1,3 | - | - | - | - | 1 | - | - | - |
| *Securinega virosa* | Eriophyoid | 20185 | - | - | - | - | 3 | 1 | - | - | - |
| FABACEAE | | | | | | | | | | | |
| *Derris heterophylla* | Cecidomyiid | 20321 | 1,3 | - | - | - | - | - | - | - | - |
| *Derris heterophylla* | Cecidomyiid | PY030 (Fig.14) | - | - | - | - | - | - | - | - | 4N |
| *Derris heterophylla* | Cecidomyiid | PY031 (Fig.15) | - | - | - | - | - | - | - | - | 4N |
| *Erythrina orientalis* | Coccoid | (1924) | 1D | 1 | - | - | - | - | - | - | - |
| *Intsia bijuga* | Cecidomyiid | PY013 (Fig.13) | - | - | - | - | - | - | 3N | - | - |
| *Millettia sericea* | Cecidomyiid | 20894 | - | - | - | - | - | - | 3 | - | - |
| *Pongamia pinnata* | Eriophyoid | 20911 | 1 | - | - | - | 1,3 | 1,3 | - | - | - |
| *Spatholobus verugineus* | Cecidomyiid | PY014 | - | - | - | - | - | - | - | 2N | 3R |
| *Spatholobus verugineus* | Cecidomyiid | PY015 | - | - | - | - | - | - | - | 2N | 3R |
| FLACOURTIACEAE | | | | | | | | | | | |
| *Flacourtia rukam* | Cecidomyiid | 20178 | - | - | - | - | - | 1 | - | - | - |
| HERNANDIACEAE | | | | | | | | | | | |
| *Hernandia peltata* | Coccoid | 20865 | - | - | - | - | 1 | 1 | - | - | - |
| *Hernandia peltata* | Eriophyoid | PY011 (Fig.12) | - | - | - | 3N | - | - | - | - | - |
| LAURACEAE | | | | | | | | | | | |
| *Cassytha filiformis* | Eriophyoid | 20837 | - | 1 | - | - | - | - | - | - | - |
| *Litsea noronhae* | Eriophyoid | 20854 | 1,3,4 | - | - | - | 1,3 | 1 | - | - | 4R |
| LEEACEAE | | | | | | | | | | | |
| *Leea sambucina* | Cecidomyiid | 21032 | 1,2,3,4 | 1,3,4 | 1,3,4 | - | 1,3 | 1,3 | 3 | 2,3 | 3,4 |
| LORANTHACEAE | | | | | | | | | | | |
| *Loranthus pentandra* | Lepidoptera | 20782 | - | - | - | - | 1,3 | - | 3 | - | - |
| *Loranthus pentandra* | Thysanoptera | 20783 | - | - | - | - | - | - | 3 | - | - |
| MALVACEAE | | | | | | | | | | | |
| *Hibiscus tiliaceus* | Eriophyoid | 20531 | 1,3 | - | - | - | - | - | - | - | - |
| *Hibiscus tiliaceus* | Eriophyoid | 20532 | 1,2,3,4 | 1,2,3 | 4R | 4R | 1,3 | 3 | - | 2 | - |
| *Hibiscus tiliaceus* | Coccoid | 21074 | 1,3 | 1,3 | - | 3 | 1 | 1,3 | 3 | - | 3 |
| *Thespesia populnea* | Psylloid | 21077 | 3 | 3 | - | - | 1 | 1 | - | - | - |
| MELASTOMATACEAE | | | | | | | | | | | |
| *Melastoma affine* | Eriophyoid | 21157 | 1,3 | 1,3 | - | 3 | - | - | - | - | - |
| MELIACEAE | | | | | | | | | | | |
| *Dysoxylum amoroides* | Psylloid | 20340 | - | - | - | - | - | - | - | - | 3 |
| *Dysoxylum densiflorum* | Cecidomyiid | 20342 | - | - | - | - | - | - | - | - | 3 |
| *Dysoxylum gaudichaudianum* | Cecidomyiid | PY016 | - | 2N | - | - | - | - | - | - | - |
| MENISPERMACEAE | | | | | | | | | | | |
| *Pericampylus glaucus* | Cecidomyiid | 20812 | 1 | - | - | - | 1,3 | 1 | - | - | - |
| *Pericampylus glaucus* | Unknown | (1924) | - | - | - | - | - | 1 | - | - | - |
| MIMOSACEAE | | | | | | | | | | | |
| *Pithecellobium umbellatum* | Eriophyoid | 20886 | 1 | - | - | - | - | - | - | - | - |
| *Pithecellobium umbellatum* | Eriophyoid | 20887 | 1 | 1 | - | - | - | - | - | - | - |
| MORACEAE | | | | | | | | | | | |
| *Ficus ampelas* | Psylloid | 20433 | 1,2,3 | 2 | 2,4 | - | 1,3 | 1,3 | - | - | - |
| *Ficus ampelas* | Eriophyoid | 20434 | 1,3,4 | 3 | 3 | - | 1,3 | 1 | 3 | - | 3 |
| *Ficus benjamina* | Thysanoptera | 20437 | 3 | - | - | - | - | - | 3 | - | 3 |
| *Ficus callosa* | Thysanoptera | 20161 | - | - | - | - | 1,3 | 1 | - | - | - |
| *Ficus fistulosa* | Eriophyoid | 20193 | 1 | - | - | - | 1 | 1 | - | - | - |
| *Ficus hispida* | Eriophyoid | 20571 | 3 | 1,3 | 3 | - | 1,3 | 1,3 | - | 3 | - |
| *Ficus pubinervis* | Cecidomyiid | 20140 | 1,3 | 4R | 3 | - | - | - | - | 3 | - |
| *Ficus pubinervis* | Eriophyoid | 20718 | 1 | - | - | - | - | - | - | - | - |
| *Ficus retusa* | Hymenoptera | 21461 | 3 | - | - | - | - | 1 | - | - | - |
| *Ficus ribes* | Cecidomyiid | 20156 | 1 | - | - | - | - | - | - | - | - |
| *Ficus subulata* | Cecidomyiid | 20163 | 1,3 | - | - | - | - | - | - | - | - |
| *Ficus tinctoria ssp. gibbosa* | Cecidomyiid | 20120 | 1,3 | 1,3 | 3 | - | - | - | - | 3 | - |
| *Ficus variegata* | Psylloid | 20167 | 3 | - | 3 | - | 1,3 | 1 | - | 3 | - |
| MYRTACEAE | | | | | | | | | | | |
| *Syzygium lineatum* | Psylloid | 20402 | 3 | - | - | - | - | - | - | 3 | - |
| *Syzygium polyanthum* | Psylloid | 20415 | - | - | - | - | - | - | - | 2 | - |
| *Syzygium polyanthum* | Cecidomyiid | 20418 | 3 | - | 3,4 | - | - | - | - | 3 | 3 |
| *Syzygium polyanthum* | Eriophyoid | PY021 (Fig.4) | 3N | - | - | - | - | - | - | - | - |
| *Syzygium zollingerianum* | Cecidomyiid | 21134 | - | - | - | - | 1,3 | 1 | - | - | - |
| *Syzygium sp. 1* | Psylloid | 21135 | - | - | - | - | 1,3 | - | - | - | - |
| *Syzygium sp. 2* | Psylloid | 21136 | - | - | - | - | 1,3 | - | - | - | - |

**Table 2.** Continued

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Syzygium sp. 3* | Psylloid | 21137 | - | - | - | - | 1,3 | - | - | - | - |
| ORCHIDACEAE | | | | | | | | | | | |
| *Calanthe zollingeri* | Cecidomyiid | 20683 | - | - | - | - | 1,3 | 1 | - | - | - |
| PIPERACEAE | | | | | | | | | | | |
| *Piper betle* | Thysanoptera | 20728 | - | - | - | - | 1,3 | 1 | - | - | - |
| *Piper betle* | Thysanoptera | 20729 | - | - | - | - | 1,3 | 1,3 | - | - | - |
| *Piper blumei* | Thysanoptera | (1931) | 1 | - | - | - | - | - | - | - | - |
| *Piper retrofractum* | Thysanoptera | 20740 | - | - | - | - | 1,3 | 1 | - | - | - |
| *Piper sarmentosum* | Thysanoptera | 20741 | - | - | - | - | 1,3 | - | - | - | - |
| *Pothomorphe subpeltata* | Aphidoid | (1924) | 1 | - | - | - | - | - | - | - | - |
| POACEAE | | | | | | | | | | | |
| *Oplismenus compositus* | Aphidoid | 20666 | - | 1 | - | - | - | - | - | - | - |
| RUBIACEAE | | | | | | | | | | | |
| *Anthocephalus chinensis* | Cecidomyiid | PY023 (Fig.5) | - | - | - | - | 3N | - | - | - | - |
| *Neonauclea calycina* | Cecidomyiid | 21342 | 1,3 | - | - | - | - | 1 | - | - | - |
| *Neonauclea calycina* | Cecidomyiid | 21343 | 1,3 | - | - | - | - | - | - | - | - |
| *Neonauclea calycina* | Eriophyoid | 21344 | 1 | - | - | - | - | - | - | - | - |
| *Neonauclea calycina* | Cecidomyiid | PY032 (Fig.16) | 4N | - | - | - | - | - | - | - | - |
| *Paederia foetida* | Cecidomyiid | 21351 | - | - | - | - | 3 | 1 | - | - | - |
| *Paederia foetida* | Eriophyoid | 21352 | - | - | - | - | 3 | 1 | - | - | - |
| *Tarrena fragrant* | Thysanoptera | 21383 | 4R | - | - | - | - | - | - | - | - |
| *Uncaria ferrea* | Aphidoid | 21389 | - | 1 | - | - | - | - | - | - | - |
| *Uncaria ferrea* | Eriophyoid | 21390 | - | 1 | - | - | - | - | - | - | - |
| RUTACEAE | | | | | | | | | | | |
| *Euodia aromatica* | Eriophyoid | 20427 | - | - | - | - | - | - | 3 | - | - |
| *Euodia sp.* | Eriophyoid | 20925 | - | - | - | - | 3 | 1 | - | - | - |
| *Luvunga sp.* | Cecidomyiid | PY025 (Fig.6) | - | - | - | - | - | - | - | - | 3N |
| SAPINDACEAE | | | | | | | | | | | |
| *Erioglossum rubiginosum* | Coccoid | (1924) | 1 | - | - | - | - | - | - | - | - |
| SAPOTACEAE | | | | | | | | | | | |
| *Planchonella obovata* | Cecidomyiid | PY026 | - | - | - | - | - | - | - | 2N | 3R |
| SONNERATIACEAE | | | | | | | | | | | |
| *Sonneratia alba* | Cecidomyiid | 21111 | - | - | - | - | 3 | - | - | - | - |
| STERCULIACEAE | | | | | | | | | | | |
| *Heritiera littoralis* | Cecidomyiid | PY027 | - | - | - | - | - | - | - | 2N | 3R |
| *Melochia umbellata* | Cecidomyiid | 21080 | 1,3 | - | - | - | - | - | - | - | - |
| *Melochia umbellata* | Eriophyoid | 21081 | 1D | 1,2 | 1D | - | 1 | - | - | - | - |
| *Pterospermum diversifolium* | Cecidomyiid | PY033 (Fig.17) | - | - | - | - | - | - | - | - | 4N |
| TILIACEAE | | | | | | | | | | | |
| *Microcos tomentosa* | Eriophyoid | 20493 | - | - | - | - | - | 1 | - | - | 3 |
| URTICACEAE | | | | | | | | | | | |
| *Pipturus argenteus* | Eriophyoid | 20754 | 1,3,4 | 1,3,4 | - | - | 1,3 | 1,3 | - | - | - |
| *Pipturus argenteus* | Thysanoptera | 20267 | - | - | - | - | 1,3 | 1 | - | - | - |
| *Poikilospermum suaveolens* | Cecidomyiid | PY028 (Fig.7) | - | - | - | - | 3N | - | - | - | - |
| *Villebrunea rubescens* | Eriophyoid | 20763 | 1 | - | - | - | - | - | - | - | - |
| *Villebrunea rubescens* | Eriophyoid | 20764 | 1 | - | - | - | 1 | 1 | - | - | - |
| VERBENACEAE | | | | | | | | | | | |
| *Avicennia marina* | Cecidomyiid | 20074 | - | - | - | - | 1,3 | 1 | - | - | - |
| *Avicennia marina* | Cecidomyiid | 20075 | - | - | - | - | 1,3 | 1 | - | - | - |
| *Callicarpa albida* | Eriophyoid | 20234 | - | - | - | - | - | 1,3 | - | - | - |
| *Callicarpa albida* | Eriophyoid | 20099 | - | - | - | - | - | 1,3 | 3 | - | - |
| *Clerodendrum inerme* | Cecidomyiid | 20249 | 3 | 1,3 | 1D | 3 | - | - | 3 | - | - |
| *Premna corymbosa* | Eriophyoid | 20612 | 1 | 3 | - | - | 1,3 | 1 | - | - | - |
| *Premna corymbosa* | Eriophyoid | 21262 | 1,3 | 1,2 | 2,3 | 2,3 | 1,3 | 1,3 | 3 | - | 3 |
| *Premna tomentosa* | Eriophyoid | 21264 | - | - | - | - | - | 1,3 | - | - | - |
| *Vitex pubescens* | Eriophyoid | 20603 | - | - | - | - | 1,3 | 1 | - | - | - |
| VITACEAE | | | | | | | | | | | |
| *Cayratia trifolia* | Cecidomyiid | 21053 | 2,4 | 3 | 3 | - | 1,3 | 1 | 3 | - | - |
| *Cayratia trifolia* | Aphidoid | 21056 | - | - | - | - | 3 | - | - | - | - |
| *Tetrastigma lanceolarium* | Cecidomyiid | 21040 | 3 | - | - | - | 3 | - | 3 | - | - |

Gall numbers are quoted from Docters van Leeuwen-Reijnvaan and Doctors van Leeuwen (1926), except those with PY, which were newly found by TP and JY in the second, third, and fourth expeditions. '(1924)' indicates galls collected in 1924 by Docters van Leeuwen (1936).
The galls with the PY numbers, 001, 002, 008, 010, 014, 015, 016, 026, 027, and 029, were recorded and illustrated in Yukawa and Partomihardjo (1997).
Numerals 1, 2, 3, and 4 indicate, respectively, that the gall was found in the first (the 1920s), second (1982), third (1991-1993), and fourth expedition (2000).
D: recorded by Dammerman, R: recorded by us, for the first time, in that area, N: newly found by us from Indonesia.
South Sumatra includes Lampung and its adjacent areas

**Table 3.** Number of sorts of arthropod gall found on the Krakatau Islands in different field surveys and relative abundance of galls among different taxonomic groups of gall inducers.

| Group of gall inducers | 1919-1922[1)] | (%) | 1982[2)] | (%) | 1991-1993 | (%) | 2000 | (%) | Accumulation from 1982 to 2000 (%)[3)] | |
|---|---|---|---|---|---|---|---|---|---|---|
| Thysanoptera | 1 | (1.6) | 0 | | 1 | (2.2) | 1 | (4.5) | 2 | (3.8) |
| Psylloidea | 3 | (4.8) | 1 | (6.7) | 5 | (11.1) | 1 | (4.5) | 5 | (9.6) |
| Aphidoidea | 5 | (7.9) | 0 | | 0 | | 0 | | 0 | |
| Coccoidea | 3 | (4.8) | 0 | | 1 | (2.2) | 0 | | 1 | (1.9) |
| Hymenoptera | 0 | | 0 | | 1 | (2.2) | 0 | | 1 | (1.9) |
| Cecidomyiidae | 18 | (28.6) | 5 | (33.3) | 18 | (40.0) | 9 | (40.9) | 20 | (38.5) |
| Tephritidae[4)] | 1 | (1.6) | 0 | | 0 | | 1 | (4.5) | 1 | (1.9) |
| Lepidoptera | 1 | (1.6) | 1 | (6.7) | 1 | (2.2) | 1 | (4.5) | 1 | (1.9) |
| Eriophyoidea | 31 | (49.2) | 8 | (53.3) | 18 | (40.0) | 9 | (40.9) | 21 | (40.4) |
| Total | 63 | (100) | 15 | (100) | 45 | (100) | 22 | (100) | 52 | (100) |

[1)] Docters van Leeuwen (1920, 1922, 1936), [2)] Yukawa and Partomihardjo (1997)
[3)] Excluding overlapping of gall sorts in the field surveys from 1982 to 2000
[4)] Recorded as Diptera, but probably Tephritidae

while the remaining nine were not recorded from the islands in the 1991-93 surveys. Three sorts of cecidomyiid gall were found for the first time from Indonesia (Figs. 3, 9 & 13). A total of 28 sorts of gall were collected from Carita from 1982 to 2000 (Table 4).

**Collection of galls from Peucang, Panaitan, and Ujung Kulon**

In the 1982 survey, a total of 12 different sorts of gall were found on Peucang and Panaitan (Fig. 1), and only three of them were common to the Krakatau Islands (Yukawa & Partomihardjo, 1997). Three of the 12 sorts were recorded from Peucang and 10 from Panaitan, including one that was common to both islands. In 1992, nine additional sorts of gall were found on Peucang (Table 2).

We visited Ujung Kulon (Fig. 1) in 1992 and 2000. A total of 27 different sorts of gall were found in the beach and inland forests, including 16 cecidomyiid, seven eriophyoid, one thysanopteran, one coccoid, one psylloid and one lepidopteran galls (Table 2). Among them, 11 were found on Peucang and Panaitan in 1982 and 1992, and 13 were on the Krakataus in 1982, 1991-1993, and 2000, while five were recorded for the first time from Indonesia (Figs. 3, 6, 14, 15 & 17). A total of 21 and 27 sorts of gall were collected from Peucang-Panaitan and Ujung Kulon, respectively, from 1982 to 2000 (Table 4).

**Collection of galls from Sebesi, Sebuku, and South Sumatra**

A total of 70 different sorts of gall were found in the beach and inland forests in the 1993 expedition to Sebesi, Sebuku, and Lampung and its adjacent areas of South Sumatra (Fig. 1). They include 28 eriophyoid, 23 cecidomyiid, six thysanopteran, six psylloid, three lepidopteran, two aphidoid, one coccoid, and one dipteran galls. Of these, 65 sorts were found on Sebesi and Sebuku, and 34 in South Sumatra (Table 2). Among the 70 from Sebesi, Sebuku, and South Sumatra, 43 sorts of gall were not found on the Krakatau Islands in 1982-2000, while 27 were found on the Krakataus. A total of 72 and 71 sorts of gall were collected from Sebesi-Sebuku and South Sumatra, respectively, from the 1920s to 2000 (Table 4).

**Comparison of galling-arthropod fauna on the Krakataus between 1919-1922 and 1982-2000**

The total number of gall sorts increased markedly from only two eriophyoid galls that had been collected by Dutch botanists in 1896-1906 (Docters van Leeuwen, 1920), to 63 during the first period from 1919 to 1922 (Table 3). Field surveys in 1982 and 2000 were less intensive than in 1991-1993, the respective numbers of gall sorts were not enough to compare with those in the other periods. Then, collection records from 1982 to 2000 were summed. Nevertheless, gall sorts decreased from 63 in the first period to 52 in 1982-2000, although the number of taxonomic groups did not change (Table 3). Such decline in gall sorts was caused mainly by a decrease in eriophyoid, aphidoid, and coccoid galls, which exceeded an increase in cecidomyiid, psylloid, and thysanopteran galls.

**Relative abundance and disharmony**

A total of 1536 sorts of arthropod galls have been recorded from Indonesia, mainly from Java and Sumatra (Docters van Leeuwen-Reijnvaan & Docters van Leeuwen, 1926). The total number of sorts of gall found on the Krakatau Islands was 63 in 1919-1922 and 52 in 1982-2000, being only 4.1% and 3.4% of the total number in Indonesia, respectively (Table 5). There was no significant difference between the percentages in 1919-1922 and 1982-2000.

The number of taxonomic groups of galling-arthropod was nine on the Krakatau Islands, compared to 11 in the whole of Indonesia (Table 5). In 1919-1922, the ratio of gall sorts on the Krakataus to that in the whole of Indonesia (K/I ratio) varied with taxonomic groups (Table 5). The ratio was lower in Thysanoptera than in Aphidoidea, Coccoidea, Tephritidae, and Eriophyoidea, and it was higher in Eriophyoidea than in Psylloidea and Cecidomyiidae. In 1919-1922, the relative abundance among different taxonomic groups on the Krakataus was significantly different from that of whole Indonesia (chi-square test with Yates correction, $\chi^2$=21.46, *df*=11,

**Table 4.** Accumulated number of sorts of arthropod gall found from the 1920s to 2000 in adjacent areas of the Krakatau Islands.

| Group of gall inducers | Sebesi & Sebuku | South Sumatra | Carita | Panaitan & Peucang | Ujung Kulon |
|---|---|---|---|---|---|
| Thysanoptera | 7 | 5 | 2 | 1 | 1 |
| Psylloidea | 7 | 5 | 0 | 4 | 1 |
| Aphidoidea | 2 | 1 | 0 | 0 | 0 |
| Coccoidea | 1 | 2 | 1 | 0 | 1 |
| Hymenoptera | 0 | 1 | 0 | 0 | 0 |
| Cecidomyiidae | 24 | 21 | 14 | 12 | 16 |
| Tephritidae[1)] | 1 | 1 | 1 | 0 | 0 |
| Lepidoptera | 3 | 2 | 2 | 1 | 1 |
| Eriophyoidea | 27 | 32 | 8 | 3 | 7 |
| Unknown | 0 | 1 | 0 | 0 | 0 |
| Total | 72 | 71 | 28 | 21 | 27 |

[1)] Recorded as Diptera, but probably Tephritidae

**Table 5.** Comparison between different taxonomic groups in the sorts of arthropod gall found on the Krakataus in 1919–1922 and 1982–2000, and their ratio to the sorts of gall recorded from the whole of Indonesia[1)].

| Taxonomic Group | Indonesia | Krakataus 1919-1922 | K/I ( % ) | Krakataus 1982-2000 | K/I ( % ) |
|---|---|---|---|---|---|
| Thysanoptera | 147 | 1 | 0.7 | 2 | 1.4 |
| Psylloidea | 145 | 3 | 2.1 | 5 | 3.4 |
| Aphidoidea | 66 | 5 | 7.6 | 0 | 0.0 |
| Coccoidea | 47 | 3 | 6.4 | 1 | 2.1 |
| Heteroptera | 11 | 0 | -- | 0 | -- |
| Coleoptera | 24 | 0 | -- | 0 | -- |
| Hymenoptera | 28 | 0 | -- | 1 | 3.6 |
| Cecidomyiidae | 600 | 18 | 3.0 | 20 | 3.3 |
| Tephritidae[2)] | 12 | 1 | 8.3 | 1 | 8.3 |
| Lepidoptera | 66 | 1 | 1.5 | 1 | 1.5 |
| Eriophyoidea | 378 | 31 | 8.2 | 21 | 5.6 |
| Unclassified | 12 | -- | -- | -- | -- |
| Total | 1536 | 63 | 4.1 | 52 | 3.4 |

[1)] Data from Docters van Leeuwen-Reijnvaan and Docters van Leeuwen (1926).
[2)] Recorded as Diptera, but probably Tephritidae.

$P<0.05$). In 1982-2000, the K/I ratio also varied with taxonomic groups, being higher in Eriophyoidea than in Thysanoptera, but the relative abundance on the Krakataus was not significantly different from that of whole Indonesia (chi-square test with Yates correction, $\chi^2=7.59$, $df=11$, $P>0.05$).

**Descriptions of arthropod galls new to Indonesia**

During the surveys in 1991-1993 and 2000, we found 16 sorts of arthropod gall that are new to Indonesia (Table 2). In order to provide information for future identification, the new galls are briefly described below together with photographs and illustrations (Figs. 2-17).

*Gall no. PY003*. Small pit galls induced by an eriophyoid on the leaf of *Garcinia dioica* (Clusiaceae); diameter 2-5mm, height 2-4mm; many mites per gall (Fig. 2).

*Gall no. PY004*. Leaf galls induced by a cecidomyiid on *Terminalia catappa* (Combretaceae); tiny, very thin spots with reddish tinge; diameter 2-5mm; one larva per gall (Fig. 3).

*Gall no. PY005*. Leaf galls induced by an eriophyoid on *Antidesma montanum* (Euphorbiaceae); diameter 5-7mm, thickness 2-4mm; many mites per gall (Fig. 8).

*Gall no. PY006*. Leaf galls induced by a cecidomyiid on *Antidesma* sp. (Euphorbiaceae); tube like swelling standing on the under surface of leaf; diameter 3-5mm, height 8-13mm; one larva per gall (Fig. 9).

*Gall no. PY007*. Leaf galls induced by a cecidomyiid on *Breynia cernua* (Euphorbiaceae); tube like swelling gradually narrower distally, standing at a slant on the under surface of leaf; maximum diameter 3-6mm, height 8-15 mm; one larva per gall (Fig. 10).

*Gall no. PY009*. Leaf galls induced by an eriophyoid on *Glochidion borneensis* (Euphorbiaceae); subglobular or sometimes irregular swellings on the upper surface of leaf; maximum diameter 2-5mm, thickness 2-5mm; many mites per gall (Fig. 11).

*Gall no. PY011*. Irregular leaf margin role galls induced by an eriophyoid on *Hernandia peltata* (Hernandiaceae) (Fig. 12).

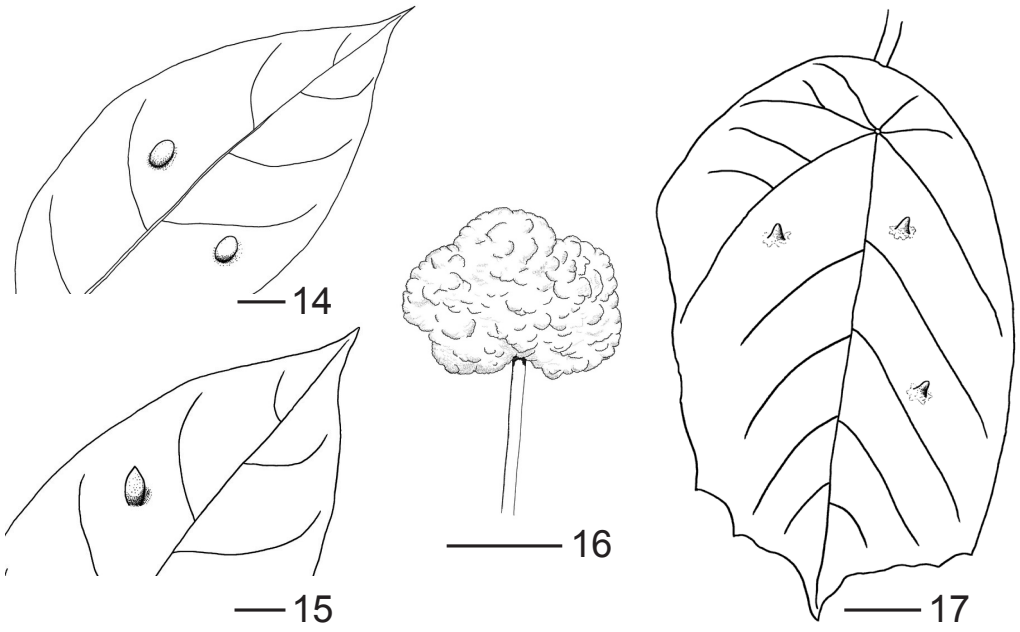
*Gall no. PY013*. Globular leaf galls induced by a cecidomyiid on *Intsia bijuga* (Fabaceae); diameter 4-7mm, thickness 4-6mm; one larva per gall (Fig. 13).

*Gall no. PY021*. Small pit galls induced by an eriophyoid on the leaf of *Syzygium polyanthum* (Myrtaceae); long axis 5-7mm, short axis 3-4mm; many mites per gall (Fig. 4).

*Gall no. PY023*. Leaf galls induced by a cecidomyiid on *Anthocephalus chinensis* (Rubiaceae); thin, feeble swelling with irregular shape; sometimes individual galls coalesced; one larva per gall (Fig. 5).

*Gall no. PY025*. Subglobular stem gall induced by a cecidomyiid on *Luvunga* sp. (Rutaceae); maximum diameter about 18mm, height about 20mm; more than one larva per gall (Fig. 6).

*Gall no. PY028*. Ellipsoidal galls induced by a




**Figs. 14-17.** Arthropod galls new to Indonesia. 14, Cecidomyiid galls on *Derris heterophylla* (Fabaceae), Gall no. PY030; 15, Cecidomyiid gall on *Derris heterophylla* (Fabaceae), Gall no. PY031; 16, Cecidomyiid gall on *Neonauclea calycina* (Rubiaceae), Gall no. PY032; 17, Cecidomyiid galls on *Pterospermum diversifolium* (Sterculiaceae), Gall no. PY033. Scale bar: 10mm.

cecidomyiid on *Poikilospermum suaveolens* (Urticaceae), along lateral veins on the under surface of leaf, with long axis 4-9mm, short axis 2-6mm; one larva per gall (Fig. 7).

*Gall no. PY030*. Leaf galls induced by a cecidomyiid on *Derris heterophylla* (Fabaceae); swelling of both sides; diameter about 6.1mm, thickness about1.2 mm; one larva per gall (Fig. 14).

*Gall no. PY031*. Leaf gall induced by a cecidomyiid on *Derris heterophylla* (Fabaceae); acorn shaped swelling standing on the upper surface of leaf; diameter about 4.2mm, height about 7.4mm; one larva per gall (Fig. 15).

*Gall no. PY032*. Fruit gall induced by a cecidomyiid on *Neonauclea calycina* (Rubiaceae); cauliflower like swelling with diameter about 18mm, height about 18 mm; three whitish larva were found in a gall (Fig. 16).

*Gall no. PY033*. Leaf galls induced by a cecidomyiid on *Pterospermum diversifolium* (Sterculiaceae); conical swelling on the upper or under surface of leaf; maximum diameter about 2.0mm, height about 4.8mm; one larva per gall (Fig. 17).

## Discussion

### Significance of collecting data on the Krakataus and in adjacent areas

Arthropod galls are appropriate targets for comparative faunistic studies. Galls are conspicuous and enable us to obtain faunistic data easily because their inhabitants are sedentary, and evidence of gall induction exists long after the event. In addition, many gall-inducing arthropods are monophagous or oligophagous and the appearance and structure of galls are specific to gall-inducing species in many instances (e.g., Yukawa & Masuda, 1996; Yukawa & Rohfritsch, 2005). When gall inducers have been described, they are frequently identified to the species level based on host plant information and the appearance and structure of galls. In the tropics, species identification is limited at least to the family level because most gall inducers have not been described. Nevertheless, we can assume that different galls are induced by different species in most cases.

We enumerated all arthropod galls that had been found on the Krakatau Islands and in adjacent areas after the 1883 eruption until 2000. This enumeration provides us with fundamental information for further faunistic studies to trace the recolonization of the Krakatau Islands by gall-inducing arthropods in relation to vegetation succession. Collecting data in the adjacent areas are useful to discuss the derivation and disharmony of gall-inducing arthropod fauna of the Krakataus.

### Relative abundance and disharmony

The total number of sorts of gall found on the Krakatau Islands was 63 in 1919-1922 and 52 in 1982-2000, being only 4.1% and 3.4% of the number for the whole of Indonesia, respectively (Table 5). Probably due to different dispersal abilities, these percentages are smaller than the 6.7% and 5.7% of butterfly species recorded from Java and Sumatra, respectively (Yukawa, 1984a). When more faunistic information on galling-arthropods is gathered from Indonesia in the future, their percentage will decrease.

Faunas of oceanic islands are frequently disharmonious (e.g., Carlquist, 1974; MacArthur, 1972), and remarkable examples of faunistic disharmony were found on the Krakataus for aculeate Hymenoptera (Yamane, 1983) and termites (Abe, 1984). As to the fauna of gall-inducing arthropods on the Krakatau Islands, disharmony was evident in 1919-1922 with the relatively high K/I ratio in eriophyoid galls compared to the other groups (Table 5). Disharmony is referable chiefly to different dispersal means of arthropod groups. Eriophyoids would be able to disperse more easily with wind than other groups. In addition, synchronization of emergence or oviposition seasons with host plant phenology, such as time of shoot growth or flowering season, is also an important factor in the establishment of galling-arthropod populations (Yukawa, 2000). Particularly for arthropods that induce flower and fruit galls, synchronization is more difficult, because the available season of host plant organ is limited. In contrast, it is easier for leaf or bud gall inducers because shoots are produced almost continuously in the tropics. Most eriophyoids are leaf or bud gall inducers and complete one generation within a relatively short period of time (Lindquist *et al*., 1996). Thus, eriophyoids might have more opportunities to colonize the islands than the other gall-inducing arthropods (Table 5). In 1982-2000, however, differences in the percentage between Eriophyoidea and groups other than Thysanoptera were reduced (Table 5). As a result, disharmony became obscure in 1982-2000 following ecological succession.

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