Lichen diversity in geothermal area of Kamojang, Bandung, West Java, Indonesia and its potential for medicines and dyes

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1Department of Biology, Faculty of Mathematics and Natural Sciences, Padjadjaran University. Jl. Raya Bandung-Sumedang Km 21, Jatinangor, Sumedang 45363, West Java, Indonesia. *Email: rp2010rikkyo@gmail.com; ruhyat.partasasmita@unpad.ac.id.
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Abstract. Kusmoro J, Noer IS, Jatnika MF, Permatasari RE, Partasasmita R. 2018. Lichen diversity in geothermal area of Kamojang, Bandung, West Java, Indonesia and its potential for medicines and dyes. Biodiversitas 19: 2335-2343. The study of lichen diversity in Kamojang, West Java was conducted by survey in geothermal field area following the line transect 6 km along to the East, North West and south from the Power House of Geothermal Power Plant. The lichen samples were taken from bark, soil, and stone. Lichen identification was done by morphological, anatomy and chemical analysis. Dyes potency of Parmotrema and Usnea test using ammoniac fermentation was done in Plant Taxonomy Laboratory of Department Biology, Faculty of Mathematics and Natural Sciences, University of Padjadjaran. The survey has successfully collected 133 species of lichens, belong to 62 genera and 17 families. Parmeliaceae was found as dominant groups, consisting of 33 species and other co-dominant groups are Graphidiaceae and Lobariaceae with 24 species and 8 species, respectively. Most lichens in Kamojang geothermal area belong to Ascomycetes, only one Basidiomycetes such as Dictyonema sericeum (Sw.) which found at Kawah Manuk (Manuk crater) area. The rare species of lichens such as Usnea longissima Ach, was found at Pine forest in Arboretum 6 km south of Powerhouse of Kamojang geothermal. Chemical analysis and literature study for Lichenic acid contains was done and generally, atranorin, usnic acid, barbatic and lecanoric acid was found in lichens samples. Ammoniac fermentation result showed that Parmotrema tinctorum produced brownish red, red and purple, which occurred within 1 week to 5 weeks after fermentation. While Usnea produced variety of brown color, which occurred within 5 days up to 4 weeks after fermentation. Lichen species containing some medical properties are Bulbothrix, Cladonia and Usnea. While lichens having dyes properties are Hypogymnia, Lobaria, Peligera, Usnea, and Parmotrema.

Keywords: Dye, fermentation, Kamojang, lichen, lichenic acid, medicine

INTRODUCTION

Kamojang Geothermal Area, which is recognized as mountain tropical rain forest, is one of Natural Conservation and Tourism forest in West Java. It is well known as hilly area with beautiful view. It has crater and hot spring water for medical purposes and the source of Geothermal Energy. Kamojang is also natural forest with high diversity of plant, mosses, and lichens. Lichens have the symbiotic phenotype with nutritious fungi and are also associated with algae (Noer 2013; Ardelean et al. 2015; Balabanova et al. 2014; Onuț-Brännström 2017). These are an outstanding group, exploiting a wide range of habitats throughout the world and dominating about 8% of terrestrial ecosystems. They have a varied chemical contains, which are useful as medicines (Noer et al. 2013 Onuṭ-Brännström 2017). Lichens contain secondary compounds that are abundant in most lichen thalli. Different lichens produce a wide variety of metabolite compounds, most of which are unique to lichens (Noer et al. 2006). It is suspected that almost 50% of species of lichens have antibiotic properties (Vartia 1973; Malhotra et al. 2007; Crawford 2015). Lichen compounds have been found to act as anti-tumor agents, antibiotics, and anti-inflammatoryatories (Bayir et al. 2006; Rezanka and Dembitsky 2006; Bessadóttir 2014). Some of the most widely studied lichen compounds are usnic acid, vulpinic acid, atranorin, and protolichesterinic acid (Asahina and Shibata 2006; Bessadóttir 2014). Some of the most widely studied lichen genera. Usnic acid is found in large quantities in Usnea spp., as well as in several other lichen genera.

It is well known that a long time ago lichens have been widely used by people such as for medicine, pollution bioindicator, perfume, decoration, and dye (Ingolfsdottir et al. 2002; Kaasalainen 2012; Vicol 2016; Tarasova et al. 2017). Lichens as natural dye sources have been used since long ago. The purple color (orchil) was firstly reported from Roccella spp. through ammoniac fermentation. The purple color of Roccella had historic importance as the “Royal Purple” in Europe before 19th century and was not been used anymore when synthetic dye substance was found.

Genus Parmotrema is foliose lichen that belongs to Parmeliaceae group. The genus characteristic is the absence of reticular maculate and pseudocyphella. An erhizinate marginal zone of the lower surface is more than 1 mm
(Noer 2013). Several Parmotrema species from Himalayas can produce colors with the help of ammonia fermentation method (Shukla et al. 2014). Livelihoods of natural dyes from lichen Parmotrema are very interesting and will be important in the use of dyes that are environmentally friendly in industry in order to reduce the pollution of water/river by dyes from industry.

The diversity of lichen in this area has been reported by Noer et al. (2006) and Noer and Rani (2007), but only one species has been used as medicine i.e. Usnea barbata, no mentioning about the species has potential for dyes. The continuous survey was done in this area to collect some species, which has potential use for medicine and dyes. Our purpose from the study were: (i) to assess the diversity and distribution of lichens in Kamojang Geothermal Area, (ii) to indicate several lichens, which could potentially be used as medicine and dyes, (iii) to analyse the lichens acids (secondary metabolites) in potential lichen genus for medicine and dyes, (iv) to monitor color produced by Parmotrema and Usnea using ammonia fermentation.

**MATERIALS AND METHODS**

**Study area**

Kamojang area belonging to mountain tropical forest is located at Laksana village, Ibun Sub-district, Bandung District, West Java, approximately 45 km southeast of Bandung City. The research area is located on latitude of 7°8′23.13” S 107°47′10.36” E to 7°00′00” S 107°00′00” E with altitude 1300-1700 above sea level (Figure 1). This exploration was held from April 2016 to August 2017.

The microclimate was recorded that the range of temperature ranging from 18°C to 26,26°C, while the humidity was from 56.13% to 78% and light intensity had 2387 lux to 6748 lux.

**Sampling**

The research material was lichen specimens from Kamojang geothermal area. The lichen collection in the study area was taken with survey method at 6 km transects towards four cardinal points (N, E, W, S) from the Power House of Geothermal Power Plant as the center point. The sample was taken from bark along the road and stone in the study area. Dry specimens were stored in paper bags and wet specimens were needed to be dried first to prevent molding. The specimens were then moistened, pressed flatly between boards, dried and placed on paper packets (3 x 4 inches) or on small boxes.

**Lichen identification**

Identification of lichens was conducted by: (i) Determine the growth form; foliose, squamulose, crustose or fructocose. These characters are important in separating...
genera. (ii) Checking the presence of soredia or isidia with a hand lens. These are by far the two most important characters used in identifying lichens at the species level and must be recognized without any doubt. Presence of cilia and the condition of lower side should also be noted. (iii) Chemical test in lichen was used i.e. color test and crystal test.

A color test was made simply by applying a drop of reagent on the thallus surface or exposed medulla. If the test is positive, there will be a rapid color change, usually red or yellow; if it is negative nothing will happen. Three different reagents were used, i.e., calcium hypochlorite (bleaching powder, abbreviated C), potassium hydroxide (caustic lye abbreviated K or KOH) and paraphenylenediamine (P). The K+ yellow test caused by atronin.

In a crystal test, the acid was dissolved from small fragments of thallus with acetone, and the remainder of crude residue was recrystallized from various reagents on a microscope slide. The reagents in common use are abbreviated as follows and mixed in the volume ratios, including: (i) G.E. (glycerin-acetic acid, 3:1), (ii) G.A.W. (glycerin-95% alcohol-water, 1:1:1), (iii) G.A. o-T (glycerin-alcohol-o-toluidine, 2:2:1), (iii) G.A.An (glycerine-alcohol-aniline, 2:2:1), (iv) G.A.Q. (glycerine-alcohol-quinoline, 2:2:1).

Fragment of the lichen thallus was heaped in the center of microscope slide, and drops of acetone was added several times. After the acetone evaporates, there should be whitish or yellowish powdery ring of residue. The thallus fragments were carefully brushed away, a small drop of reagents put on a coverslip, and the coverslip placed over the residue. The slide is gently heated over an alcohol lamp, low Bunsen flame until bubbles just began to form. On cooling a few minutes, crystal began to form first around the undissolved residue, later at the perimeter of the coverslip. Shape and of the crystals were determined under a low-power microscope (100x), and the crystal identified by comparison with photographs.

Lichen dyes

For dyeing with lichens, three different methods were used depending to the desired color: (i) BWM-simply means "boil water method". (ii) AM-"ammonia method" and (iii) POD stand for "Photo Oxidizing Dyes". In a preliminary study, the ammonia method was used with the detailed method as follow: (i) The lichens Parmotrema tinctorum were collected from clean areas in Kamojang and then are air-dried and subjected for extra Ammoniac extraction. (ii) Six gram of thallus lichens samples were put into a glass mason jar with an airtight lid. To which 100 milliliter (ml) of 10% ammonia (NH3) and 100 ml distilled water was added. (iii) Close the lid and shake vigorously. Within minutes the color shift will arise. (iv) The jar then labeled with the date, location collected and the name of species. (v) The mixed solution was fermented in the dark for 4 weeks and allowed to stand for three months and every day the jar was shaken. (vi) The monitoring of color extracts was recorded during fermentation for each week.

RESULTS AND DISCUSSION

Lichen diversity

Generally, lichens in Kamojang Geothermal areas have a high diversity consisting of more than 133 species belong to 62 genera and 17 families. Families of Parmeliaceae found in this study was dominant consisting of 33 species and the co-dominant species such as Graphidaceae and Lobariaceae with 24 species and 8 species, respectively (Table 1).

Most lichen fungi obtained in this study belong to Ascomycetes, but the fan-shaped of this lichens is a basidionycteous lichen with cyanobacterial photobionts. It is Dictyomena sericium (Sw.) Berk (Figure 2), which was found at Kawah Manuk area. Dictyomena is a symbiosis between a basidiomycete fungus and ascytonematoid cyanobacteria, resulted in both a basidiolichen and a cyanolichen, which is a very rare combination.

The protected species as Usnea longissima Ach. could only found in cleanest area at pinus forest in Arboretum area which 6 km south of Kamojang Geothermal Power Plant (Figure 2). In an effort to determine the diversity of lichens in Kamojang and to determine the species of lichen that has been utilized as medicine and dyes by the local community we performed inventory, literature study and literature process with the local community.

Lichen biodiversity is often used to assess air quality and ecosystem health within non-urban environment. This survey, in 2017 as a result in Table 1, shown one hundred thirty-three (133) species lichens have been found in Kamojang Geothermal area. But the study has been done in 1983, 1987 and 1988 lichen was found only 53 species (Noer et al. 2013). Compare to those survey, lichen in Kamojang geothermal area more diversity although the Geothermal Power Plan has operation since 1983 and produced SO2 which has been known that doses 0.018 ppm of SO2 will kill lichens (Pearson and Skye 1965; State et al. 2010; Rubio-Salcedo et al. 2017). The amazement Graphis kamojangense was found on Mangifera indica and Toena sureni trees at 0.5 km west and 1.5 km south from Geothermal Power Plan.

The lichenic acid contained in genus of lichens

Components of lichens reacting with certain test chemicals may give color reactions, which could be used in the identification of a species (Figure 3). The phytochemical screening of Usnea showed that beard moss contains alkaloid, steroid, saponin, monoterpenoid, sesquiterpenoid, quinone, and polyphenol (Choudhary et al. 2005; Fazio et al. 2007; Güllüce et al. 2006). The lichenic acid was found dominantly in Usnea are usnic acid and Stictic acid (Cansaran et al. 2006; Bessadòttir 2014). Some lichenic acids was found in several genus from Kamojang Geothermal area such as aceletic acid, atranorin acid, barbatic acid, baeomycesis acid, chloroatranorin acid, diffrafic acid, diploicin acid, divariatic acid, gyrophoric acid, grayanic acid, haematamnolic acid, isousnic acid, lecanoric acid, leucotylin acid, lobaric acid, obtusatic acid, physodalic acid, protocetaric acid, perlatalic acid, retigeric acid, rocellic acid, salazinic acid, stenosporic acid, stictic acid, thiopanic acid and usnic acid.
<table>
<thead>
<tr>
<th>Species</th>
<th>Reproduction</th>
<th>Reagent</th>
<th>Lichen acid</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acarospora</strong> sp.**</td>
<td>Apothecia</td>
<td>-</td>
<td>Norstictic acid, rhizocarpic acid, gyrophoric acids, epanorin acids</td>
</tr>
<tr>
<td><strong>Amandinea punctata</strong> (Hoffm) Coppins &amp; Scheid</td>
<td>-</td>
<td>-</td>
<td>No lichen substances</td>
</tr>
<tr>
<td><strong>Bacidia</strong> sp.**</td>
<td>-</td>
<td>-</td>
<td></td>
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<tr>
<td><strong>Buellia punctata</strong> (Hoffm) A. Massal</td>
<td>Soredia and isidia</td>
<td>-</td>
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<td><strong>Buellia</strong> sp.1**</td>
<td>Soredia and isidia</td>
<td>-</td>
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<tr>
<td><strong>Bulbothrix isidiza</strong> (Nyl.) Hale</td>
<td>Soredia and isidia</td>
<td>GAW</td>
<td>Barbatic acid, consalazinic acid, gyrophoric acid, lobaric acid, salazinic acid, atranorin</td>
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<td><strong>Caloplaca</strong> sp.**</td>
<td>Soredia and isidia</td>
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<tr>
<td><strong>Carbacanthographis marcescens</strong> (Fée) Staiger &amp; Kalb</td>
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<tr>
<td><strong>Cladonia furcata</strong> (Hudson) Schrader</td>
<td>Soredia</td>
<td>GE</td>
<td>Lecanoric acid, fumarprotocetraric acid, atranorin, divaricatic acid</td>
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<td><strong>Cladonia fimbriata</strong> (L.) Fr.</td>
<td>Soredia</td>
<td>GAW</td>
<td>Atranorin</td>
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<td><strong>Cladonia mauritiana</strong> Ahti &amp; J.C David</td>
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<td>-</td>
<td>Sekikatic acid</td>
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<td><strong>Cladonia squamosa</strong> Hoffm.</td>
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<td>-</td>
<td>Salazinic acid, gyrophoric acid, usnic acid, atranorin</td>
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<td><strong>Cocccocarpia palmicola</strong> (Spreng.) L. Arvidss. &amp; Gall.</td>
<td>Soredia and isidia</td>
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<td><strong>Collema nigrescens</strong> (Hudson) DC.</td>
<td>-</td>
<td>-</td>
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<tr>
<td><strong>Collema javanicum</strong> (Müll.Arg.) Zahlbr</td>
<td>Soredia</td>
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<td>Secondary metabolites: none detected</td>
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<td><strong>Collema pulcellum</strong> Ach.</td>
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<td>-</td>
<td>Secondary metabolites: none detected</td>
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<td><strong>Coccocarpia</strong> sp.**</td>
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<td><strong>Cryptothecia striata</strong> Thor</td>
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<td><strong>Cryptothecia</strong> sp.</td>
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<td><strong>Chrysothrix</strong> sp.**</td>
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<td><strong>Dibaeis</strong> sp.**</td>
<td>Soredia</td>
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<td><strong>Dictyonema sericeum</strong> (Swartz) Berk, Diorygma junghuhnii (Mont. V. d Busch) Kalb, Staiger &amp; Elix</td>
<td>Soredia</td>
<td>GE</td>
<td>Usnic acid</td>
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<td><strong>Dirinaria applanata</strong> (Fee) D. A. Awasthi</td>
<td>Isidia and soredia</td>
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<td>Atranorin, divaricatic acid</td>
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<td><strong>Dirinaria</strong> sp.**</td>
<td>Isidia and soredia</td>
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<td><strong>Dyplolabia</strong> sp.**</td>
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<td><strong>Flavoparmelia</strong> sp.**</td>
<td>Soredia</td>
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<td><strong>Flavopunctelia</strong> sp.**</td>
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<td><strong>Flavopunticula soredica</strong> (Nyl.) Hale</td>
<td>Soredia</td>
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<td><strong>Graphis</strong> sp. 1**</td>
<td>Lirel</td>
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<td>No lichen substances</td>
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<tr>
<td><strong>Graphis elongate</strong> Vain.**</td>
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<td>-</td>
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<td><strong>Graphis immersella</strong> Müll.Arg.</td>
<td>Lirel</td>
<td>-</td>
<td>Stictic acid</td>
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<tr>
<td><strong>Graphis kamojiangense</strong> Jatnika &amp; Noer</td>
<td>Lirel</td>
<td>-</td>
<td></td>
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<tr>
<td><strong>Graphis librata</strong> C. Knight</td>
<td>Lirel</td>
<td>-</td>
<td>Norstictic acid</td>
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<td><strong>Graphis longula</strong> Kremp.</td>
<td>Lirel</td>
<td>-</td>
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<td><strong>Graphis rhizocola</strong> (Fée) Lücking &amp; Chaves</td>
<td>Lirel</td>
<td>-</td>
<td>Glyrophoric acid</td>
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<td><strong>Graphis rustica</strong> Kremp.</td>
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<td><strong>Graphis</strong> sp. 2**</td>
<td>Lirel</td>
<td>-</td>
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<td><strong>Graphis</strong> sp. 3**</td>
<td>Lirel</td>
<td>-</td>
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<td><strong>Haeatomma persoonii</strong> (Fee) A. Massal</td>
<td>Apothecia</td>
<td>GE</td>
<td>Atranorin, Norstictic acid chloroatranorin; zeorin, salazinic acid</td>
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<tr>
<td><strong>Haeatomma accolens</strong> (Stirton) Hillm.</td>
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<td>GE</td>
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<td><strong>Heteroderma japonica</strong> (Sato) Swinscow &amp; Krog</td>
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<td>GE, GAW</td>
<td>Atranorin, Lobaric acid, consalazinic acid, gyrophoric acid, sericolic acid, atranorin</td>
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<td><strong>Heteroderma leuconela</strong> (L.) Poelt</td>
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<td>Salazinic acid</td>
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<td><strong>Heteroderma rugulosa</strong> (Kurck.) Wetmore</td>
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<td><strong>Hypogymnia</strong> sp. 1**</td>
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<td><strong>Hypogymnia</strong> sp. 2**</td>
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<td>Atranorin, physodic acid</td>
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<td><strong>Hypotrachyna</strong> sp.**</td>
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<td><strong>Lecanora argentata</strong> (Ach.) Malme</td>
<td>Apothecia</td>
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<tr>
<td><strong>Lecanora helva</strong> Stizenb</td>
<td>-</td>
<td>-</td>
<td>Atranorin dan asam chloroatranorin</td>
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<td><strong>Lecanora leprosa</strong> Fee</td>
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<td>Apothecia</td>
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<td>Atranorin</td>
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<tr>
<td><strong>Lecanora</strong> sp.2**</td>
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<td><strong>Lepraria lobificans</strong> (Nyl.)</td>
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<tr>
<td><strong>Leptogium cyanescens</strong> (Rabenh.)</td>
<td>Lobus and soredia</td>
<td>-</td>
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</table>
Letharia vulpina (L.) Hue
Lobaria pulmonaria L. (Hoffm.) Lobus and apothecia - - Stictic Acid, desmethyl stictic acid, gyrophoric acid, tenuiorin, constictic acid, norstictic acid, peristictic acid, and methylnorstictic acid
Lobaria oregana (Tuck.) Müll.Arg. Lobus and soredia - Methylstictic acid, crypto-stictic acid, cryptostic-tinolide.
Lobaria subinterversans (Gyeln.) Lobus and soredia - -
Lobaria scrobicularia (Scop.) P. Gaertn. Lobus - -
Maronina sp. - - -
Malcomiella sp. Apothecia GE Barbatic acid
Megaloスポラ sp. 1 Apothecia GAW Zeorin acid
Mycomicrothelis sp. - - -
Megaloスポラ sp. Soredia - -
Menegazzia sp. Soredia - -
Micareая pra sinis Fr. - - -
Niebla sp. 1 Pseudothecia GAW Barbatic acid, Stictic acid
Nephroma sp. Isidia and soredia - -
Ocelullaria sp. - - -
Parmelia sp. 1 Soredia and isidia - Atranorin, Lecanoric acid
Parmelia sp. 2 Soredia and isidia - Atranorin
Parmelia sp. 3 Soredia and isidia - Atranorin
Parmelieia sp. 1 Apothecia - -
Parmelieia sp. 1 Soredia and isidia - Atranorin, Lecanoric acid
Parmelia sp. 2 Soredia and isidia - Atranorin
Parmelia sp. 3 Soredia and isidia - Atranorin
Parmelieia sp. 2 Apothecia - -
Parmeliopsis sp. Soredia and isidia - -
Parmotrema cristiferum (Taylor) Hale Soredia - Atranorin and chloroatranorin; salazinic acid and consalazinic acids
Parmotrema dilatatum (Vain.) Hale soredia - -
Parmotrema mesotropum (Müll.Arg.) Hale Cilia and soredia - -
Parmotrema reticulatum (Taylor) M. Choisy Soredia Atranorin, chloroatranorin, salazinic acid and consalazinic acids
Parmotrema tinctorum (Delise ex Nyl) Hale - - Lecanoric acid, atranorin
Parmotrema sp. 1 Cilia and soredia - Salazinic acid, Atranorin, Lecanoric acid
Pannaria sp. 1 - - -
Pannaria sp. 2 - - -
Peltigera sp. 1 Lobus and soredia - -
Peltigera polydactylon (Necker) Hopf Lobus and soredia - Tenuiorin, dolichorhizin, zeo-rin, methyl gyrophate, gyrophoric acid,
Peltigera praetextata (Florke ex Sommerf.) Zopf Lobus and soredia - -
Pertusaria sp. 1 Perithecia - Stictic acid
Pertusaria cicatricose Müll.Arg. Perithecia - Stictic acid, constictic acid
Pertusaria texana Müll.Arg. Perithecia - -
Pertusaria sp. 2 Perithecia - -
Pertusaria sp. 3 Perithecia - -
Phaeographis adinoconspicua (Féc) Müll.Arg. Lirel -
Phaeographis dendritica (Ach.) Müll.Arg. Lirel -
Phaeographis dendroides (Leight.) Müll.Arg. Lirel -
Phaeographis intricans Nyl. Lirel -
Phaeographis lobata (Eschw.) Müll.Arg. Lirel -
Phaeographis schizoloma (Müll.Arg.) Lirel -
Phaeographis sp. Lirel GE Barbatic
Physcia sp. Soredia and isidia GAW Lecanoric acid
Pseudocyphellaria aurata (Ach.) Vain. Lobus GAW Gyrophoric acid
Pseudocyphellaria crocata (L.) Vain. Lobus GAW Barbatic acid
Pseudocyphellaria sp. Lobus - -
Pso ra pseu dorussell i Soredia and isidia - -
Pyrena subdunata - - -
Pyrena sp. 1 Perithecia GAAAn, GAW Barbatic acid, usnic acid, salacinic acid, gyrophoric acid
Pyxine sp. 1 Apothecia GAAAn, GAW Barbatic acid, usnic acid
Pyxine sp. 2 - - -
Ramalina celastri (Spreng.) Krog & Swinscow Soredia GE, GAW Iso-usnic acid and usnic acid
Ramalina farinacea (L.) Ach. Soredia GE Usnic acid
Ramalina pollinaria (Westr.) Ach. Soredia GAAAn Usnic acid
In general lichens in Kamojang geothermal area contains atranorin, usnic acid, gyrophoric and barbatic (Tabel 1). Those lichenic acid has reported are have potential for medicinal properties (Ashina and Shibata 1954; Cobanoglu et al. 2010; Crawford 2015). Such as usnic acid and salizilic acid were used for antiinflammation and analgesic action, and usnic acid has used as antifungal and antibiotic (Rankovic et al. 2008; 2007b). Beside that isodivaricatic, 5-propylresorcinol acid, divaricatinic acid and usnic acid which are contained in Usnea florida var. rigida. Acharius have proven good for antimicrobial activity against fungi Microsporum gypseum, Trichophyton rubrum and Trichophyton mentagrophytes growth (Fazio et al. 2007; Kekuda et al. 2016). Usnic acid showed also

**Figure 2.** Rare lichens. A. Dictyonema sericeum (Sw.) Berk, B. Usnea longisima Ach

**Figure 3.** Several displays of lichen’s acid crystals: A. Atranorin acid, B. Barbatic acid, C. Baeomycesis Acid (G.A.An), D. Gyrophoric acid (G.E), E. Lecanoric acid (GE), F. Usnic acid (G.E)
significant antibacterial activity against *Bacillus cereus*, *B. megaterium*, *Staphylococcus aureus* and *Klebsiella pneumoniae* (Saenz et al. 2006; Kukeda et al. 2016).

Atranorin isolated from lichen demonstrated an approximate and relatively strong antimicrobial activity against bacteria *Bacillus mycoides, B. subtilis, Staphylococcus aureus, Enterobacter cloacae, Escherichia coli, Klebsiella pneumoniae* and fungi *Aspergillus flavus, A. fumigatus, Botrytis cinerea, Candida albicans, Fusarium oxysporum, Mucor mucedo, Paecilomyces variotii, Penicillium purpureascens, P. verrucosum, Trichoderma harzianum* (Ranković et al. 2007a, 2007b; 2008; Kukeda et al. 2016). It is reported that *Acarospora*, contain norstictic acid, rhizocarpic acid, gyrophoric acids, epanorin acids. These acid have reported inhibit from the growing of *B. subtilis* and *S. aureus* (Řezanka and Guschina 1999).

So, from 133 species found in Kamojang Geothermal Area, there are, twenty-three (23) genus have been identified as medicine lichens. The genus has possible good potentially for medicine base on literature study were *Acarospora, Bulbothrix, Cladonia, Collema, Coccocarpia, Flavoparmelia, Graphis, Heterodermia, Hypogymnia, Leptogium, Lobaria, Leconora, Lasallia, Nephroma, Parmotrema, Pseudocyphellaria, Peltigera, Parmelia, Pertusaria, Physcia, Ramalina, Sticta,* and *Usnea*. Lichens have been used in traditional medicine since the time of the first Chinese and Egyptian civilizations (Chopra 1958; Noer 2013). Their utilization in folklore as medicine has been cited in different pharmacopeias of the world (cf. Nisyapuri et al. 2018). During the middle-ages lichens figured prominently among the herbs used by medicinal practitioners (Hale 1983). The use of lichens in medicine can be traced back to antiquity. *Evernia furfuracea* has been found in an Egyptian vase belongs to 18th Dynasty (1700-1600 BC) was used as a drug (Crawford 2015; Lal 1990). The literature review and records of medicinal plant lore of Indonesia show the word ‘janggot kai, rusuk angin and kayu angin’ are used for lichen *Usnea* for long time ago, a text where the first authentic record of ‘jamu’ (medicine) has been described (Noer 2013). The Java names of “rusuk angin” were later identified to several species of Parmelioid lichens, such as

![Figure 4](image_url)

**Figure 4.** The process of coloring clothing raw materials with lichens. A. *Parmotrema tinctorum*, B. *P. tinctorum* in ammonia solution after two weeks, C. Wool, D. Brown color produced by *Usnea* reddish up to dark purple produced by *P. tinctorum*, E. Cotton was dyed with *P. tinctorum* after a couple of months in ammonia solution, F. The lichen dyes process and dyed wool result.
Usnea longissima. U. barnata, U. missamensis. U. dasyypoga and Teloschistes. The vernacular name jamu widely used in Indonesian traditional medicine, an ancient system of locally Indonesia medicine, for different disease and disorders, for example, headache, skin diseases, urinary trouble, boils, vomiting, diarrhea, dysentery, heart trouble, cough, fever, leprosy and as a blood purifier.

Lichen dyes

Dye colors produced from Parmotrema tinctorum using ammoniac extracts were brownish red, dark red and purple. The color change of Parmotrema tinctorum ammoniac extracts occurred after 1st until 3rd weeks of fermentation. P. tinctorum had brownish red in 1st week and dark red after 3rd week of fermentation. Purple colors occurred in 4th week and dark violet color had been stable since 5th week of fermentation. While Usnea spp., produced brown color dyes and various brown since 5 days of fermentation up to 4th week. Base on the literature study, lichens at Kamojang geothermal area which has potential for dyes are Parmotrema, Usnea, Lobaria, Peltigera, and Hypogymnia.

Ammonia fermentation methods (AFM) is the best method to get a wide range of colors such as pink, violet, orange, grey, brown and yellow. Livelihoods natural dyes from lichens Parmotrema very interesting and will be important in the use of dyes that are environmentally friendly in industry that would reduce the pollution of water/river by dyes from industry.

In Ammonia extraction, lichens that have a C+ response are best for purple and violet dyes (Allen 2014). Spot test has done to Parmotrema spp. giving respond C+ red. Parmotrema tinctorum ammoniac extracts produced greyish violet. This was in accordance with studies by Casselman and Terada (2012) who stated that P. tinctorum produced purple color on fabric and thread through ammoniac fermentation. Such different colors shown from lichen ammoniac extracts were related to compounds in the lichen. Produced colors indicated the presence of particular compounds in Parmotrema tinctorum and Usnea baileyi species that reacted with ammoniac and aquades.

Purple color was produced presumably due to lecanoric acid in the Parmotrema tinctorum species. Lecanoric acid is p-depside that were hydrolyzed to orselic acid and undergoes a series of chemical reaction to form ‘orcein’ color precursor (Shukla et al. 2014). Salgado et al. (2018) reported that Parmotrema contains glyphoric acid. It has been used as a purple and red dye for thousands of years, mainly in the northern hemisphere

ACKNOWLEDGEMENTS

We thanks to Pertamina and PLN and People in Kamojang for providing the field facilities, The Lichens group of Biology for their assistance in collecting specimens, Dr. Felix Schumm and Dr. Andre Aptroot for their assistance during analysis and identification. Dr. Robert Lucking for correction and support the new species of Graphis. This paper publication is supported by ALG (Academic Leadership Grant) of Ethnobiology for Public Welfare in Support Sustainable Development. Therefore, authors would like to thank Rector of Padjadjaran University, Prof. Tri Hanggono Achmad has supported the publication.

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