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Dwinda M. Putri, Decky I. Junaedi, Vandra Kurniawan and Muhammad Efendi

LEAF TRAITS OF THE INVASIVE SPECIES *Bartlettina Sordida* (Less.) R.M. King NATURALIZED IN CIBODAS HIKING TRAIL, MT. GEDE PANGRANGO NATIONAL PARK, WEST JAVA, INDONESIA

(*KARAKTER DAUN SPESIES INVASIF (Bartlettina sordida (Less.) R.M. King) TERNATURALISASI DI JALUR PENDAKIAN CIBODAS, TAMAN NASIONAL GUNUNG GEDE PANGRANGO, JAWA BARAT, INDONESIA*)

Kebun Raya Cibodas (KRC) tidak hanya mengoleksi spesies asli Indonesia, namun juga memiliki koleksi spesies eksotik. Beberapa spesies eksotik ini telah ternaturalisasi di luar wilayah KRC dan ditemukan di wilayah Taman Nasional Gunung Gede Pangrango (TNGGP). Salah satu spesies eksotik yang ditemukan adalah Bartlettina sordida (Less.) R.M. King. Pemahaman mengenai karakter spesies dapat memberikan informasi mengenai penanganan spesies tersebut. Penelitian ini bertujuan untuk mempelajari distribusi B. sordida di jalur pendakian Cibodas, dan mempelajari variasi karakter daun spesies ini terhadap gradien ketinggian di jalur pendakian Cibodas. Sampel yang dikoleksi adalah yang berada di sepanjang jalur pendakian Cibodas hingga air terjun Cibeureum. Pada setiap titik sampling, kami mengoleksi data kehadiran. Sampel daun diambil pada setiap titik ditemukannya B. sordida. Daun kemudian segera difiksasi menggunakan metode hands-free untuk pengamatan tipe, densitas, serta ukuran stomata. Sampel daun juga digunakan untuk pengukuran Spesific Leaf Area (SLA). Ukuran stomata secara signifikan berkorelasi positif terhadap gradien ketinggian. Densitas stomata berkorelasi negatif namun tidak signifikan terhadap gradien ketinggian. Ukuran stomata berkorelasi positif dengan SLA. Karakter daun yang ditemukan berkaitan dengan efisiensi air untuk beradaptasi dengan iklim TNGGP yang sangat berbeda dengan habitat alaminya. Kemampuan untuk beradaptasi terhadap gradien ketinggian mendukung B. sordida mendominasi jalur pendakian Cibodas.

Kata kunci: kebun raya tropis, gradien lingkungan, spesies eksotik, karakter stomata

UDC/ODC 630*907.3(594.53)

Helianthi Dewi, Ricky Avenzora, Dudung Darusman, and Cecep Kusmana

THE POLARIZATION OF ORIENTATION AMONG STAKEHOLDERS ON INTERPRETATION SUBJECTS AT GUNUNG GEDE PANGRANGO NATIONAL PARK

(*POLARISASI ORIENTASI DIANTARA PEMANGKU KEPENTINGAN TERHADAP SUBJEK INTERPRETASI DI TAMAN NASIONAL GUNUNG GEDE PANGRANGO*)

Subjek interpretasi merupakan pendekatan baru dalam memandang sumberdaya dalam program interpretasi. Program interpretasi merujuk pada upaya pengembangan kemampuan individu dalam memaknai secara mendalam nilai alam bagi manusia melalui pengalaman yang bermakna dan menyenangkan, kesan, dan perasaan untuk mencapai tujuan pengelolaan kawasan. Cara pandang dari sisi subjek interpretasi ini memberikan penghormatan terhadap nilai intrinsik yang dimiliki oleh setiap komponen di lingkungan. Studi polarisasi ini memberikan informasi berharga tentang isu-isu kritis mengenai persepsi pemangku kepentingan dan implikasinya untuk mengelola interpretasi. Penelitian bertujuan untuk menganalisis dan mengevaluasi karakteristik subjek interpretasi yang dipandang penting oleh stakeholder dalam kaitan pengelolaan Taman Nasional Gunung Gede Pangrango. Penelitian dilakukan dengan menyebarkan kuesioner kepada para stakeholder (wisatawan, masyarakat, dan pengelola kawasan/operator wisata), dan dianalisis dengan menggunakan analisis cluster, uji Kruskal Wallis dan Mann Whitney. Meskipun flora, bahasa, dan komponen abiotik merupakan subjek interpretasi yang dianggap penting oleh stakeholder, namun kecenderungan persepsi wisatawan terletak pada komponen abiotik dan suasana alami yang terbangun. Penelitian ini menunjukkan bahwa pengembangan program ekowisata berbasis komponen abiotik dan budaya perlu dilakukan, untuk memastikan pengelolaan yang lestari, juga untuk meningkatkan partisipasi masyarakat dan memberikan pengenalan terhadap kekayaan hayati di kawasan taman nasional.

Kata kunci: polarisasi orientasi, subjek interpretasi, ekowisata, Taman Nasional Gunung Gede Pangrango

UDC/ODC 630*374.6

Sata Y. S. Rahayu, Dolly Priatna, Rosadi, and Suryanto

MANAGEMENT STRATEGY OF ELEPHANT RIDING AT THE ZOO

(*STRATEGI PENGELOLAAN NASIONAL GAJAH DI KEBUN BINATANG*)

Atraksi Wisata Menunggang Gajah (WMG) di Kebun Binatang telah menjadi perhatian publik dan perdebatan para ahli terkait etika, kesejahteraan gajah dan keselamatan manusia. Melalui pengajuan hipotesis antara bahwa WMG dapat meningkatkan pengetahuan manusia tentang konservasi, penelitian ini bertujuan untuk menyediakan rekomendasi strategi yang dapat diadopsi oleh Kebun Binatang berdasarkan prinsip dasar konservasi dan perlindungan satwa liar, khususnya gajah Sumatera. Pengetahuan diukur melalui kuesioner yang dibagikan kepada dua kelompok responden, yaitu yang sudah dan yang belum pernah memanfaatkan layanan WMG. Strategi dihasilkan melalui Proses Analisis Bertingkat (AHP) dari 17 responden ahli. Berdasarkan uji-t test dengan tingkat kepercayaan 95% dapat diketahui bahwa pengetahuan manusia tentang konservasi gajah meningkat secara signifikan melalui atraksi WMG. Selanjutnya para ahli dengan rasio konsistensi (CR $\leq$ 0.1) memilih strategi yang mengutamakan kualitas lingkungan sebagai strategi yang direkomendasikan dalam pengelolaan WMG, yaitu strategi yang mengedepankan kesejahteraan gajah, dengan bobot kriteria sebesar 0,40717. Selanjutnya secara berturut-turut: sebagai sarana edukasi konservasi (0,23973), menjamin keselamatan pengunjung (0,22972) dan meningkatkan kesejahteraan masyarakat sekitar Kebun Binatang (0,12338).

Kata kunci: wisata menunggang gajah, gajah sumatera, kebun binatang, AHP

UDC/ODC 630*907.13(504.73)

Ridwan Fauzi, Aditya Kuspriyangga, Fendra Suarmadi, Teguh H. Setianto, and Grace S. Saragih

KANCILAN FLORES (*Pachycephala nudigula nudigula*): THE ICONIC BIRD OF KELIMUTU NATIONAL PARK, INDONESIA

(*PACHYCEPHALA NUDIGULA NUDIGULA: BURUNG IKON DARI TAMAN NASIONAL KELIMUTU*)

Kancilan Flores (Pachycephala nudigula nudigula) adalah salah satu jenis burung legendaris yang berada di Taman Nasional Kelimutu. Burung tersebut mempunyai ciri khas yang unik dengan kemampuan berkicau dengan ragam suara yang sangat bervariasi. Masyarakat sekitar menjuluki burung ini dengan nama burung arwah, karena ukurannya yang kecil dan sulit untuk dijumpai namun memiliki kicauan yang nyaring. Beberapa literatur menyebut nama burung ini dengan nama ilmiah yang masih berbeda-beda. Penelitian ini bertujuan untuk mengidentifikasi burung ini untuk memperbaiki kesalahan penamaan secara ilmiah dan untuk mengamati perilaku, habitat, dan populasiKancilan Flores. Selain itu, Kancilan Flores adalah fauna yang menarik untuk wisatawan. Oleh karena itu, penelitian ini juga akan memberikan rekomendasi potensi lokasi bird watching Kancilan Flores. Penelitian ini menggunakan metode survei berupa jalur transek dan pengamatan secara langsung di habitat Kancilan Flores. Hasil penelitian menunjukkan dugaan ukuran populasi Kancilan Flores di Kawasan TN Kelimutu adalah sebanyak 1.667 individu dengan kisaran ukuran populasi antara 1.245–2.089 individu. Populasi burung Kancilan Flores hanya sekitar 0,53 individu per hektarnya. Kancilan Flores paling banyak dijumpai pada ketinggian 1.500–1.600 m a.s.l. Rekomendasi area sebagai lokasi bird watching Kancilan Flores, yaitu sekitaran Kebun Edelweiss, Perekonde, Arboretum bagian bawah, dan Arboretum bagian tengah. Karena itu perlu usaha perlindungan terhadap populasi Kancilan Flores dengan melarang keras perburuan dan pengrusakan habitatnya.

Kata kunci: Kancilan Flores, Flores, Garugiwa, habitat, Kelimutu, population

UDC/ODC 630*232.3(594.13)

Dindin H. Mursyidin, M. Rubiansyah, and Badruzsaufari

GENETIC RELATIONSHIP OF SEVERAL MORPHOLOGICAL AND MOLECULAR CHARACTERISTICS OF *Phalaenopsis amabilis* (L.) Blume ORCHIDS FROM THE MERATUS MOUNTAINS OF SOUTH KALIMANTAN, INDONESIA

(*KEKERABATAN GENETIK ANTARA BEBERAPA KARAKTER MORFOLOGI DAN MOLEKULER DARI ANGGREK* Phalaenopsis amabilis *(L.) Blume ASAL PEGUNUNGAN MERATUS, KALIMANTAN SELATAN, INDONESIA*)

Phalaenopsis amabilis (L.) Blume merupakan salah satu jenis anggrek terpopuler di dunia. Namun tanaman hias ini telah terancam di salah satu habitat aslinya, yaitu Pegunungan Meratus, Kalimantan Selatan, Indonesia. Tujuan penelitian ini adalah untuk menentukan dan menganalisis kekerabatan genetik dari beberapa karakter morfologi dari P. amabilis dari wilayah tersebut dan menggabungkannya dengan penanda molekuler (RAPD). Sebanyak sepuluh sampel anggrek, terdiri atas sembilan anggrek bulan (P. amabilis) dan satu spesies outgroup (P. cornu-cervi), serta sepuluh primer RAPD telah digunakan dalam penelitian ini. Berdasarkan penanda morfologi, anggrek ini memiliki tingkat keragaman genetik sedang, ditunjukkan dengan nilai indeks Shannon sebesar 0,5. Berbeda dengan penanda molekuler, plasma nutfah ini menunjukkan variasi genetik yang tinggi, ditunjukkan dengan derajat polimorfisme sebesar 100% untuk semua primer yang digunakan. Hasil analisis klaster menunjukkan bahwa plasma nutfah ini terbagi menjadi dua kelompok utama untuk penanda morfologi dan lima kelompok untuk penanda molekuler. Berdasarkan kedua penanda, pengelompokan plasma nutfah ini relatif berkaitan dengan wilayah asalnya. Dengan demikian, informasi ini diharapkan dapat digunakan sebagai acuan untuk program konservasi dan pemuliaan anggrek pada masa mendatang.

Kata kunci: Pemuliaan dan konservasi, variasi genetik, anggrek, Phalaenopsis

UDC/ODC 630*932.2(594.61)

Arie Vatresia, Rendra R. Rais, Ferzha P. Utama, and Widhia Oktarianti

MINING FIRE HOTSPOTS OVER NUSA TENGGARA AND BALI ISLANDS

(*MENAMBANG DATA TITIK KEBAKARAN HUTAN DI KEPULAUAN NUSA TENGGARA DAN BALI*)

Kebakaran hutan masih menjadi salah satu masalah yang sering terjadi di Indonesia. Padahal, kebakaran hutan tersebut banyak berasal dari ulah manusia, yakni kebakaran yang sengaja dimunculkan untuk tujuan seperti pelebaran lahan untuk persiapan musim tanam di Pulau Nusa Tenggara. Peristiwa kebakaran hutan dapat diidentifikasi dengan mengamati data titik api yang dipantau melalui satelit penginderaan jauh. Hotspot adalah suatu daerah yang memiliki suhu permukaan relatif lebih tinggi dari daerah sekitarnya berdasarkan ambang batas suhu tertentu yang dipantau oleh satelit penginderaan jauh. Area direpresentasikan sebagai titik yang memiliki koordinat tertentu. Kebakaran yang sebenarnya dapat dipantau dengan mengamati atribut hotspot yaitu Confidence, Brightness Temperature dan FRP (Fire Radiate Power). Untuk mengetahui kesamaan dari ketiga atribut tersebut maka dilakukan proses clustering untuk mempermudah monitoring. Penelitian ini bertujuan untuk mengelompokkan hotspot di Pulau Nusa Tenggara dari tahun 2013 hingga 2018 menggunakan Metode K-Means Clustering dengan 28.519 data hot spot. Hal ini dapat menjadi manfaat bagi Kementerian Lingkungan Hidup dan Kehutanan di Indonesia untuk mengidentifikasi tingkat prioritas kawasan yang akan dipantau. Dengan mengetahui hasil ini, nghkementerian dapat menggunakan data ini untuk manajemen prioritas patroli. Penelitian ini berhasil mengelompokkan tiga jenis cluster optimum hotspot berdasarkan risiko kebakaran dengan rincian sebagai berikut; High High Risk Class berisi 12212 data dengan rentang nilai mean confidence pada rentang 49.3–100%, brightness pada rentang 305.1–421.3°K dan FRP pada rentang 2.5–714.3; Medium Risk berisi 12250 data dengan rentang nilai mean confidence 20,3–74,3%, brightness pada rentang 301.06-341.86o K dan FRP pada rentang 3.6–141.4; dan Low Risk berisi 4.057 data dengan rentang nilai mean confidence pada rentang 0–39.8%, brightness pada rentang 300–365.86°K dan FRP pada rentang 3.5-275.6. Semua klaster diperoleh dengan mengimplementasikan klasterisasi K-Means atas data hotspot dan parameternya masing-masing. Kinerja cluster menunjukkan nilai kerahasiaan akurasi 88,45% menggunakan 100 data hotspot dari tahun 2019.

Kata kunci : Hotspot, Kepulauan Nusa Tenggara, Penambangan Data, K-Means, Penggerombolan

UDC/ODC 630*232.311.9

Belete Getnet, Yigardu Mulatu, Smegnew Melese, and Marshet Nigatu

EFFECTS OF GERMINATION ECOLOGY ON IN VITRO GERMINATION PERFORMANCE OF HIGHLAND BAMBOO (*Yushania alpina*) SEED COLLECTED FROM KEFA, SOUTH WEST ETHIOPIA

(*PENGARUH EKOLOGI PERKECAMBAHAN TERHADAP KINERJA PERKECAMBAHAN IN VITRO BENIH BAMBU DATARAN TINGGI (*Yushania alpina*) DARI KEFA BARAT DAYA ETHIOPIA*)

Yushania alpina adalah spesies bambu endemik Afrika, dan merupakan sumber daya yang berharga dalam nilai ekologi dan sosial ekonomi di Ethiopia. Namun demikian, daya berkecambah yang rendah merupakan tantangan dalam produksi bibit selain ketersediaan benih yang langka. Untuk meningkatkan daya kecambah benih diperlukan perlakuan ekologi perkecambahan yang berbeda. Oleh karena itu, penelitian ini dilakukan untuk menyelidiki pengaruh ekologi perkecambahan yang berbeda, dan untuk menentukan kualitas, ukuran, dan hasil benih Y. alpina. Buah matang yang dikumpulkan diproses, dan kemudian biji yang dibersihkan (murni) dan tidak dibersihkan (tidak murni) digunakan untuk penelitian ini. Penelitian ini memiliki dua fase; yang pertama adalah mengukur kemurnian, kadar air, karakter benih, hasil benih; dan yang kedua adalah menyelidiki pengaruh ekologi perkecambahan yang berbeda untuk perkecambahan benih in vitro Y. alpina menggunakan benih murni dan tidak murni. Hasil penelitian

menunjukkan kemurnian, kadar air, ukuran benih, berat benih, dan hasil biji ditentukan untuk benih Y. alpina yang dibersihkan. Pengaruh interaksi jenis benih dan ekologi perkecambahan sangat nyata pada semua parameter perkecambahan. Kapasitas perkecambahan tertinggi (55%) benih murni tercatat pada T2 (kertas + suhu lingkungan), diikuti oleh 38% pada T1 (pasir + suhu lingkungan), dan 31% pada T3 (kertas + inkubator (25°C)). ; namun, perlakuan ini menunjukkan hasil yang lebih rendah pada benih yang tidak murni. Selain itu, waktu perkecambahan rata-rata tertinggi (23,5 hari) tercatat pada T3, diikuti oleh 13,06 pada T2 menggunakan benih tidak murni, tetapi nilai terendah (2,5 dan 2,01) tercatat pada T1 dan T2 benih murni. Oleh karena itu, hasil ini menyimpulkan bahwa penggunaan media pasir pada suhu kamar sebagai ekologi perkecambahan lebih disukai untuk meningkatkan kapasitas perkecambahan benih Y. alpina. Selain itu, desinfeksi permukaan benih menggunakan antijamur dianjurkan untuk mengurangi kontaminasi benih.

Kata kunci: Ekologi perkecambahan, perkecambahan, Y. alpina, benih murni dan benih tidak murni

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Firda A. Syamani, Agus Z. Arifqi, Sasa S. Munawar, Sudarmanto, Lilik Astari, Kurnia W. Prasetiyo, Mohamad Gopar, Ismadi, Sukma S. Kusumah, Mohd H. Hussin, Subyakto, Yusuf S. Hadi, and Kenji Umemura

UTILIZATION OF CITRIC ACID AS BONDING AGENT IN SEMBILANG BAMBOO (*Dendrocalamus giganteus* Munro) PARTICLEBOARD PRODUCTION

(*PEMANFAATAN ASAM SITRAT SEBAGAI AGEN PEREKATAN PADA PEMBUATAN PAPAN PARTIKEL BAMBU SEMBILANG (*Dendrocalamus giganteus *Munro)*.)

Asam sitrat digunakan sebagai agen perekatan dalam pembuatan papan partikel bambu Sembilang. Keterbatasan penggunaan bambu untuk pembuatan papan partikel adalah kandungan silika pada kulit bambu dapat mempercepat ketumpulan mesin pengolah papan partikel dan mengurangi kerekatan antar partikel. Penelitian ini bertujuan untuk mengetahui pengaruh kulit bambu terhadap karakteristik papan partikel bambu Sembilang. Papan partikel dibuat menggunakan partikel bambu lengkap dengan kulit bambu (tipe A) dan partikel bambu tanpa kulit (tipe B). Larutan asam sitrat (59%) disemprotkan pada permukaan partikel bambu untuk memperoleh tiga kadar asam sitrat yang berbeda, yaitu 15, 20, dan 25% (berdasarkan berat kering partikel bambu). Papan partikel bambu Sembilang diproduksi menggunakan mesin kempa panas pada suhu 200°C, 5 MPa selama 10 menit. Kepadatan papan partikel yang ditargetkan adalah 0,8 g/cm^3. Papan partikel tipe B menunjukkan keteguhan lentur (MOR), keteguhan tarik tegak lurus permukaan (IB), penyerapan air (WA) dan pengembangan tebal (TS) yang lebih baik dibandingkan dengan papan partikel tipe A. Hal ini dipengaruhi oleh konsentrasi silika yang lebih rendah pada papan partikel tipe B, cenderung mempererat area kontak antara partikel dan asam sitrat sehingga menghasilkan kualitas papan partikel yang lebih baik dibandingkan dengan papan partikel tipe A. Papan partikel tipe B memenuhi persyaratan JIS A 5908 untuk papan partikel tipe 18 dalam hal MOR, modulus elastisitas dan IB, namun hanya memenuhi papan partikel tipe 8 dalam hal keteguhan cabut sekrup. Sifat fisik papan partikel bambu Sembilang tipe B dengan asam sitrat pada kadar 25%, lebih baik dibandingkan papan partikel bambu sembilang lainnya dalam penelitian ini..

Kata kunci: Asam sitrat, bambu Sembilang, papan partikel, sifat fisis, sifat mekanis, silika

UDC/ODC 630*145.2(540)

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(*KEANEKARAGAMAN ORTHOPTERAN PADA EKOSISTEM TROPIS DI CENTRAL KERALA, INDIA*)

Orthoptera adalah takson arthropoda beragam yang mencakup belalang, belalang belibis, belalang bertanduk pendek, belalang bertanduk panjang, jangkrik semak, jangkrik dan jangkrik mol. Mereka memainkan peran penting dalam rantai makanan, siklus nutrisi dan penyerbukan. Keanekaragaman orthoptera di agroekosistem dan padang rumput yang terletak di dataran tinggi dan dataran rendah Central Kerala dipelajari dari Desember 2019 hingga Maret 2020. Penelitian dilakukan di Avoly, Distrik Ernakulam dan Venmony, Distrik Idukki di Kerala dengan menggunakan random sampling pada kuadrat 10 x10 m. Tercatat sebanyak 35 spesies orthoptera, yang termasuk dalam dua subordo, 10 famili, 20 subfamili, dan 33 genera. Famili Acrididae dengan empat belas spesies merupakan famili yang paling dominan diikuti oleh Tettigoniidae Dua spesies yaitu, Chitaura indica dan Burrinia burri adalah endemik negara bagian Kerala. Ditemukan bahwa kisaran sebagian besar genera orthopteran yang dilaporkan dalam penelitian ini meluas ke seluruh negara-negara Asia Tenggara. Jumlah Orthoptera tertinggi dilaporkan pada bulan Desember di kedua lokasi dan menurun pada bulan Maret. Nilai indeks keanekaragaman Simpson menunjukkan bahwa kedua wilayah memiliki komunitas orthopteran yang sangat beragam. Nilai indeks keanekaragaman Venmony relatif lebih tinggi yang mungkin disebabkan oleh kedekatan lokasi penelitian dengan ekosistem hutan alam dan gangguan yang lebih sedikit. Studi lebih lanjut tentang fauna orthopteran Kerala direkomendasikan yang akan membantu mengendalikan status hama mereka dan memanfaatkan potensi ekonomi mereka sebagai makanan di peternakan.

Kata kunci: Belalang, dataran tinggi, West Ghats, ekoton, keanekaragaman, Kerala

LEAF TRAITS OF THE INVASIVE SPECIES *Bartlettina sordida* (Less.) R.M. King NATURALIZED IN CIBODAS HIKING TRAIL, MT. GEDE PANGRANGO NATIONAL PARK, WEST JAVA, INDONESIA

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LEAF TRAITS OF THE INVASIVE SPECIES *Bartlettina sordida* (Less.) R.M. King NATURALIZED IN CIBODAS HIKING TRAIL, MT. GEDE PANGRANGO NATIONAL PARK, WEST JAVA, INDONESIA. Cibodas Botanical Garden (CBG) maintains not only native plant species but also introduced plant species. Some of these have been naturalized from CBG to the adjacent Mt. Gede-Pangrango National Park (GPNP). One of the reported naturalized species is *Bartlettina sordida*. Understanding species traits will give information for the future management of *B. sordida*. This research investigates the distribution of *B. sordida* in the Cibodas hiking trail and studies leaf traits variation of this species along with an altitudinal change in the Cibodas hiking trail. Samples were collected along the Cibodas hiking trail from the entrance gate to the Cibeureum waterfall. At every survey location, we recorded *B. sordida* occurrences. In the sample plots we also collected leaf samples from detected *B. sordida*. The leaves were then fixated using the hands-free method to observed stomatal type, density, and size. The leaves were also treated for specific leaf area (SLA) measurements. Stomata size is significantly correlated along the altitudinal gradient. Stomata density is negatively correlated but not significant along the altitudinal gradient. Stomata size is positively correlated with SLA. These traits are related to water-efficient adapting to GPNP climate, which is very different from its natural habitat. The ability to adapt to altitudinal gradient helps *B. sordida* to dominate the Cibodas hiking trail.

Keywords: Tropical botanical garden, environment gradient, alien species, stomatal traits

*KARAKTER DAUN SPESIES INVASIF (*Bartlettina sordida *(Less.) R.M. King) TERNATURALISASI DI JALUR PENDAKIAN CIBODAS, TAMAN NASIONAL GUNUNG GEDE PANGRANGO, JAWA BARAT, INDONESIA. Kebun Raya Cibodas (KRC) tidak hanya mengoleksi spesies asli Indonesia, namun juga memiliki koleksi spesies eksotik. Beberapa spesies eksotik ini telah ternaturalisasi di luar wilayah KRC dan ditemukan di wilayah Taman Nasional Gunung Gede Pangrango (TNGGP). Salah satu spesies eksotik yang ditemukan adalah* Bartlettina sordida *(Less.) R.M King. Pemahaman mengenai karakter spesies dapat memberikan informasi mengenai penanganan spesies tersebut. Penelitian ini bertujuan untuk mempelajari distribusi* B. sordida *di jalur pendakian Cibodas, dan mempelajari variasi karakter daun spesies ini terhadap gradien ketinggian di jalur pendakian Cibodas. Sampel yang dikoleksi adalah yang berada di sepanjang jalur pendakian Cibodas hingga air terjun Cibeureum. Pada setiap titik sampling, kami mengoleksi data kehadiran. Sampel daun diambil pada setiap titik ditemukannya* B. sordida*. Daun kemudian segera difiksasi menggunakan metode hands-free untuk pengamatan tipe, densitas, serta ukuran stomata. Sampel daun juga digunakan untuk pengukuran Spesific Leaf Area (SLA). Ukuran stomata secara signifikan berkorelasi positif terhadap gradien ketinggian. Densitas stomata berkorelasi negatif namun tidak signifikan terhadap gradien ketinggian. Ukuran stomata berkorelasi positif dengan SLA. Karakter daun yang ditemukan berkaitan dengan efisiensi air untuk beradaptasi dengan iklim TNGGP yang sangat berbeda dengan habitat alaminya. Kemampuan untuk beradaptasi terhadap gradien ketinggian mendukung* B. sordida *mendominasi jalur pendakian Cibodas.*

Kata kunci: Kebun raya tropis, gradien lingkungan, spesies eksotik, karakter stomata

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I. INTRODUCTION

Cibodas Botanical Garden (CBG) was first established to acclimate high economic value plants (Efendi, Hapitasari, Gresia, Rustandi, & Supriyatna, 2016). These plants were carried mostly from subtropical areas to be naturalized and planted in Indonesia during the colonial era. However, this function has recently been altered following the need to conserve plant biodiversity (Heywood, 2011), and CBG is an ex-situ plant conservation institution. It collected not only native plant species but also exotic plant species. Exotic species were collected in the past, and CBG keeps these plant collections in good condition (Mutaqien, Tresnanovia, & Zuhri, 2011).

Botanical gardens conducted integrated conservation by documenting plant information (Mounce, Smith, & Brockington, 2017). This information includes distribution, morphological characters, molecular traits, physiology to support plant species conservation (Schulman & Lehvävirta, 2011). On the other hand, botanical gardens were also responsible for distributing exotic invasive species in the past. For example, during the 19th century, the Royal Botanic Gardens Kew, London, spread quinine tree (*Cinchona* spp.) across the British islands. (Hulme, 2011). While in Indonesia, Bogor Botanical Garden introduced the water hyacinth (*Euchhornia crassipes*) for ornamental plants. It has instantly covered the water body, and the excessive were dumped into the Ciliwung river (Tjitrosoedirdjo, 2005). Invasive pathways were also facilitated by trading seeds by the colonials in the 18th and 19th centuries that drove tropical botanical gardens (Dawson, Mndolwa, Burslem, & Hulme, 2008). Although the number of naturalized species is relatively low (Galera & Sudnik-Wójcikowska, 2010), the botanical gardens should be aware of the opportunistic behavior of these introduced plant species to prevent the spreading into the adjacent areas (Reichard & White, 2001).

Cibodas Botanical Garden is located next to Mt. Gede-Pangrango National Park (GPNP). Some reports found that several CBG's living collections have been naturalized into GPNP. These naturalized species were *Bartlettina sordida*, *Brugmansia candida*, *Cestrum aurantiacum*, *Chimonobambusa quadrangularis*, and *Passiflora ligularis* (Wahyuni & Tjitrosoedirdjo, 2013; Zuhri & Mutaqien, 2013; Padmanaba, Tomlinson, Hughes, & Corlett, 2017). CBG, as a conservation institution, needs to carry out a risk assessment of introduced species to prevent the spreading and minimize the invasion risks (Hardwick et al., 2010; Andersen, Naylor, Endress, & Parks, 2015). CBG has conducted a weed risk assessment of 25 introduced threatened species with two approaches (Junaedi, Putri, & Kurniawan, 2021), namely by specific leaf area (SLA) and *Tropical Weed Risk Assessment Protocol* (TWRAP) *scoring* (Jefferson, Havens, & Ault, 2009). Invasive species risk assessment could also be conducted using other traits such as stomata density and size (Klich, 2000; Huang, Ratkowsky, Hui, Wang, Su, & Shi, 2019), seed productions, leaf N:P ratios, and biomass (Pyšek et al., 2012).

Bartlettina sordida (Less.) R.M.King & H.Rob. or blue mist plant belongs to the family of Asteraceae, and many species from this family are listed as invasive species. *B. sordida* is an evergreen shrub, with large, opposite, broadly obovate, hairy leaves, with purplish veins. Flowers are purple, blue, or pink, and each inflorescence contains 8-150 fruits to be dispersed by the wind (Csurhes, 2016). This species is originating from Mexico and well known as an ornamental plant. It was reported as invasive species in Africa (Henderson & Wilson, 2016), Australia (Randall, 2007), New Zealand (Webb, 1987), and Indonesia (Sunaryo & Tihurua, 2012; Wahyuni & Tjitrosoedirdjo, 2013).

Bartlettina sordida was firstly collected in CBG in 1899 (Mutaqien et al., 2011). There was not much information about the leaf traits of this species, and it was mostly found in the Cibodas hiking trail. We also found no data explaining the ability of this species to spread outside its native range. We obtained SLA data as a response of light captured, photosynthesis rate,

plant growth and reproduction (Rindyastuti, Hapsari, & Byun, 2021) According to Junaedi and Mutaqien (2018), SLA is one of the important indicators to distinguish natural exotic plant species (which have started and/ or spread to new areas and have the potential to increase plant populations in new areas. Stomata traits also showed plant adaptation ability in several environment conditions (Hong, Lin, & He, 2018). Mountain ecosystems are highly suitable for investigating potential range extention of invasive species across latitudinal gradient (Arévalo et al., 2005). Environmental gradient often triggered phenotypic plasticity (Drenovsky et al., 2012), we also found no report of *B. sordida* plasticity. Thus, this research aims to study *B. sordida* leaf traits responding to environmental gradient in the Cibodas hiking trail. Mountain ecosystems are highly suitable for investigating potential range extensions of invasive species across latitudes (Arévalo et al., 2005). This study will capture the adaptation capacity of *B. sordida* along an altitudinal gradient. This information will be useful for stakeholders to adequately manage and minimize the invasion risks of this naturalized species in GPNP in particular and tropical mountainous forests in general.

II. MATERIALS AND METHOD

A. Study Site

The research was conducted inside Mt. Gede-Pangrango National Park (GPNP) on the Cibodas hiking trail from the entrance gate to the Cibeureum waterfall. GPNP is located in Cianjur district, West Java, Indonesia. The GPNP vegetation type zonation were categorized into sub-montane zone (1.000-1.500 m asl), montane zone (1.500-2.400 m asl), and sub-alpine zone (2.400-3.019 m asl) (van Steenis, 1972)). Based on Schmidt and Ferguson classification, GPNP has a type A climate with annual rainfall 3000-4200 mm per year. Air temperature ranging from 0ºC (on the top of the mountains) to 18ºC (in Cibodas), and the relative air humidity range is 80-90% (Rozak et al., 2016). Samples were collected in December 2019.

B. Methods

Data were collected in December 2019 using the tracking method alongside the Cibodas hiking trail (Figure 1). The survey was conducted repeatedly at every 100 m distance on the hiking trail pathway. There were 18 survey points at 18 locations along the hiking

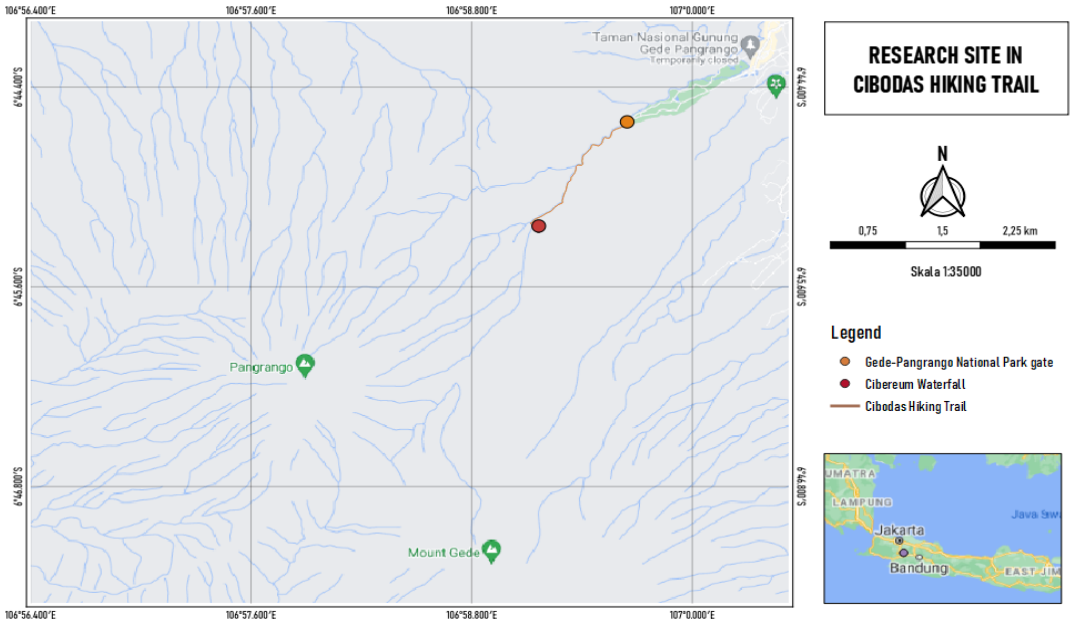

Figure 1. Research site along the Cibodas hiking trail, Mt. Gede-Pangrango National Park

trail. It was recorded *B. sordida* presence data at every survey location. In the plots we also collected leaf samples from detected *B. sordida*. The leaves were then fixated using the hands-free method to observed stomatal type, density, and size. The leaves were also treated for specific leaf area measurements. The leaf data in this study consists of stomata density, size and specific leaf area (SLA). Leaf stomata were immediately fixated from *B. sordida* leaves using the hands-free section method (Sari & Harlita, 2013). Stomata density and size were observed under 10x10 magnification using microscope Olympus CX22LED®. Stomata type and size were measured using Image Raster 3.0. Specific leaf areas (SLA) of B. sordida were measured based on the protocol of SLA data collection (Pérez-Harguindeguy et al. (2013). The leaves samples for SLA measurement were collected by choosing old leaves with dark green color. Leaves samples were stored in Ziplock to maintain humidity after the photo of the leaf was taken. Leaf area was measured from leaf photo data analyzed in ImageJ (Schneider, Rasband, & Eliceiri, 2012). To obtain dried leaves mass, leaves were dried in the oven for 72 hours at 65^{o}C temperature then weighed using digital scale. The SLA value was obtained from the ratio between the dried leaf mass and the measured leaf area.

C. Analysis

We used linear regression analysis to model the leaf traits variation (stomata size, stomata density, and SLA) along the elevational gradient (Preacher, Curran, & Bauer, 2006). We conducted stepwise regression to decide which variable should be included in the model (model 1), then conducted linier regression as follow:

$$Y = a + bx + e \quad \text{.....(1)}$$

where: Y is leaf traits (stomata density, stomata size and/or SLA), x elevation (m asl) and e is normally distributed error. All analysis conducted in R and R studio.

III. RESULT AND DISCUSSION

Based on the conducted stepwise regression result, the model analysis found that all leaf traits affected by altitude (Figure 2). The regression shows stomata density negatively correlated with altitude (Figure 3). The higher the habitat of *B. sordida*, the lower the stomata density is. Results have shown that the stomata density are not statistically significant with the elevation (Figure 3).

Bartlettina sordida was originally grown in a tropical climate with full sun and dry habitats. CBG imported it for being an ornamental plant. Recently, some reports that *B. sordida* has been naturalized in adjacent forests; one of the reported areas is Mt. Gede-Pangrango National Park (GPNP). This species was reportedly found along hiking trails, and there has been no report that it was found deeper in the forest. GPNP has a wet tropical highland climate with high rain intensity throughout the year and high

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Subset selection object
Call: regsubsets.formula(altitude..mdpl. ~ stomata.density + stomata.size +
    SLA, datsor, nvmax = 3, method = "seqrep")
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stomata.size        FALSE      FALSE
SLA                 FALSE      FALSE
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Figure 2. Model analysis results

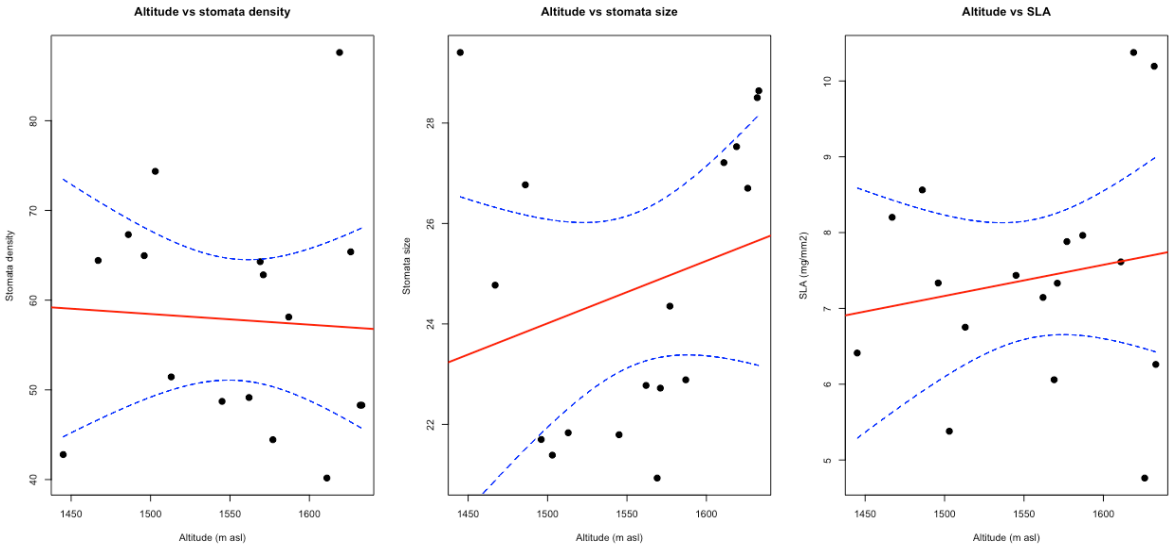

Figure 3. Predicted correlation between a) altitude and stomata size (left); b) altitude and stomata density (middle); c) specific leaf area (SLA) and stomata size (right)

UV exposure. These extreme conditions affect the leave traits of *B. sordida* inside GPNP. Data shows that *B. sordida* leaf traits are affected by the altitudinal gradient. The data shows that *B. sordida* SLA positively correlates with stomata size, which is uncommon for plant adaptation in highland areas. Usually, SLA is negatively correlated with stomata size. This is presumably a defense mechanism when sunlight is high at noon and wind velocity is also high. Small stomata means a smaller open area for leaves, reducing water loss during evapotranspiration. This plasticity is presumably because of the wet climate conditions in the Cibodas hiking trail. *B. sordida* is originally grown in full sun and dry climate; thus, it doesn't need much water for photosynthesis. *B. sordida* has shown its ability to survive in a different climate from its origin, which is why it's alarming as an invasive species (Kleunen et al., 2018). Invasive species have also shown the tendencies of high SLA to compete with native species (Mathakutha et al., 2019).

Stomata density is decreasing with higher altitude. This adaptation is common for herbs to allow efficient use of water. Highland plants are very efficient in water use due to extreme climate (low temperature, high UV intensity, high wind velocity) (Woodward et al., 2002). However, although stomata densities are correlated with altitude, statistically it is not significant. This is presumably because the main factor that drives stomata frequency is other environmental factors. Plants behave differently at higher altitudes; most of the strategies correspond to extreme climate. Highland plants tend to develop their stomata density correlated with stomata opening. Higher stomata frequency also correlated with higher stomatal conductance; species with higher conductance are most likely to distribute with a wider range. At lower elevations, shrubs and herbs tend to occur in the understory where competition for sunlight is strong, while at higher elevations, these plants commonly grow in more open habitats.

Stomata are found on the abaxial surface; the type of *B. sordida* stomata is normocytic. It means that the non-differentiated epidermis guards the stomata. This character is typical of Asteraceae and gives some advantages; it can survive through drought and the rainy season. The leaves also covered by trichomes, which have contributed to the control of transpiration and temperature, as reported in other species of Asteraceae (Borges et al., 2018). This trait helps Asteraceae grow easily in a new area and dominating it if the environment is suitable.

Not only the stomata size, but also SLA is increasing with higher altitude. High altitude

caused low-temperature stress. It can break the plant carbon balance, thus lead to growth restriction, supporting the "source limitation" hypothesis (Chai et al., 2015). Highland soil is usually nutrient-deficient, especially in tropical forests; the higher the altitude, the poorer the soil nutrient. Therefore, plants develop a mechanism to keep their food storage in biomass and store carbon in leaves and the stem. These conditions also force plants to produce seeds when the environment is extreme to maintain the continuity of the species (Seipel, Alexander, Edwards, & Kueffer, 2016).

The competition at high altitudes also involving light competition, the open area along Cibodas hiking trail with partial shading provides suitable habitat for *B. sordida* to invade the area immediately. Along the Cibodas hiking trail, the side is an open area where light can reach the soil surface, supporting seedling growth (Zuhri & Mutaqien, 2013). *B. sordida* was not recorded inside the undisturbed forest due to canopy interlock. This condition creates no chance for *B. sordida* to germinate. *B. sordida* was found abundant only in a shaded area where no other invasive species were found. There were some areas where *B. sordida* was absent; in an open area, along Gayonggong bridge, was dominated by *Brugmansia* spp. until some shading at the end of the bridge. This shifting might be caused by interspecific competition of sunlight; *B. sordida* seedlings require partial shade.

Environmental stress acting as a filter against invasive species, while disturbances open another bare land area for invasive species to dominate (Dullinger et al., 2017). The highland ecosystem is a natural barrier for exotic species; however, open areas for recreational purposes create a pathway for invasive plants. Only species with particular traits such as high SLA and protected stomata will survive in extreme highland ecosystem. More studies should be performed until the last *B. sordida* is found along the hiking trails. Comparing other exotic species to native species can also compare how exotic species adapted to the highland ecosystem (El-Barougy et al., 2020). Using community-based and species-based research also has advantages in confirming environmental resistance against invasive species (Gallien & Carboni, 2017). It is suggested that botanical gardens to perform risk assessment of exotic species, before it is planted in the garden's collections.

IV. CONCLUSION

Bartlettina sordida is one of CBG's collections that have been naturalized in GPNP. It was brought into CBG as ornamental plants. This species native range is a dry and full sun habitat, but it dominates the Cibodas hiking trail in GPNP with a wet highland ecosystem. However, *B. sordida* can only be found along the hiking trail, not deeper in the forest. From its stomata traits, *B. sordida* has an advantage by its stomata characteristics. Like other Asteraceae, the stomata of *B. sordida* are protected by trichome to help water maintenance through extreme climate conditions. *B. sordida* shows plasticity in Cibodas hiking trail that leads to invasive character. There are two suggested ways to avoid the further possibility of plants naturalized from CBG collection spreading to the mountain forest: 1. To evaluate the negative impact of invasive plants before collections in CBG, 2. Conduct applied research to carry out appropriate invasive plant control techniques in CBG and restore natural forests that have been disturbed by these invasive plants.

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THE POLARIZATION OF ORIENTATION AMONG STAKEHOLDERS ON INTERPRETATION SUBJECTS AT GUNUNG GEDE PANGRANGO NATIONAL PARK

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THE POLARIZATION OF ORIENTATION AMONG STAKEHOLDERS ON INTERPRETATION SUBJECTS AT GUNUNG GEDE PANGRANGO NATIONAL PARK. Interpretation subject is a novel approach to observing resources in the interpretation program. Interpretation programs refer to the efforts to develop an individual's ability to deeply interpret the value of nature for humans through meaningful and pleasant experiences, impressions, and feelings to achieve management goals. The viewpoint of interpretation subject considers the intrinsic value of each resource. These polarization studies provide valuable information on critical issues concerning stakeholder perception and their implications for managing interpretations. The purpose of this study is to analyze and evaluate the characteristics of the interpretation subject that stakeholders thought were crucial in Gunung Gede Pangrango National Park management. The survey was done by distributing questionnaires to related stakeholders (tourists, communities, and area managers/tour operators) and evaluated by cluster analysis, Kruskal-Wallis, and Mann-Whitney test. Although the stakeholder considered flora, language, and abiotic components essential in interpretation, tourists' perception tended to focus on abiotic components and the built natural environment. The research showed that abiotic and cultural component-based-ecotourism-programs shall be developed to ensure sustainable management, increase community participation, and introduce the biological wealth in the national park area.

Keywords: Polarization of orientation; interpretation subject; ecotourism; Gunung Gede Pangrango National Park

POLARISASI ORIENTASI DIANTARA PEMANGKU KEPENTINGAN TERHADAP SUBJEK INTERPRETASI DI TAMAN NASIONAL GUNUNG GEDE PANGRANGO. Subjek interpretasi merupakan pendekatan baru dalam memandang sumber daya dalam program interpretasi. Program interpretasi merujuk pada upaya pengembangan kemampuan individu dalam memaknai secara mendalam nilai alam bagi manusia melalui pengalaman yang bermakna dan menyenangkan, kesan, dan perasaan untuk mencapai tujuan pengelolaan kawasan. Cara pandang dari sisi subjek interpretasi ini memberikan penghormatan terhadap nilai intrinsik yang dimiliki oleh setiap komponen di lingkungannya. Studi polarisasi ini memberikan informasi berharga tentang isu-isu kritis mengenai persepsi pemangku kepentingan dan implikasinya untuk mengelola interpretasi. Penelitian bertujuan untuk menganalisis dan mengevaluasi karakteristik subjek interpretasi yang dipandang penting oleh stakeholder dalam kaitan pengelolaan Taman Nasional Gunung Gede Pangrango. Penelitian dilakukan dengan menyebarkan kuesioner kepada para stakeholder (wisatawan, masyarakat, dan pengelola kawasan/operator wisata), dan dianalisis dengan menggunakan analisis cluster, uji Kruskal Wallis dan Mann Whitney. Meskipun flora, bahasa, dan komponen abiotik merupakan subjek interpretasi yang dianggap penting oleh stakeholder, namun kecenderungan persepsi wisatawan terletak pada komponen abiotik dan suasana alami yang terbangun. Penelitian ini menunjukkan bahwa pengembangan program ekowisata berbasis komponen abiotik dan budaya perlu dilakukan, untuk memastikan pengelolaan yang lestari, juga untuk meningkatkan partisipasi masyarakat dan memberikan pengenalan terhadap kekayaan hayati di kawasan taman nasional.

Kata kunci: Polarisasi orientasi, subjek interpretasi, ekowisata, Taman Nasional Gunung Gede Pangrango

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I. INTRODUCTION

Interpretation subject is highly essential in the interpretation program. The definition of interpretation programs from various sources refers to the efforts to develop an individual's ability to deeply interpret the value of nature for humans through meaningful and pleasant experiences, impressions, and feelings to achieve management goals (Orams, 1996; Sharpe, 1982; Packer, Ballantyne & Hughes, 2014; Sim, Kim, Lee, & Poung-Sik, 2018). In an interpretation program, the area manager displays things and natural and cultural phenomena to tell stories and convey messages about the uniqueness characteristics (Moscardo, 2017). Objects such as natural and cultural phenomena commonly known by various types of resources, including flora and fauna, mountains, rivers, limestone, waterfalls, caves, traditional houses, rice fields, music, language or commonly referred to as the object of interpretation (Jupendri, Amri & Effendi, 2020; Lonardi, Martini & Hull, 2020; Tang, Erawati, Nur, & Thosibo, 2020).

In viewing and communicating objects and phenomena in the natural and cultural environments, the terms subject and object of interpretation have different meanings (Ursini & Acquaviva, 2019). The lexical meaning can be used to understand the meaning of the word "subject". Lexical meaning demonstrates that a subject refers to what he does to the object, whereas the object is subject that works or receives treatment from the subject. In the interpretation program, an object will be perceived and interpreted based on a person's perception and goal. Placing something as an object is similar to understanding anthropocentrism (Hausmann et al., 2020), which considers humans as the main subject whose interests must be satisfied. Everything in nature has value as it supports and benefits humans, and humans are the focal point of all-natural life (Gao, Zhang, & Huang, 2018; Indrawan, Primack, & Supriatna, 2007).

Furthermore, caring for nature is solely done to meet human needs, not because nature has value in and of itself; thus, it deserves to be protected (Keraf, 2002). Consequently, interpretive thinking in the context of placing something as an object means interpreting something based on one's interests (interpreter/audience). Waterfalls, for example, become the main attraction because it provides several tourist activity alternative and pleasure, or tourists can feel the coolness when they are nearby. It's different when looking at a frog or aquatic plant around the waterfall. It is not discussed as it is not interesting and unrelated to satisfy the audience`s recreational needs (Moscardo, 2017; Tatarusanu, Butnaru, Nita, Neculaesei, & Ciortescu, 2021).

On the other hand, in the context of interpretation subject, everything in the natural and cultural environment is seen as having an intrinsic value, regardless of human interests (Keraf, 2002; Girard & Vecco, 2021). The intrinsic value is the natural and innate nature of the ecosystem and implies the holism of the ecosystem, with its integrative relationships, interactions and networks (Sheng, Xu, Zhang, & Chen, 2019). This intrinsic value stems from its unique evolutionary history and the ecological role and its existence (Indrawan et al., 2007; Woźniak, Kulzyck, & Derek, 2018). Essentially, all elements in the environment (both living things and abiotic components) play roles in life. All living things have their own dignified lives and complex interdependencies and interactions (Begon, Towsend, & Harper, 2006).

The concept of interpretive thinking that places something as a subject will pay attention to all the components that exist in nature and pay respect to the intrinsic value of each element. If the waterfall is viewed from the subject's point of view, it provides only one aspect of its role. The interpreter can still provide additional information such as water source, how waterfall phenomena occur and its ecological role (Hudson, 2016). All things that exist in the natural environment and culture will be "interesting" from the standpoint of

the subject of interpretation, in the sense that interpretation can be made by providing specific information related to the values that each subject has (Kim & Coghlan, 2018).

The preceding description also demonstrates that, in conservation area management, treating everything in the area as an object of interpretation has at least two problems. The first is that understanding the object of interpretation leads to selecting specific objects or phenomena as the focus of interpretation. The selected focus is the one with the greatest attraction for tourists. Related to this, there are many examples of resources that are major attractions for tourist attractions, such as certain charismatic animal species (Marschall, Granqiust, & Burns, 2017), natural and cultural attractions of lakes and rivers (Bricker & Kerstetter, 2002), caves and hot springs (Jupendri et al., 2020; Tang et al., 2020), and landscape views (Qi, Zhang, Wang, Liu, & Li, 2017).

These conditions raise concerns about the impact of tourists' interactions with nature and the potential disruption of natural processes (Cornelisse, 2020). As a result, other resources become less well known, if not ignored entirely. The area will be recognised as a tourist destination (with certain/spectacular objects), while the management objective of the conservation area will be difficult to understand. The second disadvantage is that the wider community is unaware of natural or cultural resources. The important role of every resource is not communicated to the wider community. As a result, many people do not realize how critical it is to protect the region's resources. Because of the confusion of the subject/object position, various interpretation programs are highly subjective, especially depending on the interpreter's motives and preferences; as a result, the expected output in the audience is not optimal.

A study on interpretation, which relates resources to their intrinsic value, needs to be done. Interpretation management needs to consider the motivations and preferences of stakeholders for various resources and environmental interpretation activities (Gao et al., 2018). Management of conservation areas involve lots of stakeholder interests; hence, the incorrect response will harm area management. For managing interpretations in the area, area managers must understand the issue of polarization related to perceptions, motivations, and stakeholder preferences (Dileep, Kumar, Govindarajo, & Khen, 2020). The first reason is that the interpreter program manager must continue minimising the negative impact of management errors (Kim & Coghlan, 2018). Polarization studies provide valuable information on critical issues concerning stakeholder needs and their implications for managing interpretations (Mocior & Kruse, 2016).

The second reason is that managers need to improve existing programs (Elwell, López-Carr, Gelcich & Gaines, 2020). When interpretation management fails to consider the stakeholder interests, the program design becomes incompatible with the needs of users or other stakeholders, and the messages in the interpretation are not conveyed properly. The third reason is that polarization studies provide information about the diversity of tourist segments (Kim & Coghlan, 2018; Mutanga, Vengesayi, Chikuta, Muboko & Gandiwa, 2017) and their interest in resources and interpretation activities (López-Guzmán, Torres Naranjo, Pérez Gálvez & Carvache Franco, 2019). Therefore, managers can explore the various potentials of the existing program designs that are more varied and unique for each tourist segment based on available visit time. The purpose of this study is to analyze and evaluate the characteristics of the interpretation subject that stakeholders consider and the polarization of perceptions of the interpretation subject among stakeholders concerning the management of Gunung Gede Pangrango National Park.

II. MATERIAL AND METHOD

A. Study Site

This study was conducted in Gunung Gede Pangrango National Park (GGPNP) from September 2019 – May 2020. The GGPNP area is a catchment area and maintains an important life support system for the surrounding major cities (Bogor, Sukabumi, and Cianjur). Geographically, the national park area is located at 06°41' South Latitude - 06°51' South Latitude and 106°51' East Longitude - 107°02' East Longitude. Data were collected around Cibodas, Mandalawangi, Sarongge Village, Situ Gunung, and Selabintana. GGPNP is one of the oldest conservation areas in Indonesia. Although it has organized natural interpretation programs, GGPNP does not yet have a solid foundation regarding the design of interpretation programs, and still adheres to the requests of program users. Therefore, the study of the interpretation subject of interpretation can fill this gap.

B. Methods

The data used were collected from primary and secondary data. Primary data were obtained by distributing questionnaires to relevant stakeholders. This study collected the data from 425 respondents, containing 381 tourists, 25 area managers/tour operators, and 19 community members. The questionnaires were designed to refer to one criterion one indicator scoring system method (Avenzora, 2008), made as closed-ended questions. Each answer to the question was given a score of 1 to 7 to obtain qualitative data, besides simplifying the appropriate assessment collected from respondents. A score of 1 to 7 was according to the Indonesian characteristics which represented: 1) very unattractive, 2) unattractive, 3) quite unattractive, 4) moderate, 5) moderately attractive, 6) attractive, and 7) very attractive. In the study, the subjects of interpretation were classified into 12 groups, which resulted in 396 subjects of interpretation being evaluated by the respondents if described in greater detail (232 natural subjects and 164 cultural subjects). Validity and reliability tests were conducted to assess the questionnaire feasibility as the study instrument to obtain respondents' assessments in the study. Secondary data were obtained by reviewing area management documents and literature studies.

C. Analysis

The cluster analysis identified the stakeholders' perceptions, namely the multiple variable analysis that can classify complex variables into several groups (clusters) based on their similarity level. Cluster analysis was carried out on each respondent category (tourists, area managers/tour operators and community members). The clustering technique used was hierarchical clustering, which is a multiple variable analysis that can group/classify complex variables into several groups based on their level of similarity. A descriptive analysis on each cluster member element was carried out based on the cluster formed to understand the information cluster and basis (Dwyer, Gill & Seetaram, 2012). The difference test between stakeholders was carried out with the Kruskal-Wallis and Mann-Whitney tests. The Kruskal-Wallis test compared two variables measured from the independent samples in more than two compared groups, while the Mann-Whitney compared each stakeholder regarding their perceptions of the interpreted subject. IBM SPSS ver. 25 software was used to analyze the data.

III. RESULT AND DISCUSSION

A. Diversity of Interpretation Subjects for Gunung Gede Pangrango National Park

The subject of interpretation is very diverse, but in this study, it is grouped into the subject of interpretation of nature and culture. Information on the subject of interpretation obtained in the research area was from literary sources, especially from the Long-Term National Park Management Plan document owned by the area manager (BBTNGGP, 2018). The description of the grouping of

interpretation subjects is as follows.

1. Subjects of natural interpretation. The subject of natural interpretation primarily consists of biological and non-biological elements as a result of nature's creation, natural formations, natural interactions, and natural phenomena. The subject of interpretation of nature consists described as follows:

a. **Flora** includes various plant species with different characteristics. The national park has a high diversity of flora species. There are 925 species that grow in GGPNP, of which 412 are tree species, and 199 of them are orchid species. It was reported there was 349 floras native to the area. Interpretation subjects of flora include various species and plant habitus (trees, shrubs, vines and lianas, herbs, epiphytes, ferns, mosses, mushrooms, grasses, and bamboo), body parts of the plant (roots, stems, bark, branches and twigs, leaves, flowers, fruits, and crowns), the shape of body parts (form roots, stems, leaves, flowers, fruit, crown, and architecture) (Bell, 1991), colour (colour on the roots, stems, leaves, flowers, fruits), and substances secreted by plant organs (oils, essential oils, nectar, latex, allelopathy, and aroma).

b. **Fauna** includes a wide range of animals with different characteristics. In the GGPNP, there are more than 300 insects, 250 birds, 75 reptiles, 20 amphibians and 110 mammal. There are 5 primates (Javanese gibbon, surili, Javan langur, long-tailed monkey, and slow loris), large carnivores (leopards/ panthers), and molluscs. The interpretation subjects of fauna includes the body parts (such as the head, body, skin, limbs, and tail), form diversity (body shape, head, mouth and beak, limbs, and tail), colour diversity (colour on body parts, head, limbs, and tail), the diversity of substances released from the animal body (scent, pheromones, honey, eggs, feces, chicks), and behaviour (social behaviour such as gathering behaviour, family group, solitary, nesting behaviour, child-rearing, mating, territorial and home range; physiological behaviour such as laying eggs, wallowing, and grooming).

c. **Abiotic**/non-biological. It is distinguished based on the physical form of objects, namely solid, liquid, and gas. Abiotic components consist of various types of abiotic/non-biological components that make up land (Motiejūnaitė et al. 2019), water, and air with various characteristics. The area's topography ranges from sloping to mountainous with an altitude of 700-3,019 m above sea level (asl). Mount Gede (2,958 m asl) and Mount Pangrango (3,019 m asl) are in this area, as well as 20 waterfalls, hot springs, caves, camping grounds, lake, and beautiful landscape. Abiotic components include the variety of landscapes including mountain, valleys, hills, soil, and rocks; water forms such as rivers, lakes, and waterfalls; air formations such as various forms of wind, colour diversity (soil colour, rocks, waters), properties and substances diversity contained in abiotic components (aroma, texture, temperature, humidity, light intensity, acidity).

d. **Ecological** phenomena that includes different types of interaction that occur in ecosystems including interactions between plants and animals, interactions between biotic and abiotic components, and human interactions with the environment. Ecosystems in the GGPNP consist of types of ecosystems based on their altitude, namely: lower mountain forest (1,000 to 1,500 m asl), upper mountain forest (altitude of 1,500 – 2,400 m asl), and subalpine ecosystems (2,400-3,019 m asl). In addition to the three ecosystems, other types of ecosystems are not affected by altitudes, such as lake ecosystems, swamps, and plantation forest ecosystems (pine, resin, eucalyptus, and calliandra). Another form of the ecological phenomenon is the rarity and

endemicity of species. The national park is a vital habitat for various endangered species such as the Javan leopard (*Panthera pardus melas*), jungle cat (*Felis bengalensis*), root cat (*Mustela flavigula*), Javan gibbon (*Hylobates moloch*), surili (*Presbytis comata*), Javan langur (*Trachypithecus auratus*), ajag or coyote (*Cuon alpinus javanicus*), deer (*Muntiacus muntjak*), mouse deer (*Tragulus javanicus*), and skunk (*Mydaus javanensis*). The diversity of bird species is known to be quite high, consisting of more than 50% of bird species that live in Java. Still, there are rare species, namely 19 endemic bird species to Java Island, 58 protected bird species, 2 rare species of birds, 34 species of birds rarely found, and one extremely rare species (Nisaetus bartelsi). Three species of birds that have an endemic status as well as are rarely found and protected, namely: the Javan eagle (Nisaetus bartelsi), the mountain celepuk (Otus angelinae), and the cerecet (Psaltria exilis).

e. **Natural phenomena**; Events that occur in nature due to certain conditions, the magnitude of which varies depending on the circumstances of the causative factors. Even if the conditions are similar, natural phenomena may not occur in every location. In the national park, fog characterizes and frequently covers the mountainous area. The top of the exploded mountain forms a crater. Four active craters on the island are Ratu Crater, Lanang Crater, Wadon Crater, and Baru Crater. A stretch of meadow and edelweiss flowers also formed the square (Suryakancana Square and Mandalawangi Square).

2. Subjects of cultural interpretation. It encompasses all human creations, tastes, and intentions manifested in various ideas and concepts, objects, and works of art. The classification of the subject of cultural interpretation refers to the cultural elements proposed by Koentjaraningrat (2009) described as follows:

a. **Language**

It is a set of arbitrary spoken symbols that community use to communicate and interact with one another in the context of a shared culture. Language is generally divided into spoken and written language. There are three kinds of languages spoken in the national park area. The area manager uses Indonesian as the official language, carrying out daily tasks, making reports and correspondence, and delivering information to visitors. Sundanese is a widely spoken language in the surrounding area and is still the primary language used in everyday interactions. Foreign languages are used for specific purposes, such as communicating with foreign tourists.

b. **Living equipment and technology**

Houses and shelters, clothing and jewellery, cooking and eating utensils, work equipment, and modes of transportation are all examples of human-made equipment. Community houses come in various typologies, most of which are similar to the shape of houses in other places. Sundanese house architecture is scarce.

c. **Livelihood system**

It is related to human activities to meet their daily needs. Livelihood systems are classified as agriculture, plantation, fishing, and trading systems. The main livelihoods of the surrounding population are farmers and farm labourers. Other types of livelihoods are self-employed, private employees/ factory workers, traders, and some work as civil servants/TNI. Some residents hunt wild animals (sonari worms) in the area.

d. **Art**

It is the result of human creation and is expressed through movement, sound, composition, layout, or objects. Typically, art is performed during ceremonies or traditional events such as weddings and circumcisions.

Jipeng, one of the traditional arts in West Java Province, was created by combining three elements of art, namely *tanji* or *tanjidor*, *tapak tilu* or *kliningan*, and masks (Sundanese plays). *Jipeng* performances can take place indoors and in open spaces. *Angklung dog-dog lojor* is a musical instrument made of large diameter bamboo sticks wrapped in goat skin. This musical instrument comprises five angklungs with various tone marks and one *dog-dog* (percussion instrument). Another art is *wayang golek*, a puppet show that tells the story of Ramayana and Mahabharata using wooden puppets and accompanied by *gamelan* strains.

e. **Religion and belief system**

The religion and belief system is a form and mechanism of a belief that leads to power beyond human strength. The system of belief and religion includes religion, ceremonies, and forms of community belief in an event or supernatural thing. Islam is the dominant religion. The most common types of celebrations are religious holidays and national holidays.

f. **Knowledge system**

Many human knowledge systems are founded on nature, experience, or studies. The knowledge system is divided into two sections: knowledge about humans and nature and its surroundings. For centuries, communities around the forest have interacted with forest resources. The community also knows using plants and animals as medicine. There are 300 medicinal plants species commonly used for medicine. Necklace worms and sonari worms are extremely beneficial for curing various diseases.

g. **Social organizations and social systems**

The social system is a concrete patterned action consisting of human activities in society (Koentjaraningrat, 2009). The social system consists of the social structure, kinship and marriage relations, social organizations, rules, and norms that govern society. Sundanese people make up most of the existing local communities. The national park is surrounded by 65 villages. Mutual cooperation activities such as building houses, cleaning religious facilities, weddings, maintaining waterways, and mourning events are common in the community.

B. Stakeholders Perception of Interpretation Subjects

Stakeholders gave relatively equal ratings for each subject of interpretation (Figure 1).

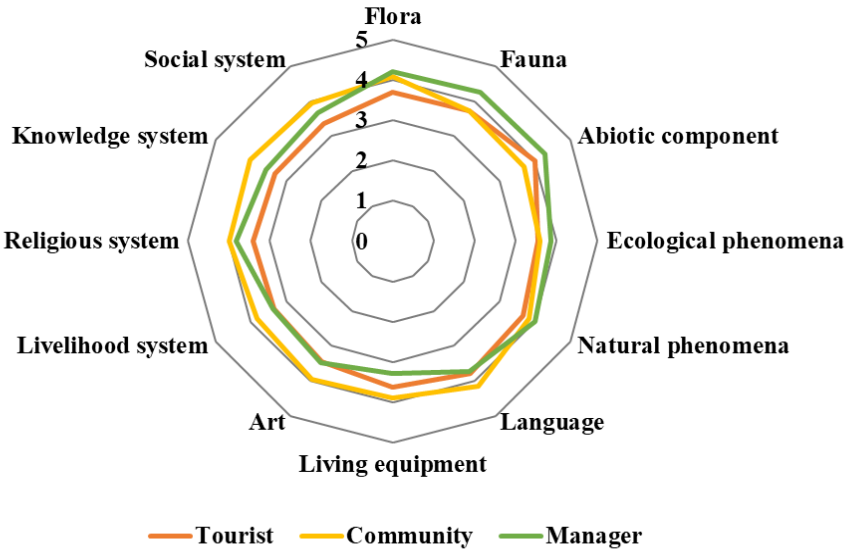

Figure 1. Orientation of stakeholders' perception to natural and cultural subjects at GGPNP area

The average score ranges from 3 (somewhat unattractive) to 4 (moderate). The tourists gave a higher average score (score 4 = moderate) on the abiotic components than other subjects. The communities gave higher average scores on the subjects of flora, language, and knowledge systems (score 4 = moderate). The managers gave a higher average score on the subjects of flora, fauna, and abiotic components (score 4 = moderate).

Cluster analysis of interpretation subjects at the GGPNP area took place in 3 tourist clusters, 2 community clusters, and 2 manager clusters (Table 1). The formed cluster consists of respondents who provide a similar composition of assessments (subject choice and the score given). Clusters with a high proportion of respondents also contributed to a widespread perception of stakeholders' proclivity towards interpretation subjects. The interpretation subjects with the highest average score in each cluster are shown in Table 1.

In general, tourists' perception of interpretation subjects is divided into three categories i.e.: perceptions of natural subjects, natural-cultural subjects, and cultural subjects (Table 1). Perceptions of natural subjects were demonstrated in the second cluster, with the highest scores on abiotic, flora, and fauna components. Perceptions of natural-cultural subjects were shown in the first cluster, with the highest scores on language, abiotic components, and natural phenomena. Perceptions of cultural subjects are expressed in the third cluster, with the highest scores on social systems, knowledge systems, religious systems, and life equipment. Overall, most tourists have a natural-cultural perception of the subject. Only a small number of tourists demonstrate a pure perception of cultural subjects.

The perception of community in the national park areas is categorized into two groups: perception for cultural aspects (second cluster of the community) and perception for nature-culture (the first cluster of the community). Living equipment had the highest average score in the second cluster, while social systems and abiotic components obtained the highest average score in the first cluster. Judging from the number of respondents who were members of the cluster formed, the perception of community respondents is more likely to choose the natural-cultural aspect.

The perception of GGPNP area managers/ tour operators is also classified into two sections: perception for nature-culture (the first cluster of managers) and perception for natural aspects (the second cluster of managers). Religious systems, fauna, and abiotic components got the highest average

Table 1. Selected interpretation subject by stakeholder groups

Subject	Clusters formed in each category of stakeholder						
	Tourist 1 (n=246)	Tourist 2 (n=129)	Tourist 3 (n=6)	Com 1 (n=11)	Com2 (n=8)	Man 1 (n=16)	Man 2 (n=9)
Flora	5.06	**1.18**	1.92	5.35	1.62	5.22	**2.39**
Fauna	5.28	**0.92**	1.17	5.25	1.12	**5.33**	**2.36**
Abiotic components	**5.35**	**1.53**	1.77	**5.51**	1.35	**5.32**	**2.47**
Ecological phenomena	5.29	0.32	1.72	5.31	0.94	5.12	1.61
Natural Phenomena	**5.34**	0.64	1.05	4.94	0.89	5.18	1.92
Language	**5.46**	0.64	2.43	5.40	1.45	5.15	1.25
Living equipment	5.18	0.66	**4.04**	5.32	**2.12**	4.55	1.04
Art	5.04	0.43	2.55	5.28	1.13	4.98	0.85
Livelihood system	4.95	0.28	3.43	5.24	0.96	4.71	1.03
Religious system	5.03	0.31	**4.40**	5.25	1.21	**5.37**	1.08
Knowledge system	4.97	0.12	**4.46**	5.42	1.14	5.06	0.90
Social system	4.97	0.24	**4.63**	**5.80**	1.25	5.04	1.24

Remarks: Data obtained from the results of cluster analysis. Score is the average value in the cluster that is formed. The number written in bold is the highest value in the cluster.

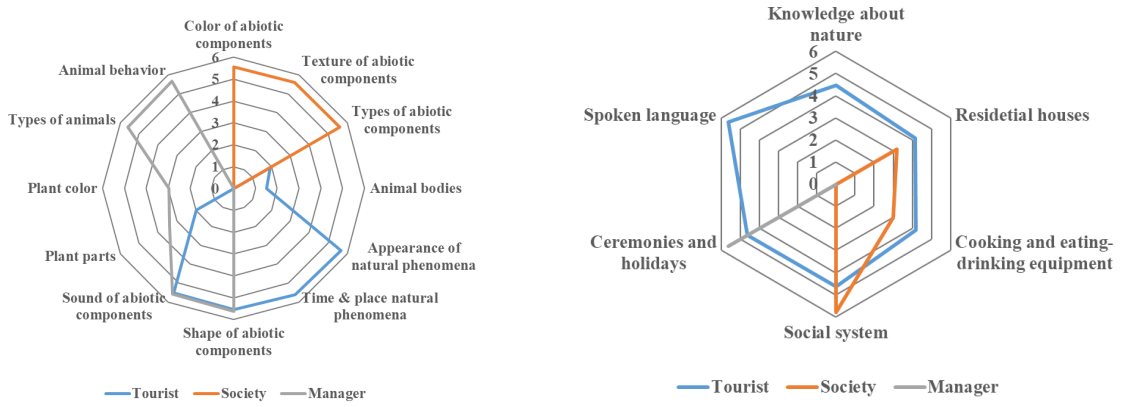

Figure 2. Stakeholder's perception to interpretation subject; (a) natural subjects; (b) cultural subjects

score in the first cluster. Whereas in the second cluster, the abiotic components, flora and fauna acquired the highest average score. Based on the number of respondents who are members of the clusters, the manager's perception for the natural-cultural aspect achieved the highest score. This is presumably due to the difference in vision among the managers/tour operators (Cochrane, 2000) and their understanding that the subject of interpretation is considered to be interesting if it can provide enthusiasm for visitors and has uniqueness hence it can attract tourists. If this assumption is correct, then the subject of interpretation of nature, with its uniqueness and value, has failed to communicate the management message to the larger community.

The abiotic component is the subject of interpretation, identified as the stakeholders` perception in GGPNP (Table 1). Knowledge systems, language, and natural phenomena are some of the subjects specifically identified in the tourist groups. Livelihood systems, arts, and ecological phenomena are not subjects of interpretation identified as respondents' perception.:

Tourist perception for natural subjects in the area is depicted in Figure 2a. Flora, abiotic components, natural phenomena, and fauna were identified as attractive, but fauna subjects received the lowest score by tourists. In abiotic components, tourists concern more about sound, shape, and types of abiotic components. The sound of abiotic components received a higher average score than the type and form of abiotic components. Natural phenomena were also among the natural subjects with a high average score of tourist interest. The aspects that drew attention were the time and place of natural phenomena occurrence and the appearance of natural phenomena. Natural subjects of flora and fauna got a low score from tourists. These results indicated that the scenery and the unity of the natural components in the national park created a different natural atmosphere for most tourists. Many visitors may simply want to enjoy scenery and have little interest in studying plants and ecosystems (Ballantyne, Packer, & Hughes, 2008).

A small number of tourists' perceptions of cultural subjects were identified (Table 1) and certain cultural subjects, such as language, social systems, knowledge systems, religious systems, and living equipment, can attract tourists. Spoken language has the highest average score. A house, as well as cooking and eating utensils, attracts tourists` attention, while ceremonies and holidays are two religious subjects that also attract tourists` attention. Furthermore, knowledge of natural and social systems can be an attraction in the GGPNP area.

Many villages border the GGPNP area. The villages located around the national park can attract tourists (Djatmiko, Syarifuddin, Raharja

& Fitriani, 2021), where the language and daily life of the community serve a different atmosphere for tourists. The lack of interest in the cultural subject is most likely because the entrances to the national park point to natural destinations as is the main attraction. White, Buultjens and Shoebridge (2013) stated that the lack of tourists' awareness, the lack of products available to tourists, and limited partnerships between local product suppliers and tour operators caused the low interest of domestic tourists in some countries to the culture of local communities.

Our study found that stakeholder perception in the national park is converging on the subject of nature (in this case, the abiotic component), and the atmosphere built by natural elements. This result is in line with Sunarminto, Alikodra and Avenzora (2014) who found that in Cibodas tourist area the tourists` recreational or tourism motivation is for recreation, picnics, photographs, playing and social contact, (Farkic, Isailovic, & Taylor, 2021) as well as cool air to relax, remove boredom from everyday life. Similar findings by Cochrane (2000) found that domestic tourists from Indonesia and Asia tended to enjoy (national) parks as a pleasant place to relax with friends and family, rather than appreciate the wilderness and protected biodiversity.

Community favoured natural-cultural subjects, but there was a stronger perception for the subject of cultural interpretation (Table 1). The subject of abiotic components (types, colour, and texture) was identified as the characteristics of natural subjects of interest for the GGPNP area (Figure 2a). The social system is a prominent perception in the GGPNP area from a cultural aspect and received the highest score from the community. The social system concerning the structure of society, kinship, marriage, rules and norms, and social organization is regarded as attractive (Djatmiko et al., 2021). These findings indicate that the cultural aspects inherent in everyday life are attractive to tourists. Community culture also provides educational value for tourists (Mocior & Kruse, 2016).

The managers valued three crucial natural subjects: flora, fauna, and abiotic components. Animal behaviour, animal species, plant colour, plant parts, the sound and the shape of abiotic components were natural subjects that obtained higher scores. Figure 2a showed that managers were more likely to choose the subject of fauna and abiotic components, while flora (colour of plants and plant parts) did not receive a high score from the respondents. Ceremonies and holidays had higher scores in the cultural subject. It is presumed that this result is related to the image of the area that is identical as a natural area and its main potential is in a natural setting can improve welfare through tourist experiences, and the motives of tourist visits (Mutanga et al., 2017; Farkic et al., 2021; Tauro et al., 2021).

From all stakeholders perspective, four natural subjects (flora, fauna, abiotic components, and natural phenomena) in GGPNP including 1) characteristics of flora consist of plant parts (leaves, flowers, crowns), and plant colour (leaf colour), 2) characteristics of fauna consist of types of animals (primates, birds, and large mammals), animal bodies (body parts), and animal behaviour (nesting behaviour and parenting behaviour), 3) characteristics of abiotic components consist of types (water, air temperature, air humidity), shape (waterfalls, water flows), colour (watercolour), sound (sound of waterfalls, river sound), and textures (soil texture), and 4) characteristics of natural phenomena, namely its colour and scarcity .

National park areas with diverse plant species have a lot of opportunities for interpretation of tree species. Some species are well-known to the public, but many more are not. Several factors that affect the introduction of species such as the ability to recognize morphology, interest in nature, the duration of appearance and observation of species, and the size of species (Ishibashi, Akasaka, Koyanagi, Yoshida & Soga, 2020). The introduction of flora types focuses on morphological characteristics that distinguish species (De Bastiani, Nervo, Singer

& Buzatto, 2020). The number of species used for people's daily life and the species that are often found are still too few compared to the number of species richness found in the national park area. Some of the data collected in the field included pine (*Pinus merkusii*), areca nut (*Arenga* sp.), rasamala (*Altingia excelsa*), ki hujan (*Samanea saman*), puspa (*Schimma wallichii*), kiriung anak (*Castanopsis acuminatissima*), and pasang (*Quercus gamelliflora*). In addition, human knowledge is still limited regarding the use of various types of flora hence people tend to leave species that are considered useless. Therefore, the introduction of various species is necessary to increase public awareness of nature conservation.

Primates, birds, and large mammals are the three groups of fauna that are the main attraction in the national park area. Several groups of primates can be found in several locations, either because they have a settled territory in certain areas or because they get used to the presence of humans. Primates are interesting because of their human-like characteristics both in its anatomical structure and social behaviour. Citing Hughes and Ballantyne (2013), some animals are inherently more attractive and evoke more positive emotional responses than others.

The creatures that display human-like characteristics are most likely to have the most impact on people's emotional responses (Hughes & Ballantyne, 2013). Types of primates that tourists have known include the long-tailed monkey (*Macaca fascicularis*), the javan langur (*Trachypithecus auratus*), and the javan gibbon (*Hylobates moloch*). The diversity of bird species in the area has also attracted the attention of tourists. Eagles (such as *Nisaetus bartelsi*) and finches (*Pycnonotus* sp.) are widely known to tourists. The shape and size of the body, feather colour, sound, and behaviour of bird species are interesting. The shape of the beak is related to the type of feed, while the type of bird feed varies such as seeds, fruit, insects, nectar, or meat. The diversity of bird species and their food types illustrate the complex interactions in the ecosystem. Another interesting aspect from the wild life is its behaviour that is different from other elements of the nature. Physiological and social needs drive behaviour in wildlife that is often used to monitor the population. Nests of the Javan eagle (*Nisaetus bartelsi*) for example are used to track the population of this endemic animal to Java Island.

Wild animals are common in the area. Primates, birds, reptiles, amphibians, and insects can be found along the tourist trail. Furthermore, the manager has created a specific path for bird watching in areas with high bird species diversity. Body size and colour affect the ease of viewing in the wild (Ishibashi et al. 2020). Small body size and body colour that blends with nature become a strategy for wildlife to avoid predators.

Meet with wildlife in their natural habitat can have a significant impact on tourists (Cornelisse, 2020; Dell'Eva, Nava & Osti, 2020; Hughes & Ballantyne, 2013). This activity will encourage physiological and psychological connections with the natural environment (Cooley, Jones, Kurtz & Robertson, 2020; Moscardo, 2017; Servidio & Ruffolo, 2016). This is generally done in wildlife tourism environments, where animals are used to evoke feelings of wonder, empathy, and concern, and it requires specially designed tools and methods (Ballantyne, Hughes, Lee, Packer & Sneddon, 2021; Flower, Burns & Jones, 2021; Lück, 2016). Hughes and Ballantyne (2013) found a correlation between feelings of wonder and respect for the animals seen and the desire to save these animals.

The characteristics of the national park area as a mountain forest ecosystem with many rivers and waterfalls, with atmosphere (the effect of vitality, richness of colour, sensation of joy, beauty), and sounds heard in nature (Qi et al., 2017), seem to make the subjects related to this get more attention from tourists. There is a relationship between the character of the physical environment and the activities undertaken (Lane & Stoltman, 2017). Many respondents said that the purpose of tourists coming to the national park is to enjoy the waterfalls and the natural atmosphere. The

peace and serenity of park spaces and their spiritual and restorative benefits have also been characteristics that attract people (Ballantyne et al. 2008).

In GGPNP, five cultural subjects (language, living equipment, religious systems, knowledge systems, and social systems) have been identified from all stakeholders: 1) language characteristics consist of spoken language (regional language), 2) characteristics of living equipment consist of residential houses (architecture, direction towards the house, decoration), cooking and eating-drinking equipment (material storage equipment, material preparation equipment, food processing equipment, burning equipment, food serving equipment, eating-drinking equipment, and shape, motifs, and colour cooking and eating-drinking utensils), 3) characteristics of a religious system consist of ceremonies and holidays (time of worship, celebration of holidays, thanksgiving/ salvation ceremonies), 4) characteristics of the knowledge system consist of knowledge about nature (knowledge about natural objects/ the surrounding environment), and 5) the characteristics of the social system consist of youth organizations.

The languages (especially the local language) instigate pride in their cultural identity. In addition studies have shown that minority cultures and languages create unique travel experiences for guests (Lonardi et al., 2020). Language is strongly related to a particular culture. Learning a language for tourists will open up a better understanding of a new place (Martin & Woodside, 2011). The rules of social life bind the overall behaviour in social interactions. These rules of life are usually specific to a particular society following the philosophy of life they hold (Mavhura & Mushure, 2019). The principle of harmony with nature still becomes the national park area`s people`s philosophy of life and serves as an example for tourists with different cultural backgrounds (Djatmiko et al., 2021; Gunara, Sutanto & Cipta, 2019).

The house`s architecture is physical evidence of the culture uniqueness in the community. In general, the shape of the house in the countryside around the national park is not much different from other areas. Houses with its characteristics (architecture, decoration, and direction of building), as identified from the research results, cannot be separated from the life principles in society, and describes the hope for the welfare of its inhabitants.

C. Polarization of Stakeholders` Perception of Interpretation Subjects

Stakeholders have different motivations and perceptions of various subjects found in one region (Villamediana-Pedrosa, Vila-López & Küster-Boluda, 2020). However, it is necessary to identify whether the subjects are considered important to meet the needs and satisfaction of the visits made or which subjects need more attention to support the achievement of management objectives.

In the GGPNP area, there was a weak polarization of stakeholders; perceptions to the attractiveness of natural and cultural subjects. Kruskal-Wallis test also showed that there were no significant differences between respondents (Asymp. sig. > 0.05) (Table 2). Table 2 demonstrates that stakeholders have stronger polarization, as shown by the highest Kruskal-Wallis test, on the subject of abiotic components, fauna, flora, and knowledge systems. High polarization of abiotic components occurs in tourists-community and community-managers with lower significance values (Table 3). As mentioned before, there are differences in perceptions of abiotic components among stakeholders (Figure 2a).

Based on the previous description, tourists' preference for natural-cultural subjects is stronger, with the highest score for natural subjects (abiotic components) in the second cluster of tourists. Flora, fauna, and abiotic components are the main interpretation subjects for managers. The gap in this case, is that the subject of abiotic components is still rarely

Table 2. The test results of differences in stakeholders perceptions regarding the attractiveness of the interpretation subject

Subject	Mean	Test Statistics[a,b]		
		Kruskal-Wallis H	df	Asymp. Sig.
Flora	3.76	1.624	2	0.444
Fauna	3.77	1.953	2	0.377
Abiotic components	3.99	3.921	2	0.141
Ecological phenomena	3.57	1.345	2	0.511
Natural Phenomena	3.71	0.591	2	0.744
Language	3.81	0.062	2	0.97
Living equipment	3.64	0.396	2	0.82
Art	3.49	0.05	2	0.975
Livelihood system	3.39	0.739	2	0.691
Religious system	3.49	1.226	2	0.542
Knowledge system	3.40	1.543	2	0.462
Social system	3.43	0.375	2	0.829

Remarks: a. Kruskal Wallis Test, b. Grouping Variable: Stakeholder

Table 3. The results of the pairwise difference test among stakeholders related to the attractiveness of the subject of interpretation

Subject	Asymp.sig Value Test Statistics [a]		
	Tourist-Community	Tourist-Manager	Community-Manager
Flora	0.390	0.323	0.536
Fauna	0.327	0.386	0.112
Abiotic components	0.060	0.672	0.093
Ecological phenomena	0.291	0.753	0.231
Natural phenomena	0.586	0.584	0.582
Language	0.950	0.796	0.940
Living equipment	0.934	0.554	0.445
Art	0.894	0.854	0.880
Livelihood system	0.411	0.986	0.371
Religious system	0.414	0.421	0.804
Knowledge system	0.260	0.563	0.508
Social system	0.623	0.698	0.526

Remarks: Mann Whitney Test, a. Grouping variable: Stakeholder

raised in the delivery of interpretation. The biodiversity of flora and fauna is more regularly appointed by the manager for interpretation in the area, while the motive of tourists coming to this national park is to enjoy the waterfalls and rivers. Furthermore, the knowledge system appears as tourist`s perception. As the owner of this subject, the community group does not make its knowledge system available to tourists.

Stakeholders showed the weakest polarization on the subject of living equipment, social systems, language, and the arts. Stakeholders had a perception of the natural-cultural subject (Table 3). In general, cultural subjects had not been seen as the main perception of stakeholders in the GGPNP area. Great interest in cultural subjects appeared in a small number of tourists. Nevertheless, several subjects had potential attractiveness for tourists, namely language, living equipment, social systems, knowledge systems, and religious systems. Table 3 shows that the subjects with weakest polarization

among stakeholders are language and living equipment that have a high significance value among stakeholders. In general, stakeholders gave language subjects high scores. However, they solely appeared as the main subject in the tourist cluster, while living equipment appeared as the main subject in a small group of tourists and the community (Table 1).

Perceptions among stakeholders also showed a negative direction of polarization (mean value <4) on each subject of the interpretation assessed. The abiotic component got a score close to 4. This shows that the abiotic component is considered more important by stakeholders. Observations at the study site showed that the abiotic component provided considerable motivation for tourist arrivals. Waterfalls, rivers, cool air, and landscape views are natural attractions that tourists want to enjoy. The motivation to study flora and fauna is owned by a smaller group of students or researchers. The negative polarization of all subjects indicates that the subjects have not received much attention from stakeholders. The components of the ecosystem do not receive individual attention, but natural nuances formed from the unity of the ecosystem are what they want. So far, the interpretation in the region is primarily focused on the subject of flora and fauna. The findings of this study recommend greater attention to the interpretation of abiotic components. Various studies in the ecology field show that abiotic components are crucial components for living things (as a habitat for flora and fauna and provide environmental service) and a foundation for ecosystem balance (Motiejūnaitė et al., 2019; Vanermen et al., 2020).

D. Implications for Ecotourism Management in National Park

Conservation and natural tourism should be able to run simultaneously in the national park management. Therefore, decision-makers need to understand and incorporate tourists' perception of nature appreciation, infrastructure development, usage restrictions, and other attributes of national parks. Tourist perception on interpretation subjects is considered to increase the sense of connectedness with the area (Bricker & Kerstetter, 2002; Dileep Kumar et al. 2020; López-Guzmán et al. 2019; Rivera, Fa & Villar, 2019; Zhu, Davis & Carr, 2021).

The mission of preserving the area must be interpreted to ensure the sustainability of this life. People understand this as much as possible in an acceptable way (Ababneh, 2018). The increased support for conservation efforts from the larger community will have an impact on the area (Stoffle, Seowtewa, Kays & Van Vlack, 2020). All-natural and cultural components in and around the national park area have intrinsic value that must be recognized as much as possible for their role in life. The larger community must continuously improve its capacity to realize its participation and behaviour in environmental ethics (Alikodra, 2012; Dileep Kumar et al. 2020; Djatmiko et al. 2021; Meilani, Andayani, Faida & Maryudi, 2019; Murti, 2019).

GGPNP has a long history of protecting nature. Currently, the national park areas raise three main species as superior species, namely the Javan tiger (Panthera pardus), Javan eagle (Nisaetus bartelsi), and Javan gibbon (Hylobates moloch) (BBTNGPP, 2018). Superior species refers to those that are unique and get a lot of attention (Root-Bernstein & Bennett, 2017; Radomskaya & Pearce, 2021). It is intended to attract and maintain public commitment to play a thorough role in the required conservation measures (Qian et al. 2020) and attract large number of visitors with a positive impact on the destination (Weidenfeld, 2010). Our study found that, abiotic components (waterfalls and bodies of water, air temperature and air humidity) tended to be accepted as subjects that provide the main perception for tourists to come to the GGPNP. Therefore, these subjects will further introduce the values and role of the ecosystem to tourists (Bricker & Kerstetter, 2002; Elwell et al., 2020; Hudson, 2016).

Interpretation can be done with various methods (Ababneh, 2018; Beattie & Schneider,

2018; Lane & Stoltman, 2017; Martin & Woodside, 2011; Muneenam, Suwannattachote & Mustikasari 2017; Tatarusanu et al., 2021; Tan & Choy, 2020; Zhu et al., 2021), but considering that tourist arrivals are more due to the attractiveness of outdoor space, the interpretation for the use of outdoor space must be strengthened (Cooley et al., 2020; Moscardo, 2017; Mutiara, Rachmawati & Sunkar, 2021; Tarver, Cohen, Klyve, & Liseki, 2019). Interpretation methods in outdoor spaces that can be applied in the GGPNP area are: traveling around, interpretation paths, and on-site panels (Fang, Yamanaka, & Trencher, 2021; Marschall et al., 2017). Traveling around are allowed to enjoy more of the elements in outdoor spaces. One of the challenges in its implementation is tourists` willingness to accept the presence of a guide/interpreter on their tour since some tourists consider it as private activities. There are several interesting routes for visitors. Hiking trails in the national park area serve the primary route for visitors. There are also bird-watching paths and a canopy trail. Interpretation along the path is accomplished by strategically placing important information about natural subjects.

The visitor center can also explain information during direct observation. Nature`s mechanisms, such as the hydrological cycle, can be explained through the process flow in the form of images. Likewise, visitors to the national park can see samples of soil (soil type and texture) and rocks collected from difficult-to-reach locations. Waterfalls and rivers are subjects that receive great attention from stakeholders. Water bodies and waterfalls need to be managed carefully, as they are vulnerable to overuse and environmental mismanagement (Hudson, 2016). Management needs to be done by developing a water component-based interpretation program. In addition to ensuring that these natural resources are managed sustainably, it aims that ecotourism development can reach further areas outside the national park (Muzambiq, Walid, Ganie & Hermawan, 2021) and connected to the flow of water from waterfalls. This development will ultimately increase the participation of the community around the national park area in tourism activities (Bushell & Bricker, 2017; Mayaka, Croy & Cox, 2018; Sinaga, Ginting & Marpaung, 2020).

Regarding the cultural aspect, local wisdom still needs attention from conservation area managers (Vitasurya, 2016). The local community already knows natural resource management through observation and factual experience, application of management practices, social institutions, and the knowledge of nature (Joa, Winkel, & Primmer, 2018). The knowledge possessed by the community can be transmitted to tourists through interpretation programs that raise natural and cultural subjects (Gunara et al., 2019; Kausar & Gunawan, 2018; Mavhura & Mushure, 2019). At the same time, this will help introduce the biological richness found in the national park area, which is not widely known by the public.

IV. CONCLUSION

Interpretation subject is a novel approach to observing resources in the interpretation program. This viewpoint considers the intrinsic value of each component of the environment. Research results show that perceptions among stakeholders against the subject of interpretation in Gunung Gede Pangrango National Park indicate weak polarization and a relatively uniform perception of the subjects of interpretation in the region. Natural and cultural subjects have not received high interest as interpretation subjects, in the sense that their attraction is still used to the extent of fulfilling tourist desires. In general, stakeholders prefer natural and cultural subjects. However, abiotic components should get greater attention in the management of GGPNP interpretation. This knowledge is essential for the role of abiotic components in the ecosystem and considering stakeholders' perceptions that place a higher value on this subject.

This research provides recommendations for the development of interpretation programs by increasing the attractiveness of various

interpretation subjects in the national park area, paying attention to tourists' preferences as the main stakeholders of the interpretation program targets, and developing cultural interpretations based on local wisdom of the communities related to natural management. This is also an effort to increase public participation in the management of interpretation in GGPNP. Considering the importance of tourist experience and satisfaction for the success of interpretation goals in the national park area, a more in-depth research on tourist motivations on various interpretation subjects is needed so that managers can design appropriate programs for various tourist segments. In addition, looking at the diversity of natural and cultural characteristics of national parks in Indonesia, similar research can be conducted on different national parks characteristic..

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MANAGEMENT STRATEGY OF ELEPHANT RIDING AT THE ZOO

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MANAGEMENT STRATEGY OF ELEPHANT RIDING AT THE ZOO. Elephant Riding (ER) in zoos has become a matter of public interest, raising debates among experts regarding animal ethics, elephants' welfare, and human safety. Through the submission of the Middle Hypothesis that ER tends to enhance human knowledge about conservation, this study's aim is to provide strategies to help zoo managements in their works based on the basic principles of wildlife conservation and protection, especially Sumatran elephants. The participants' knowledge was measured using questionnaires distributed to two groups of respondents: people who have and people who have not utilized ER services. Meanwhile, the strategy was recommended through the Analytical Hierarchy Process of 17 expert respondents. According to the independent sample t-test performed with 95% confidence level, human knowledge of elephant conservation increased significantly through ER. Furthermore, experts with consistency ratios (CR) ≤ 0.1 selected a strategy where environmental quality was prioritized as a recommended strategy in ER management. This strategy is to put forward the principles guaranteeing the elephants' welfare, which has a criterion weight of 0.40717. The other recommended strategies include conducting conservation education (0.23973), ensuring the safety of visitors (0.22972), and improving the welfare of the community around zoo (0.12338).

Keywords: Elephant riding, Sumatran elephant, zoo, and analytical hierarchy process

MANAJEMEN STRATEGI WISATA MENUNGGANG GAJAH DI KEBUN BINATANG. Atraksi Wisata Menunggang Gajah (WMG) di Kebun Binatang telah menjadi perhatian publik dan perdebatan para ahli terkait etika, kesejahteraan gajah dan keselamatan manusia. Melalui pengajuan hipotesis antara bahwa WMG dapat meningkatkan pengetahuan manusia tentang konservasi, penelitian ini bertujuan untuk menyediakan rekomendasi strategi yang dapat diadopsi oleh Kebun Binatang berdasarkan prinsip dasar konservasi dan perlindungan satwa liar, khususnya gajah Sumatera. Pengetahuan diukur melalui kuesioner yang dibagikan kepada dua kelompok responden, yaitu yang sudah dan yang belum pernah memanfaatkan layanan WMG. Strategi dihasilkan melalui Proses Analisis Bertingkat (AHP) dari 17 responden ahli. Berdasarkan uji-t test dengan tingkat kepercayaan 95% dapat diketahui bahwa pengetahuan manusia tentang konservasi gajah meningkat secara signifikan melalui atraksi WMG. Selanjutnya para ahli dengan rasio konsistensi (CR) ≤ 0,1 memilih strategi yang mengutamakan kualitas lingkungan sebagai strategi yang direkomendasikan dalam pengelolaan WMG, yaitu strategi yang mengedepankan kesejahteraan gajah, dengan bobot kriteria sebesar 0,40717. Selanjutnya secara berturut-turut: sebagai sarana edukasi konservasi (0,23973), menjamin keselamatan pengunjung (0,22972) dan meningkatkan kesejahteraan masyarakat sekitar Kebun Binatang (0,12338).

Kata kunci: Wisata menunggang gajah, gajah sumatera, kebun binatang, AHP

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I. INTRODUCTION

The Sumatran elephant (*Elephas maximus sumatranu*s) is a protected wildlife species (Appendix I) with a critically endangered status (Gopala et al., 2011; Hankinson, Nijman, & Abdullah, 2020). Based on a survey carried out in 2017, the Sumatran elephant population in Indonesia reduced from 1,694 - 2,038 to 928 -1379 in 2019 (DBC, 2020). The majority of these species live in natural habitats of 36 habitat pouches in the seven provinces within Sumatra island: Aceh, North Sumatra, Riau, Jambi, South Sumatra, Bengkulu, and Lampung (Nofinska, Sumayyah, Andayani, Maryanto, Kheng, & Sugiharti, 2019; Sitompul, Griffin, & Fuller, 2013; Sukmantoro et al., 2019; Tohir, Mustari, & Masy'ud, 2016). According to previous studies, a total of 483 Sumatran elephants, which were moved from their native habitat and due to a history of conflict with humans, now live in the conservation area created in the existing protection and conservation program (Armanda & Abdullah, 2018; Qomariah, Rahmi, Said, & Wijaya, 2019). The Elephant Training Center (*Pusat Latihan Gajah*, PLG) or Elephant Conservation Center is a rescuing center specifically focused on protection and rehabilitation program (*Pusat Konservasi Gajah*, PKG or Elephant Rescue Unit/ERU, Flying Squad, or Conservation Response Unit/CRU). Based on related records, 231 elephants are under Indonesian government management, while 252 elephants are controlled by private zoos and aquarium management known as *Taman Safari* (Safari Park), as well as animal parks, and ex-situ conservation managements (Braverman, 2014). However, only 26 out of 81 zoos have received permits to exhibit the Sumatran elephant, distributed across Sumatra and Java, including *Taman Safari Indonesia*, Bali Zoo, Gembira Loka, Medan Zoo, Bandung Zoo, and Lagoi Bintan Safari Park.

Generally, the presence of Sumatran elephants in zoos has become a priority as a genetic reserve (Febryano et al., 2019; Rustiati et al., 2020). Besides being rescued and rehabilitated, these elephants are also used for educational and ecotourism purposes (Pirotta & Lusseau, 2015), in this case, Elephant Riding (ER) activities, where the animals are introduced and exhibited. Several experts and observers have discussed the pros and cons of these activities (Taylor, Hurst, Stinson, & Grimwood, 2020), for instance, some claim ER prioritizes business aspects (Duffy & Moore, 2011), rather than the ethics and principles of conservation (Gunaryadi, Sugiyo, & Hedges, 2017; Kaffashi, Yacob, Clark, Radam, & Mamat, 2015; Wahyu, 2019). However, others have claimed these activities are ethical and consider the welfare of wildlife (Kuswanda, Situmorang, Berliani, Barus, & Silalahi, 2018; MoEF, 2019; Polyapipat & Loh, 2015). This study, therefore, aims to evaluate the current opinion of experts in support of ER, starting from the middle hypothesis where ER was postulated to increase human knowledge on the Sumatran elephant and the species' conservation aspects (Mellish, Ryan, Pearson, & Tuckey, 2019; Moss et al., 2017). Furthermore, this study aims to provide zoos with strategies for handling the Sumatran elephant based on the basic principles of wildlife conservation and protection (*Elephas maximus sumatranu*s).

II. MATERIAL AND METHODS

A. Scope of the Study

The object of research is Elephant Riding (ER) in zoos, while the scopes of study are perception and improvement of public knowledge about elephants and related conservation efforts, and ER management strategies. Data collection was performed using the questionnaire method with a minimum number of 30 respondents (Kerlinger & Lee, 2000). The form A questionnaire was used to obtain the perceptions of the public and measure the difference in knowledge between people with experiences in using ER services and people with no experience in using these services. Meanwhile, the form B questionnaire was distributed to expert respondents and

contained several questions on the criteria (level 1) and strategies (level 2) mapped based on literature studies and interviews. Subsequently, the data obtained were processed through the *Analytical Hierarchy Process* to measure the consistency of expert respondents in making pairwise comparisons between alternative criteria and alternative strategies. The analysis was then enriched through in-depth interviews with several consistent expert respondents or respondents with a consistency ratio $\leq$ 0.1 (Saaty & Vargas, 2012).

B. Procedures

1. Public Perception and Knowledge About ER and Elephant Conservation

Due to the Covid-19 pandemic restrictions, the distribution questionnaire was carried out online using Google Forms with the link address https://bit.ly/FormA-Elephant-Riding. The A form questionnaires were distributed purposively to the public respondents through WhatsApp. Data collection was carried out for 4 weeks: April to May 2020, and the respondents were verified based on the telephone numbers provided. Subsequently, the data obtained from verified respondents were further processed.

2. Determination of Criteria and Strategy Alternatives

According to Figure 1, the hierarchy was built on three levels: objectives, criteria, and choices. The aim was the same as the research objective: to recommend an improved ER management strategy for zoo managements based on basic conservation principles. In a hierarchical structure, elephant conservation principles were identified as criteria and strategy choices. These criteria and strategy choices were determined through analysis of references from ER-related literature and regulations, which was further strengthened by expert interviews who have knowledge, experience and/or authority related to elephant, conservation and ER (Saaty, 1993, 2012).

The questionnaires were based on the hierarchical structure in Figure 1, containing 1 pair of comparison questions for the criteria and several pairwise comparison questions for the strategy, where n is the number of elements. Meanwhile, Table 2 shows the number of paired comparisons (cn) for n elements on each criterion, and the strategy question was several n [(n-1) / 2]. Therefore, in total, the questionnaires for nk criteria elements and

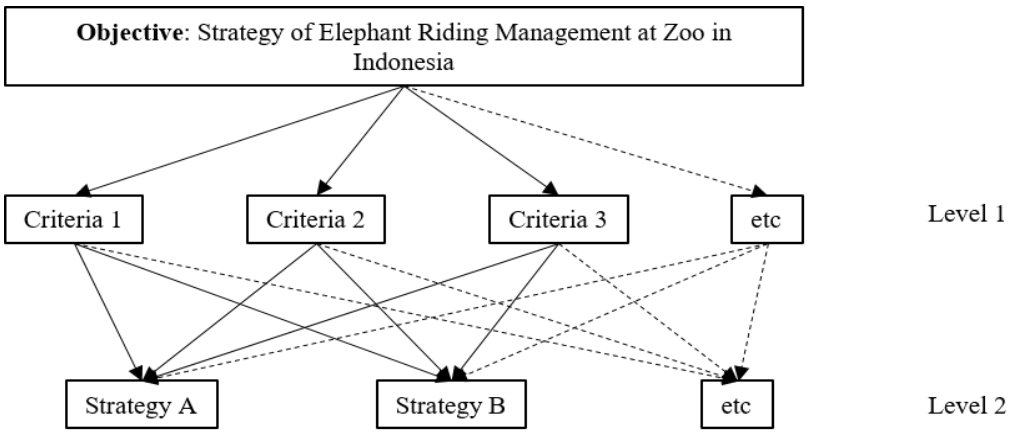


Figure 1. The hierarchical structure of questionnaires

Table 1. Number of comparison questions based on element amounts per questions group

∑ element (n)	1	2	3	4	5	6	7	8	N
∑ comparison (c_n)	0	1	3	6	10	15	21	28	n[(n-1)/2]

Source: Saaty and Vargas (2012)

ns strategy elements are bound to contain a total of (nk [(nk-1)/2]) + (nk {ns [(ns-1)/2]} pairwise comparisons (Saaty & Vargas, 2012).

Table 2 shows the Pairwise comparisons performed using 9 scale comparisons between elements. Table 3 shows the sample question format used for all the questions on criteria and strategies for 3 elements samples, while Table 4 shows the n x n matrix format used to tabulate the data contents. Based on these two tables, element A is more important, compared to element B (9), element A is a little more important, compared to element C (3), while element B is a little less important, compared to element C (1/3).

All comparison questions between elements were formulated in the Form B questionnaire and distributed to expert respondents selected using a purposive sampling technique, with the inclusion criteria of experts who fulfilled competencies related to elephant conservation and ER and expressed willingness to become respondents. Due to the Covid-19 pandemic restrictions, the form B questionnaires were distributed by email. Further information was acquired through in-depth discussions with the experts after the forms had been filled, submitted, and accepted by the researchers. The time for data collection and in-depth interviews were performed during a period of 3 weeks, from April 14, 2020, to May 5, 2020.

C. Data Analysis

1. Public Knowledge About ER and Elephant Conservation

Respondent characteristics data were tabulated, while the knowledge data was analyzed using the Statistical Package for the Social Science Program for window version 20 (SPSS 20), which includes validity, reliability, normality, and homogeneity analyses, as well as a t-test. The validity and reliability tests were conducted to test the accuracy and consistency of the A form questionnaire which comprised

Table 2. Scale comparison between elements; an example of a comparison between elements X and Y

The scale of importance between elements	Comparison Scale
Element X is as important as element Y	1
Element X is a little more important than Element Y	3
Element X is a little *not* more important than Element Y	1/3
Element X is clearly more important than element Y	5
Element X is clearly *not* more important than element Y	1/5
Element X is very clearly more important than element Y	7
Element X is very clearly *not* more important than element Y	1/7
Element X is absolutely more important than element Y	9
Element X absolutely *not* more important than element Y	1/9
Given if there is a little difference with the above benchmark	2,4,6,8, or ½,1/4,1/6,1/8

Source: Saaty and Vargas (2012)

Table 3. An example of a question format with 3 elements compared

Left Element	Importance scale in left element								Equally important	Importance scale in right element								Right Elemen
A	⑨	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	B
A	9	8	7	6	5	4	③	2	1	2	3	4	5	6	7	8	9	C
B	9	8	7	6	5	4	3	2	1	2	③	4	5	6	7	8	9	C

Table 4: An example of a matrix with 3 elements, before and after filling

Element / Element	A	B	C
A	A vs A	A vs B	A vs C
B	B vs A	B vs B	B vs C
C	C vs A	C vs B	C vs C

⇨

Element / Element	A	B	C
A	1	9	3
B	1/9	1	1/3
C	1/3	3	1

18 questions. These questions are deemed valid in cases where the calculated r-value is greater than the value of r in the product-moment table at a significance level (α) of 5%. Meanwhile, the questionnaire is said to be reliable in cases where the value of Cronbach's Alpha (Cα) is greater than the critical r-value at a significance level of 5% and the degree of freedom (df) on two sides (df = n-2) (Kogar, Demirduzen, Gelball, & Inal, 2016).

Subsequently, normality and homogeneity tests were conducted to test the distribution and uniformity of respondents' data knowledge. The respondents with and without experience in using ER services were identified using the Kolmogorov-Smirnov normality test and the Levene homogeneity test. In cases where these tests fulfill the significance requirements, an *Independent Sample t-test* is to be performed (Kim, 2015).

2. Criteria and Strategy Choices

The significance level is with a consistency ratio (CR) value below or equal to 1, meaning CR $\leq$ 0.1 (Saaty and Vargas, 2012). The CR was calculated for all pairwise comparisons per respondent, per group of respondents, and combined, using the excel program following equation 1. Subsequently, the *eigen* values were calculated using equation 2, and the highest weighted *eigen* value was selected as the chosen strategy (Csató, 2017; Xu & Wang, 2013). Equations 1 and 2 are given below.

$$CR = \frac{CI}{IR}; \text{Where } CI = \frac{\lambda max - n}{(n-1)} \text{ dan } Ax = \lambda_{max} x \quad \text{.....(1)}$$

$$|A - \lambda I| = 0 \quad \text{.....(2)}$$

Where:

CR= consistency ratio; CI=consistency index; IR =random index (Table 5); λmax= maximum eigen value; n =amount of element; A =matrix n x n; λI=matrix of eigen identity; λ= eigen value; x =eigen vector

III. RESULT AND DISCUSSION

A. Knowledge Enhancement

1. Respondents' Characteristics

A total of 50 A forms were received from respondents with or without experience in using ER services. The majority (54%) of the respondents were men, while 46% were women. The Majority of the respondents were below 43 years (87%) and 76% ranged from 20 to 43 years . Furthermore, most respondents had acquired university graduate education (83%) and were currently employed (74%), while 4% were house wives. Based on sample data, the majority (56%) of the respondents with experience in using ER services were female, while 44% were male.

2. Data Validity, Reliability, Normality, and Homogeneity

Based on the results, the 18 questions on the A form questionnaire are all valid research measurement tools. The questionnaires can also be repeatedly marked with Cronbach's Alpha values of 67% and 71%. These values are above 60%, therefore, the six indicators asked through the questionnaire are valid and reliable to measure public knowledge about elephants and related conservation efforts (Table 6).

Furthermore, the respondent's knowledge data variable is spread normally, and the diversity of data from the two data groups is homogeneous or the same. This is indicated by the significance values of 0.469 and 0.104, respectively. These two values are above 0.05, and have, therefore, fulfilled the significance to test the difference between the two samples through the independent t-test sample.

3. Acceptance of the Intermediate/Middle Hypothesis

With each n sample of 50 people, public knowledge on elephants and related

Table 5. Number Random Index (IR) based on amount of elements (n)

N	1	0	3	4	5	6	7	8	9	10	11	12	13	14	15
IR	0	0	0.58	0.9	1.12	1.24	1.37	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Table 6. Themes and indicators of knowledge on elephants and related conservation efforts

Theme	Indicator of question	Question
Knowledge of Wildlife Conservation, Especially Elephants	Sumatran Elephant Conservation	Knowledge of elephants
		Knowledge about Conservation
	Environment	Knowledge about Environmental Conservation
Knowledge of ER at Zoo	Elephant Riding	Knowledge about Elephant Riding
	Animal welfare	Knowledge about elephant utilization by paying attention to the animal welfare
Knowledge of conservation / Zoo functions as a means of education	General zoo	Knowledge of zoo functions
		Knowledge of Visitor Comfort and Improvement of Community Welfare

conservation efforts gained due to the use of ER services amounted to 14.92. This value is higher, compared to the counterparts without experience in using ER services, which amounted to 12.88 (Table 7).

According to Table 8, the *Asymp.sig* (*2 tailed*) value is about 0.002, which is below 0.05, therefore, H0 is rejected, and H1 is accepted. This test explains the differences in the average value of knowledge about elephants and related conservation efforts. At a 95% confidence level, ER can be said to significantly influence an increase in public knowledge about elephants and their conservation efforts. Therefore, ER managers can optimize the function of zoo as an educational tool. However, materials and messages need to be conveyed in appropriate manners as required, to grow public awareness of wildlife conservation through direct interaction between visitors and keepers or mahout, both before and during the attraction. The zoo's animal exhibition activities provide opportunities for the community to receive knowledge about wildlife directly from the keepers. Table 6 shows the keepers are able to explain the details of elephants and their interactions with humans, the history of the elephant exhibited, and whether the attraction exhibited is in accordance with animal welfare. At this stage, information in the form of pictures, symbols, or instructions will also play a good role (Kuswanda et al., 2018). Subsequently, managers need to maintain a linked interaction between the management unit and visitors, to ensure the zoo's function as a means of education and knowledge development and fulfill the requirements of ethical management.

C. Criteria

In wildlife exhibitions, zoos must be guided by certain management and animal welfare ethics. Based on the analysis from several literary sources as well as in-depth interviews, 4 criteria were proposed. These criteria are the welfare of the elephants, security of humans as users of ER services, conservation education, and community welfare improvement around zoos.

1. Criteria of Elephant Welfare

Humans control captive animals in existing conservation programs, therefore, all needs related to the animals' life and welfare must be properly fulfilled (McGowan, Traylor-Holzer, & Leus, 2017). These needs are closely related to the quality of the environment in new habitats because a good environmental quality implies a guarantee of adequate food, resistance to disease (nature provides medicine), comfort of socializing, as well as improved reproduction cycle in elephants (Gusset & Dick, 2015). In this study, elephant welfare was measured based on five criteria (Demartoto, Soemanto, & Zunariyah, 2017; Williams, Carter, Hall, & Bremner-Harrison, 2019; Wolfensohn, Shotton, Bowley, Davies, Thompson, & Justice, 2018): freedom from hunger and thirst, freedom from discomfort, freedom from pain, injury, and disease, freedom to express normal behavior, as well as freedom from fear and distress (MoF, 2011). These criteria are based on certain

principles which are explained below.

a. Freedom from hunger and thirst

Elephants spend most (41%) of their time eating, while 34%, 9%, and 2% of their time is spent resting, bathing or wallowing, and drinking, respectively. According to Kuswanda et al., (2018) and Sitompul et al., (2013), the proportions of mealtime, drinking, walking and resting activities are 82.2%, 1.7%, 9.5%, and 6.6%, respectively. This highlights a need for the amount of feed in the ex-situ area to be similar to the amount of feed eaten in the wild. Generally, elephants require about 10% of body weight in feed, per day. Therefore, the Sumatran elephant with an average body weight of 2,378 kg, requires about 200-237 kg of feed, daily. The species of elephant feed in the wild are more varied, with at least 273 plant species belonging to 69 plant families, particularly Poaceae, Cyperaceae, Moraceae, and Fabaceae which comprise 29 grass species, while the common non-grass species include twigs, tubers, certain fruits, and various kinds of palm, and vines (Sitompul et al., 2013). In the dry season, additional species of feed, for instance, bran, rice, rice dregs, green beans, brown sugar, sugar cane, pineapple, papaya, banana leaves, coconut leaves, and banana stems, are often consumed by elephants (Tohir et al., 2016). However, banana stems as feed ought to be given in moderation, due to the high risk of ventral edema, a fluid retention condition that leads to the formation of lumps. Also, elephant feed must not be placed on the ground to avoid contamination with pathogens. Therefore, zoo managers must consider the animals' species, frequency, age factors, and present. Elephants also require about 100-300 liters of water per day (Thohir, 2016; Kuswanda, 2018). Besides drinking, elephants need water for wallowing, which is necessary to reduce dehydration and fulfill the mineral salts requirements, for instance, calcium, magnesium, and potassium (Kuswanda et al., 2018). The zoo must, therefore, provide water tanks within the cages to meet these water needs. Also, the floor of the cage can be covered with sand to increase the elephant's comfort.

b. Freedom from discomfort

This is fulfilled by providing the animals with comfortable cages by considering certain requirements (Tohir et al., 2016). Based on these requirements, the minimal number of elephants per cage is 3, and open cages must have a minimum area of 500 to 2000 m2, while the minimal area of the enclosures is 6 to 12 m2, and the quarantine enclosures must have a minimum area of 200-577 m2. Other requirements include the construction of wooden poles and iron pipe barriers, concrete cement material, minimal roofs of non-zinc roof tiles (Tohir et al., 2016), equipment, carrying capacity, temperature, and cage humidity (Tohir et al., 2016; Wahyu, 2019). For the maintenance aspects of the cage, it is necessary to pay attention to the floor, protective conditions, cleanliness of the cage, and the condition of the drainage canal (Tohir et al., 2016; Wahyu, 2019).

c. Freedom from pain, injury, and disease

Zoo managers need to ensure adequate medical services are constantly available for the animals. For instance, the physical conditions of elephants must be checked every 3 to 6 months, the bodyweight/Body Correction Index must be measured regularly, periodic internal parasite restrictions must be performed every 3 to 4 months. Furthermore, electronic records must be created to document every disease and disorder, as well as the treatments performed for each animal. Also, appropriate elephant health must be identified through testing of diagnostic schemes that affect elephant health, provision of vitamins, as well as carrying out periodic feces examinations every 3 months (Zemek et al., 2016). Therefore, all the zoo's medical/veterinary and paramedical staff must be competent in handling new diseases, administering the required drugs at the proper dosage, as well as collecting blood samples and ulas samples from respiratory holes (blowhole

swabs) (Wahyu, 2019). Zoo managers must also openly provide the government with information about diseases arising in the management of animals.

d. Freedom from fear and distress

Fear and stress tend to have a negative effect on elephant health, growth, and reproductive capacity (Kuswanda et al., 2018; Wahyu, 2019). However, this can be prevented by establishing interaction between mahout and the elephant, for instance, being invited to talk, walk, exercise, and socialize with other elephants in the camp. This can influence the concentration of salivary cortisol production and, consequently, reduce stress (Bansiddhi et al., 2019; Plotnik & de Waal, 2014). To increase the sense of security and comfort of elephants used for wildlife attractions, there is a need for an agreement in the use of working tools, for instance, the eccentric tool, *ankus*, and *howdah* (saddle). Managers must ensure the howdah is attached to a thick, soft cloth before being worn on the elephant, to avoid discomfort. Subsequently, the howdah is then bound to the bottom using a strong rachet tie-down. The *gancu* and *ankus* are suitable for controlling animals, however, animal welfare must always be prioritized in the use of this tool.

e. Freedom to express normal, natural behavior

These criteria are required to ensure optimum reproduction rates. According to the Indonesian Government Regulation, the main program of most zoos is to increase the populations of rare and endangered animals through breeding (MoF, 2011). Zoo managers must prioritize breeding programs based on the reproductive power of elephants, through adequate planning, for instance, optimizing genetic diversity, maintaining collections for attractions, providing the appropriate number of mahouts, and expertise regarding elephant reproduction (Nofinska et al., 2019). Gusset & Dick (2015) showed a quality relationship between mahout and elephant tends to have a positive effect on elephant reproduction, therefore, managers need to recruit experienced mahouts, for instance, PLG/PKG trainees. Zoo management must also provide adequate space, facilities, and same-species friends for animals, to provide animals with the freedom to behave normally (Tohir et al., 2016).

2. Criteria of Conservation Education

Apart from being recreation, zoos also serve as a means of education, scientific development, research, and genetic reserves. In this instance, education emphasizes the environment of elephants in their habitat (Demartoto et al., 2017; Moss et al., 2017; Schultz & Joordens, 2014). The delivery method must be packaged attractively to arouse the interest of individuals and community groups towards the conservation of natural resources. Furthermore, the Delivery Method must provide opportunities to gain awareness, knowledge, and expertise, form environmentally-friendly behavioral patterns, develop conservation ethics, eradicate conservation blindness, and improve attitudes, as well as skills, consequently, instilling visitor satisfaction. The seven sciences which can be studied in zoos are basic observational, reproductive-physiological, veterinary, genetics, behavior, and productivity sciences.

Conservation education/environmental education can be implemented in zoos through several delivery methods, including exhibition, experiments, inquiry, field trips, project teaching, discussions, case studies, role-playing, simulation, brainstorming, and learning contracts. A report by McGowan et al. (2017) showed information also ought to be dissipated through journals, print, and electronic media. This aims to build support for zoo activities within the whole community regarding fulfilling administrative and legal aspects. Managers can also deliver educational materials through direct interactions with zookeepers/mahout, film/slide exhibitions before elephant riding, visiting schools, or indirectly through symbols/ornaments.

3. Criteria for Improving Community Welfare

The relationship between zoo managers and the surrounding community must be built with mutual openness and mutual respect. Febryano et al., (2019) showed both attitudes tend to create opportunities to improve the economy of the community, consequently, raising a sense of sympathy and consciously safeguarding the security of the tourist area, maintaining order and the location's cleanliness, as well as providing appropriate/comfortable accommodation. Therefore, managers must provide employees with skill training programs on safety, security, making traditional food, providing tourist souvenirs, building groups of observers, building tourism service cooperatives to open community involvement in tourism operations, and providing other supporting facilities (Berliani et al., 2018; Gunaryadi et al., 2017; Polyapipat & Loh, 2015; Pratiwi et al., 2020).

4. Visitor Safety Criteria

Febryano et al., (2019) explained zoos must always guarantee visitor safety, indirect interactions with elephants because this affects visitor satisfaction. This can be achieved through strengthening the promotion, by providing complete information to the public on the services provided to fulfill visitor satisfaction, resulting in a good perception. In addition to the safety of visitors, zoos must also pay attention to animals safety by refusing to exhibit animals in heat or musth period, providing animal companions and nurses to supervise visitors and prevent any harassment, humiliation, or abusive treatments to the animals (Plotnik & de Waal, 2014; Williams et al., 2019; Zemek et al., 2016). These four criteria listed above were presented in a random hierarchical structure to produce a sequence: Elephant Welfare, Visitor Safety, Conservation Education, and Improvement of community welfare.

D. Alternative Strategy

The advanced content analysis based on the principles manifested as the criteria above produced 4 strategic choices which are explained below.

1. Environmental Quality Management

The environment plays a crucial role in the survival of animals. According to the principle model of modern captive animal management, there are four physical domains: environment, nutrition, physical health, and behavior, and the fifth domain is mental health. This implies the need for a quality and comfortable environment which mimics the conditions of the animals' natural habitat (Braverman, 2014; Gunaryadi et al., 2017; Gusset & Dick, 2015; Holden, 2019; Wahyu, 2019).

2. Aesthetics Improvement

This is fulfilled by improving visitor comfort and animal comfort, for instance, through improved cage infrastructures and visitor facilities (Kuswanda et al., 2018).

3. Travel Segmentation Regulation

To avoid overload of visitors and ensure the welfare of the elephants, there is a need to implement tourism segmentation, through diversification of activities, as this is the most appropriate solution to increase tourist satisfaction with various choices of tourism activities (Duffy & Moore, 2011; Febryano et al., 2019; Kaffashi et al., 2015).

4. Imposition of competitive Ticket Prices

The ticket prices offered by business units are based on the uniqueness and superiority of each attraction. Therefore, zoo managers need to create unique attractions -tours that are in demand by visitors but do not seem to exploit elephants (Bennett & Dearden, 2014). The options above use the eco-tourism approach, which is based on the principles of nature and environmental sustainability (Kuswanda et al., 2018). The natural resources in this case, which are elephants, are sustainable and must be developed in terms of the cultural value of elephants and conservation programs, to improve the community's economy. Furthermore, the use of elephants with

consideration for welfare aspects using the principle of ecotourism is very appropriate. Therefore, the ER development strategy research in zoos is expected to become a model for achieving sustainable management of the natural resource, in this case, elephants, to increase the opportunities for breeding, genetic preservation, research objects, and eco-tourism purposes.

E. Hierarchical Structure

Figure 2 shows the hierarchical structure built to formulate a strategy for improved ER management based on the basic principles (criteria) of conservation in the zoo. Based on the structure above, a form B questionnaire was created. This questionnaire contained 1 group of level 1 questions related to the achievement of objectives and 4 groups of level 2 questions related to each element of the criteria. Each level comprised 4 elements, and each question group comprised 6 comparison questions between elements, therefore, the total number of comparison questions is 30.

F. Suggested Strategy

1. Consistency

Consistency is measured by the consistency ratio for each question group per expert respondent. In level 1, 12 expert respondents obtained perfect consistency, which fulfilled the consistency ratio <= 0.1 for all questions. However, 7 expert respondents obtained a consistency ratio> 0.1 for 1 to 3 question groups. After verification was conducted, the Form B questionnaires were resent to the 7 expert respondents with inconsistent pairwise answers and only 5 forms were returned. The second verification and refill produced consistent results for all groups of questions. Subsequently, data processing was continued and the eigen vector (weight), as well as the eigen value of the criteria and strategies, were calculated.

2. Criteria Weight/Eigen Vector

Of the 17 expert respondents in this study, 4 are from the regulator group (government), 5 are from the researcher group (BRIN, Forestry Research and Development Agency, and university), and 8 belong to the operator group (zoo, veterinary associations, NGOs and zoos associations). Table 9 and Figure 2 show the criteria weights per each group of expert respondents.

Based on Table 9, the expert groups selected welfare as the main criteria in the management of ER within zoos. This option is bound to assist managers in prioritizing the interests of elephant's welfare compared to human aspects and business interests. Elephant ethics and needs must be arranged following the

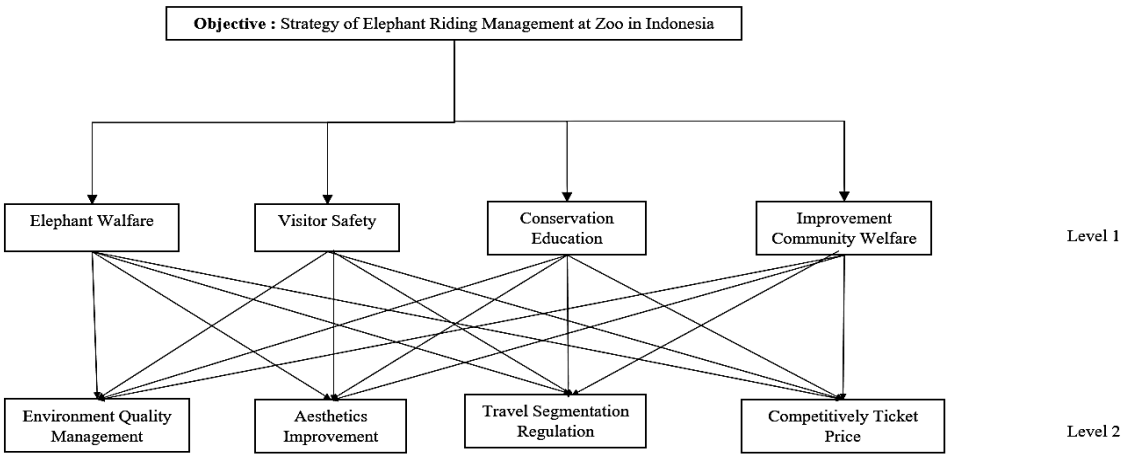


Figure 2. The hierarchical structure of achieving improved ER Management at the zoo

Table 9. The single and combined Eigen vector/weight of the criteria for the respondent groups

Criteria	Criteria Weight from Expert Group/priority			Combined / priority
	Regulator	Researcher	Operator	
Welfare of elephant	0.37336 [1]	0.43505 [1]	0.39795 [1]	0.40717 [1]
Visitor Safety	0.19717 [4]	0.26236 [2]	0.22254 [3]	0.22972 [3]
Conservation Education	0.22561 [2]	0.18922 [3]	0.28043 [2]	0.23973 [2]
Improvement of Community welfare	0.20386 [3]	0.11336 [4]	0.09908 [4]	0.12338 [4]

Remarks: 0,32273: 1 Means the first order

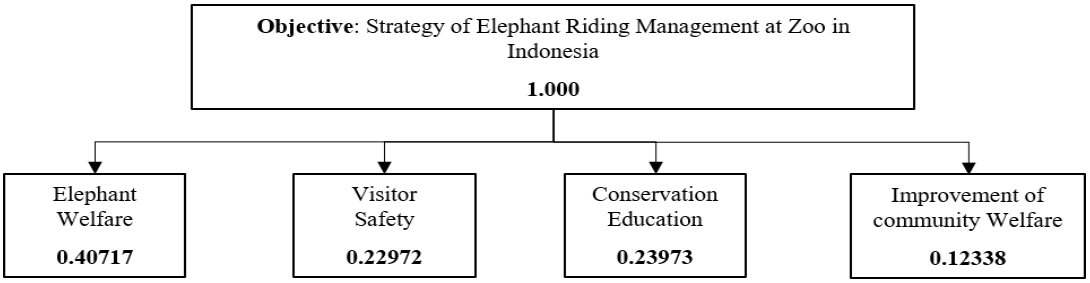
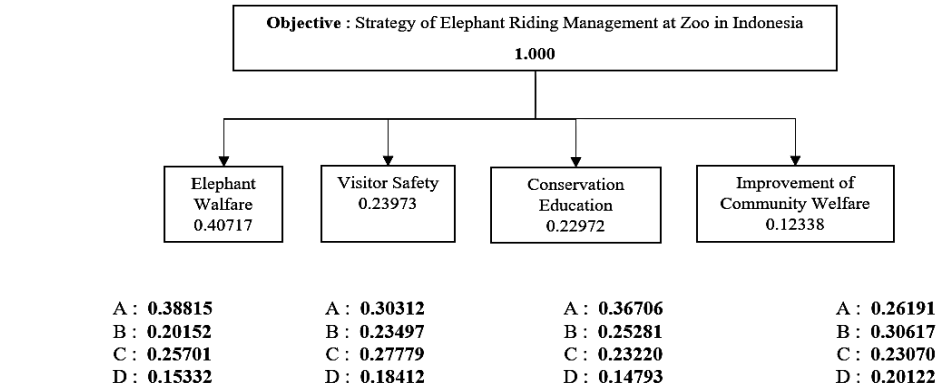


Figure 3. The weight of the criteria in a hierarchical structure



Remarks: A= Environment Quality management B= Travel Segmentation Regulation C= Aesthetic Improvement D= Competitively Ticket Price

Figure 4. The hierarchical arrangement of the weight of strategy choices (eigen values)

standards for use of animals, as appropriate and acceptable tourism guidelines. In addition, several choices were selected by the expert groups for the 2nd, 3rd, and 4th priorities, with visitor safety and conservation education as the second and third priorities, respectively, albeit with fairly thin weight differences. Therefore, this option needs to be implemented into ER management programs because a sense of security and comfort of ER service users is bound to instill positive perceptions (Curtin, 2010; Kuswanda et al., 2018) and influence public knowledge (Clayton et al., 2017) on animals and related conservation efforts. Also, welfare improvement was selected as the 4th criterion, thus, the eigen vector can be arranged hierarchically (Figure 2).

3. Weight/Eigen Strategy

Figure 3 shows the eigen values produced from pairwise comparisons at the second level, while Figure 4 shows the arrangement of these eigen values into a priority matrix. Meanwhile, Figure 5 and Table 10 shows the eigen values

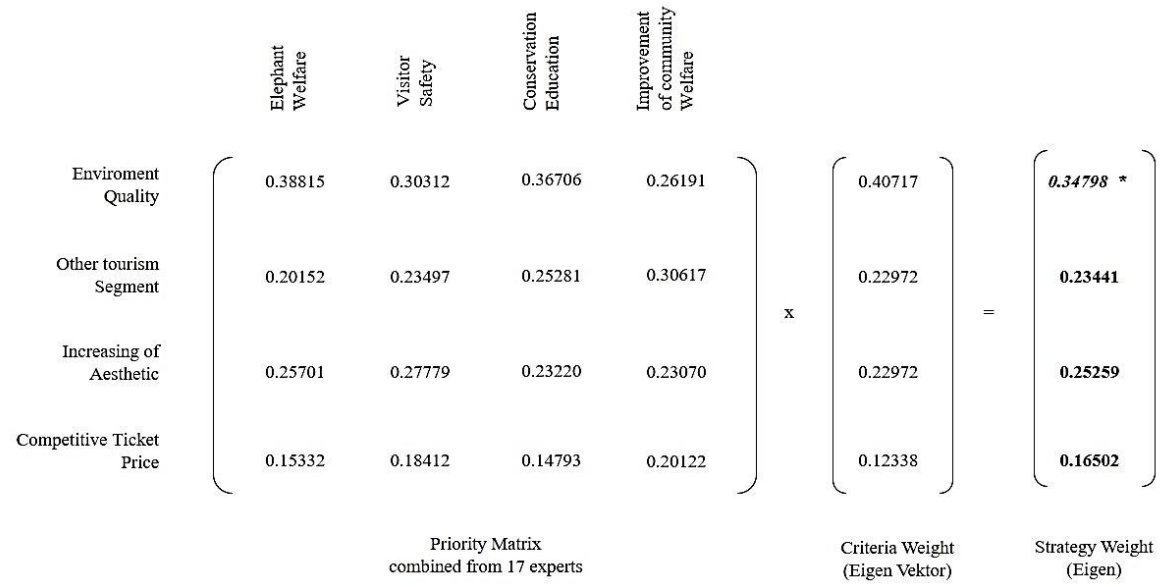


Figure 5. The priority matrix, eigen vector, and eigen vectors in achieving the goals

Table 10. The single and combined eigen vector/weight criteria for the respondent groups

Strategy	Strategy Weight from Expert Group/priority			Combined / priority
	Regulator	Researcher	Operator	
Environmental Quality Management	0.32273 [1]	0.32350 [1]	0.32350 [1]	0.34798 [1]
Travel Segmentation Regulation	0.26936 [2]	0.22357 [3]	0.22357 [3]	0.23441 [3]
Improve Aesthetics	0.22183 [3]	0.29200 [2]	0.29200 [2]	0.25259 [2]
Competitive Ticket Prices Imposition	0.18608 [4]	0.16093 [4]	0.16093 [4]	0.16502 [4]

Remarks: 0,32273 ; 1 means the first order

or weights obtained for each strategy choice, by multiplying the priority and eigen vector matrices. In this table, information on strategy weights per expert group is added to review the attention for each expert group.

Based on Table 10, the experts undoubtedly selected environmental quality as the priority strategy 1 in managing ER within Zoos. The experts also determined the pricing strategy for the final choice of tickets. This explained the choice of pricing strategy is very sensitive and has the capacity to strengthen the ER requirements in business aspects, compared to conservation (Lötter et al., 2018). Despite the different views for options 2 and 3, the choice of strategies aesthetics improvement and travel segmentation regulation were selected as the second and third priorities, with a thin difference in weight number.

4. Priority Strategy: Environmental Quality Management

Animals are bound to be comfortable in environments that simulate the conditions of their natural habitat, and this has a significant influence on the health of wild animals. The Indonesian government, through the Minister of Environment and Forestry Regulation Number:P.22/Menlhk/Setjen/Kum.1/5/2019, has implemented regulations that require certain commitment documents to be readily available, including the Environmental Management Actions and Environmental Monitoring Efforts (UKL and UPL), as well as environmental permits. This section recommended the following programs as suitable techniques for ER managers to meet elephant welfare requirements.

a. Providing UKL-UPL documents as a reference in EC development

The tourism environment comprises the physical environment, including landscape, certain features such as rivers, rock outcrops, beaches, as well as flora and fauna. To reduce the environmental damage caused by ecotourism activities, the UKL-UPL document is required. This document aids the identification of susceptible environmental components around the zoos, estimation, and evaluation of possible impacts of zoo infrastructure development, as well as provision of certainty and compulsory commitments/obligations which must be implemented to achieve sustainable development and a sound environment.

b. Providing of Environment Permit documents

The environmental permit contains the identity of zoos, planned business activities, possible environmental impacts, as well as environmental management and monitoring programs, including wastewater disposal permits and B3 waste temporary storage permits.

c. Fulfillment of regional targets as Green Open Space

Under Law Number: 26 of 2007, the existence of zoos as open green spaces can be assessed based on the diversity of vegetation, aesthetics, and usefulness, to determine the capacity to provide comfort to visitors, surrounding communities, and animals. Zoo managers can optimize green space by grouping animals, circulation, cages, and enclosures, as well as the transition space between the zoo and the surrounding environment, as well as supporting facilities and vegetation.

d. Environment

The environment comprises biotic aspects, including flora and fauna, as well as abiotic aspects, including temperature, water, and shade. All wildlife in a tourist environment must be identified and assessed for potential benefits and threats in the region (Kuswanda et al., 2018). The suitable temperature range for elephants is 26–37°C, while the temperature in a closed enclosure is above 15–21°C (Tohir et al., 2016). Therefore, tree canopies need to be filled to regulate the temperature and humidity and protect the animals from extreme weather conditions. The zoo must also have an installation and clean water network to fulfill all water needs in the elephant nursery for drinking and wallowing, as well as for caring and bathing of elephants. A clean environment is bound to give a sense of comfort to both the animals and visitors.

5. Secondary Strategy

The secondary strategies include aesthetics improvement, travel segmentation regulation. and competitive ticket price imposition.

a. Aesthetics Improvement

Kuswanda (2018) showed the aesthetics and the beauty of tourism sites have the capacity to provide satisfaction and comfort to customers, in cases where the environment is in quality tourism. This study recommended the following three programs/activities to achieve improved aesthetics.

1) Arrangement of an ecotourism business management plan

The ecotourism business management plan must be adjusted to the carrying capacity of the area, management of animal collections, cage placement, cage size, cage shape, visitor facilities as well as the information on the species' biology, scarcity status, required breeding space, and freedom to exhibit natural behavior.

2) Visitor Facility Design

According to Kuswanda (2018), the design of visitor facilities can provide knowledge on the importance of wildlife conservation. For instance, the creation of an elephant gallery, a dining area that doubles as a waiting room decorated with elephant knick-knacks, and is equipped with a series of information about the species' history, current issues,

and reasons for exhibition. Another suitable example is designing a place for animals/ cages/exhibition/display space in the wild to sensitize the imagination of visitors to the behavior of animals within natural habitats, for instance, providing fallen tree trunks which are usually used by elephants to reach fruit or twigs in higher positions, and providing tree trunks to support the natural habits of elephants who like to rub their bodies against trees, wallow, ropes, rocks, as well as providing hiding places and cages to sleep.

3) Increasing the diversity of potential tree species

In addition to developing the physical sector, aesthetics for the comfort of visitors can also be improved by increasing the diversity of potential tree species (Fant et al., 2016; Parker, 2020). This is bound to support the reduction of air pollution and fulfill certain environmental commitments. The zoo management is advised to pay particular attention to (*Ficus benjamina*), white teak (*Gmelina arborea*), angsana (*Pterocarpus indicus*), trembesi (*Samanea saman*), and red dadap (*Erythrina cristagalli*) species which can be planted in the zoo area (Kuswanda et al., 2018).

b. Travel Segmentation Regulation

The occurrence of excess visitors can be mitigated by grouping visitors into several attraction categories. This is in line with the report by Febryano et al., (2019), where the diversification of attractions was reported to be the most appropriate solution to increase tourist satisfaction while reducing the risk of threats to animals. The availability of multiple choices of tourist attractions will provide space and time for wildlife to rest. These variations of attractions can be packaged uniquely with creative marketing, for instance, accompanied by information stating the purpose of attraction is to maintain a balance between business and animal welfare, as a means of increasing income whilst improving wildlife sustainability. In this study, four main programs/activities were recommended to increase tourism segmentation.

1) Ensuring the carrying capacity of elephants is fulfilled

According to Febryano et al., (2019), the carrying capacity of elephants at the Way Kambas National Park Office is 20 minutes for two people per round and each elephant should not be used for more than one hour every day, except for old, pregnant, and disabled elephants which must not be used. This carrying capacity is often determined at a level where there is a balance between protection and utilization of elephants, by maintaining the pattern of elephant activity in the wild (Febryano et al., 2019). The carrying capacity of elephants can also be calculated through the elephant's estimated Body Correction Index / BCI measurements. A report by Wahyu (2018), showed the BCI is used as a reference in analyzing other health parameters, and the trend in its value implies whether an elephant is suitable for attraction or not.

2) Increasing creativity and innovation for zoo managers.

In elephant-based tourism areas, training in the knowledge of elephant behavior ensures the safety of visitors and mental training for mahouts/keepers to manage emotions when training elephants. Mahout's closeness to elephants can be increased through more engaging activities such as running, walking, and training (Demartoto et al., 2017; Ward and Melfi, 2015; Williams et al., 2019). Zoos must increase the knowledge of mahout/keepers and other technical staff by providing training programs to improve the zoo's service/number/visitor safety and animal welfare. These programs include elephant-based tourist scout training, training to analyze tourist market trends, training to provide services based on tourists' desires, training to arrange simple scouting programs following elephant-based dynamics and specialties, training in appropriate guiding techniques to increase

tourist flow and length of stay within the area, as well as training in the knowledge of elephant behavior to ensure visitor safety, and mental training for mahouts/keepers to manage emotions while training elephants.

3) Determination of visitor quota
In cases of excess visitors, the manager must restrict visitors by implementing a quota system. This implementation can be performed online, which is supported by strengthening promotions and information. The implementation mechanism for determining quotas can also be stated in the zoo's SOP, which can also contain standards for animal welfare and educating visitors on elephant riding in tourist areas (Duffy and Moore, 2011).

4) Attraction type of elephant specific tour
The management of elephant-based tourism must consider necessary morals and ethics (Duffy and Moore, 2011). The community must be educated on the importance of elephant conservation to ensure protection and tourism are achieved simultaneously. According to Kuswanda (2018), elephant-based ecotourism activities are interactions between elephants and visitors, for instance, tracking with elephants into the forest, elephants bathing, and herding elephants into the forest, as well as observing the educational anatomy and behavior of elephants, in addition to enjoying natural or artificial conditions in the elephant tourism area, for instance, exploring rivers and mountains, observing natural plants of elephant feed, making elephant feed (elephant cake), and camping. Duffy and Moore (2011) reported the Elephant Conservation Center in Thailand offers numerous tourism services using elephants that cannot be released back to nature, for instance, elephant riding, shows, selling of elephant paintings, or other activities, to meet the welfare requirements of elephant tourism.

Examples of potential attractions for the development of elephant-based ecotourism services include the Green Valley Wildlife Park (Taman Satwa Lembah Hijau), which offers elephant care exhibition activities including cutting elephant nails, as well as bathing and herding elephants in their natural/artificial habitat in KHDTK (Forest Area with Special Purposes) Aek Nauli, as well as the Way Kambas National Park Office. Tours with special interests like these need to be developed by zoo managers in addition to tours where visitors interact directly with elephants. Think Elephants International has also developed educational-based tourism in Thailand, where students are invited to interact directly with elephants either through skype or visit conservation centers. These activities are aimed at increasing empathy and motivating students to learn about ecosystems and conservation issues through elephants.

c. Competitive ticket Prices Imposition

Ticket prices are one of the main factors determining the number of tourists. Kuswanda (2018) suggested offering products with the same quality but relatively lower prices to provide increased value. In this study, two programs/activities were recommended to achieve a competitive ticket price, as explained below.

1) Unique tours which favored visitors but did not seem to exploit elephants usually took longer time at higher costs, for instance, tourist activities involving direct interactions with elephants. A report by Febryano et al., (2019) showed these types of tours were not popularly demanded by local visitors, as these visitors often selected packages with lower prices, compared to foreign tourists. This challenge can be overcome by determining prices in the tourism sector, for instance, through price discrimination. The determination of tourist entrance ticket price in a tour/price discrimination is highly

beneficial for zoo managers. Therefore, offering competitive ticket prices to visitors by providing a large selection of attractions, each with unique benefits, is bound to result in additional acceptance for managers and fulfill aspects of elephant welfare.

2) Zoo managements must always demonstrate consideration for the local community, to ensure the sustainability of natural resources, in this case, the elephant in the wild. This is achievable by donating additional revenue in the form of Corporate Social Responsibility programs to the communities where the elephants come from.

IV. CONCLUSION

The pros and cons of Elephant Riding (ER) ought not to be a long debate. Apart from increasing human knowledge and awareness, ER can help fulfill elephant welfare properly in zoos. This can help zoo managers optimize both opportunities with environmental quality management as an ER priority strategy, for example, restoring the natural habitat to improve elephant health and visitors' comfort. Other recommended strategies: improving zoo aesthetics, regulating travel segmentation, and imposing competitive ticket prices.

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KANCILAN FLORES (*Pachycephala nudigula nudigula*): THE ICONIC BIRD OF KELIMUTU NATIONAL PARK, INDONESIA

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KANCILAN FLORES (*Pachycephala nudigula nudigula*): THE ICONIC BIRD OF KELIMUTU NATIONAL PARK, INDONESIA. Kancilan Flores (*Pachycephala nudigula nudigula*) is an iconic bird of Kelimutu National Park. The bird has a unique characteristic with the ability to make a wide variety of song. The local people call this bird '*Garugiwa*' and also '*burung arwah*' or 'spirit bird' because it is small and hard to spot but has a loud chirp. Some literature mentions this bird with different scientific names. This study aimed to identify this bird to rectify this misnaming scientifically and to observes Kancilan Flores behavior, habitat, and population. Kancilan Flores is an attractive fauna for tourists. Therefore, this study also recommended potential birdwatching locations for Kancilan Flores. This study used a transect line and direct observation methods. The results showed that the estimated population size of Kancilan Flores in the Kelimutu National Park was 1,667 individuals with a population size range of 1,245–2,089 individuals. The population density of Kancilan Flores was estimated at 0.53 individuals per hectare. The Kancilan Flores is most commonly found at an altitude of 1,500–1,600 m a.s.l. Recommended areas as bird watching locations for Kancilan Flores, namely the Edelweiss Garden, Perekonde, the lower Arboretum, and the Kancilan Flores middle Arboretum. Therefore, it is necessary to protect the population of Kancilan Flores by strictly prohibiting hunting and destruction of their habitat.

Keywords: Kancilan Flores, Flores, Garugiwa, habitat, Kelimutu, population

*PACHYCEPHALA NUDIGULA NUDIGULA: BURUNG IKON DARI TAMAN NASIONAL KELIMUTU. Kancilan Flores (*Pachycephala nudigula nudigula*) adalah salah satu jenis burung legendaris yang berada di Taman Nasional Kelimutu. Burung tersebut mempunyai ciri khas yang unik dengan kemampuan berkicau dengan ragam suara yang sangat bervariasi. Masyarakat sekitar menjuluki burung ini dengan nama burung arwah, karena ukurannya yang kecil dan sulit untuk dijumpai namun memiliki kicauan yang nyaring. Beberapa literatur menyebut nama burung ini dengan nama ilmiah yang masih berbeda-beda. Penelitian ini bertujuan untuk mengidentifikasi burung ini untuk memperbaiki kesalahan penamaan secara ilmiah dan untuk mengamati perilaku, habitat, dan populasiKancilan Flores. Selain itu, Kancilan Flores adalah fauna yang menarik untuk wisatawan. Oleh karena itu, penelitian ini juga akan memberikan rekomendasi potensi lokasi bird watching Kancilan Flores. Penelitian ini menggunakan metode survei berupa jalur transek dan pengamatan secara langsung di habitatKancilan Flores. Hasil penelitian menunjukkan dugaan ukuran populasi Kancilan Flores di Kawasan TN Kelimutu adalah sebanyak 1.667 individu dengan kisaran ukuran populasi antara 1.245–2.089 individu. Populasi burung Kancilan Flores hanya sekitar 0,53 individu per hektarnya. Kancilan Flores paling banyak dijumpai pada ketinggian 1.500–1.600 m a.s.l. Rekomendasi area sebagai lokasi bird watching Kancilan Flores, yaitu sekitaran Kebun Edelweiss, Perekonde, Arboretum bagian bawah, dan Arboretum bagian tengah. Karena itu perlu usaha perlindungan terhadap populasi Kancilan Flores dengan melarang keras perburuan dan pengrusakan habitatnya.*

Kata kunci: Kancilan Flores, Flores, Garugiwa, habitat, Kelimutu, population

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I. INTRODUCTION

Kelimutu National Park is located in Ende Regency, Flores Island, East Nusa Tenggara, Indonesia. The three-coloured crater lake in this national park is one of the major tourist destinations in East Nusa Tenggara. During the past five years (2015-2019), it attracted approximately 81.887 visitors per year. Conservation areas are rich in biodiversity but are often only a few of the species that have been studied. In Kelimutu National Park, there are 176 species of flora, 13 species of reptiles and amphibians, 13 species of mammals, and 93 species of birds (Balai Taman Nasional Kelimutu, 2019; Hidayat & Kuspriyangga, 2020). In this national park, there are also several endemic flora and fauna. There are four species of endemic and rare flora: *Begonia kelimutuensis*, *Rhododendron renschianum*, *Alstonia scholaris*, and *Timonius timon*. In addition, there are 16 rare and endemic species of Lesser Sunda Island, one of which is Bare-throated Whistler/Kancilan Flores (*Pachycephala nudigula*) (Balai Taman Nasional Kelimutu, 2019). In the local language (Lio tribe), people in Kelimutu called the bird 'Garugiwa or Gerugiwa'. People in Manggarai call it 'Kiong or Ngkiong' (Verheijen, 1963), while in West Nusa Tenggara this species is known as 'Samyong'. The local people believe that this bird is an ancestral spirit (*burung arwah*), and they shall not hunt it.

Kancilan Flores is an Australasian songbird from the Pachycephalidae family, originated in Australo-Papua with a beautiful and loud song (whistler) (Jønsson, Irestedt, Christidis, Clegg, Holt, & Fjeldså, 2014). Kancilan Flores consists of two subspecies, namely *Pachychepala nudigula nudigula* Hartert 1897 (spread on the island of Flores) and *P.n. ilsa* (spread on Sumbawa Island) (Bibby, Jones, & Marsden, 2000; BirdLife International, 2016; Bishop, 2017; Jønsson et al., 2014). Kancilan Flores is a species belonging to the genus Pachycephala with an old lineage (Jønsson et al., 2014), and its speciation occurs sympatric ally with the rusty-breasted whistler (*Pachycephala fulvotincta*) (Jønsson et al., 2014). *P. nudigula* was found throughout Papua Island to the Lesser Sunda Islands, especially Flores Island and Sumbawa Island 4-1.8 million years ago, during the Pliocene period (Jønsson et al., 2010).

Kancilan Flores is spread on Sumbawa Island and Flores Island in the montane forest with an altitude above 1.200 m a.s.l (Bishop, 2017). According to Jønsson et al. (2014), Kancilan Flores is spread in the undisturbed forest at an altitude of 1.000 m a.s.l. Kancilan Flores was first identified in the Kelimutu National Park Area as *Monarcha* sp. (Wawo et al., 2010). Several scientific publications also refer to the Kancilan Flores as *Monarcha* sp. (Karimah & Hastuti, 2018; Rodja, 2013; Winarto & Sitepu, 2019). Kancilan Flores can be recognized by its beautiful singing and can produce a variety of chirp. This bird lives in relatively high forest land areas, in mountainous areas within the Kelimutu National Park (Fauzi, 2013; Hermawan, Chandra, & Sitepu, 2019). Kancilan Flores is also found in mixed natural forests with an altitude above 1.000 m a.s.l in the Kelimutu National Park (Bishop, 2017). Until 2008, the scientific identification of the Kancilan Flores bird has not been carried out. Special observations of this bird in Kelimutu National Park only started in 2009. In 2009 identification was carried out, and based on its morphology, this bird was identified as *Pachycephala nudigula*. Kancilan Flores is in the IUCN Least Concern category with decreasing population status (BirdLife International, 2016; Langkamau, Purnama, & Kaho, 2020; Nyanasengeran, Yong, & Chiok, 2020).

This study aims to scientifically identify the Kancilan Flores bird and observe its activities habitat, and population in Kelimutu National Park. Data obtained from this study will be used as a baseline for continuous monitoring of the Kancilan Flores population. Moreover, Kancilan Flores is an attractive fauna for tourists. Therefore, this study also provides recommendations for potential birdwatching locations for Kancilan Flores.

II. MATERIAL AND METHOD

A. Study Area

Kelimutu National Park is located in S 8°43' 21" - 8°48' 24" and E 121°44' 24" - 121°50' 15" and covers an area of 5.356,5 ha (Figure 1). In 2009 a survey of the Kancilan Flores population was carried out in the utilization zone of 96.50 hectares of Kelimutu National Park. Meanwhile, in 2014 a population survey was conducted in all areas of Kelimutu National Park (core zone, wilderness zone, utilization zone, and rehabilitation zone).

The Kelimutu National Park area has two types of forest ecosystems: the sub-montane forest and the montane forest. The sub-montane forest has an altitude between 1,000-1,500 m a.s.l with temperatures ranging from 27°C to 30°C. While montane forest in Kelimutu is at an altitude of 1,500–1,700 m a.s.l with a temperature of 25°C–27°C (Zona Pengelolaan Taman Nasional Kelimutu Provinsi Nusa Tenggara Timur, 2016). The dominant vegetation is *Casuarina junghuhniana*. At altitudes above 1,200 m a.s.l, many typical mountain flora species are found, namely Vaccinium varingiaefolium and *Rhododendron renschianum*. Based on forest type, it can be divided into 2, namely Primary Forest (2,630.49 ha) and Secondary Forest (515.89 ha).

B. Population

The survey was conducted in August 2009 and September 2014 in Kelimutu National Park. In 2009 the survey was only conducted in the utilization zone. Meanwhile, the survey in 2014 was conducted in a wider area. The survey conducted in 2009 aims to identify, obtain population data and explore the potential of birdwatching as an alternative tourist attraction for visitors to Lake Kelimutu. Surveys were conducted to invent possible sites occupied by Kancilan Flores. To identify Kancilan Flores, the observers follow, take photos, and record videos of the birds. The survey line is a tracking route from the area entrance (Post Moni) to the top of Mount Kelimutu.

The survey in 2014 was only to obtain population data in existing routes (trekking routes, inventory routes, and patrols routes) that already existed in the Kelimutu National Park area. The method used for estimating the Kancilan Flores population in this study was the strip transect method. Observations were made on a transect line with a length of 1 km and a width of 40 m to the left or right of the line (Bibby, Jones, & Marsden, 1998) (Figure 2). The Kancilan Flores population survey was conducted on 21 transect lines in the Kelimutu National Park or 21 Km in total. Observers

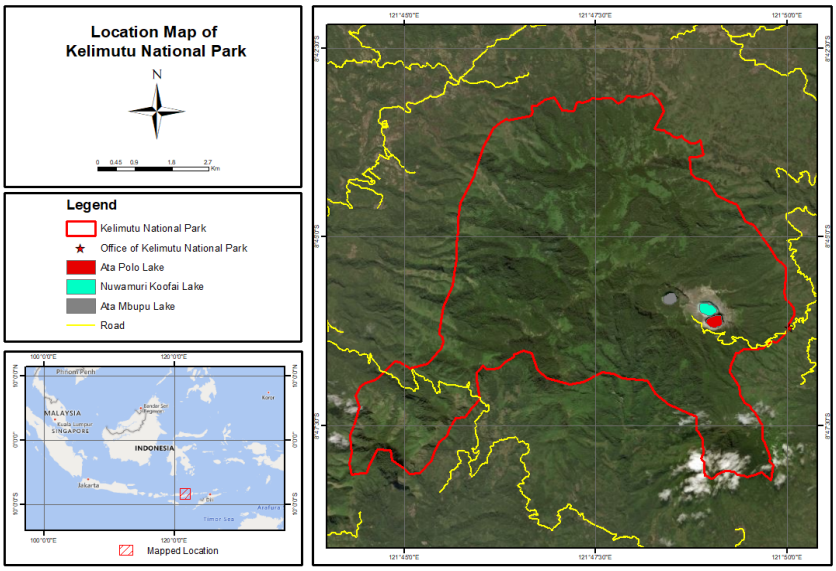

Figure 1. Location map of Kelimutu National Park

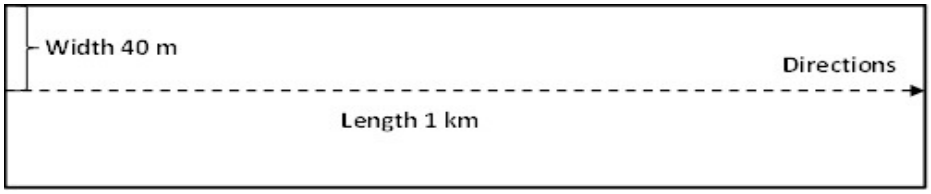

Figure 2. Transect method

walked at a constant speed while noting any Kancilan Flores found on the route and making sure not to record birds outside the transect to avoid double counting. The data taken during the observation were the number of individuals, location coordinates, sighting angle, altitude, habitat type, and time of observation.

Population size estimation is done by counting the number of Kancilan Flores found in each observation line and then calculating the density using the King equation as follows (Bibby et al., 1998):

$$D = \frac{\sum x_i}{2.L.w} \text{ or } D = \frac{\sum x_i}{a} \quad \text{.....(1)}$$

Where:
D = Estimated population density according to King (individuals/km^2) or (individuals/ha)
xi = the number of individuals found at contact-i
L = observation track length (m)
a = extent of observation area (km^2 or ha)
w = left or right width of the observation track(m)

The population size for the entire observation area can be determined using the following equation (Bibby et al., 1998):

$$\bar{P} = \frac{\sum x_i}{2 \sum L_j w_j} \text{ or } \bar{P} = \frac{\sum D_j}{k} \times A \quad \text{.....(2)}$$

Where:
$\bar{P}$ = Estimated population density (individual)
k = number of observation track
A = the total extent of the observation area
D_j = population density at contact-j (individual/ km^2 or individual/ ha).

The range of population size estimation results can be determined using the following equation (Bibby et al., 1998):

$$\bar{D}_j = \frac{\sum D_j}{k} S^2 = \frac{\sum D_j{}^2 - (\sum D_j)^2/k}{k-1} \quad \text{.....(3)}$$

$$S_{\bar{D}} = \sqrt{\frac{S^2}{k}} \quad \text{.....(4)}$$

Where:
$\bar{D}_j$ = average of population density of all observation tracks (individual/ km^2 or individual/ ha)
S^2 = sample variance
$S_{\bar{D}}$ = standard deviation of the observation

Based on the calculation above, the range of population sizes in all areas studied is (Bibby et al., 1998):

$$P = \left[\bar{D} \pm \left(t_{a/2;\, db} . S_{\bar{D}}\right)\right] \times A \quad \text{.....(5)}$$

The locations where Kancilan Flores were found were selected to be recommended as potential locations for Kancilan Flores birdwatching. Behavioural observations were carried out in the morning (06.00-10.00) and afternoon (16.00-17.30) using the focal animal sampling method. Observations were conducted for six days at different locations. There were 21 birds observed. The data recorded are the time of encounter, the number of individuals, altitude, and the location's coordinates. Activities observations were made by documenting all Kancilan Flores activities with a camera.

In observing the Kancilan Flores habitat, the data collected included the location, species of observed trees, and the part of the canopy used. For the observation of canopy occupied by Kancilan Flores, the canopy area of each tree was divided vertically into the upper, middle, and lower crown (Makarova & Sharikov, 2015).

III.RESULT AND DISCUSSION

A. Identifications

Based on the photos obtained, relatively clear photos of the shape and colour of Kancilan Flores can be seen. When compared with the pictures of Flores Monarch *Symposiachrus sacerdotum*, the difference with Kancilan Flores is noticeable. *S. sacerdotum* has black and white colour, while Kancilan Flores is green with some yellowish-green.

B. Morphology

The distinguishing morphological feature of males and females is the colour of the head and wattles on the neck. The female individual has a grey head and does not have a red wattle on the neck (Figure 3). Male individuals have black head-to-neck hair (Figure 4). On the front, under the neck, there is a red wattle that bulges when singing. There is black fur under the neck. The top feathers of the crown sometimes form a crest when chirping loudly. Individual females do not sing like individual males.

The colour of the male and female body parts is the same. The breast and belly of the body is yellow-brown. In comparison, the back and wings are olive green or brownish yellow, darker than the bottom. The undertail of the tail is black but not as dark as the feather on its crown. The beak is black, with a white stripe on the mandible of the beak. Tail length is about ± 1/3 of body length. In general, when compared to the subspecies *P.n. ilsa*, the color of *P. n. nudigula* is darker (Bishop, 2017; Van Beirs, 2017). Kancilan Flores is a perching bird. Its feet are anisodactyl type (3 front toes and 1 hind toe) typical of songbirds. The middle toe is longer than the inner and outer toe.

C. Activities

Kancilan Flores is a solitaire bird and territorial. Kancilan Flores found at the altitude of less than 1,400 m a.s.l has ± 12 sounds variation. Meanwhile, Kancilan Flores observed at an altitude of more than 1,400 m a.s.l has a variation of ± 17 sounds. Kancilan Flores can imitate sounds; therefore, two possible reasons to cause variations in the chirping of Kancilan Flores at higher altitude are: 1) the diversity of vegetation at that altitude is greater so that the diversity of birds and other animals is also higher, 2) more tourism activities at the altitude of 1,400 m a.s.l so that Kancilan Flores may hear more sounds at that altitude. There are many animal sounds and sounds from tourism activities that Kancilan Flores can imitate. Its territory is around the road, making this bird accustomed to the presence of humans and vehicles. Each individual can be distinguished from the chirp and always occupy the same area.

In the morning, Kancilan Flores occupies the upper and middle canopy strata of the tree. The canopy strata preference is related to Kancilan Flores's behaviour when singing to get enough sunlight. The selection of this canopy strata also allows Kancilan Flores to monitor and defend its territory from disturbances by other animals, especially other species of birds.

Figure 3. A female Kancilan Flores

Figure 4. A male Kancilan Flores

During the singing, Kancilan Flores birds move between trees on an area of ± 500 m². When actively singing, the body's position is to the side or opposite the sun's direction. However, when the weather is foggy or cloudy, the Kancilan Flores bird faces the direction of the sunlight.

D. Population and Distribution

Of the 21 transect lines surveyed, Kancilan Flores was found on 19 transects (Figure 5). It is thought that the Kancilan Flores was absent in two transects because the vegetation was homogeneous, dominated by *Eucalyptus urophylla*. This study found 89 encounters with Kancilan Flores individuals (Table 1). Based on the population survey results, from 89 encounters, only 7 were female individuals. It is because the female individual does not sing, so it is very difficult to observe it. Therefore, because the bias was too high, the estimated density of each sex cannot be calculated separately.

The estimated density of Kancilan Flores in the Kelimutu National Park area was 0.53 individuals/ha, with a range of 0.40–0.66 individuals/ha. Therefore, the estimated population size of Kancilan Flores in the Kelimutu National Park is 1,667 individuals, with a population size of 1,245–2,089. The total transects surveyed are ± 168 ha, or about 5.34% of the total natural forest area in the Kelimutu National Park. In the previous study in 2012, the estimated population density of Kancilan Flores was 0.0389–0.3481 individuals/ha or around 186.41–1,668.07 individuals, which is smaller than the population estimate in this study (Kuspriyangga, 2013). The cause of differences in population estimates may be due to differences in the area surveyed.

Based on observations, Kancilan Flores was found in the morning until 10:58 AM. The majority of encounters were when Kancilan Flores singing on *Casuarina junghuhniana*. But besides *Casuarina junghuhniana*, Kancilan Flores was also singing in the big trees on the upper tree crown. These trees include Ampupu/ Timor white gum (*Eucalyptus urophylla*), Gari (*Schefflera lucida*), Longgobaja/Cheese tree (*Glochidion philippicum*), Kelo/common red stem fig (*Ficus variegata*), Teru/elephant's ear tree (*Macaranga gigantea*), Deo/Charcoal tree (*Trema orientalis*), Urubara (*Prunus arborea*) and Keba/beetroot tree (*Elattostachys verrucosa*). This indicates that Kancilan Flores needs high trees to sing, marking its territory.

The distribution of Kancilan Flores was only found in natural forests which have various forest canopy strata. Therefore, observation tracks were only set up in natural forests (primary and secondary). Kancilan Flores is more commonly found at altitudes >1,000 m a.s.l, especially at an altitude of 1,500–1,600 m a.s.l (Figure 7). The air temperature is lower at this altitude, and the relative humidity is

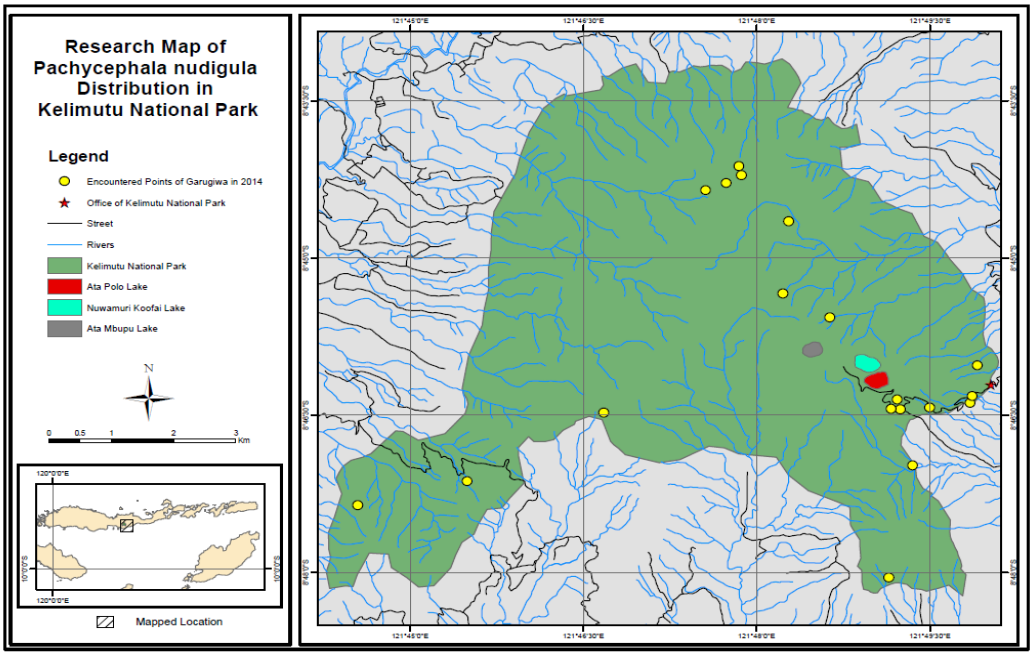

Figure 5. Kancilan Flores encounter locations

Table 1. Encounters with Kancilan Flores in 2009

No.	Track	Male (individual)	Female (individual)	Altitude (m. a.s.l.)	Dominant Vegetation Types
1	Track 01 Post Moni	3	0	1,227	*Casuarina junghuhniana, Cyathea* sp., *Melastoma polyanthum, Pittosporum moluccanum, Eupatorium odoratum*
2	Track 02 Kebun Edelweiss	9	0	1,317	*Casuarina junghuhniana, Melastoma polyanthum, Pittosporum moluccanum, Eupatorium odoratum*
3	Track 03 Perekonde	6	0	1,465	*Casuarina junghuhniana, Cyathea* sp., *Glochidion philippicum, Saurauia nudiflora*
4	Track 04 Arboretum	3	0	1,538	*Litsea resinosa, Prunus arborea, Ficus variegata, Casuarina junghuhniana, Treima orientalis, Macaranga giganteus, Cyathea* sp., *Eupatorium odoratum.*
	Total	21	0		
	Average (individual/ track)	5.25	0		
	Standard deviation	± 2.49	0.00		

Table 2. Encounters with Kancilan Flores in 2014

No.	Track	Male (individual)	Female (individual)	Altitude (m. a.s.l.)	Dominant Vegetation Types
1	Track I Dedumodi	3	0	1,337	*Glochidion philippicum, Eucalyptus urophylla, Cyathea* sp., *Prunus arborea, Eupatorium odoratum*
2	Track II Aemoka	3	1	1,339	*Litsea resinosa, Prunus arborea, Ficus variegata, Glochidion philippicum*
3	Track V Melo	7	0	1,535	*Litsea resinosa, Prunus arborea, Ficus variegata, Glochidion philippicum*
4	Track VI Melo	1	0	1,583	*Prunus arborea, Schefflera lucida, Ficus variegata, Macaranga giganteus*
5	Track VII Melo	6	0	1,494	*Eucalyptus urophylla, Melastoma malabathricum, Melastoma polyanthum, Casuarina junghuhniana,*
6	Track VIII Melo	5	0	1,458	*Eucalyptus urophylla, Casuarina junghuhniana, Melastoma polyanthum, Melastoma malabathricum*
7	Track IX Deturia	5	2	1,635	*Pittosporum moluccanum, Melastoma malabathricum, Casuarina junghuhniana, Eucalyptus urophylla, Eupatorium odoratum*
8	Track X Alotube	5	1	1,631	*Prunus arborea, Litsea resinosa, Glochidion philippicum, Ficus variegata, Eupatorium odoratum*
9	Track XI Okisobe	1	0	1,202	*Ficus variegata, Macaranga giganteus, Cyathea* sp., *Glochidion philippicum, Eupatorium odoratum*
10	Track XII G18	6	1	1,290	*Casuarina junghuhniana. Eucalyptus urophilla, Pittosporum moluccanum, Melastoma polyanthum, Eupatorium odoratum*
11	Track XIII 288-294	7	2	1,557	*Casuarina junghuhniana, Macaranga giganteus, Pittosporum moluccanum, Melastoma polyanthum*

No.	Track	Male (individual)	Female (individual)	Altitude (m. a.s.l.)	Dominant Vegetation Types
12	Track XIV 298-300	4	0	1,656	*Eucalyptus urophilla, Casuarina junghuhniana, Pittosporum moluccanum, Melastoma polyanthum, Eupatorium odoratum*
13	Track XV Jalur Trekking	3	0	1,656	*Eucalyptus urophilla, Macaranga giganteus, Pittosporum moluccanum, Melastoma malabathricum, Eupatorium odoratum*
14	Track XVI Rimba	4	0	1,484	*Casuarina junghuhniana, Glochidion philippicum, Prunus arborea, Ficus variegata*
15	Track XVII Kelibara	2	0	1,656	*Ficus variegata, Glochidion philippicum, Litsea resinosa, Casuarina junghuhniana*
16	Track XVIII Nira Roa	5	0	1,666	*Glochidion philippicum, Prunus arborea, Litsea resinosa, Cyathea* sp., *Casuarina junghuhniana*
17	Track XIX Post Moni - Kebun Edelweis	4	0	1,351	*Casuarina junghuhniana, Cyathea* sp., *Melastoma polyanthum, Pittosporum moluccanum, Eupatorium odoratum*
18	Track XX Jalan baru Pemo – km 11	7	0	1,477	*Casuarina junghuhniana, Ficus variegate, Cyathea* sp., *Melastoma polyanthum, Eupatorium odoratum*
19	Track XXI Arboretum	4	0	1,583	*Litsea resinosa, Prunus arborea, Ficus variegata, Casuarina junghuhniana, Treima orientalis, Macaranga giganteus, Cyathea* sp., *Eupatorium odoratum.*
	Total	82	7		
	Average (individual/track)	4.32	0.37		
	Standard deviation	± 1.81	± 0.67		

high, and there is little disturbance to human activities. Bird abundance can be correlated with vegetation type and altitude (Champness et al., 2019; Domokos & Domokos, 2016; Girma et al., 2017).

In addition, the lower the altitude in the Kelimutu National Park area, the closer it is to gardens and residential areas. Meanwhile, at an altitude of >1,600 m a.s.l, the canopy cover is increasingly open as it approaches the top of

a mountain or lakes crater. At this altitude, some of the plants are Arngoni (*Vaccinium varingiaefolium*) and Turuwara (*Rhododendron renschianum*).

E. Habitat

The research location is a sub-montane ecosystem. This is related to the type of vegetation covered and the area of activity of Kancilan Flores. The existence of sufficient cover allows the emergence of insect species, the main food of Kancilan Flores (Jønsson et al., 2010).

The Kancilan Flores is found mostly in the upper canopy. Based on observations, 48.15% of Kancilan Flores birds carried out activities in the upper canopy. Meanwhile, 28.40% of Kancilan Flores activities were in the middle canopy. The remaining 23.46% of Kancilan Flores activities were in the lower canopy. At the time of chirping, Kancilan Flores occupies the upper canopy strata at 06.00 AM and the middle crown at 08.30 AM. The Kancilan Flores occupies the same area during their singing activities, covering an area of ± 500 m². The upper and middle canopies are ideal territories for singing activity (Ario, 2011). Utilization of the upper canopy dominates during the chirping activities. However, towards noon, Kancilan Flores often descends to the lower canopy (Figure 6).

Based on observations, Kancilan Flores was not found at an altitude of <1,000 m a.s.l or near the border of the national park and residential areas. Kancilan Flores only can be found at altitudes above 1,100 m a.s.l (Figure 7).

F. Birdwatching

Birdwatching tourism has large market potential and can last all year round (Kronenberg, 2016; Li et al., 2013; Ocampo-Peñuela & Winton, 2017). The Kancilan Flores bird watching locations are divided into 2 (two) different places: 1) Kelimutu National Park tourism regular road (2 locations), and 2) Arboretum area (2 locations). The location selection is based on the availability of access to the road. These locations are accessible and have a natural landscape that does not need much modification. However, birdwatchers must be mindful because nature tourism can also harm bird populations, physiological changes, behaviour, and reproduction (Bateman & Fleming, 2017; Geffroy et al., 2015; Putri et al., 2020).

From observations along the regular route of Kelimutu National Park tourism, three locations can be used as places of interest for observing Kancilan Flores birds, namely:

a. Edelweiss Garden

In the area around the Edelweiss Garden, Kancilan Flores birds can be observed directly at a distance of 20 meters from the side of the road. The road above the ridge will make it easier to observe Kancilan Flores birds

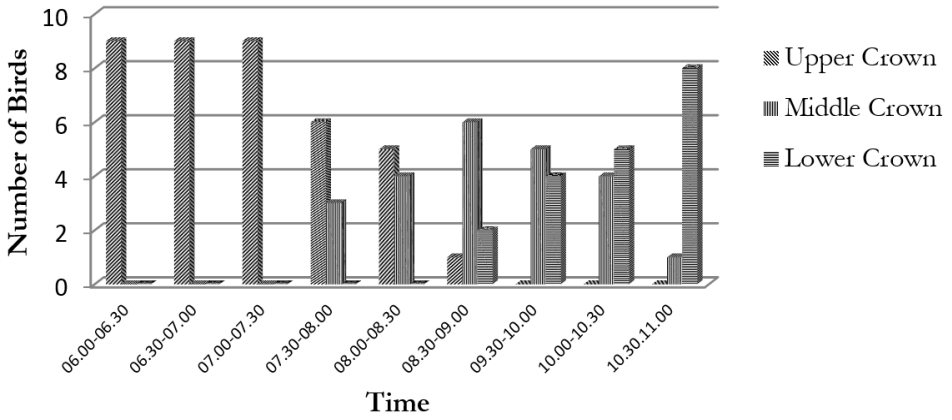

Figure 6. Utilization of tree crown by Kancilan Flores from 06 AM to 11 AM

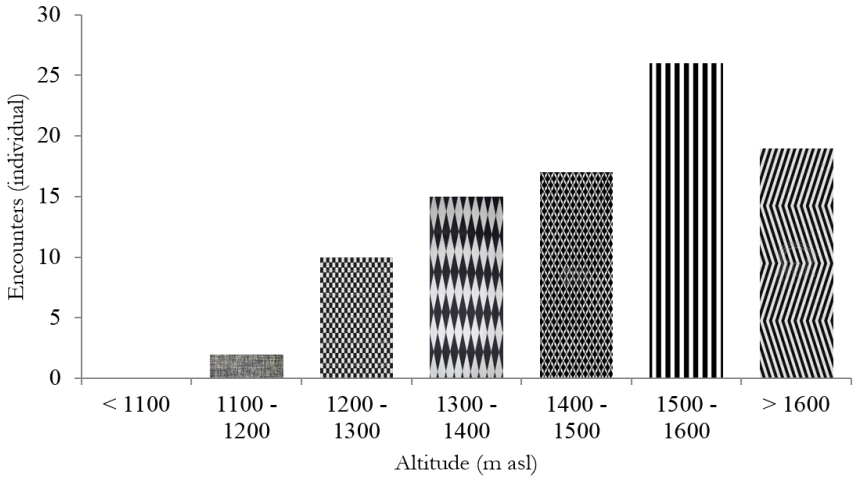

Figure 7. Kancilan Flores's distribution at different altitudes

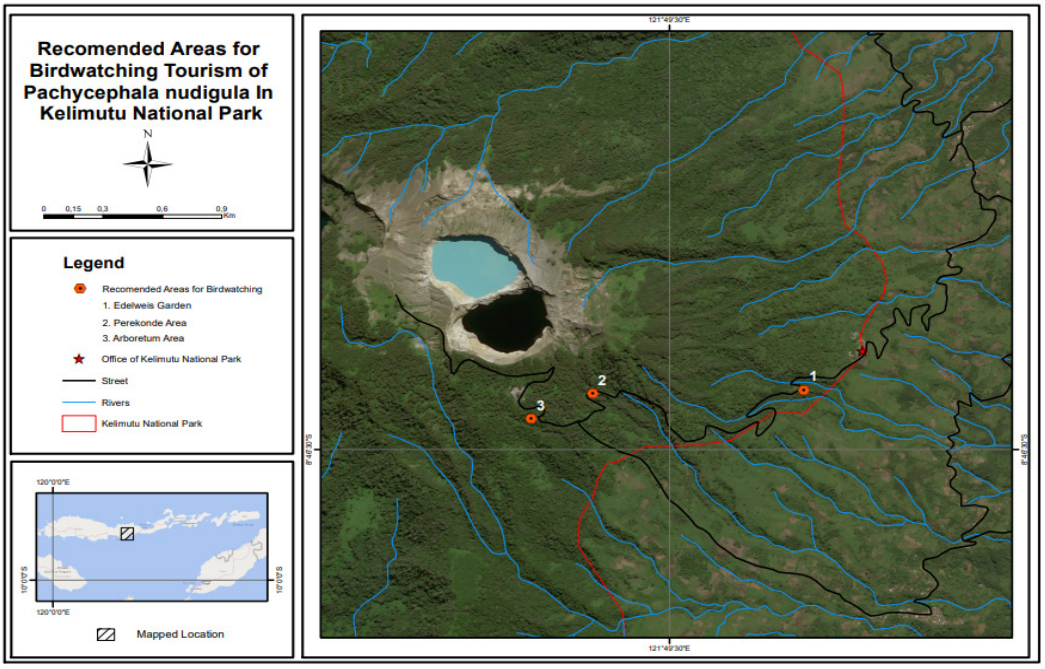

Figure 8. Recommended areas for Kancilan Flores birdwatching

during their chirping activity in the morning on the top canopy of *Casuarina junghuhniana*. In addition, visitors can at the same time see the sunrise emerging from behind the mountains on the east side. Edelweiss garden is located at the top of the ridge, allowing visitors to see the valley below and the mountains and sea in the distance. If this Edelweiss Garden area has developed well, it will become a combination of birdwatching, landscape and sunrise sightseeing spot, and agricultural/agro-tourism areas.

b. Perekonde

In the Perekonde area, visitors can see Kancilan Flores and a cultural site (an offering area for the ancestors' spirits). This location is a combination of nature tourism and cultural tourism. At the same time, visitors can experience the relationship between nature (Kelimutu National Park area) and the culture of the people around the area. In this area, observing Kancilan Flores birds is combined

with observing plants and forests as their habitat.

c. Arboretum

In the centre of the Arboretum, visitors can immediately see Kancilan Flores birds on the trees. Observations can be made from 2 circular paths in the middle of the Arboretum. At the lower Arboretum, visitors can see the Kancilan Flores in their chirping territory at the end of the road. Kancilan Flores in this area are often found at a distance of 70 meters.

The Arboretum has a high diversity of species. There are 37 species of woody plants consisting of 23 families. The family with the highest number of plant species is the Euphorbiaceae (Fauzi, 2016). In addition to the high diversity of flora, the Arboretum is also equipped with trekking routes to observe flora and fauna (Djou, Baiquni, Widodo, & Fandeli, 2017).

IV. CONCLUSION

Kancilan Flores, one of the icons in Kelimutu National Park, is identified as *Pachycephala nudigula nudigula*. The estimated population size of Kancilan Flores in the Kelimutu National Park is 1,667 individuals, with a population size of 1,245–2,089 individuals. The population density of Kancilan Flores birds is estimated at 0.53 individuals per hectare. Kancilan Flores is most commonly found at an altitude of 1,500–1,600 m a.s.l. There are 4 recommended areas for birdwatching Kancilan Flores locations: 1) the Edelweiss Garden, 2) the Perekonde area, 3) the Centre Arboretum, and 4) the Lower Arboretum. Therefore, it is necessary to protect the population of Kancilan Flores birds by strictly prohibiting hunting and habitat conversion. In addition, research on the breeding ecology of Kancilan Flores birds is needed to support its conservation efforts.

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GENETIC RELATIONSHIP OF SEVERAL MORPHOLOGICAL AND MOLECULAR CHARACTERISTICS OF *Phalaenopsis amabilis* (L.) Blume ORCHIDS FROM THE MERATUS MOUNTAINS OF SOUTH KALIMANTAN, INDONESIA

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GENETIC RELATIONSHIP OF SEVERAL MORPHOLOGICAL AND MOLECULAR CHARACTERISTICS OF *Phalaenopsis amabilis* (L.) Blume ORCHIDS FROM THE MERATUS MOUNTAINS OF SOUTH KALIMANTAN, INDONESIA. *Phalaenopsis amabilis* (L.) Blume orchid is one of the most popular orchid species in the world. However, this ornamental plant is threatened in its natural habitat, the Meratus Mountains of South Kalimantan, Indonesia. This study determines and analyzes the genetic relationship among several morphological characteristics of *P. amabilis* from this region combined with molecular (RAPD) markers. A total of ten orchid samples comprised of nine moth orchids (*P. amabilis*) and one species (*P. cornu-cervi*) as an outgroup, as well as ten RAPD primers were used in this study. Based on the morphological markers, the moth orchids have a moderate level of genetic diversity, indicated by Shannon's index value of 0.5. In contrast to molecular markers, this germplasm shows high genetic polymorphism, shown by the polymorphism degree of 100% for all primers used. The cluster analysis shows that this germplasm can be divided into two clusters for morphological and five for molecular markers. Following these markers, the grouping of moth orchids was nearly corresponding to their origin. Thus, this information could be useful as a reference for orchid conservation and breeding programs in the future.

Keywords: Breeding and conservation, genetic polymorphism, orchid, *Phalaenopsis*

KEKERABATAN GENETIK ANTARA BEBERAPA KARAKTER MORFOLOGI DAN MOLEKULER DARI ANGGREK Phalaenopsis amabilis *(L.) Blume ASAL PEGUNUNGAN MERATUS, KALIMANTAN SELATAN, INDONESIA.* Phalaenopsis amabilis *(L.) Blume merupakan salah satu jenis anggrek terpopuler di dunia. Namun tanaman hias ini telah terancam di salah satu habitat aslinya, yaitu Pegunungan Meratus, Kalimantan Selatan, Indonesia. Tujuan penelitian ini adalah untuk menentukan dan menganalisis kekerabatan genetik dari beberapa karakter morfologi dari* P. amabilis *dari wilayah tersebut dan menggabungkannya dengan penanda molekuler (RAPD). Sebanyak sepuluh sampel anggrek, terdiri atas sembilan anggrek bulan (*P. amabilis*) dan satu spesies outgroup (*P. cornu-cervi*), serta sepuluh primer RAPD telah digunakan dalam penelitian ini. Berdasarkan penanda morfologi, anggrek ini memiliki tingkat keragaman genetik sedang, ditunjukkan dengan nilai indeks Shannon sebesar 0,5. Berbeda dengan penanda molekuler, plasma nutfah ini menunjukkan variasi genetik yang tinggi, ditunjukkan dengan derajat polimorfisme sebesar 100% untuk semua primer yang digunakan. Hasil analisis klaster menunjukkan bahwa plasma nutfah ini terbagi menjadi dua kelompok utama untuk penanda morfologi dan lima kelompok untuk penanda molekuler. Berdasarkan kedua penanda, pengelompokan plasma nutfah ini relatif berkaitan dengan wilayah asalnya. Dengan demikian, informasi ini diharapkan dapat digunakan sebagai acuan untuk program konservasi dan pemuliaan anggrek pada masa mendatang.*

Kata kunci: Pemuliaan dan konservasi, variasi genetik, anggrek, Phalaenopsis

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I. INTRODUCTION

The Meratus Mountains of South Kalimantan Province, Indonesia, is one of the diversity centers of native orchids in the world. In this region, hundreds of native orchids germplasms are currently threatened by natural and human impacts, making it difficult to find in their customary habitat (Muslimah, Rachmawaty, Hoesain, Ninsyh, & Yulianto, 2011). Even though some of them have been categorized as endangered species by CITES (Committee of the International Trade of Endangered Species). One orchid species that is very difficult to find in their customary habitat is the moth orchid (*Phalaenopsis amabilis* (L.) Blume). The local people of this region recognized three forms of the orchids, namely the 'Pelaihari' from the Birah Bajuin Mountain, Tanah Laut Regency, the 'Meratus' from the Hulu Sungai Selatan Regency, and the 'Halong' from the Balangan Regency of South Kalimantan (Rusmayadi, Sumardi, Sudjatmiko, & Kuswidyosusanti, 2017). For some orchid collectors, these three forms are very difficult to distinguish morphologically. Hence, further verification using molecular markers is very necessary.

The moth orchid of 'Pelaihari' is one of the most famous orchids in the world (Muslimah et al., 2011). This moth orchid is generally recognized based on the flower characteristics, both shape, size, motif, and length of the flowering period (Tsai, Chou, Wang, Ko, Chiang, & Chiang, 2015). In general, the flower of the 'Pelaihari' orchid is white, decorated with a yellow-brown spot motif on the labellum, and has flowers with florets reaching more than 50 units on each stalk. The orchid stalk could reach 80 cm, the length of the flowering period is up to 6 months (Muslimah et al., 2011). Consequently, it is not surprising that this orchid is the most searched and is very popular with collectors and breeders around the world. In 2009, this moth orchid was even designated as one of Indonesian's national flowers or "Puspa Pesona" (in Indonesian terms) making it a national superior variety or the best cross-parent material for the breeding program (Muslimah et al., 2011).

In Indonesia, the moth orchids is spread across several large islands, such as Java, Sumatra, Sulawesi, Kalimantan, and Papua (Fatimah & Sukma, 2011). However, the existence of the moth orchids in Meratus Mountain of the South Kalimantan Province is more worrying than the others, as mentioned earlier. Thus, the conservation and breeding programs of the orchid are very urgent to implement. The Indonesian Orchid Association of South Kalimantan branch has carried out some activities to conserve and preserve this germplasm. While these efforts have not been optimally carried out, some activities showed less satisfactory results (Muslimah et al., 2011). The limited information about orchid genetics is one of the obstacles to these two activities.

In general, the conservation and breeding tasks involve several principal activities, one of which is identifying and characterizing germplasm with a comprehensive study (van de Wouw, van Hintum, Kik, van Treuren, & Visser, 2010). According to Pellens and Grandcolas (2016), critical and accurate information about germplasm sources is urgently needed to support these programs. Hence, the objective of our study was to determine and analyze the genetic relationship among several morphological and molecular characteristics of this orchid, particularly by RAPD/Random Amplified Polymorphic DNA markers. While these markers have certain limitations, a combination of these two markers may represent a comprehensive feature of the genetic diversity of this germplasm (Rocha et al., 2020). Until now, many researchers have been using these markers for assessing the genetic diversity of various germplasms, like orchids (Khoddamzadeh, Sinniah, Kadir, & Kadzimin, 2010). In Indonesia, RAPD has been used for analyzing the genetic diversity of orchids but is still very limited. Moreover, the orchid samples are the hybrids, not from the natural areas, as employed by Sulistianingsih and Purwantoro (2012). Thus, the results of our study are

valuable in supporting orchid conservation and breeding programs in the future.

II. MATERIAL AND METHOD

A. Plant Materials

A total of ten orchids samples with several morphological characteristics (Table 1), comprising nine moth orchids (*P. amabilis*) species and one of the deer-antlered orchid *P. cornu-cervi* (as an outgroup) were collected randomly from three locations of the Meratus Mountains, including three regencies of South Kalimantan, Indonesia, namely Tanah Laut (Tala), Balangan and Hulu Sungai Selatan (HSS) (Figure 1). Specifically, for the hybrid orchid outgroup samples were obtained from the Food, Agriculture, and Fisheries Service Agency of Banjarmasin City and an orchid collector in Banjarbaru regency, South Kalimantan. For morphological analysis, samples were directly observed at the sampling locations. For molecular analysis, orchid leaves were sampled and put into a plastic bag containing silica gel.

B. Morphological Observation

The morphological observations were carried out directly at the sampling locations on six morphological characters, those were: resilience of flowers, thickness of the petals, length of the flower stalk, number of blossoms

Table 1. List of orchid samples employed in the study

Local Name	Code	Scientific Name	Origin (Regency)
Anggrek bulan 'Pelaihari'	PA-01	*P. amabilis*	Tanah Laut
Anggrek bulan 'Halong'	PA-02	*P. amabilis*	Balangan
Anggrek bulan 'Halong'	PA-03	*P. amabilis*	Balangan
Anggrek bulan 'Halong'	PA-04	*P. amabilis*	Balangan
Anggrek bulan 'Halong'	PA-05	*P. amabilis*	Balangan
Anggrek bulan 'Meratus'	PA-06	*P. amabilis*	Hulu Sungai Selatan
Anggrek bulan 'Halong'	PA-07	*P. amabilis*	Balangan
Anggrek bulan[a]	PA-08	*P. amabilis*	Tanah Laut
Anggrek bulan[a]	PA-09	*P. amabilis*	Tanah Laut
Anggrek bulan gergaji[b]	PC	*P. cornu-cervi*	Tanah Laut

Remarks: ahybrid, as comparison ban out group

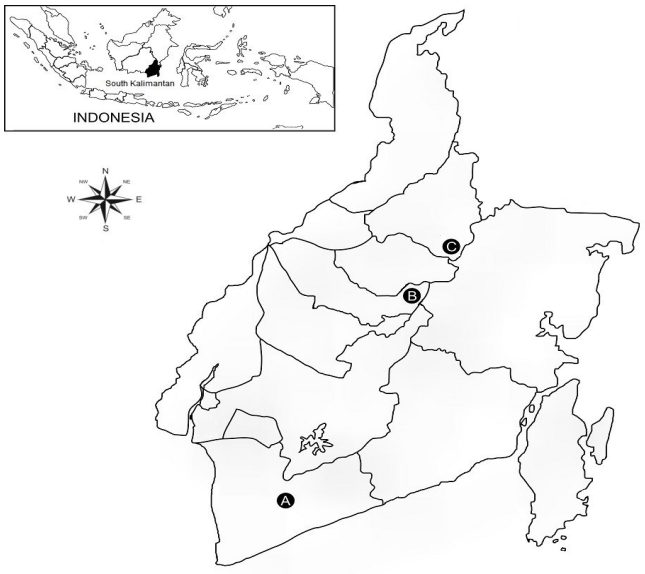

Figure 1. A map of South Kalimantan showing the three sampling locations (along the Meratus Mountains), where the moth orchids were collected: The regency of Tanah Laut (A), Hulu Sungai Selatan (B), and Balangan (C)

per stalk, and visibility of veins on leaves, as well as leaf shapes.

C. Molecular Analysis

Molecular analysis of the orchid was conducted in the Laboratory of Genetics and Molecular Biology, Faculty of Mathematics and Natural Sciences, Universitas Lambung Mangkurat, Indonesia. The activities started with the extraction of DNA by the DNAzol kit protocol following manufacturer's procedure. The DNA was then quantified and measured by UV-Vis spectrophotometer at 260 nm wavelengths. Amplification of this genetic material was conducted using 10 of the 22 selected RAPD primers (Table 2) (Sulistianingsih & Purwantoro, 2012) with a total volume of 20 µl, consisting of 17 µl master mix PCR (containing deionized water; PCR buffer; dNTPs; $MgCI_2$, Taq DNA polymerase), 1.5 ng/µL of each primer (100 picomoles) and 1.5 ng/µL of genomic/template DNA.

This reaction was performed by using Thermal Cycler PCR (Techne, TC3000G, USA) with a cycling condition (Mursyidin & Daryono, 2016): initial denaturation at 94°C for 5 min; denaturation at 94°C for 30 secs, annealing at 37°C for 30 secs, and extension to 72°C for 1.5 min (these stages were repeated for 45 cycles); and a final extension at 72°C for 7 min. The amplified DNA was separated by 1.5% of agarose gel electrophoresis and 1X TBE buffer (pH 8.0) as a supporting medium. These samples were stained by nucleic acid gel stains (GelRed, Biotium, USA) and observed with the DNA ladder (100 bp, Vivantis). Observation of DNA fragment of each primer which was generated conducted by UV transilluminator and digital camera (Nikon Coolpix L610).

Table 2. Selected RAPD primers employed in the study

Primers	Sequences (5'-3')	GC content (%)
OPA-02	TGCCGAGCTG	70
OPA-04	AATCGGGCTG	60
OPB-01	GTTTCGCTCC	60
OPB-06	TGCTCTGCCC	70
OPB-07	GGTGACGCAG	70
OPS-12	CTGGGTGAGT	60
OPA-09	GGGTAACGCC	70
OPA-10	GTGATCGCAG	60
OPB-05	GATGACCGCC	70
OPB-10	CTGCTGGGAC	70

Source: Sulistianingsih and Purwantoro (2012)

D. Data Analysis

Data were analyzed both for morphological and molecular markers. Data analysis was started with scoring and standardizing the obtained morphological dataset. Shannon-Weaver diversity index (H') was used to determine the phenotypic diversity of this germplasm. Diversity indices were calculated based on phenotypic frequency using the standardized Shannon-Weaver Diversity index formula (Rabara, Ferrer, Diaz, Newingham, Ma, & Romero, 2014). Multivariate statistical analyses of characterization data were conducted using cluster analysis. This analysis was done using the MVSP ver. 3.1 software (Kovach, 2007). The distance matrix was generated using the Euclidean Distance Coefficients and used as input for clustering using the unweighted pair group of arithmetic means (UPGMA) method.

For molecular data, each DNA fragment that develops at a particular rate of electrophoresis gel was measured by using a linear regression equation and considered as a single locus. Hence, the same DNA fragments of some individual plants were interpreted as one homologous locus. The locus was then converted into binary matrix data by scoring the value of one (1) if there is a DNA fragment and zero (0) if there is no DNA fragment. The binary matrix data was then derived into a genetic distance matrix. To calculate the genetic distance of the genotype pairs found in different individuals, the Dice coefficient was applied. Based on the value of genetic similarity then the clustering analysis was conducted. The clustering analysis and reconstruction of a phylogenetic relationship of this germplasm were performed using the UPGMA with the assistance of the NTSys ver. 2.2 (Rohlf, 2009). A bootstrap analysis was also

performed to evaluate the internal nodes on the dendrogram.

III. RESULTS AND DISCUSSION

A. Morphological Characteristics

Although the three forms of orchids from the Meratus Mountains appear to be the same (relatively difficult to distinguish) morphologically (Figure 2), the results of further observations of some of these characters show quite significant differences (Table 3). For example, based on leaf shape, the three forms of orchids could be distinguished because the leaf shapes are different, namely *ovate* for 'Pelaihari', *elliptic* for 'Meratus', and *lanceolate* for 'Halong' (Table 3). Other differences appear in the leaf veins and thickness of petals, whereas the 'Pelaihari' orchids has visible leaf veins and thin petals (Table 3). Based on Table 3, it is also seen that 'Pelaihari' orchids have different characteristics compared to the other two orchids found in the Meratus Mountains, namely a long stalk of the flower with 9-17 blooms, a long resilience of the flower blooms (4-6 months), and a yellow-brown spot at the labellum, as well as a V-shape at the end of the labellum. The complete information on the differences in morphological characters of the orchids was presented in Table 3.

In brief, morphological observations reveal the unique feature of the three forms of moth orchids found in the Meratus Mountains. The unique feature is characterized by the resilience of flowers bloom and the number of blossoms per stalk, as well as the shape of the observed leaves (Table 3). According to van

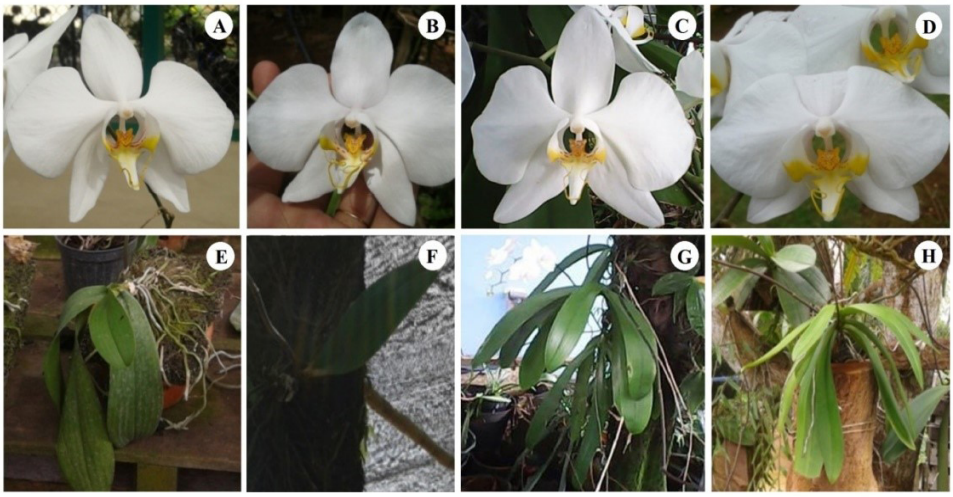

Figure 2. The morphological features of the moth orchid flowers (A-D) and its plant habitus (E-H).

Remarks: A = *P. amabilis* 'Halong'; B = *P. amabilis* 'Meratus'; C = *P. amabilis* 'Pelaihari'; D = *P. amabilis* hybrid, as a comparison)

Table 3. The morphological differentiation of the moth orchids endemically from the Meratus Mountains, South Kalimantan, including the hybrid (a comparison)

Traits observed	*P. amabilis 'Halong'*	*P. amabilis 'Meratus'*	*P. amabilis 'Pelaihari'*	*P. amabilis 'Hybrid'*
The resilience of flowers bloom	± 4-5 months	±2 months	± 4-6 months	< 2 months
The thickness of the petals	Thick	Thick	Thin	Thick
Length of the flower stalk	± 1.5 m	± 1.0 m	± 1.5 m	± 1.0 m
Number of blossoms per stalk	5-15 unit	5-10 unit	9-17 unit	5-10 unit
Visibility of veins on leaves	Invisible	Invisible	Visible	Invisible
Leaf shape	Lanceolate	Elliptic	Ovate	Lanceolate

Huylenbroeck (2018), the uniqueness of this germplasm is also based on the triangular shape of the labellum and the color sharpness of the flowers. Interestingly, based on this study, the 'Pelaihari' shows distinct flower formation; the number of florets in one stalk, and the length of the flowering period is more striking than the other two orchids found in the region. So, it is not surprising that in 2009 this orchid had obtained formal legality from the Indonesian minister of agriculture as a superior national cultivar (Muslimah et al., 2011).

According to Anumalla, Roychowdhury, Geda, Mazid, and Rathoure (2015), although morphological marker has a weakness because it is strongly influenced by environmental factors, breeders are using this marker to evaluate germplasm in the early stages of plant growth and development. In other words, morphological analysis is still used in determining the genetic diversity of germplasm. In genetics, the morphological marker or phenotype is the results of the expression of genotype which is influenced by environmental factors. Thus, further verification of the germplasm studied using more stable molecular markers on environmental factors is very important. Furthermore, a combination of the two markers (morphological and molecular) is expected to produce a more comprehensive feature of the genetic diversity of germplasm (Rocha et al., 2020).

B. Genetic Diversity

Based on the morphological markers, the moth orchids of the Meratus Mountains have a moderate level of genetic diversity, indicated by Shannon's index value of 0.5 (Table 4). However, two of the morphological traits observed in this study were shown to have a high level of diversity, i.e., the resilience of flowers bloom and the number of blossoms per stalk, with an index of 0.92 each.

Table 4. Genetic diversity (H' index) of the moth orchid based on morphological traits

Morphological traits	H' index
The resilience of flowers bloom	0.92[c]
The thickness of the petals	0.19[a]
Length of the flower stalk	0.19[a]
Number of blossoms per stalk	0.92[c]
Visibility of veins on leaves	0.19[a]
Leaf shape	0.60[b]
Average	0.50[b]

Remarks: [a]low, [b]moderate, [c]high

Table 5. Polymorphism degree of the moth orchids from the Meratus Mountains of South Kalimantan, including their number and size of amplified DNA fragments generated by RAPD markers

Primer	The size range of amplified DNA fragment (bp)	Total of DNA fragment (loci)	Number of polymorphic DNA	Polymorphism (%)
OPA-02	221-1157	24	24	100
OPA-04	312-1698	27	27	100
OPB-01	294-2027	24	24	100
OPB-06	165-1721	32	32	100
OPB-07	171-1501	31	31	100
OPS-12	162-2099	16	16	100
OPA-09	189-527	8	8	100
OPA-10	558-1622	7	7	100
OPB-05	132-319	7	7	100
OPB-10	129-1522	16	16	100
Total/Average		192	192	100

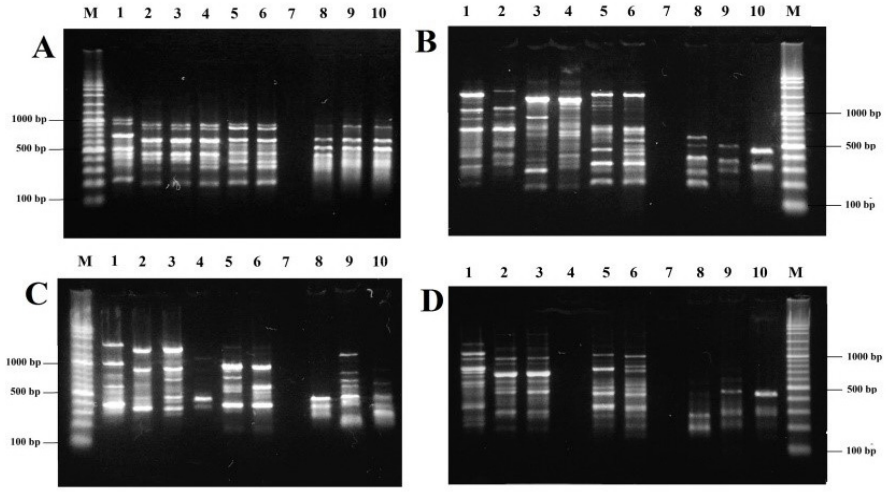

Figure 3. Visualization of amplified DNA fragments generated by four representative RAPD markers used in this study

Remark: A = OPA-02; B = OPB-06; C = OPB-01; D = OPB-07; M = 100 bp DNA ladder (Vivantis); Lane 1 = *P. amabilis* 'Pelaihari'; Lane 2-5, 7 = *P. amabilis* 'Halong'; 6 = *P. amabilis* 'Meratus'; 8-9 = *P. amabil*s hybrid; 10 = *P. cornu-cervi*, an outgroup

In contrast to molecular markers, this germplasm shows high genetic diversity, shown by the polymorphism degree of 100% for all primers used (Table 5). According to Mursyidin and Daryono (2016), genetic diversity can be described using polymorphism, average heterozygosity, and allelic diversity. In RAPD, this genetic diversity or polymorphisms are analyzed by measuring the presence vs. absence of random amplified DNA fragments (Mursyidin and Daryono, 2016).

In this case, the moth orchids of the Meratus Mountains of South Kalimantan, showed a unique profile of DNA fragments generated by RAPD markers (Figure 3). In general, a total of 192 DNA fragments (loci) have been generated by these primers, where each primer resulted in a different number and size of DNA fragments (Table 5). Furthermore, OPA-10 and OPB-05 produced the lowest number of DNA fragments (7 bands), whereas OPB-06 was the highest (32 bands).

The differences in the number and size of DNA fragments in PCR may depend on the attachment site of a DNA primer to the genome of the sample (Clark & Pazdernik, 2013). It means, that each primer has a specific sequence, and the attachment site must be different (Clark & Pazdernik, 2013). These differences are influenced by other factors as well, such as the concentration of $MgCl_2$, DNA template, and DNA polymerase, as well as PCR annealing temperature (Dominigues, 2017; Maddocks & Jenkins, 2017). Siddiqi and Nollet (2019) stated that the presence of polymorphic DNA fragments in a genome reveals the genetic diversity of germplasm. In other words, polymorphic DNA fragments explained the genetic status of germplasm in the population (Chenu, 2015).

C. Genetic Relationships

The cluster analysis shows that this orchid germplasm is divided into different groups, two for morphological (Figure 4) and six for molecular markers (Figure 5). According to Ewens (2013), these differences may be caused by several factors, such as the evolution and adaptation to the local conditions, cross-breeding, population history, speciation, population distribution, and gene flow (Ewens, 2013).

Following the morphological markers, the moth orchid of 'Meratus' was joined by the hybrid in the first cluster, whereas 'Halong' and 'Pelaihari' were in the second. For the molecular

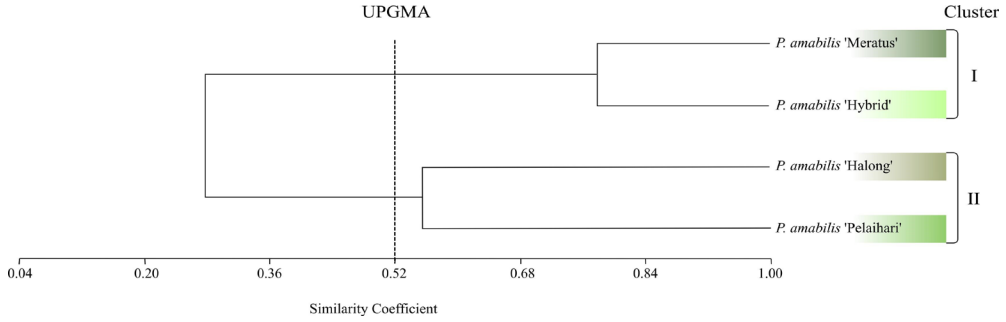

Figure 4. Relationship of the moth orchids from the Meratus Mountains of South Kalimantan, based on morphological characters

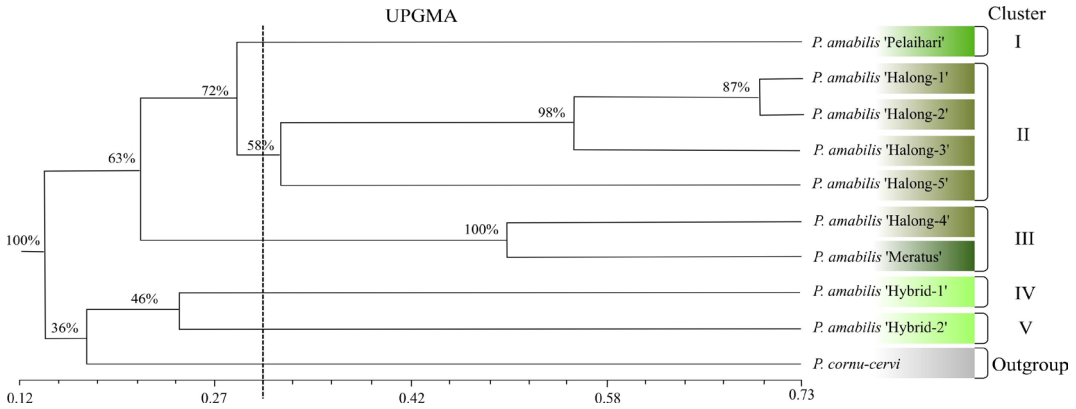

Figure 5. Relationship of the moth orchids from the Meratus Mountains of South Kalimantan, based on RAPD analysis. Note. percentage on nodes were generated by bootstrap 1,000 replicates

marker, the moth orchid of 'Pelaihari' was separated from other samples and formed a single group (Cluster I). The 'Halong' moth orchids were grouped into Cluster II, except for one sample which was grouped to Cluster III, and joined with the 'Meratus'. The hybrids (Clusters IV & V) formed a closely related group to an outgroup.

Following the dendrograms (Figures 4 & 5), the clustering of moth orchid germplasm was near corresponding to their geographic origins. According to Cotrim, Monteiro, Sousa, Pinto, & Fay (2016), the pattern of this relationship may be caused by hybridization and genetic introgression (repeated back-crossing). In this context, hybridization may accelerate speciation via adaptive introgression, or cause near-instantaneous speciation by allopolyploidization (Cotrim et al., 2016).

In brief, these two relationships (dendrograms) also represented a linearization or congruency between morphological and molecular markers. While this congruence needs further verification, some researchers have shown this matter. For example, for forage palm genotype (Rocha et al., 2020), neotropical passerine (Garcia, Barreira, Lavinia, & Tubaro, 2016), and Calochromini (Motyka, Masek, and Bocak, 2017).

Further, a comprehensive analysis of this orchid relationship has been done by several researchers, for example, by Tsai, Chiang, Huang, Chen, & Chou (2010) using the internal transcribed spacer (ITS) sequences. Based on their study, *P. amabilis* is incorporated in the same cluster as *P. sanderiana*, whereas *P. cornu-cervi* is closely related to *P. borneensis*. Based on microsatellite markers, *P. amabilis* is closely

related to *P. fuscata* (Fatimah & Sukma, 2011). Using the RAPD marker, Niknejad, Kadir, Kadzimin, Abdullah, and Sorkheh (2009) reported that P. amabilis has a close relationship with *P. hieroglyphica*, whereas *P. cornu-cervi* with P. mannii and *P. pantherina*. Based on the results of our study, *P. amabi*lis has a distant relationship with *P. cornu-cervi*.

Finally, this information may be valuable for improving the efficiency and effectiveness of plant conservation and breeding programs in the future (Flint-Garcia, 2013; Pellens & Grandcolas, 2016; Singh, 2019). For conservation, information on genetic relationships can apply in inferring species and their evolutionary history, including helping analyze species delimitation, gene flow, and genetic differentiation. In other words, the use of this relationship is of current interest given its objective metrics for conservation in the past evolution history, the present genetic status of species, and management for future ones (Fernández-García, 2017). For plant breeding programs, similar information can be used in predicting the genetic diversity of the offspring when individuals cross (Acquaah, 2012; Turner-Hissong, Mabry, Beissinger, Ross-Ibarra, & Pires, 2020).

IV. CONCLUSION

In this study, morphological and molecular markers provided a unique feature of the genetic relationship of the moth orchids of the Meratus Mountains of South Kalimantan, Indonesia. Based on the cluster (UPGMA) analysis, this germplasm is divided into two (for morphological markers) and five groups (for molecular ones). The results indicate that the grouping of orchid germplasm has quite corresponded to geographic location. While the results provide valuable information to support orchid conservation and breeding in the future, it requires further verification, especially using more accurate molecular markers, such as SNP.

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MINING FIRE HOTSPOTS OVER NUSA TENGGARA AND BALI ISLANDS

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MINING FIRE HOTSPOTS OVER NUSA TENGGARA AND BALI ISLANDS. Forest fires are still one of the most common problems in Indonesia. In fact, many of these forest fires origin from human activities, namely fires that are intentionally raised for a purpose such as widening the land to prepare for the planting season in the Nusa Tenggara Island. Forest fire events can be identified by observing hotspot data which are monitored through remote sensing satellites. Hotspot is an area that has a relatively higher surface temperature than the surrounding area based on certain temperature thresholds monitored by remote sensing satellites. The area is represented as a point that has certain coordinates. The actual fires can be monitored by observing the hotspot attribute, namely Confidence, Brightness Temperature and FRP (Fire Radiate Power). To find the similarities of the three mentioned attributes, the clustering process is carried out to make monitoring easier. The objective of this research is to cluster hotspots in the Nusa Tenggara and Bali Islands from year 2013 to 2018 using the K-Means Clustering Method with 28,519 hot spot data. This could be a benefit for the Ministry of Environment and Forestry in Indonesia to identify the priority level of the area to be monitored. By knowing this result, the ministry can use this data for patrol priority management. This research successfully clustered three types of hotspot classes based on the risk of fire with details as follow; High Risk Class contains 12,212 data with ranges of mean values of confidence in the range of 49.3–100%, brightness in the range of 305.1–421.3° K and FRP in the range of 2.5–714.3; Medium Risk contains 12,250 data mean values of confidence with a range of 20.3–74.3%, brightness in the range of 301.06–341.86o K and FRP in the range of 3.6–141.4; and Low Risk contains 4,057 data with a range of mean values of confidence in the range of 0–39.8%, brightness in the range of 300–365.86° K and FRP in the range of 3.5–275.6. All of the clusters were obtained by the implementation of K-Means clustering over the hotspot data and its parameter as mentioned, respectively. The cluster performance showed the confidential value of 88.45% accuracy using 100 hotspot data from 2019.

Keywords: Hotspot, Nusa Tenggara and Bali Islands, Data Mining, K-Means, Clustering

MENAMBANG DATA TITIK KEBAKARAN HUTAN DI KEPULAUAN NUSA TENGGARA DAN BALI. Kebakaran hutan masih menjadi salah satu masalah yang sering terjadi di Indonesia. Padahal, kebakaran hutan tersebut banyak berasal dari ulah manusia, yakni kebakaran yang sengaja dimunculkan untuk tujuan seperti pelebaran lahan untuk persiapan musim tanam di Pulau Nusa Tenggara. Peristiwa kebakaran hutan dapat diidentifikasi dengan mengamati data titik api yang dipantau melalui satelit penginderaan jauh. Hotspot adalah suatu daerah yang memiliki suhu permukaan relatif lebih tinggi dari daerah sekitarnya berdasarkan ambang batas suhu tertentu yang dipantau oleh satelit penginderaan jauh. Area direpresentasikan sebagai titik yang memiliki koordinat tertentu. Kebakaran yang sebenarnya dapat dipantau dengan mengamati atribut hotspot yaitu Confidence, Brightness Temperature dan FRP (Fire Radiate Power). Untuk mengetahui kesamaan dari ketiga atribut tersebut maka dilakukan proses clustering untuk mempermudah monitoring. Penelitian ini bertujuan untuk mengelompokkan hotspot di Pulau Nusa Tenggara dari tahun 2013 hingga 2018 menggunakan Metode K-Means Clustering dengan 28.519 data hot spot. Hal ini dapat menjadi manfaat bagi Kementerian Lingkungan Hidup dan Kehutanan di Indonesia untuk mengidentifikasi tingkat prioritas kawasan yang akan dipantau. Dengan mengetahui hasil ini, kementerian dapat menggunakan data ini untuk manajemen prioritas patroli. Penelitian ini berhasil mengelompokkan tiga jenis cluster optimum hotspot berdasarkan risiko kebakaran dengan rincian sebagai berikut;

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High High Risk Class berisi 12212 data dengan rentang nilai mean confidence pada rentang 49.3–100%, brightness pada rentang 305.1–421.3o K dan FRP pada rentang 2.5–714.3; Medium Risk berisi 12250 data dengan rentang nilai mean confidence 20,3–74,3%, brightness pada rentang 301.06–341.86°K dan FRP pada rentang 3.6-141.4; dan Low Risk berisi 4.057 data dengan rentang nilai mean confidence pada rentang 0–39.8%, brightness pada rentang 300–365.86°K dan FRP pada rentang 3.5–275.6. Semua klaster diperoleh dengan mengimplementasikan klasterisasi K-Means atas data hotspot dan parameternya masing-masing. Kinerja cluster menunjukkan nilai kerahasiaan akurasi 88,45% menggunakan 100 data hotspot dari tahun 2019.

Kata kunci: *Hotspot, Kepulauan Nusa Tenggara, Penambangan Data, K-Means, Penggerombolan*

I. INTRODUCTION

Indonesia has lost more than 70% of the total forest area due to deforestation (van Etten 2018) (Sirat, Setiawan, & Ramdani, 2018) (Hansen et al., 2013; Santika et al., 2017). One of the causes is forest fires caused by hot temperatures on the surface as a trigger for fires. With its form as an archipelago, it is very difficult for MoEF (Ministry of Environment and Forestry) (Langmann and Heil 2004) to monitor in real terms in the field without the assistance of indication areas that need priority protection (Thah and Sitanggang 2016). Forest and land fire incidents in Indonesia occurred on a large scale in 1982-1983, 1991, 1994, 1997-1998, 2006 and 2015 (Albar et al., 2018; Dennis, 1999; Riyanto et al., 2020). Forest and land fires in 2015, which again threatened Indonesia, had occurred over 80% of Sumatra and Kalimantan lands resulting in the areas were covered with thick smoke (Dennis, 1999; Sutomo and van Etten, 2018). The impacts of forest and land fires have not only affected the health, economy and social society of the community and the nation but have also affected other countries. The forest and land fires in 2015 damaged 2.61 million ha of forest and burned land which caused economic loss of up to 221 trillion rupiah (about 15.4 trillion USD). For this reason, serious efforts are needed to overcome this catastrophe. Prevention efforts need to be initiated by knowing the location of the fire potential spots for further analysis over the causes of forest and land fires (Dennis, 1999). In 2016, efforts to prevent and overcome forest and land fire disasters were showing an improvement due to favourable weather with relatively high and even rainfall throughout the year (Chuvieco, 2011). This improvement was continued in 2018, satellite data showed the number of land and forest fires were decreasing (83%) as the number of hotspots were also decreasing significantly (90%). This phenomenon leads to an interesting correspondence between the number of hotspot data and the number of land fire distribution over Indonesia's landscape. This dynamics event is an interesting things to be analysed to see the occurrences of emerging hotspots (Albar et al., 2018; Andrienko et al., 2010). Furthermore, with the existence of satellites and hotspot detection, protection and prevention processes will run better (Phua et al., 2008; Thah and Sitanggang, 2016; Young et al., 2017).

The Ministry of Environment and Forestry (MoEF) has taken the necessary steps in the field to control forest and land fires by mobilizing support for facilities and infrastructure both at the central and regional levels (Manggala Agni, Forest Ranger), and involving various parties, including the Government. Regions, Disaster Mitigation Body, Indonesian army and Indonesian police department. Apart from taking concrete actions in the field, the MoEF should also conduct efforts to analyse hotspot data and the area of forest and land fires using remote sensing technology. Monitoring activities are carried out through analysis of hotspot data obtained from MODIS Aqua-Terra satellite imagery. The data on the distribution and area of forest and land fires were obtained from

the on-screen delineation process based on the latest Landsat 8 OLI imagery data guided by hotspot data (Foga et al., 2017; Viewer et al., n.d.). From the data, we can see that the main problem of fire hotspots in Indonesia is because the fire was not carried out intentionally (Dennis, 1999; Tacconi et al., 2007). Hotspot distribution is clustered naturally, so that if a cluster of hotspot location is known, it can be used in the analysis of fire hotspots. This research tried to cluster the hotspot data from 2013-2019 to obtain the group of hotspot occurrences. Focus area of the clusters covered Nusa Tenggara and Bali Islands, including Bali, which are in the eastern part of Indonesia. . This location is also one of the sources of natural wonders in the world where the biodiversity hot spot taking place, yet there is no current analysis regarding to the term of hot spot over this area. Hence, the processing of data mining could help to understand the problem.

Data mining is an activity that includes collecting, using historical data to find order, pattern and relationship in large datasets; one of the very popular is K-Means clustering (Fischer et al., 2020; Li et al., 2018; Pei et al., 2020). K-Means clustering is a non-hierarchical grouping method that aims to group objects so that the distances of each object to the centre of the group in one group are minimum. K-Means is included in unsupervised learning clustering that is not using training data to make predictions or classifications (Sirat et al., 2019; Wu and Peng, 2017). Distribution and grouping of hotspots can be analysed by the attributes of confidence, brightness, temperature and FRP on hotspot data using the K-Means Clustering method. This research proposed the implementation of K-means clustering algorithm over web based application to help the process of hotspot monitoring in this area within 5-years duration. This also helps the Ministry to integrate the technology for conservation activity. This study showed a new approach in the process of forest fire control using computational algorithms that can classify vulnerable areas with 3 different levels according to their vulnerability based on the recommendation of the best clusters. This research also shows the system that was built on a web basis to facilitate monitoring and changes in the location of hot spots that appear in the Nusa Tenggara and Bali areas. This system is also equipped with interactive graphics and images that make it easier to read and interpret the emergence of hotspots in the area. Furthermore, this research would also show the rate of confidential of the clusters. This result can be implemented along the hotspot data to show the accuracy rate of the algorithm performances.

II. MATERIAL AND METHOD

A. Hotspot

Hotspot is an area that has higher temperature than other areas which can be detected by satellite. The area is represented in a point that has certain coordinates. Satellites known to detect hotspots are NOAA-18/AVHRR, Terra/Aqua MODIS (Wijedasa et al., 2012) and remote sensing satellite data (Thah and Sitanggang, 2016; Wijedasa et al., 2012). Hotspot's data has attributes to detect fire hotspots. The attributes used in the research are described as **a) Location** at a hotspot using latitude, and longitude as indicating the place where the location of a hotspot occurs; **b) Confidence** or confidence level of hotspot where quality scaled from 0% to 100%. Confidence shows the probabilities of fire occurrences in the field monitored by the

Table 1. Cluster Definition (Thah and Sitanggang, 2016)

Confidence (C)	Class	Action
$0\% \leq C < 30\%$	Low	Need to have attention
$30\% \leq C < 80\%$	Medium	Watchfull
$80\% \leq C \leq 100\%$	High	Immediate countermeasures

satellite image (Broich et al., 2011). The higher the confidence interval, the higher the potential that the hotspot is actually a forest or land fire. The following levels of confidence are shown in Table 1; **c) Brightness temperature,** a descriptive measure of radiation emission in the form of temperature emitted in parts of the Earth's atmosphere (Obregon et al., 2014; Zhu and Woodcock, 2014). Brightness temperature is a basic feature in remote sensing images that are detected in a specific location and measured in units of Kelvin measurement. This research used the temperature that was already captured by the satellite and defined in data columns in each hotspot data to be clustered using K-Means algorithm; **d) FRP** (Fire Radiative Power), describes the radiation power of fire pixels which is then integrated into MW (MegaWatts). FRP provides information on the output of heat radiation from a fire detected. The amount of radiant heat energy is released per unit time (FRP) which is thought to be related to the level of fuel consumed. This research used the value of FRP that was already captured by the satellite for each column in hotspot data.

Table 1. Cluster Definition (Thah and Sitanggang, 2016)

Confidence (C)	Class	Action
0% ≤ C < 30%	Low	Need to have attention
30% ≤ C < 80%	Medium	Watchfull
80% ≤ C ≤ 100%	High	Immediate countermeasures

B. Data Mining

DData mining is an activity of extracting or mining knowledge from large-sized/large amounts of data, this information will later be very useful for development. The purpose of data mining is to specify patterns that must be found in data mining tasks. In general, the purpose of data mining can be grouped into 2, namely to be able to understand more about the behaviour of the observed data, or often referred to as Descriptions, and to be able to estimate conditions that will occur in the future or called Prediction (Phua and Batcha, 2020; Wu et al., 2016).

C. K-Means Clustering

Clustering is an effort to group records, observations, or group them into classes that have similar objects. Clustering is different from classification which has no target variables in clustering. Clustering does not try to classify, estimate, or predict the value of the target variable. However, clustering algorithms try to divide the entire data into groups that have similarities (homogeneous), where the similarity of records in a group will be of maximum value, while similarities with records in other groups will be of minimal value (Atluri et al., 2018). K-Means is one method of non-hierarchical clustering data that attempts to partition existing data into one or more clusters/groups (Compieta et al., 2007). K-Means is included in unsupervised learning clustering that does not use training data or training data to make predictions or classifications. Based on the mathematical model, this algorithm does not have a variable target. One purpose of this algorithm is to group objects that are almost the same in a particular area (Tork, 2012; Wu, 2012). The clustering process begins by identifying data to be clustered. At the beginning of the iteration, the center of each cluster is set freely. Then the distance between the data with each cluster center is calculated. Euclidean formula can be used to calculate the distance of the i data in the center of the cluster (Ren et al., 2020; Wu, 2012) as in equation (1):

$$d(x,y) = \sqrt{\sum_{j=1}^{d}\{x_j - y_j\}^2} \quad \text{..... (1)}$$

where:
$d(x,y)$ = distance between x-data to y-data center
xj = data *object*
yj = data *centroid*
P = Number of Attributes

The new central cluster value can be calculated by finding the average value of the data that is a member of the cluster, using the formula in equation (2) (Ren et al., 2020).

$$Vxy = \frac{\sum_{k=1}^{Ny} Xkx}{Ny} \quad \text{..... (2)}$$

where:
Vxy= x-cluster data for column y
Xkx = the k-data for the x-column
Ny = number of y cluster members

D. Data Normalization

Normalization is a transformation process to change the value of data and is used to equalize the scale of data attributes into a smaller specific range such as -1 to 1 or 0 to 1. Min-Max Normalization is a normalization technique by performing linear transformations on the original data attributes to produce a range of the same value in equation (3) (Young et al., 2017).

$$v' = \frac{v - Min_A}{Max_A - Min_A} \quad \text{..... (3)}$$

where:
v '= normalized v data
v = data v
MinA = minimum value in column A
MaxA = maximum value in column A

E. Data Collection Method

Satellites known to detect hotspots are NOAA Satellite, Terra/Aqua MODIS, and remote sensing satellite data. All of data and material in this study was collected from NASA's Fire Information for Resource Management System (NASA FIRMS) Modis Catalog (https://firms.modaps.eosdis.nasa.gov/) for the area of Nusa Tenggara and Bali Islands (2013 to 2018). Currently, this data is still the most effective in monitoring quickly land and forest fires for a large area. Current remote sensing satellite technology allows monitoring of land and forest fires in near real time (Endrawati, 2018; Langner and Siegert, 2009; Wijedasa et al., 2012).

F. Data Processing Method

Data processing aims to convert raw data from measurement results into finer data so as to provide direction for further assessment. This stage is done to remove hotspot attributes that are not needed by using Microsoft Excel software. The hotspot attributes used are latitude, longitude, acq_date, Confidence, Brightness Temperature, and Fire Radiative Power. After the data is clean, the data in excel format (.xml) is transformed into the format in the database (.csv). The next clean data will be input into the MySQL database and then proceed with making the program using the PHP programming language and CodeIgniter Fremework using the K-Means Clustering method. The flow diagram of the K-Means Clustering method is described in Figure 1.

The data processing was started by determining the optimum cluster numbers. This step occupied the Elbow method (Liu and Deng, 2021; Purnima et al., 2014; Shi et al., 2021) that resulted the optimum number of clusters in the data was 3. After determining the number of clusters, the process was continued to select the centroid of the data for each clusters available, the data will be grouped based on the nearest distance from the centroid

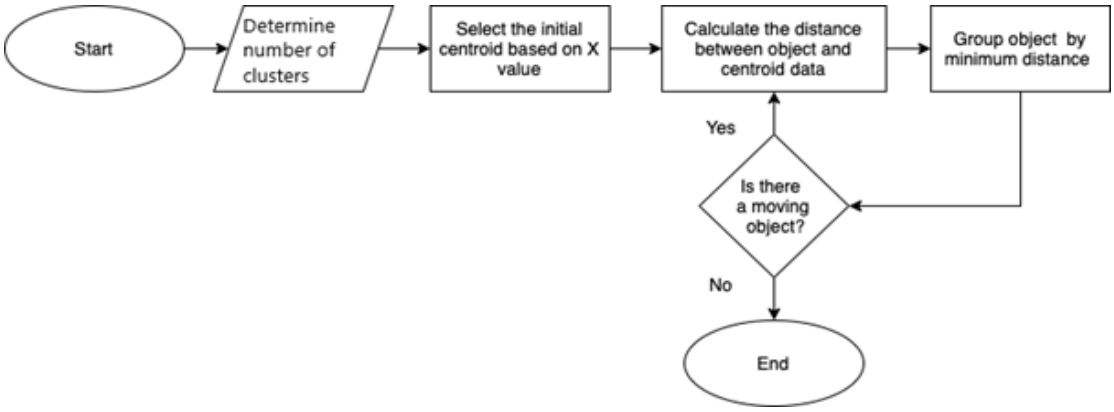

Figure 1. Flow Diagram of K-Means Clustering Method

as previously stated. If there was still moving objects, then the progress would repeat the calculation to the nearest distance until all of the data were clustered.

G. Calculation of K-Means Clustering Algorithm

In the process of calculating vulnerability using the K-Means attribute algorithm that is used 3 attributes of hostpots, i.e. confidence, brightness and FRP with total hostpot data of 28,519. Following are the steps for calculating K-Means Clustering:

1) Enter the hotspot attribute data into the table in the database

The hotspot attribute data is entered into the database displayed in the form of a table consisting of latitude, longitude, area, date, confidence, brightness, and FRP based on 28,519 data.

2) Determine many classes and initial centroids

This research used 3 classes of Medium Clusters for nominal hotspots, High Clusters for high hotspots and Low Clusters for low hotspots. The number of clusters were determined by Elbow method to see the optimum clusters of the data (Liu and Deng, 2021; Purnima et al., 2014). Clusters were performed by determining the centroid value based on hotspot's monthly data and set the data on certain cluster based on the nearest distance. The selection of the initial centroid value was done so that the value of the cluster each month will be the same. The following samples from the initial centroid in January to April 2013 is described in Table 2:

3) Data Normalization: using equation (3)

Data normalization is the process of scaling attribute values from data so that it can fall in a certain range. In this study using min-max normalization, standardizing data by placing data in the range 0 to 1, the smallest value as 0, and the largest value as 1.

4) Calculate Cluster distance : using equation (1)

The next step is to calculate the distance between the data object and the initial centroid (Liu and Deng, 2021; Wu, 2012). The data were grouped on the clusters based on the distance calculation process. After doing the calculation, the value of the distance was obtained for each cluster. Finally, the results of the cluster one and the others are compared, then for the value of the distance the results of the smallest cluster is chosen as a member of the cluster of the group.

5) Calculating the new centroid (cluster center): equation (2)

After the cluster value is obtained, then calculate the new centroid value instead of the initial centroid value for the next iteration. The

Table 2. Table of sample values from the initial centroid

Month	Cluster	Confidence	Brightness	FRP
January	K1	46	311.6	8.3
	K2	25	311.6	14.5
	K3	92	315.8	15.7
February	K1	48	306.7	10
	K2	15	305.1	6.1
	K3	78	312.2	11.3
March	K1	41	312.2	4.4
	K2	0	328.1	21.5
	K3	97	318.8	24.4
April	K1	47	315.7	18
	K2	22	313.6	10.7
	K3	100	324.9	49.2

process of finding a new centroid by summing the value of the data object included in a group is then divided into a lot of data from the group.

6) Calculate the cluster distance value again: equation (1)

After obtaining the new centroid value, we will return to the initial calculation using formula 1 in grouping the data based on the results of calculations in the next iteration. The clustering process will continue to be carried out until the results of the last iteration grouping are the same as the results of grouping the previous iterations which in this case the data object has not changed position in the previous iteration.

III. RESULT AND DISCUSSION

1. System Development

The system was built using the Data Flow Diagram and was developed using PHP and CodeIgneter framework. The hotspot classification page is a page that contains the results of the implementation of the clustering process and displays it into a map (Figure 2) and the data will be in the form of colored coordinate points based on the level of vulnerability.

On this page, there are categories of choices that are used to display the results of clustering. The categories are **(1) Date Category**: a choice category for displaying data based on the selected date or time range; **(2) Regional Categories**: The contents of this category are 4 major islands in the Nusa Tenggara and Bali Islands, namely Bali Island, West Nusa Tenggara Island, East Nusa Tenggara Island and Southwest Maluku Island; **(3) Cluster Category**: This research clustered the hotspot data by its risk level that were defined as Low Risk Cluster, Medium Risk Cluster and High Risk Clusters. The clustering page shows the distribution of hotspot in Nusa Tenggara and Bali Islands, including Bali based on 3 clusters as criteria. The page also allowed one to modify the result based on date, area, and criteria. This would help the users to fit the needs of each criterion. In addition, on this page there is a choice of regional categories where one can choose the area to be displayed, namely the 4 large islands in the Nusa Tenggara Islands, namely Bali Island, West Nusa Tenggara Island, East Nusa Tenggara Island and Southwest Maluku. In addition to category choices, this mapping page displays the amount of data for each existing cluster and there is detailed hotspot information when the user presses one of the data on the map.

The clustering results page displays a hotspot data table with attributes of latitude, longitude, area, date, confidence, brightness,

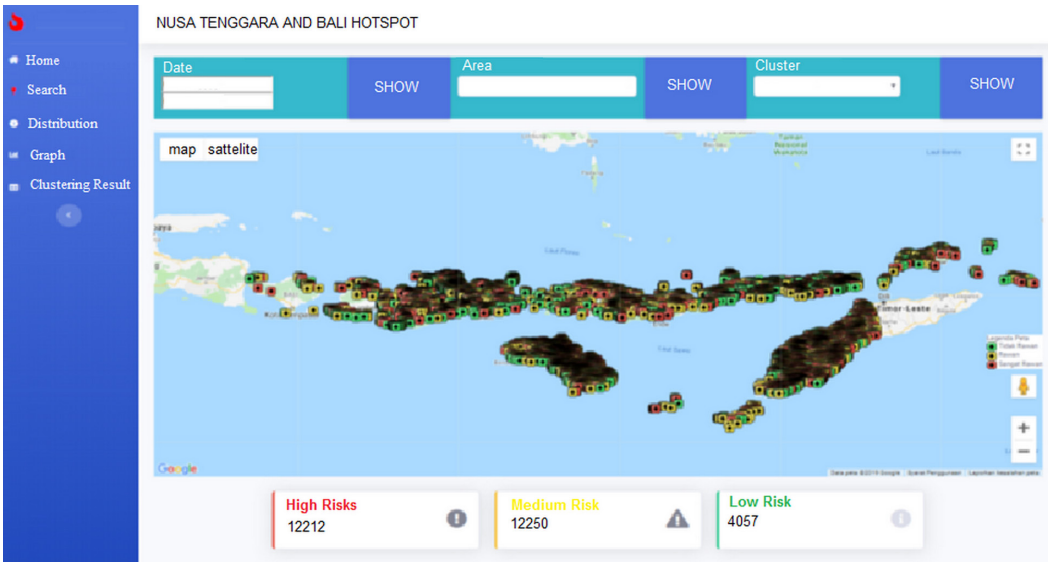

Figure 2. Hotspot classification page

FRP, C1 value, C2 value, C3 value and cluster. The colors in columns C1, C2, and C3 represent the classes in the cluster results. Green colour represents low risks, yellow colour represents medium risks and red colour represents very high risks. This colour determination is based on the smallest C value in the data. Figure 3 is the page containing instructions for carrying out the clustering process by generating data that will be clustered by year with one clustering process using monthly data every year. On this page, one can also perform the order to print the clustering result table data by entering the existing print categories, region and year.

In the website system, the description contains a display of data from the clustering process that has been implemented into a map where each coordinate point represents a data. This description aims to see the distribution of hotspot that occurs in a range of months in each year. Hotspot distribution can be selected certain years by moving the slider in the month section. In Figure 4, it can be seen that the average number of hotspots has showed the lowest number in January and the highest numbers were in October each year. The visualization of hotspot occurrence over Nusa Tenggara islands and its distribution of the data in 2013 are shown in Figure 4.

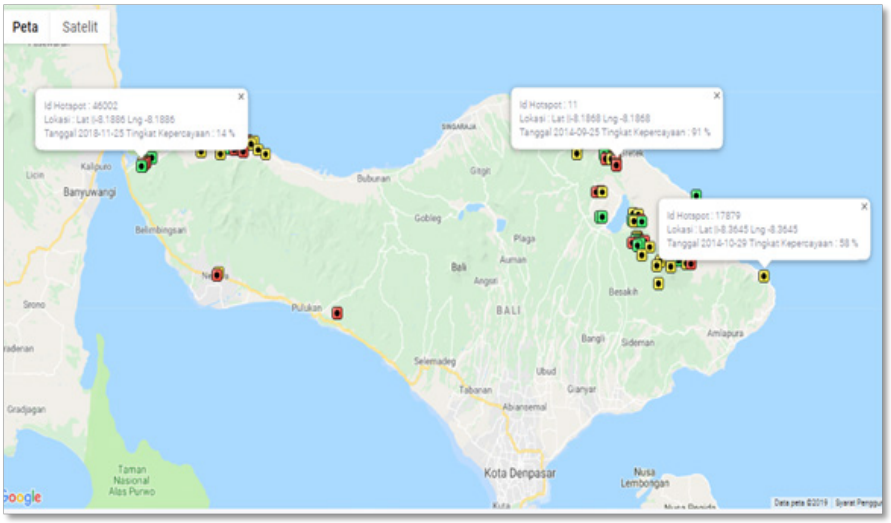

Figure 3. Detailed view of hotspot data

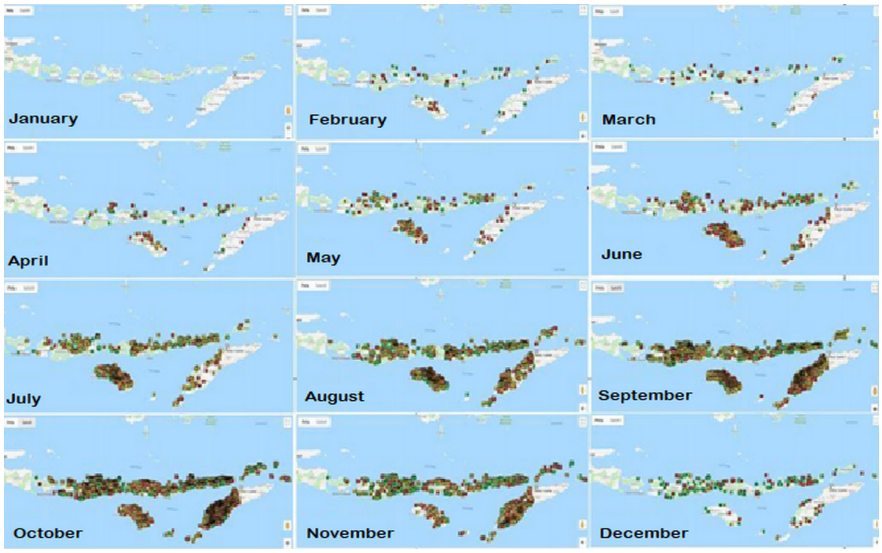

Figure 4. Monthly Hotspot Distribution in 2013

2. Clusters Distribution

From the results of the monthly data clustering process from 2013 to 2018 it was found that the results of this study obtained 3 types of Cluster classes with details of high risks reaches as many as 12,212 data with a range of average values of confidence in the range of 49.3 – 100%, brightness in the range of 305.1 - 421.3 oK and FRP in the range of 2.5–714.3, medium risks reaches as many as 12,250 data with a range of mean values of confidence in 20.3–74.3%, brigthness in the range of 301.06 - 341.86oK and FRP in the range of 3.6 - 141.4 and low risks reaches 4,057 data with a range of average values of confidence in the range of 0 - 39.8%, brightness in the range of 300–365.86 °K and FRP in the range of 3.5–275.6. Figure 5 shows the monthly clustering results over a year. From Figure 5 we found that the high risks cluster represented in red are higher than the medium risk cluster represented in yellow colour, and the low risks cluster represented by color green. The clustering results showed that the lowest number of hotspot data occurred in February and the highest number occurred in October.

In 2014, the results of hotspot showed 7,234 data comprised of 45 data for Bali, 4,883 data for West Nusa Tenggara, 2,078 data for East Nusa Tenggara and 273 data for Maluku. Low risks cluster showed 1,163 data results, medium risks cluster 3,263 data results and high risks 2,808 data results.

The description and interpretation of the clusters are described in Table 3. From Table 3, it is found that the brightness and FRP values are related where the brightness value is high, the FRP is also high in each cluster group but the value is not constant every month. This is because brightness and FRP have no definite range of values such as confidence. Furthermore, from Table 3 an average range of all years will be sought so that the differences in the values of each cluster are shown in Table 3.

In Table 3 it can be seen that the clear differentiator of each cluster is seen in the value of confidence. In cluster 1, confidence clusters was in the normal range of hotspots which meant this cluster belong to the medium risk class. The confidence value in cluster 2 range was included in the low risk hotspot class, which means that the area in this class has the lowest risk from fire burn. Cluster 3 was included in

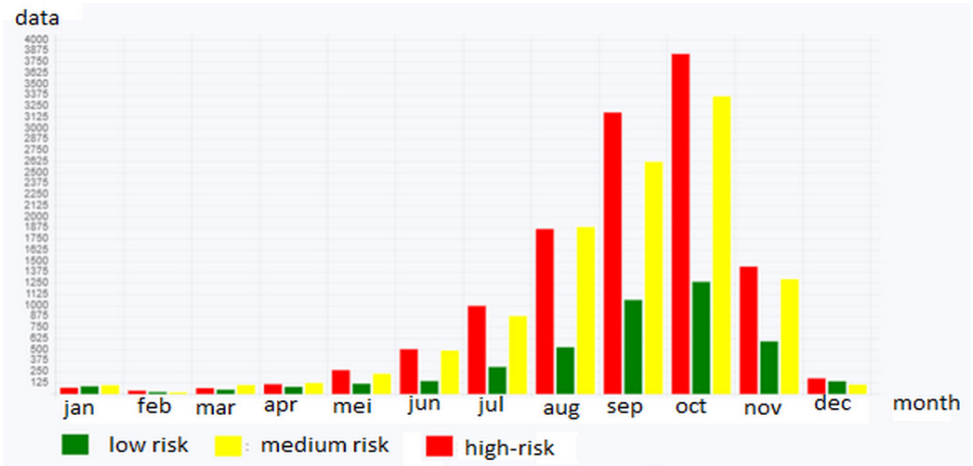

Figure 5. Graph of Clustering Result in 2013

Table 3. Average Clustering Results

Cluster	Confidence	Brightness	FRP	Status
Cluster 1	20.3-74.3	301.06-341.86	3.6-141.4	Medium
Cluster 2	0-39.8	300-365.86	3.5-275.6	Low
Cluster 3	49.3-100	305.1-421.3	2.5-714.3	High

the high risk hotspot class which means the class was very vulnerable to burn with fire. The distribution of the criteria were changed over time and affected the hotspot to be grouped in different clusters. The distribution of the dynamic change of criteria is described in Figure 6. It describes the results of clustering of confidence, brightness and FRP for each year.

This research clustered over 5 years of hotspot's occurrences over the area and found the distribution of hotspots as described in Figure 7. From the Figure we can see that the highest occurrence of the hotspot over Nusa Tenggara islands were in year 2014 while the lowest occurrence was in 2016 that dropped over 250% of hotspot occurrence over the area. In Figure 7 we can also see that the low risk has occurred very low every year and was dominated by the high risk over the year.

C. Validation

This research includes the process to measure the performance of K-Means to see how the algorithm worked over the hotspots clustering. The performance of K-Means clustering algorithm was increasing as the number of data processed increased. The average of the hotspots running time was 0.321 s for 4,500 hotspot data. Furthermore, this research used the data of hotspot occurrence in 2019 data and mapped the model with the algorithm to validate the result of clusters. Over 100 data were used to measure the accuracy of the clustering method. This research showed that the performance of K-Means for hotspot data were valid at a rate of 88.45%.

IV. CONCLUSION

This research has succeeded in mining hotspot data on the Nusa Tenggara Islands in 2013 using the K-means clustering algorithm method using 3 hotspot attributes (confidence, brightness and FRP). The results of the study obtained 3 types of hotspot classes. Clustering results attributes were generated in each cluster group. Determination of the name of this cluster by looking at the ranking of the results of the 3 clusters and looking at the value of the attribute range. Cluster 1 is categorized as medium risks (12,250 data) with an average value range of confidence in the range of 20.3 – 74.3%, brigthness in the range of 301.06 – 341.86oK and FRP in the range of 3.6–141.4. Cluster 2 belongs to the low risks (4,057 data) with an average value range the average of

Figure 6. (a) Annual Confidence Chart; (b) Annual Brightness Chart; (c) Annual FRP Chart

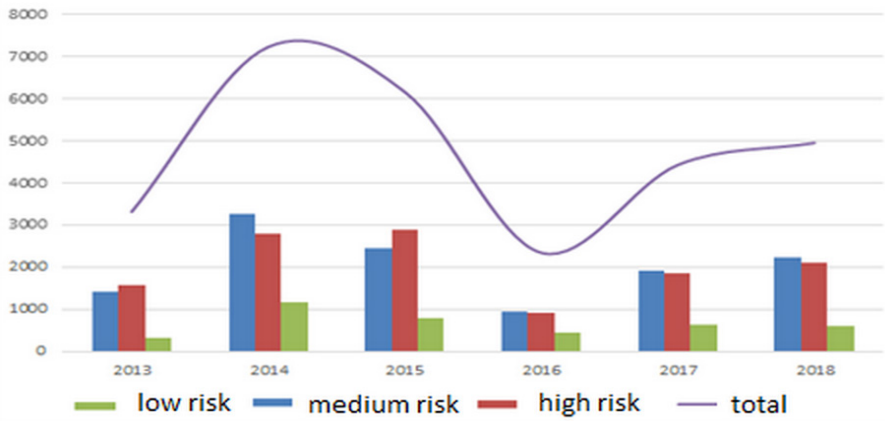

Figure 7. Annual Hotspot Occurrences Comparison

confidence in the range of 0 - 39.8, brightness in the range of 300–365.86 and FRP in the range of 3.5–275.6. Cluster 3 is included in the high risk (12,212 data) with an average value range of confidence in the range of 49, 3–100, brightness in the range of 305.1–421.3 and FRP in the range of 2.5–714.3. The results of this study show that the Nusa Tenggara Islands hotspot from 2013-2018 has an average confidence value range above the average set by LAPAN and the brightness and FRP values in each cluster have a different range each month and the highest range. is in October which month has also a lot of data. The more hotspot data, the greater the brightness and FRP range. This system has succeeded in visualizing the distribution of hotspots, it is found that the distribution of hotspots occurs the most in October and least in February in every year from 2013– 2018. .

ACKNOWLEDGEMENT

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EFFECTS OF GERMINATION ECOLOGY ON IN VITRO GERMINATION PERFORMANCE OF HIGHLAND BAMBOO (*Yushania alpina*) SEED COLLECTED FROM KEFA, SOUTH WEST ETHIOPIA

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EFFECTS OF GERMINATION ECOLOGY ON IN VITRO GERMINATION PERFORMANCE OF HIGHLAND BAMBOO (*Yushania alpina*) SEED COLLECTED FROM KEFA, SOUTH WEST ETHIOPIA. *Yushania alpin*a is an African endemic bamboo species, and it is a valuable resource in ecological and socioeconomically value in Ethiopia. However, low germination is a challenge for seedlings production besides its seed availability is scarce. To improve the seed germination capacity, using different germination ecology treatments are needed. Hence, this study was initiated to investigate the effects of different germination ecology, and to determine the qualities, size, and yield of *Y. alpina* seed. The collected matured fruits were processed, and then the cleaned (pure) and not cleaned (impure) seed were used for this study. This study had two phases; the first was to measure the purity, moisture content, seed character, seed yield; and the second was to investigate the effects of different germination ecology for in vitro seed germination of *Y. alpina* using pure and impure seeds. In this result, the purity, moisture content, seed size, seed weight, and grain yield were determined for cleaned *Y. alpina* seed. The interaction effects of seed type and germination ecology were highly significant on all germination parameters. The highest germination capacity (55%) of pure seed was recorded on T2 (paper + ambient temperature), followed by 38% on T1 (sand +ambient temperature), and 31% on T3 (paper + incubator (25°C)); however, these treatments produced lower results in the impure seed. In addition, the highest (23.5 days) mean germination time was recorded on T3, followed by 13.06 on T2 using impure seed, but the lowest (2.5 and 2.01) value was recorded on T1 and T2 of pure seeds. Hence, this result concluded that using sand media at ambient temperature as germination ecology is preferred to enhance the germination capacity of *Y. alpina* seed. Also, seed surface disinfection using antifungals is recommended to reduce seed contamination.

Keywords: Germination ecology, germination, *Y. alpina*, pure and impure seed

*PENGARUH EKOLOGI PERKECAMBAHAN TERHADAP KINERJA PERKECAMBAHAN IN VITRO BENIH BAMBU DATARAN TINGGI (*Yushania alpina*) DARI KEFA BARAT DAYA ETHIOPIA.* Yushania alpina *adalah spesies bambu endemik Afrika, dan merupakan sumber daya yang berharga dalam nilai ekologi dan sosial ekonomi di Ethiopia. Namun demikian, daya berkecambah yang rendah merupakan tantangan dalam produksi bibit selain ketersediaan benih yang langka. Untuk meningkatkan daya kecambah benih diperlukan perlakuan ekologi perkecambahan yang berbeda. Oleh karena itu, penelitian ini dilakukan untuk menyelidiki pengaruh ekologi perkecambahan yang berbeda, dan untuk menentukan kualitas, ukuran, dan hasil benih* Y. alpina. *Buah matang yang dikumpulkan diproses, dan kemudian biji yang dibersihkan (murni) dan tidak dibersihkan (tidak murni) digunakan untuk penelitian ini. Penelitian ini memiliki dua fase; yang pertama adalah mengukur kemurnian, kadar air, karakter benih, hasil benih; dan yang kedua adalah menyelidiki pengaruh ekologi perkecambahan yang berbeda untuk perkecambahan benih in vitro* Y. alpina *menggunakan benih murni dan tidak murni. Hasil penelitian menunjukkan kemurnian, kadar air, ukuran benih, berat benih, dan hasil biji ditentukan untuk benih* Y. alpina *yang dibersihkan. Pengaruh interaksi jenis benih dan ekologi perkecambahan sangat nyata pada semua parameter perkecambahan. Kapasitas perkecambahan tertinggi (55%) benih murni tercatat pada T2 (kertas + suhu lingkungan), diikuti oleh 38% pada T1 (pasir + suhu lingkungan), dan*

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31% pada T3 (kertas + inkubator (25°C). ; namun, perlakuan ini menunjukkan hasil yang lebih rendah pada benih yang tidak murni. Selain itu, waktu perkecambahan rata-rata tertinggi (23,5 hari) tercatat pada T3, diikuti oleh 13,06 pada T2 menggunakan benih tidak murni, tetapi nilai terendah (2,5 dan 2,01) tercatat pada T1 dan T2 benih murni. Oleh karena itu, hasil ini menyimpulkan bahwa penggunaan media pasir pada suhu kamar sebagai ekologi perkecambahan lebih disukai untuk meningkatkan kapasitas perkecambahan benih Y. alpin*a. Selain itu, desinfeksi permukaan benih menggunakan antijamur dianjurkan untuk mengurangi kontaminasi benih.*

Kata kunci: Ekologi perkecambahan, perkecambahan, Y. alpina*, benih murni dan benih tidak murni*

I. INTRODUCTION

Yushania alpina (K. Schum) is a monocarpic plant that generates flowers and gives seeds once in its lifetime, and it's growth is restricted to highland areas at altitudes varying from 2400 to 3500 masl (Ramanayake & Yakandawala, 1998). It propagates sexually and asexually from seed and vegetative parts, respectively. The vegetative propagation (through stump, rhizome, culm cutting, and offset) may be disastrous if the age of the source plant is too high besides its high labor cost requirement, difficult for transportation, and also it is not much liked for large scale propagation because of explants shortage could occur (Ayana, Gure, & Embaye, 2014; Embaye, 2003; Mulatu & Fetene, 2014). Hence, propagation through seed ought to be the priority if there is no germination challenge because of physical and biological behaviors. However, propagation of *Y. alpina* through seed remains a challenge to establish and develop small and large scale plantation forests due to long flowering cycles, poor storage characteristics, and short viability of seeds as a result of its recalcitrant, presence of disease and pests (Ayana et al., 2012, 2014; Bahru et al., 2015).

Moreover, seeds are a living biological end product of genetic and environmental interactions, and their behavior can`t be predicted with certainty (Loha, Tigabu, Teketay, Lundkvist, & Fries, 2006; Mamo, Mihretu, Fekadu, Tigabu, & Teketay, 2006). Hence, seed germinations explain high variability between species and seed lots, and even within seed lots. In addition, effects of provenances on germination of different species' seeds and seedlings related traits quality exhibited high significant differences besides the magnitude of genetic variation that is considerably more than the environmental variation (Bahru et al., 2015; Derero et al., 2012; Fredrick, Muthuri, Ngamau, & Sinclair, 2015; Loha et al., 2006, 2008; Mamo, Mihretu, Fekadu, Tigabu, & Teketay, 2006). Carles, Lamhamedi, Beaulieu, Stowel, Colas, & Margolis (2009) also reported the strong influence of genotype and growing environment of the mother tree on the weight and size of the seed; besides to this the required average time for germination can also be correlated positively with seed size and weight (Norden, Daws, Antoine, Gonzalez, Garwood, Chave, 2008).

In addition, a procedure for collection and storage of seed, pre-sowing treatment, and sowing media with the environment have determined the physical quality (purity), moisture content, and germination of the seed, which the latter depends on the condition of the first two parameters (Loha et al., 2006, 2008; Wang, Lu, & Zhao, 2009). So far, the storage period at which the seed is able to germinate and also can be used for planting and production depends on its genetic makeup and storage condition (Mrda, Crnobarac, Dušanić, Jocić, & Miklič, 2011). Hence, seed longevity is especially important for low-cost propagation for plantation forest development and to maintain the quality of seedlings. However, the *Yushania alpina* seed longevity is seriously very short and shows low germination performance. Hence, finding different seed germination enhancement techniques using growing media with environments, and different cleaning stage

seed is an urgent issue to foster and support the current interest of bamboo forest development endeavors. Therefore, the objective of the study was to enhance the germination potential by using different growing media with the environment in addition to determining seed size and yield, and seed quality of *Yushania alpina* seed for releasing alternative propagation technology to produce in mass and quality seedlings.

II. MATERIAL AND METHOD

A. Study Area Description

Mature fruits of *Y. alpina* were collected in August 2020 from Desta site, Buta Kebele of Adeyo District in the Kefa Zone of South Nation, Nationalities and Peoples Region, Ethiopia. It is far distance, about 530 km from Addis Ababa and lies between 7°8' to 7°26'N latitude and 36°15' to 36°50'E longitude. The elevation ranges from 500 to 3000m above sea level.

This study was conducted in the Tree Seed Quality Control laboratory of Central Ethiopia Environment and Forest Research Center, Addis Ababa. This laboratory had been established in 1975 in the forest sector, which is now well designed and organized in all aspects of tree seed quality test, and it is the only place for tree seed quality test in the country.

B. Seed Collection, Handling, and Processing

To ensure maximum genetic diversity, mature fruits were collected from ten selected clumps of bamboo stands at a distance of at least 100 m apart between them (FAO, 1975). The collected fruits stayed in dispersing and open for overnight to avoid mold and then put in perforated plastic bags to transport safely to the Central Ethiopia Environment and Forest Research Center (CE-EFRC). In the seed processing section, the fresh mature fruits were subjected to open-air drying on the net bed covered by nylon cloth for one week. After drying, it was rubbed to extract naked and covered seeds, and then also further cleaned by using mortar and pistil for onward laboratory test, storage, and distribution. Finally, the cleaned seeds were placed in perforated plastic bags and stored at room temperature for experiment and distribution. Then, seed yield, seed size, seed quality test, and other different experimental tests were started and continued step by step within a month after the collection of the seeds..

C. Determination of Purity Analysis and Moisture Content of Seeds

After the collected seeds were processed, purity analysis and moisture content of *Y. alpina* seeds were determined in the CEE-FRC Tree Seed Quality Control laboratory following the methods used by FAO (1985). For purity analysis, two samples of 30 gm each were taken from the total seed lots of *Y. alpina* containing all the impurities and weighed. Following this, only the pure seeds were selected and reweighed separately. The percentage of pure seed was calculated as follows:

$$Purity\% = \frac{Weight\ of\ Pure\ seed}{Total\ Weight\ of\ Original\ Sample}\ X\ 100 \quad ..(1)$$

For moisture content analysis, two samples of 2 mg each were taken from the total seed lot of *Y. alpina*, and then the weighted sample was subjected to drying and the moisture content was determined using an automatic analyzer machine (Keren DBS -Kern & Sohn Company, Germany). This advanced machine worked both in the weighing and drying process; finally, it gave the moisture content result automatically within 15 to 30 minutes.

D. Determination of Grain Yield, Seed Size and Weight of *Y. alpina* Seed

The seed weight of *Y. alpina* was determined by following the FAO guide for forest seed handling with special reference (FAO, 1985). Accordingly, eight replicates of 100 pure seeds were randomly taken from the total seed lot and then the weight of thousand seeds was calculated to put as a report. Hence, the 1000

pure seed weight was converted to the number of pure seeds per kg:

Number of seed/kg= 1000gm X TSW(gm) .....(2)

To measure the size of *Y. alpina* seed, a total of sixty seeds in 3 replicates of 20 seeds per unit were randomly taken from the total seed lot of Yushania alpina. Following this, the seed length and seed width/girth were measured in centimeters (cm) using a seed caliper (Mamo et al., 2006).

E. The Effect of Growing Media and Environment on *Y. alpina* Germination Capacity

As growing media with the environment is the most important factor for germination, different growing media such as moisture blotting paper and pure sand were prepared by using 11 cm and 16.5 cm diameter petri dish, respectively before the moisture content was done. The treatments were set from their growing media and environment, i.e.; T1= sand +ambient temperature, T2 = paper + ambient temperature, and T3= paper + incubator (25°C) were tested for pure and impure seed. A total of hundred seeds with four replications were used for each treatment, and it was laid out in a completely randomized design (CRD) in the laboratory bench and germination cabinet. To maintain the optimum moisture, the experiment was sprayed equally using distilled water as required through the observation. Finally, data on the germinated seed was recorded in five-day intervals until 30 days of sowing. Also, the number of seedlings raised per kg of seeds was also calculated after the germination percentage was obtained using the following formula:

$$\frac{\text{No of seedlings raised}}{\text{kg of seeds}} = \frac{\text{No.of seeds}}{\text{Kg}} \text{ X germination(\%)X purity(\%)} \quad .(3)$$

F. Germination Percentage and Mean Germination Time

1. Germination Percentage

Pure seed samples were taken from the stock stored at room temperature, and hence a total of sixty seeds were used to conduct germination test. Seeds were sown uniformly and watered as needed to keep moist but not wet. Then after continues attendant germination data record took place. Accordingly, germination percentage was the dividend of germinated and total sowed seed, and its value was expressed in percent as follows:

$$Germination\ Capacity(\%) = \frac{Total\ Germinated\ Seed}{Total\ Sowed\ Seed}\ X\ 100 \quad ...(4)$$

The emergence or development of a radicle from the seed embryo was considered as germinated seed to evaluate germination capacity (FAO, 1985). The number of germinated seeds was recorded through seven days intervals, and also abnormal seeds, seeds infected with fungus, and not geminated seeds were considered non-viable.

2. Mean germination Time (MGT)

MGT was also calculated by adopting Eq.5 from Ellis and Roberts (1980 as cited in Mavi et al. (2010).

$$MGT = \frac{\Sigma Dn}{\Sigma n} \quad .....(5)$$

Where :
n is the final germinated seeds on day D, and D is the total days of the germination time.
Germination speed/Peak Value – which is adopted from Ayana, Tadesse, and Kebede (2012)

$$PV = \frac{GP}{\Sigma Dn} \quad .....(6)$$

Where:
PV= peak value, GP= germination percentage,
Dn= total germination days

G. Data Analysis

Germinated seed, seed yield and quality, seed size, and others were collected as required. Germination percentage, mean germination time, peak value, seedlings produced from 1 kg seed (SPs/Kg), purity%, moisture%, and seed size and yield were calculated from the collected raw data using simple statistics in MS excel 2016. In addition, germination percent, peak value, mean germination time, and seedlings production per 1 kg seed (Sps/

Kg) data were subjected for analysis of variance using SAS 9.4 version (SAS, 2008). Also, the data were evaluated using tables and graphs. Then, Duncan multiple range test (DMRT) at 5% confidence interval was used for mean separation.

III. RESULT AND DISCUSSION

A. Analysis of Variance

The analysis of variance revealed that the interaction effect of seed cleaning stage (SCS) and treatment is very highly significant (P≤ 0.001) on germination percentage (GP), mean germination time (MGT), and seedlings production per 1kg seed, but only highly significant on Peak value (PV), i.e., germination speed (Table 1). In addition, both factors alone are also very highly significant on GP, PV, MGT, and SpKg, however, the treatment is highly significant at PV (P≤ 0.01). Accordingly, Bahru, Mulatu, and Kidane (2015) and Bahru et al. (2012) also reported the significant effect of different seed germination ecology (presowing treatment) on the germination performance of Ethiopian indigenous bamboo species. However, the germination performance is also highly influenced by the growing ecology of the seed sources. Due to this, the significance of germination treatments in this study was agreed with the previously mentioned reports, but the magnitude of germination percentage obtained from Yushania alpina seed was completely different. This is due to variations from genetics through segregation and the mother plant's growing agroecology condition.

B. Determination of Purity Analysis and Moisture Content of Seeds

According to the FAO guideline, (1985), the purity and moisture content of *Y. alpina* seed were found at 88.4% and 3–5.4%, respectively (Table 1). Hence, the seeds are said to be pure seeds, and also the sowing material moisture content has a vital conditioning effect for storage, germination energy, and capacity (Domin et al., 2020). Purity analysis of a given seed sample is the first test to identify mature, pure, and germinating seeds for storage and further tests such as the determination of moisture content, seed weight, and seed length and width (FAO, 1985). Also, seed moisture has an influence on seed longevity in the storage, and hence checking the moisture level of the seed in the given sample is very crucial before storage (FAO, 1985). This seed purity (88.4%) is slightly better, however, its moisture content range (3 –5.4%) is highly lower than that of compared with Bahru et al. (2015) who reported 86% and 6.9–8% for *Arundinaria Alpina* seed purity and moisture content percent, respectively; this might be due to the difference of seed source location and its time of collection.

The analysis of the seed moisture content gave 5.4% when tested within ten days after collection, but it was gradually declining to 3% after a month which is very low according to the seed moisture standard range (ISTA, 1993; Hartmann & Kester, 1983) and it leads to low germination capacity. This indicates that the germination capacity depends on the moisture content of the seed which is supported by the

Table 1: ANOVA summary of Seed Germination Parameters of *Yushania alpina* L

Variation Source	DF	GP MS	PV MS	MGT MS	SpKg MS
SCS	1	6016.67***	0.60***	758.93***	8642.35***
Treatment	2	482.00***	0.03**	161.02***	692.31***
SCS*Treatment	2	232.67***	0.02**	136.48***	334.03***
CV		**10.29**	**25.73**	**28.86**	**10.29**

Remarks: *** = very highly significant (p≤0.001), ** = highly significant (p≤0.01), SCS= Seed Cleaning Stage, MS = Mean Square, SpKg = Seedlings production from 1 kg seed

reports of Loha, Tigabu, Teketay, Lundkvist, and Fries (2006), and Loha, Tigabu, and Teketay (2008) stated the complex adaptive traits of seed germination which depends on the condition of purity and moisture content parameters in addition to its genes makeup and environmental factors. Wang, Lu, and Zhao (2009) also stated the influence of temperature, storage time length, and light on seed germination, which are great determinants to maintain seed moisture content and viability.

In addition to low germination capacity, the low moisture content could also affect the growth of some of the radicals into shoots which means it becomes dead rather than developing shoots and roots for release into the nursery as a seedling. Because *Y. alpina* seed is a recalcitrant seed and has short longevity which are the major causes that the radicals could die rather than grow to complete seedlings as reported by Embaye (2003) but not only this, it might be due to loss or absence of enough endosperms as a source of food for the seed embryo to stay alive and to have enough energy for germination. Furthermore, the germination capacity has also been determined by the size and weight of the seed besides the influence of moisture and purity parameters.

C. Determination of Grain Yield, Seed Size and Weight of *Y. alpina* Seed

Grain yield is an important parameter to determine the extracted seed output from the collected fresh fruit biomass, and know how to have enough amount of seed for planned bamboo species propagation through seed besides being cost-effective by minimizing collection time and cost. According to this, about 201.7 gm of extracted seed yield was obtained from 1500 gm of collected fresh fruit, which is 13.5% of the total collected biomass (Table 2). This indicates that the grain yield of *Y. alpina* is very low, and needs to collect a huge amount of fresh fruit biomass because above 86% of biomass yield is changed to trash or straw when it was processed and cleaned to produce pure seed. However, the seed size and its weight are key determinant factors for grain yield and germination capacity or percentage.

In this study, the mean value of *Y. alpina* seed length and width were 0.47 and 0.25 cm, respectively, and also the weight of thousand seeds was recorded at 7.38 gm which is highly against the result of Bahru et al. (2015) who reported 17 gm of thousand seed weight from the *Y. alpina* sample collected from the Dawa district Guji zone, Oromia Regional State, Ethiopia. This might be due to the difference of seed size (length and width) difference that is influenced by environmental factors.

Table 2: Determination of seed size and quality parameters

Species	Purity (%)	MC (%)	TSW (gm)	No of Seed /kg	Seedlings /kg	SL (cm)	SW (cm)
Yushania alpina	88.4	3 -5.4	7.38	135567.945	65,913.14	0.47	0.25

Remarks: MC – moisture content, TSW – thousand seed weight, SL – seed length, SW – seed weight

Table 3: Determination of grain yield and tree diameter

Species	Min DBH (mm)	Max DBH (cm)	FFW (gm)	ESY (gm)	ESY (%)
Yushania alpina	1.3	6cm - 19cm	1500	201.7	13.45

Remarks: DBH – diameter at breast height, FFW – fresh fruit weight, ESY – extracted seed yield

Moreover, Carles et al. (2009) also reported the strong influence of genotype and growing environment of the mother tree on the weight and size of the seed; besides the required average time for germination can also be correlated to the seed size and weight (Norden et al., 2008). The lowest and largest seed length was also 0.4 and 0.5 cm whereas the lowest and largest seed width was also 0.2 and 0.3 cm, in respective order.

According to the mean seed weight determination, the computed number of seeds was 135, 567.95 in one kilogram of *Y. alpina* pure seed (Table1). Therefore, 65, 913.14 seedlings were raised from one kilogram of *Y. alpina* pure seeds using the first 5.4% moisture content with (55%) of seed germination capacity that was sowed on a petri dish with moist blotting Whatman paper, however, the germination capacity differed based on the growing media and the environment for the studied seed (Figure 1). This indicates that it has more than 43.41% seedlings advantages when compared with the reports of Bahru et al. (2015) who obtained 37,301 seedlings from 17 gm of thousand seed weight having 6.9–8% moisture content and 73% germination capacity of *Y. alpina* pure seeds. Moreover, there were 1.3cm and 6–19cm lowest and largest diameter at breast height of *A. alpina* natural forest trees, respectively, which seems to have corresponded with the maximum diameter (up to 20 cm) of indigenous bamboo species of Ethiopia (Embaye, 2003).

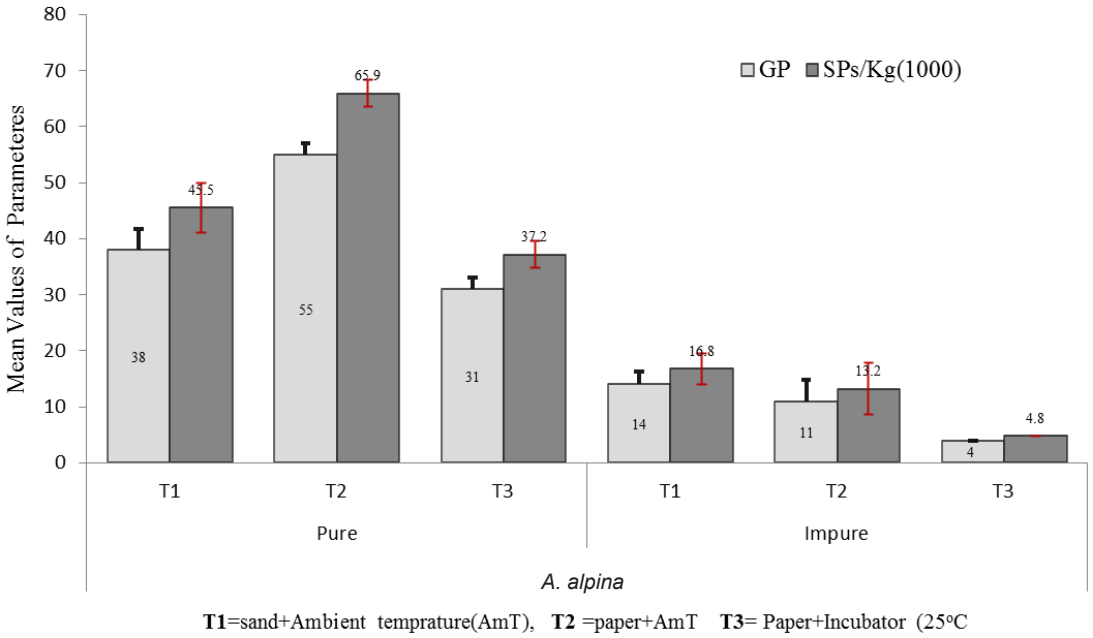
D. The Effect of Growing Media and Environment on Seed Germination Capacity

According to the ANOVA result in Table 1, the interaction of treatments and seed cleaning stage has shown significant influence on studied parameters in the germination of *Yushania alpina* seed. In this result, the combinations of two different factors; seed cleaning stage and seed germination ecology treatments showed different germination percentages. Pure seeds having 5.4% moisture content gave the highest germination percentage (55%) on T2 and also followed by 38% on T1 and 31% on T3 (Table 4; Figure 1). Such a wide range of germination percentage differences might be due to a very crucial factor of seed germination such as temperature and moisture variation of growing media, and the environment in addition to favorable internal conditions of the seed as reported by Hartmann and Kester (1983). Also, Yerima, Tiamgne, Fokou, Tziemi, and Van-Ranst (2015) reported that growing substrates had a significant effect on germination and seedling emergence. In addition, the highest germination obtained on T2 was recorded after the shoot emerged above the sand; hence there might be a probability that not all seeds that can radicle emerge as a shoot. Therefore, comparing the germination percentage of seeds sowed on Whatman paper, and sand growing media may not be always true, but the seed sowed on sand media is cost-effective, and applicable everywhere either at farmer level or nursery site of governmental and private institutions.

Table 4: Means of seed germination parameters of *Yushania alpina* L.

Genotype	SCS	Treatment	GP (mean±SD)	PV (mean±SD)	MGT (mean±SD)	Sps/Kg (mean±SD)
Yushania alpina	Cleaned seed	T1= Sand + AmT	38.00±3.65b	0.41±0.04ab	2.49±0.24c	45.54±4.37b
		T2= Paper + AmT	55.00±2.00a	0.52±0.14a	2.03±0.55c	65.91±2.40a
		T3= Paper + Incubator (25°C)	31.00±2.00c	0.33±0.06b	3.14±0.65c	37.15±2.40c
	Not cleaned seed	T1= Sand + AmT	14.00±2.31d	0.18±0.00c	5.59±0.10c	16.78±2.77d
		T2= Paper + AmT	11.00±3.83d	0.09±0.03c	13.06±5.07b	13.18±4.59d
		T3= Paper + Incubator (25°C)	4.00±0.00e	0.05±0.01c	22.75±2.63a	4.79±0.00e
CV			**10.29**	**25.73**	**28.86**	**10.29**

Remarks: the values having the same letter are not significantly different, AmT = Ambient Temperature



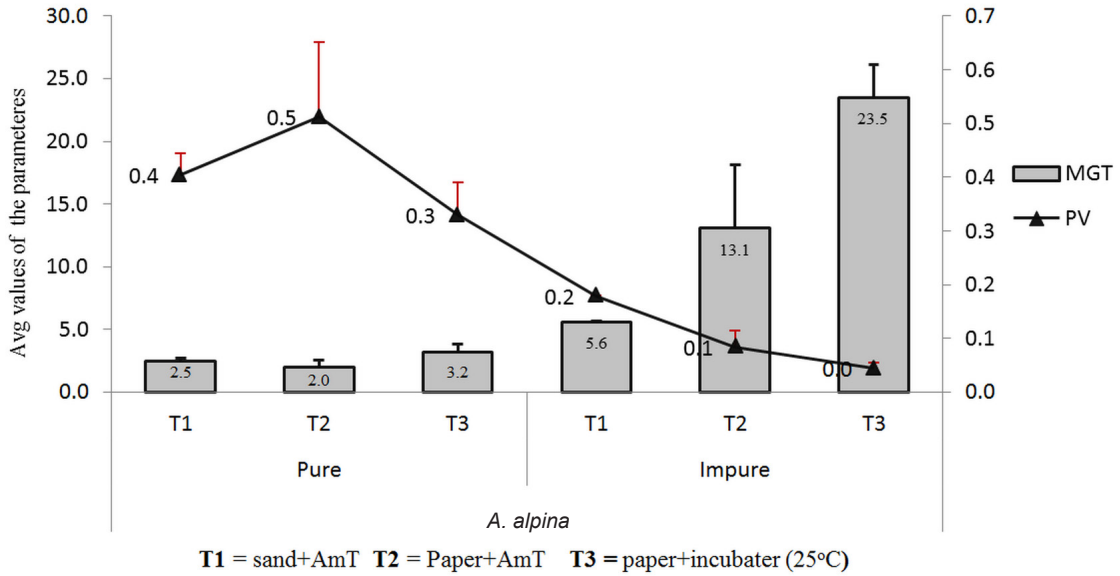
T1=sand+Ambient temprature(AmT), **T2** =paper+AmT **T3**= Paper+Incubator (25°C

Figure 1. In vitro germination capacity of *Y. alpina* seed cleaning stage at different germination ecology treatments

On the other hand, the impure seeds having 5.4–6% moisture content gave the highest (14%) germination percentage on sand media at room temperature (T1) which was better than that of those sowed on T2 (11%) and (4%) on T3 (Table 4; Figure 1). The lowest germination capacity (4%) was recorded from the impure seed sowed on Whatman paper in a 25°C incubator (T3). As shown in Figure 1, the germination capacity of the impure seed was highly lower than that of the pure seed. This indicates that impure seeds should not be preferred to use as a valuable source of propagation for *Y. alpina* neither in small nor large-scale forest establishment and development purposes.

As compared to Bahru et al. (2015) who reported 73% germination of *A. alpina* pure seed having 0.59 cm length and 0.17 cm width, this highest recorded germination percentage (55%) of pure seed is very low. This might be due to the difference in seed size and agroecology of germplasm sources. Moreover, this might also be due to seeds living in biological end products of genetic and environmental interaction, in which the magnitude of genetic variation is considerably more than the environmental variation (Bahru et al., 2015; Derero et al., 2012; Fredrick et al., 2015). Hence, the seed conditions explain high variability between species and seed lots, even between seed lots, across years and provenances due to environmental factors besides genetic differences (Loha et al., 2006, 2008; Mamo et al., 2006). Because of this, the seeds' behavior cannot be predicted certainly (Mamo et al., 2006). FAO (1985), and Ghosh and Singh (2011) also reported heavy and larger seeds had weighed more per seed, and hence they contained more food reserves which are more likely to have higher germination percentages by providing more energy to produce initially vigorous seedlings. Therefore, seed size and weight are important characters in the selection of well-adapted and highly productive seed sources.

In addition to the germination capacity of seeds, the influence of seed germination ecology treatments also determined the pattern and mean germination time. Accordingly, the lowest (2.01) mean germination time was recorded from pure seed sowed on T2 and followed by 2.5 on T1 (Table 4, Figure 2). However, the



T1 = sand+AmT **T2** = Paper+AmT **T3** = paper+incubater (25°C)

Figure 2. The effect of in vitro seed germination ecology treatments on MGT and PV

highest (23.5 days) mean germination time was obtained from impure seed sowed on T3, followed by 13.06 days on T2. As a result, using pure seed sowed on Whatman paper in ambient temperature (T2) had vigorous and fast germination; hence it seems to have better germination speed than germination on T1 and T3. This difference might be due to the presence of direct light in addition to sustaining conducive moisture and optimum temperature to the seed for reducing the periods or duration of mean germination time. This also indicates that the seed cleaning stage has a significant detrimental effect on germination. This agrees with the statement of Yerima et al. (2015), the short duration to germinate is highly important for the vigoursity of seedling emergence whereas the long duration becomes fatal.

According to Figure 2, the recorded values of mean germination time were significantly different regarding the seed cleaning stage and growing medium with the environment. However, it is better to use pure seed sowed on sand media at ambient temperature (T1) as a germination ecology treatment, considering the cost and applicability of the technology at community level for bamboo establishment and development without any advanced and cost incurring materials requirements besides the mandated institution. As an economically and environmentally valuable plant, the development and adaptation of easy to apply and effective propagation method of highland bamboo in every aspect is an urgent affair for sustainable use and socioeconomic value. Hence, the output of this research could be helpful and used as an input to propagate *Y. alpina* species for the developmental endeavors and income source of the community.

IV. CONCLUSION

Germination improving technology is an urgent affair for successful forest development of Yushania alpina plantations. However, it has unsatisfactory seed germination due to its recalcitrant seed behavior, and hence its seed longevity is seriously very short and becomes a low germination performer. To confront the low germination challenge, different germination ecology treatments using seed cleaning stages were tested to promote germination potential. Hence, the pure seed had a significant influence to increase germination percentage using seed germination ecology treatments. The highest germination percentage and short mean germination time were obtained on T2 (paper +

ambient temperature), followed by germinations on T1 (sand +ambient temperature), and T3 (paper + incubator (25°C)), respectively. However, the impure seed revealed the least and most unsatisfactory germination percentage in all treatments. Hence, this concluded that using pure seed on sand media with ambient temperature is more advisable and preferred to adopt cost-wise and easy propagation of Yushania alpina everywhere and by whomever.

Based on the current research result the following recommendations can be given as follows:

- The germination study on different germination ecology treatments is a one season seed collection so that it should be conducted using across season collection.
- Also, the germination study on different germination ecology treatments used seeds at 10 days after collection, hence it should be designed and conducted using seeds having different storage period.

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UTILIZATION OF CITRIC ACID AS BONDING AGENT IN SEMBILANG BAMBOO (*Dendrocalamus giganteus* Munro) PARTICLEBOARD PRODUCTION

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UTILIZATION OF CITRIC ACID AS BONDING AGENT IN SEMBILANG BAMBOO (*Dendrocalamus giganteus* Munro) PARTICLEBOARD PRODUCTION. Citric acid was utilized as a bonding agent in the production of Sembilang bamboo particleboard. The limitation in using bamboo for particleboard production is that the silica content in bamboo skin can accelerate particleboard processing machines' bluntness and reduce particle adherence in particleboard manufacturing. This research aimed to investigate the influence of bamboo skin and citric acid content on the characteristics of sembilang bamboo particleboard. Particleboards were prepared using bamboo particles (type A) and unskinned bamboo particles (type B). The citric acid solution (59%) was sprayed over the surface of bamboo particles to obtain three different levels of citric acid, i.e., 15, 20, and 25% (based on bamboo particles' dry weight). The sembilang bamboo particleboards were manufactured using a hot-pressing machine at 200°C, 5 MPa for 10 min. The particleboard targeted density was 0.8 g/cm^3. The type B particleboards' internal bond (IB), modulus of rupture (MOR), water absorption (WA), and thickness swelling (TS) were superior compared to the type A particleboards. This was influenced by the lower concentration of silica in type B particleboards, which tend to allow an intimate contact area among particles and citric acid then produced better quality particleboards compared to type A particleboards. The type B particleboards met the obligation of JIS A 5908 for type 18 particleboard in terms of modulus of rupture, modulus of elasticity, and internal bond, however, only fulfilled the type 8 particleboard in terms of screw holding power. The physical properties of Sembilang bamboo particleboard were also improved when using type B bamboo particles and adhered with citric acid at a level of 25%.

Keywords: Sembilang bamboo, particleboards, citric acid, physical properties, mechanical properties, silica

*PEMANFAATAN ASAM SITRAT SEBAGAI AGEN PEREKATAN PADA PEMBUATAN PAPAN PARTIKEL BAMBU SEMBILANG (*Dendrocalamus giganteus *Munro). Asam sitrat digunakan sebagai agen perekatan dalam pembuatan papan partikel bambu Sembilang. Keterbatasan penggunaan bambu untuk pembuatan papan partikel adalah kandungan silika pada kulit bambu dapat mempercepat ketumpulan mesin pengolah papan partikel dan mengurangi kerekatan antar partikel. Penelitian ini bertujuan untuk mengetahui pengaruh kulit bambu terhadap karakteristik papan partikel bambu sembilang. Papan partikel dibuat menggunakan partikel bambu lengkap dengan kulit bambu (tipe A) dan partikel bambu tanpa kulit (tipe B). Larutan asam sitrat (59%) disemprotkan pada permukaan partikel bambu untuk memperoleh tiga kadar asam sitrat yang berbeda, yaitu 15, 20, dan 25% (berdasarkan berat kering partikel bambu). Papan partikel bambu sembilang diproduksi menggunakan mesin kempa panas pada suhu 200°C, 5 MPa selama 10*

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menit. Kepadatan papan partikel yang ditargetkan adalah 0,8 g/cm³. Papan partikel tipe B menunjukkan keteguhan lentur (MOR), keteguhan tarik tegak lurus permukaan (IB), penyerapan air (WA) dan pengembangan tebal (TS) yang lebih baik dibandingkan dengan papan partikel tipe A. Hal ini dipengaruhi oleh konsentrasi silika yang lebih rendah pada papan partikel tipe B, cenderung mempererat area kontak antara partikel dan asam sitrat sehingga menghasilkan kualitas papan partikel yang lebih baik dibandingkan dengan papan partikel tipe A. Papan partikel tipe B memenuhi persyaratan JIS A 5908 untuk papan partikel tipe 18 dalam hal MOR, modulus elastisitas dan IB, namun hanya memenuhi papan partikel tipe 8 dalam hal keteguhan cabut sekrup. Sifat fisik papan partikel bambu Sembilang tipe B dengan asam sitrat pada kadar 25%, lebih baik dibandingkan papan partikel bambu sembilang lainnya dalam penelitian ini.

Kata kunci: Asam sitrat, bambu Sembilang, papan partikel, sifat fisis, sifat mekanis, silika

I. INTRODUCTION

Commercially, particleboards were bonded with formaldehyde-based adhesive. Unfortunately, formaldehyde emission during the use of particleboard, especially for interior furniture purposes, can be harmful to human health. Therefore, the application of formaldehyde-free adhesives for particleboard production has become a critical concern. Some biopolymers have been utilized as the main constituent in formaldehyde-free adhesives. A starch-based adhesive was applied as a binder in particleboard production, although its water resistance property has not met the requirement for application (Amini, Hashim, & Sulaiman, 2019; Salleh et al., 2015) Some lignocellulosic plants contain lignin or tannin that can be utilized as formaldehyde-free adhesives. Lignin is known as the third largest biopolymer. Lignin exists in the structure of lignocelluloses such as wood, agricultural residues, grasses, and other plants (Khalil et al., 2006; Younesi-Kordkheili, 2017). Lignin has a similar structure to phenol. This means lignin can substitute phenol-based adhesive such as phenol-formaldehyde (PF) (Nasir, Zakaria, Sipaut, Sulaiman, & Hashim, 2011).

However, one of the lignin-based adhesive disadvantages is low reactivity due to its complexity and the low number of reactive sites (Pizzi, 2006). Naturally, tannin is present in the skin of several trees, such as mimosa, pine, and quebracho (Fechtal & Riedl, 1993; Kim, 2009). Tannin is a water-soluble compound. Tannin's chemical structure is similar to phenolic compounds and can react with formaldehyde to replace phenolic resins (Faris, Ibrahim, & Rahim, 2016). A tannin-based adhesive has been utilized as a binder in particleboard production (Cui et al., 2015; El-Sayed, El-Sakhawy, Kamel, El-Gendy, & Abou-Zeid, 2019). Nevertheless, the current use of commercial tannin for leather and in the beverages industries limits their availability as an industrial adhesive.

One of the bio-based wood adhesives that attract many researchers' attention is citric acid-based adhesive. Umemura et al. began to study the potential of citric acid as a binder in molded products and as a wood adhesive (Munawar, Umemura, & Kawai, & Kawai, 2009; Umemura et al., 2011, 2012). A citric acid-based adhesive has been used for a binder in the production of particleboard made from *Agave sisalana* (Syamani & Munawar, 2012), bamboo (Widyorini et al., 2013; Widyorini, Umemura, et al., 2016a), oil palm frond (Syamani & Munawar, 2013), sugarcane (Liao et al., 2016; Syamani et al., 2020), sweet sorghum bagasse (Kusumah et al., 2016; Kusumah, Umemura, et al., 2017b), *Imperata cylindrica* (Syamani et al., 2018), corn stalk (Prasetiyo, Octaviana, et al., 2018), and corn husk (Prasetiyo, Gopar, Kurniawati, Syamani, & Kusumah, 2018).

The advantages of using citric acid-based adhesive are renewable, non-toxic, produce particleboards with physical and mechanical properties that meet the standard application. Nevertheless, some disadvantages need to be overcome, such as the required high temperature to set the bonding linkage between

particles, which can affect the particleboards processing machine due to adhesive acidity, and produce particleboards with a darker color than particleboards bonded with urea-formaldehyde adhesive. Certain procedures were employed to increase the performance of the citric acid adhesive. Additive agents, such as sucrose, can resolve the particleboard brittleness (Kusumah et al., 2017), increase the number of ester groups to improve the bonding ability of citric acid adhesive (Widyorini, et al., 2016a), increase the hydrogen bond, also the molecular linkage force between particles to produce stronger particleboards (Liao et al., 2016).

There are 1,662 bamboo species in 121 genera spread worldwide (Canavan et al., 2017). Among them, 145 bamboo species belonging to 20 genera are found in Indonesia (Nurdiah, 2016). Bamboo was utilized for furniture, handicrafts, chopsticks, and so on. Moreover, bamboo used as a building material because bamboo culms are strong, tough, straight, easy to bend, and lithe (Widjaja, 2000). Bamboo can also be utilized as particleboard raw materials due to the limitation of wood as particleboard raw material. Sembilang bamboo (*Dendrocalamus giganteus* Munro), has large biomass with a diameter of 20.5 cm and 30.5 m in height, and a thickness of 16.5 mm (Park et al., 2020), that has the potential to be utilized as particleboard raw material. Furthermore, sembilang bamboo can be cultivated after 3 years, providing more sustainability and continuity regarding the availability of particleboard raw materials compared to wood plants.

On the other hand, compared to woods, most bamboo species contain much more silica (0.5-4% w/w) (Ding et al., 2008). The silica is stored as amorphous hydrated silica ($SiO_2.H_2O$) in bamboo with few crystalline phases (Motomura et al., 2006). (Yin et al., 2016) reported that 2-years-old bamboo (*Neosincalamus affinis*) outer skin contains a high concentration of silicon (6.21%). High silica content in some tropical wood species is still a challenge for the woodworking industry due to its abrasive action (Cristóvão, 2013). Moreover, in particleboards production when using urea-formaldehyde resin, the high ash content, primarily silica, contributed to non-uniform resin distribution (Hiziroglu & Suzuki, 2007).

This study aims to examine the properties of particleboards made from bamboo particles (type A) and unskinned bamboo particles (type B) of Sembilang bamboo using citric acid as adhesive. Type A particles were obtained by directly processing bamboo slats with a ring flaker. While the outer skin of Sembilang bamboo was removed and then processed using a ring flaker to obtain type B particles. Using these raw materials, the particleboards were manufactured by hotpressing. The effect of bamboo particles types and citric acid content on particleboards properties were discussed.

II. MATERIALS AND METHODS

Sembilang bamboo (*Dendrocalamus giganteus* Munro) was harvested from the bamboo garden of the Research Center for Biomaterial. We prepared two types of bamboo particles: bamboo particles (type A) and unskinned bamboo particles (type B). Bamboo culms were cut into 40 cm lengths to obtain slats. The bamboo slats were further processed using a planer to remove external layers of bamboo (to obtain unskinned bamboo particles). The bamboo particles were prepared by splitting and chopping bamboo slats, then treated using a ring flaker. Subsequently, bamboo particles were separated with No. 4-mesh and No. 14-mesh screens to obtain bamboo particles with size of 1.41 ~ 4.76 mm. All of the bamboo particles were oven-dried at 60°C to reduce the moisture level of bamboo particles to below 5%. The technical grade of anhydrous citric acid (manufacturer: Weifang Ensign Industry Co., Ltd.) was used without further purification. The citric acid solution with a concentration of 59-60 wt% was obtained by dissolving the citric acid powder in a certain amount of distilled water. This liquid was used as the bonding agent in Sembilang bamboo particleboard manufacturing.

A. Measurement of Bamboo Particles Size Distribution

As many as 3 g bamboo particles were classified using a laboratory vibrating sieve shaker, with sieves of 18 mesh (1000 μm), 14 mesh (1410 μm), 10 mesh (2000 μm), 7 mesh (2830 μm), and 4 mesh (4760 μm). Particles of 5 granulometric classes were used for bamboo particle size distribution: -18 mesh; -18+14 mesh; -14+10 mesh; -10+7 mesh and -7+4 mesh. Symbols (-) and (+) indicate passage and retention of particles, respectively. Afterward, the weight of each particle class was measured and presented.

B. Measurement of Bamboo Particles Geometry

The length, width, and thickness of 100 bamboo particles were measured using a caliper (Mitutoyo Digital Caliper 500-170-30). Based on data of bamboo particle geometry, the slenderness ratio was calculated by dividing particles' length to particles' width. The aspect ratio was calculated by dividing particles' length to particles' thickness of the two types of bamboo particles.

C. Measurement of Bamboo Particles Bulk Density

Particles' bulk density was calculated based on the proportion of the mass to the volume engaged (Cardoso et al., 2013; Omoniyi & Olorunnisola, 2014). Bamboo particles were oven-dried for 24 h before calculation. Firstly, the weight of the 50-mL cylinder was measured. Bamboo particles were placed into the cylinder until they filled the cylinder to reach the 50-mL mark, then the cylinder was re-weighed. The bulk density was calculated based on the difference in weight between the bamboo particles loaded cylinder and the empty cylinder, then was divided by the volume loaded by the bamboo particles.

D. Measurement of Silica Content in Bamboo Particles

The silica content in bamboo particles was measured using a modified method from previous research (Yuan, 2017). Five grams of dried Sembilang bamboo powder was placed in a weighted ceramic crucible, then entirely ashed at 525°C. After cooling, crucible content bamboo ash was weighted to determine the ash content in bamboo. A 10 mL of HCl (6 mol/L) was poured onto the ash. The acid-soluble ash solution was slowly boiled to near dryness using a boiling water bath. HCl treatment was conducted for 10 min and repeated three times. The other 15 mL of HCl (6 mol/L) was added to the solution. After 2 more minutes, the solution was filtered off through No. 42 ashless filter paper (Fisher Scientific, Canada), weighted. The precipitate (silica) was washed 5-6 times with 1 mol/L HCl solution, subsequently 5-6 times with hot deionized water (≈ 50°C). The filter paper with the precipitate and filter paper only (as control) was put in a different ceramic crucible and put in a muffle furnace to be ashed at 600°C to reach a constant weight. The difference in weight of ceramic contains filter paper residue and filter paper + silica residue was calculated to determine silica content.

E. Measurement of Bamboo Particles Wettability

Wettability of bamboo particles was conducted by dropping citric acid solution (0.1 mL) on the outer part (representing type A particles), and on the inner part (representing type B particles) of the bamboo slat. The citric acid solution spread onto the bamboo surface was recorded for 3 minutes with a Digital Microscope (Dino-lite Basic AM2111). The contact angle was measured using Image J software every 10 sec. Shi and Gardner (2001) presented a wettability model with the following equation.

$$\theta = \frac{\theta i \theta e}{\theta 1 + (\theta e - \theta i) \exp\left[\left(\frac{\theta e}{\theta e - \theta i}\right) t\right]} \quad \text{.....(1)}$$

Where:
θ = contact angle
θi = initial contact angle
θe = equilibrium contact angle
K = contact angle change rate constant
t = time

F. Production of Particleboard

The citric acid solution was sprayed over the surface of Sembilang bamboo to obtain particles with three different levels of citric acid, which were 15, 20, and 25 wt% (based on dry bamboo particle weight). Afterward, the particles were oven-dried at 80°C for 6 h to reduce water content. Following this, the particles were placed in a wooden forming mold with a dimension of 30 cm × 30 cm to form a mat. The hot-pressing machine pressed the particle mat at 200°C for 10 min. A 9-mm thick steel bar was positioned to control the board thickness during the hot-pressing process to produce particleboard with a target density of 0.8 g/cm^3. Once the upper part of the pressing plate reached the steel bar, the pressing pressure was 25 MPa.

G. Evaluation of Particleboards Surface Roughness Properties

The surface roughness analysis was performed by using a fine stylus profilometer (Mitutoyo SJ-201). Triplicate measurements were conducted for each particleboard. The average roughness (Ra) as roughness parameters were determined. The calculation of surface roughness parameters was based on digital information generated by the equipment. The particleboard surface roughness in this study was measured with a sensitivity of 0.5 μm. Pin diameter, pin top angle, and measuring the tool's speed were 4 μm, 90°and 0.5 mm/sec, respectively. The length of the tracing line (Lt) and cut-off were 12.5 and 2.5 mm (c), respectively. The measuring force of the scanning arm on the samples was 4 mN (0.4 gf). Measurements were conducted at room temperature, and the pin was calibrated before the tests.

H. Particleboards' Mechanical Properties Characterization

The bamboo particleboards were tested to investigate the modulus of elasticity (MOE), modulus of rupture (MOR), internal bond (IB), by the Japanese Industrial Standards for particleboards (JIS A 5908:2003). The particleboard bending strength properties, including MOR and MOE, were measured by a three-point bending test method using Universal Testing Machine (Shimadzu Autograph 50kN). The bending strength analysis was using a board specimen with dimension length x width of 200 mm × 50 and was tested in dry condition. During the bending strength analysis, load cell speed was 10 mm/min, and the effective span was 150 mm. Meanwhile, IB analysis was conducted on sample test dimension of length x width of 50 mm × 50 mm, and with load cell speed of 2 mm/min.

I. Particleboards' Physical Properties Characterization

The bamboo particleboards were subjected to water absorption (WA) and thickness swelling (TS) analysis, based on JIS A 5908:2003. Physical properties testing was conducted following 7 days of conditioning at room temperature. The specimen size of 50 x 50 x 9 mm was applied to evaluate TS and WA. Specimens were immersed in water for 24 h at room temperature. The thickness and weight differences before and after immersion were calculated.

J. Statistical Analysis

The mechanical and physical particleboards properties data were evaluated using a balanced analysis of variance (ANOVA) procedure for a completely randomized design. The experimental design consisted of two parameters (type of particleboards and citric acid content), and their interactions. Tukey's pairwise comparison test was performed to permit the separation of means. Results were considered significant at 95% confidence levels, by using Minitab Software.

K. Particleboard's Durability Analysis by Cyclic Aging Treatment

Particleboards's durability was tested by treating sample specimens under successive severe conditions, based on the method by Kusumah et al. (2016) with slight modification. Cycling aging treatment involves five steps: 1)

soaking in water at room temperature for 24 h, 2) oven-dry at 105°C for 8 h, 3) immersion in warm water (70°C) for 10 h, 4) oven-dry at 105◦C for 10 h, 5) immersion in boiling water for 4 h, and 6) oven-dry at 105°C for 16 h. The changes in weight and thickness of the samples during the treatment were recorded. Each experiment was performed with five replications. The standard deviation and the mean values were calculated. The thickness swelling (TS) and water absorption (WA) of the particleboard after each treatment cycle were measured.

L. Bonding adhesion of Bamboo Particles and Citric Acid Analysis by FTIR

The edge of the particleboard was scratched to obtain particles. The particles were ground into a powder, and the powder obtained was dried in a drying oven at 60°C for 16 h. Infrared (IR) spectral data were obtained with an FTIR spectrophotometer (Spectrum Two, Perkin Elmer) using the Universal Attenuated Total Reflectance (UATR) method and were recorded by an average of 16 scans at a resolution of 4 cm^{-1}.

III. RESULT AND DISCUSSION

A. Particleboards Surface Roughness

Bamboo particle size in this study was distributed unevenly, as demonstrated in Figure 1. Most of them have particle size more than 2830 μm (2.83 mm) or passed through No 7-mesh screen, 90.78% for type A bamboo particles and 74.56% for type B bamboo particles.

Type B bamboo particles consist of more fine particles (9.64%) than type A bamboo particles (0.63%). After bamboo slats were peeled off, the hardest parts of bamboo slats no longer existed. So that during the processing in ring-flaker, type B bamboo slats produced extra fine particles (Figure 2). While the width

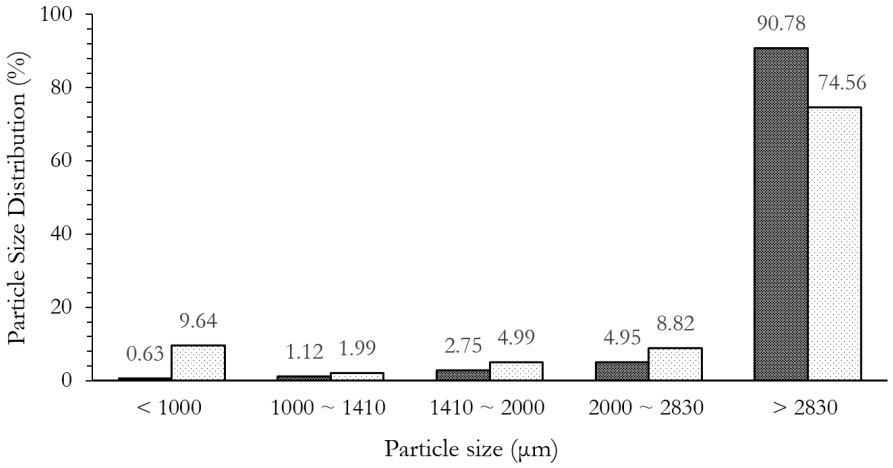

Figure 1. Bamboo particles size distribution

Figure 2. Type A bamboo particles and Type B bamboo particles

and thickness of type A bamboo particles and type B bamboo particles show no significant difference (Figure 3).

The average of particle bamboo geometry from 100 particles of each type is presented in Figure 3. Type B bamboo particles tend to split along the longitudinal direction. The length of type B bamboo particles (41.49 mm average) was longer than that of type A bamboo particles (22.40 mm average). Based on data of particle geometry, we can calculate the slenderness ratio (length/width) and aspect ratio (length/thickness) of the two types of bamboo particles (Table 1).

de Lira Bazzetto et al. (2019) produced bamboo particleboards from bamboo (Dendrocalamus asper) particles with a size of 0.210 mm~0.500 mm and classified them into 4 groups, which were -0.500+0.420 mm, -0.420+0.297 mm; -0.297+0.250mm; -0.250+0.210 mm. Symbols (-) and (+) indicate passage and retention of particles, respectively. Those bamboo particle sizes were relatively smaller than the size of bamboo particles used in this study.

Type B bamboo particles' slenderness ratio and aspect ratio are higher than of type A bamboo particles. Thinner and longer particles yield a higher aspect ratio, larger surface area, and increased contact area in the glue line, contributing to better interaction and thus higher strength (Juliana et al., 2012; Kasim et al., 2018). Nonetheless, the bulk density of both types of bamboo particles shows no significant difference.

Smaller particles produced particleboard with improved surface smoothness nevertheless tend to reduce strength properties and dimensional stability and increase the difficulty in blending resin and mat-forming (Kelly, 1977). The particleboards' characteristics and properties are affected by the type of raw material, the particle geometry, the chemical content in the raw material, and the type and level of adhesive. Particle geometry closely interacts with all these parameters, responsible for the particleboard properties (Maloney, 1993). Furthermore, the particleboard structures are defined by the conditions in which the pressing conditions and the mattress are formed.

Table 1. The geometry ratio and bulk density of bamboo particles

	Slenderness Ratio	Aspect Ratio	Bulk Density (g/cm^3)
Type A bamboo particles	37.06	21.17	0.054
Type B bamboo particles (unskinned)	67.70	31.81	0.053

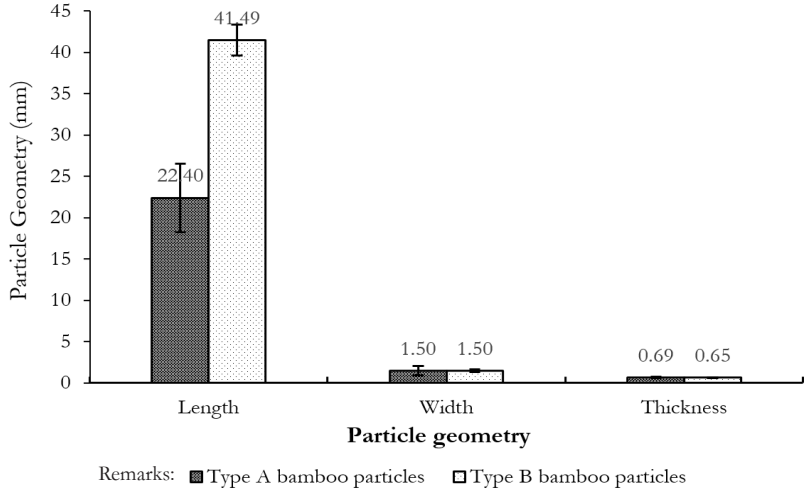

Figure 3. Bamboo particles geometry

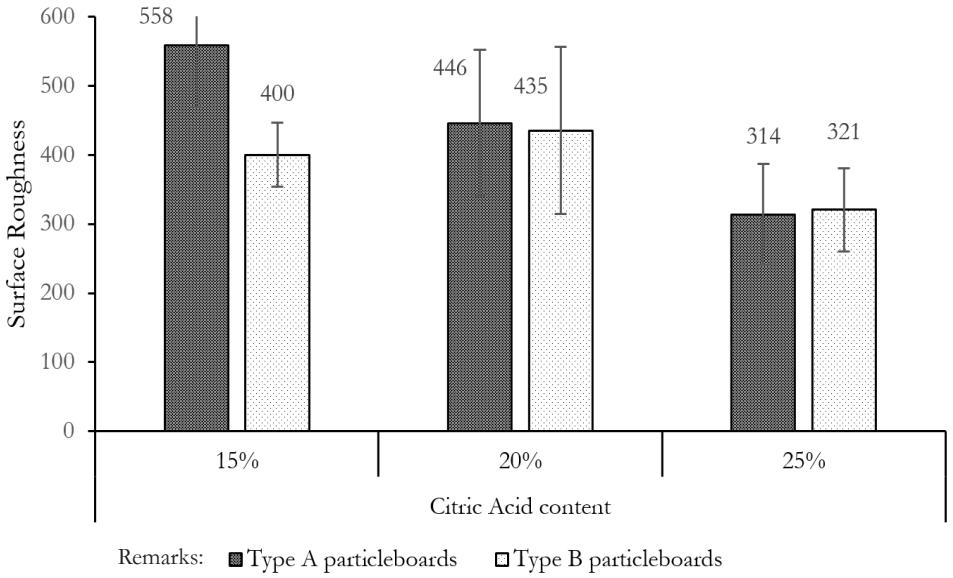

Figure 4. The surface roughness of bamboo particleboards

As explained in the previous section, Type B bamboo particles have a higher slenderness ratio and aspect ratio than type A bamboo particles. With small and thin characteristics, type B bamboo particles could transfer more easily to fill void spaces during hot pressing and create smooth surfaces. Particle geometry has a considerable effect on panel surfaces and edges. The small and thin particles result in smooth board surfaces. The smooth surface is appropriate for different coating types due to their ability and flexibility to fill void spaces.

A standard commercially manufactured particleboard could have average surface roughness (Ra) values of 3 to 6 μm (Hiziroglu, 1996). Type B bamboo particleboards show a smoother surface compared with type A particleboards (Figure 4). The average roughness value was 400 μm for type B bamboo particleboards and 558 μm for type A particleboards when bonded with 15% citric acid. At the same time, the surface roughness of bamboo particleboard bonded with 20% and 25% citric acid when using type A or type B bamboo particles showed no significant differences. The higher amount of citric acid application for adhering bamboo particleboard produced smoother particleboards. The average roughness of type B bamboo particleboards bonded with 20% and 25% citric acid were 435 μm and 321 μm, respectively. Regrettably, it seems that the board surface characteristic of all the particleboards is very rough. So, the sanding process needs to be applied when overlaying application is desired.

Particleboard made from fine particles had a smoother surface compared to that of coarse particles. The usage of citric acid developed a better contact among bamboo particles; therefore, better adhesion, producing a smooth particleboard surface. Rising resin content level would cause the particleboard surface to become smoother or decrease Ra value (Widyorini, Umemura, et al., 2016b).

Other than particle geometry, silica in bamboo skin might also affect the particleboard surface roughness. Silica content in type A bamboo particles was 1.07 %, while in type B bamboo particles was 0.93 %. The effort of peeling off Sembilang bamboo slats can improve particleboard surface smoothness, particularly when applying lower content of citric acid.

B. Particleboards Wettability

In this study, the contact angle between type A bamboo particles and water or citric acid was higher than the contact angle of type B bamboo particles and water or citric acid (Table 2).

Table 2. The contact angle of water and citric acid on the bamboo surface

	Contact angle (°)	
	Water	Citric acid
Type A bamboo particles	69 ± 5	78 ± 6
Type B bamboo particles	35 ± 13	52 ± 11

K values of water and citric acid on the type B bamboo surface were higher than of type A bamboo (Table 3). The higher the K value is, the more the contact angle is; thus, the curve is steeper (Figure 5), indicating the type B bamboo surface has higher wettability than type A bamboo.

Moreover, the bamboo skin's initial contact angle against the water was greater than 83° indicating that water could not spread easily on bamboo skin. Yuan and Lee (2013) said contact angles greater than 90° commonly mean that wetting is critical, so the fluid will minimize its contact with the surface and form a dense liquid droplet.

The surface's wettability indicates the condition that determines the extent to which the fluid will be spread by the surface, affecting the absorption, adsorption, penetration, and spread of adhesive (Marra, 1992). Wettability is an essential property of the wood surface, and it influences bonding properties directly (Tang et al., 2012). In the liquid wetting process, the contact angle change as a function of time is a decreasing function (Shi & Gardner, 2001).

Silica content in bamboo skin was higher than in unskinned bamboo, so bamboo skin was more hydrophobic. The contact angle value is also influenced by material surface macroscopic

Table 3. Bamboo dynamic wettability towards the water and citric acid (R= correlation coefficient, θe = equilibrium contact angle, θi = initial contact angle)

		K ($L.sec^{-1}$)	R	θe (°)	θi (°)
Type A particles	Water	0.0065	0.9124	65.3460	83.0887
	Citric acid	0.0061	0.9133	71.4629	93.3712
Type B particles	Water	0.0479	0.9442	25.9650	75.6353
	Citric acid	0.0203	0.9478	43.0043	82.0578

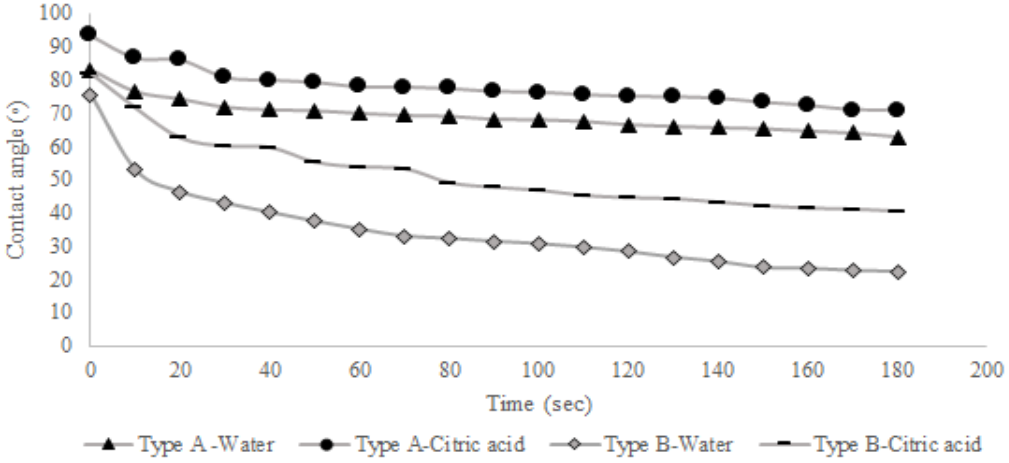

Figure 5. Citric acid and water contact angle change on the surface of type A and type B bamboo particles as a function of time

properties such as porosity, surface smoothness, pH, and chemical compound (Lu & Wu, 2006).

In bamboo culms, silica was considered as a major constituent of the epidermis with values between 1.5 % (*Bambusa vulgaris*) and 6.4 % (*Schizostachyum lumampao*) (Liese, 1998). Van Acker et al. (2000) reported values of 0.066 % in the lower part and 0.082 % in the upper part of *Phyllostachys praecox* culms and values of 0.120 % in the lower part and 0.355 % in the upper part of *Phyllostachys nigra* culms. (Lybeer, 2006) indicated lower values between 0.04 and 0.11 % Si for *Phyllostachys nigra* and *Phyllostachys viridiglaucescens* and 0.08 to 0.11% Si for the tropical species *Gigantochloa levis* and *Dendrocalamus asper*. Compared to another genus of bamboo, as previously stated, the silica content in sembilang bamboo was quite high.

C. Particleboards Mechanical Properties

Figure 6 shows the internal bond (IB) of Sembilang bamboo particleboards. The range IB value of 0.79 – 0.97 N/mm2 was recorded in type B bamboo particleboards, and 0.57-0.78 N/mm^2 was recorded in type A bamboo particleboards. The internal bond of sembilang bamboo particleboards bonded with citric acid was higher than the requirement (0.3 N/mm2) for the Type 18 particleboard internal bond, based on JIS A 5908.

Analysis of variances shows, P-value <0.05 (Table 4), that the type of bamboo particle has a significant effect on the IB value of particleboard.

Further tests using the Tukey comparison method, with 95% confidence level, are presented in Table 5, showing that type B bamboo particles produce particleboards with

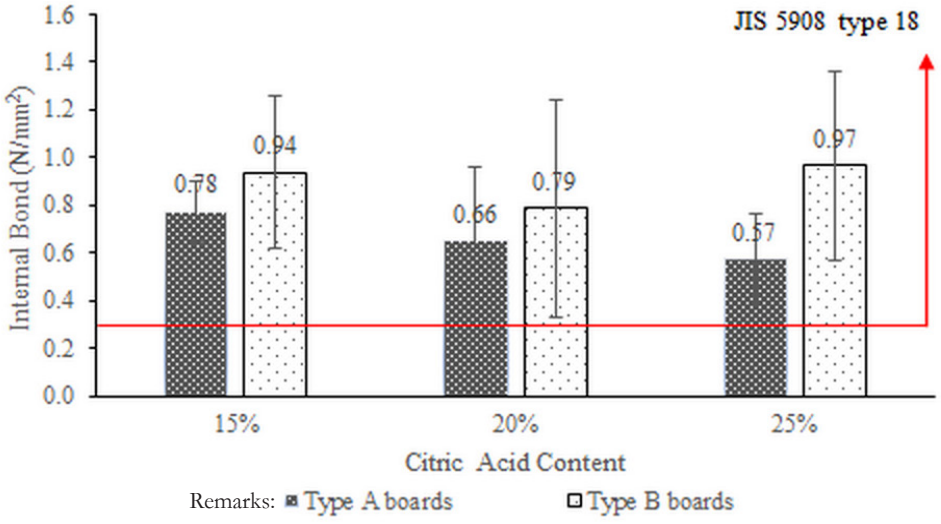

Figure 6. Internal bond of particleboards made from type A and type B bamboo particles

Tabel 4. Analysis of variance for particleboard's internal bond

Source	DF	SS	MS	F	P
Replication	4	0.79150	0.19787	2.38	0.086
Particleboards type	1	0.39496	0.39496	4.74	0.042
CA content	2	0.09468	0.04734	0.57	0.575
Particleboards type*CA content	2	0.10127	0.05064	0.61	0.554
Error	20	1.66525	0.08326		
Total	29	3.04766			

Tabel 5. Grouping information using the Tukey Method and 95% confidence

Particleboards type	N	Mean	Grouping
Type B	15	0.897777	A
Type A	15	0.668298	B

Remarks: *Means that do not share a letter are significantly different.*

higher IB values and are significantly different from type A bamboo particleboard.

The results of the wettability analysis were in accordance with the results of the IB analysis, which show that the particleboard's IB values were not influenced by citric acid content but influenced by the type of bamboo particles. IB values of particleboards made from Sembilang bamboo particles demonstrate an interesting value. It shows that 15 % of citric acid was enough to bond type A and type B bamboo particles to produce particleboards that fulfilled the Type 18 particleboard standard, based on JIS A 5908. The citric acid solution can easily cover and fill the void of bamboo particles whether or not the skin bamboo is still attached to the bamboo particles. Due to hot-pressing, citric acid was reacted with hydroxyl groups of bamboo particles, producing a strong internal bond (explained further in the bonding mechanism at the end of the article). The same bonding mechanism was observed in another grass family, such as Imperata cylindrica (Syamani et al., 2018) and sugarcane (Syamani et al., 2020).

Citric acid is expected to act as a bonding agent in bamboo-based particleboard. However, the presence of silica in type A boards drives citric acid to be reacted to destruct silica rather than reacted with hydrogen groups in bamboo particles. Therefore, the internal bond in type A boards was lower than in type B boards.

MOR average values of two kinds of bamboo particleboards at various citric acid contents are presented in Figure 7. It is indicated that the type of bamboo particles affected the particleboards MOR significantly. Analysis of variances shows that the type of particleboard, has a value of P<0.01 (Table 6), indicating that the type of bamboo particles has a very significant effect on the MOR value of particleboard.

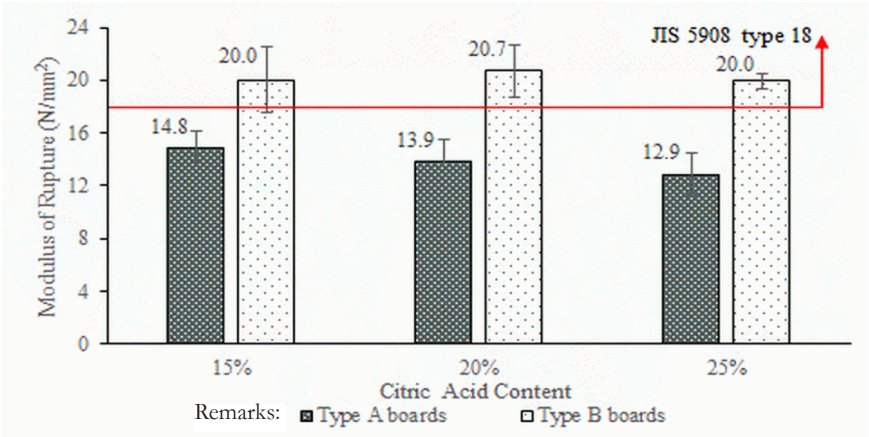

Figure 7. Modulus of rupture of particleboards made from type A and type B bamboo particles

Tabel 6. Analysis of variance for particleboards' modulus of rupture

Source	DF	SS	MS	F	P
Replication	4	21.844	5.461	2/31	0.093
Particleboards type	1	304.388	304.388	128.74	0.000
CA content	2	6.075	3.038	1.28	0.299
Particleboards type*CA content	2	5.169	2.585	1.09	0.354
Error	20	47.288	2.364		
Total	29	384.764			

Further tests using the Tukey comparison method, with 95% confidence level, are presented in Table 7, showing that type B bamboo particleboard produces a higher MOR value and is significantly different from type A bamboo particleboard.

Tabel 7. Grouping information using the Tukey method and 95% confidence

Particleboards type	N	Mean	Grouping
Type B	15	20.2352	A
Type A	15	13.8646	B

Remarks: *Means that do not share a letter are significantly different.*

The MOR values of type B bamboo particleboard, bonded with 15, 20, 25 % citric acid, were higher than type A bamboo particleboard, i.e. 20.0, 20.7, and 20.0 N/mm^2, respectively, and fulfilled the requirement for type 18 particleboard by JIS 5908. The high MOR values indicated that the type B bamboo particles developed good bonding strength with citric acid. In contrast, particleboards made from type A bamboo particles showed lower MOR values, considering that the adhesion between bamboo particles could be obstructed by the existence of silica in bamboo skin. However, all particleboards made from type A bamboo particles could fulfill the obligation of Type 13 of JIS A 5908, where MOR of 13.0 N/mm^2 or more is obliged. Regarding the citric acid amount applied to bond bamboo particles, the MOR values were not significantly affected.

In contrast to MOR value, particleboards made from type B bamboo particles showed a lower MOE value (Figure 8) compared to particleboard made from type A bamboo particles when bonded with 15% or 20% citric acid. Nonetheless, the MOE values of particleboards made from type A and type B bamboo particles were high that can fulfill the requirement of type 18 of JIS A 5908, where MOE of 3000 N/mm^2 or more is obliged. Based on the analysis of variances, the interaction of particleboard type and citric acid content gave a significant effect on the MOE value of particleboard (Table 8).

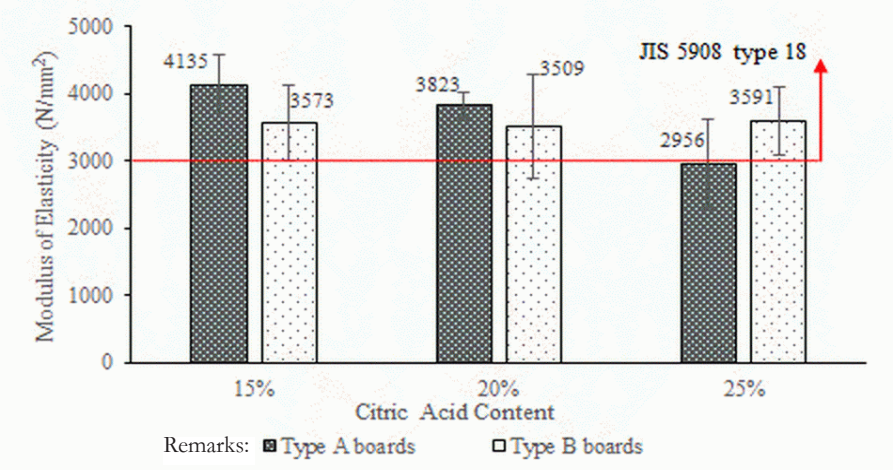

Figure 8. Modulus of elasticity of particleboards made from type A and type B bamboo particles

Tabel 8. Analysis of variance for particleboard's modulus of elasticity

Source	DF	SS	MS	F	P
Replication	4	2209546	552387	2,18	0,109
Particleboards type	1	48710	48710	0,19	0,666
CA content	2	1756876	878438	3,46	0,051
Particleboards type*CA content	2	1997017	998508	3,93	0,036
Error	20	5078729	253936		
Total	29	11090878			

Further testing of the effect of particleboard type used the Tukey comparison method, with 95% confidence level is presented in Table 9 and Table 10, indicating that the type of particleboard or the level of citric acid does not affect the MOE value of the particleboard. As reported by (Li & Beijing, 2004) and (Yuan, 2017), in general, bending properties (MOR and MOE) decreased as the portion of the outer bamboo surface removed increased. The outer bamboo surface shows higher bending properties than the inner part of bamboo. In line with Li's statement, this study result shows that the MOE of particleboards made from type B bamboo particles was lower than that of MOE particleboard made from type A bamboo particles when bonded with 15% and 20% citric acid. Type B particleboard, which no longer has bamboo skin, shows lower stiffness compared to type A particleboard.

Tabel 9. Grouping information using the Tukey method and 95% confidence

Particleboardstype	N	Mean	Grouping
Type A	15	3638.17	A
Type B	15	3557.58	A

Remarks: *Means that do not share a letter are significantly different.*

Tabel 10. Grouping information using the Tukey Method and 95% confidence

CA content	N	Mean	Grouping
CA 15%	10	3854.04	A
CA 20%	10	3666.34	A
CA 25%	10	3273.25	A

Remarks: *Means that do not share a letter are significantly different.*

Both types of Sembilang bamboo particleboards (type A and type B) demonstrate screw holding power (SHP) value greater than 300 N (fulfilling type 8 particleboards based on JIS A 5908) when bonded with 15% and 20% citric acid. However, the addition of citric acid until 25% causes particleboard SHP value to decrease (Figure 9). Analysis of variances from the treatment of citric acid levels, has a value of $P < 0.01$ (Table 11), indicating that the levels of citric acid have a very significant effect on the value of the screw holding power of the particleboard.

Further testing of the effect of citric acid levels using the Tukey comparison method, with 95% confidence level is presented in Table 12, showing that 15% citric acid content produces particleboard with higher SHP values and is significantly different from bamboo particleboard with a citric acid content of 20% and 25%.

Citric acid affected the power of the screw to hold the particleboard due to its acidity. Based on this data, it is suggested to use not more than 20% citric acid content to bond the particle, especially when the particleboards are intended to be used as furniture. The SHP of type A

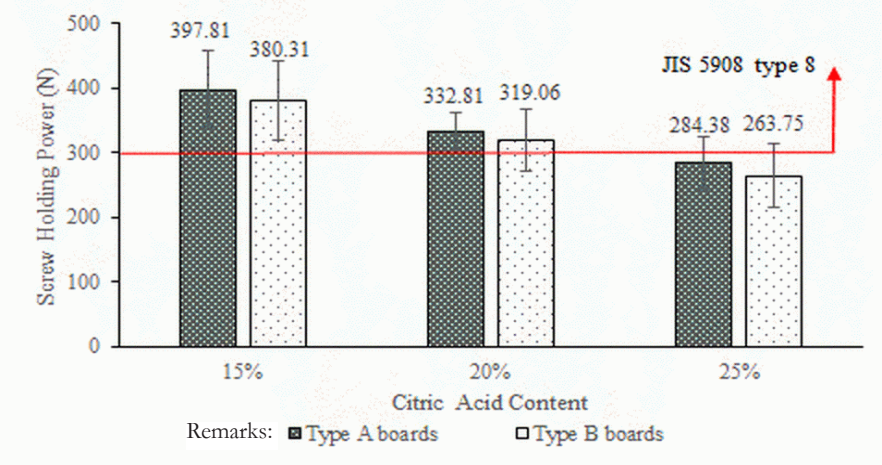

Figure 9. Screw holding power of particleboards made from type A and type B bamboo particles

Tabel 11. Analysis of variance for particleboard's screw holding power

Source	DF	SS	MS	F	P
Replication	4	11383	2845.7	1.18	0.351
Particleboards type	1	2243	2242.5	0.93	0.347
CA content	2	66336	33168.1	13.72	0.000
Particleboards type*CA content	2	59	29.6	0.01	0.988
Error	20	48358	2417.9		
Total	29	128379			

Tabel 12. Grouping information using the Tukey method and 95% confidence

CA content	N	Mean	Grouping	
CA 15%	10	389.063	A	
CA 20%	10	325.938		B
CA 25%	10	274.062		B

Remarks: *Means that do not share a letter are significantly different*

particleboards was higher than that of type B particleboards. Particleboard strength, nail, and screw withdrawal resistance are important characteristics of particleboards and are mainly affected by particle geometry. As stated in Table 1, the slenderness ratio and aspect ratio of type A bamboo particles were lower than of type B bamboo particles. It means that the shape of type A bamboo particles is wider and thicker than of type B bamboo particles. Therefore, particleboards made from type A bamboo particles have more power to hold the screw.

D. Particleboards Physical Properties

Particleboards' water absorption and thickness swelling characteristics were analyzed to explain bamboo particleboards' physical properties. It is obvious from Figure 10 that the resistance of the particleboards to absorb water was improved significantly when using type B bamboo particles. The water absorption (WA) values were 19.38 ~ 23.35 % for type B bamboo particleboards bonded with various citric acid content. On the other hand, the particleboards using type A bamboo particles show WA values in a range of 32.69 ~ 33.53 %. The influence of bamboo particle type was more significant compared to citric acid content. Analysis of variances due to particleboard type has a value of P<0.01 (Table 13), indicating that particleboard type has a very significant effect on the water absorption (WA) value of particleboard.

Further testing of the effect of particleboard type using the Tukey comparison method, with

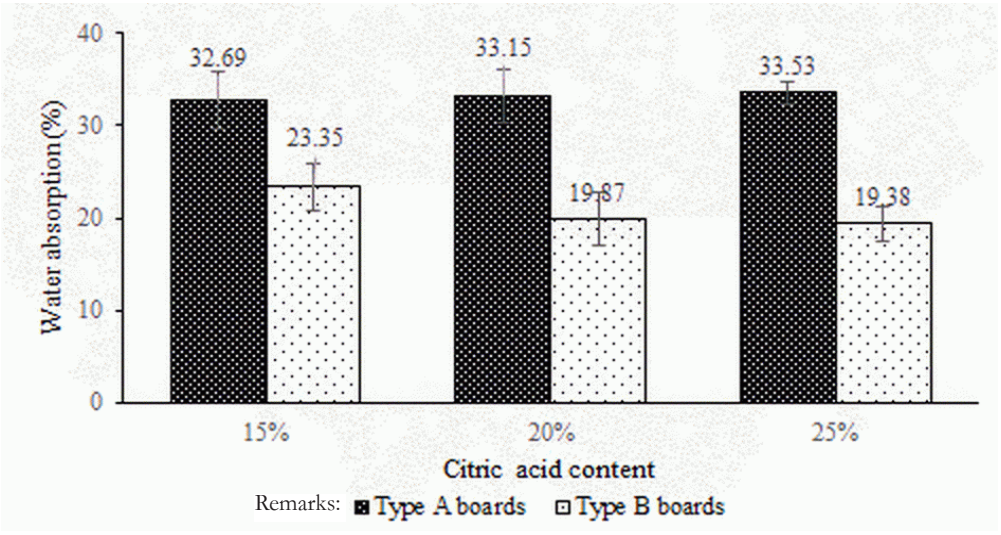

Figure 10. Water absorption of particleboards made from type A and type B bamboo particles

Tabel 13. Analysis of variance for particleboards' water absorption (%)

Source	DF	SS	MS	F	P
Replication	4	23.74	5.94	0.94	0.462
Particleboards type	1	1127.08	1127.08	178.04	0.000
CA content	2	15.79	7.89	1.25	0.309
Particleboards type*CA content	2	32.73	16.37	2.59	0.100
Error	20	126.61	6.33		
Total	29	1325.95			

Tabel 14. Grouping information using the Tukey method and 95% confidence

Particleboards type	N	Mean	Grouping	
Type A	15	33.1238	A	
Type B	15	20.8650		B

Remarks: *Means that do not share a letter are significantly different.*

a 95% confidence level is presented in Table 14, showing that type B bamboo particles produce particleboard with a lower water absorption value than type A particleboard. This indicates the stability of the type B particleboard is better than the type A particleboard.

(Widyorini et al., 2016) applied 15% and 30% citric acid content to bond various bamboo species with different sizes of particles. She explained that citric acid content was more principal on particleboards dimensional stability than bamboo species or particle size. The WA values were 35%, 17%, and 26% for particleboards made from 15% citric acid and fine particles of petung, wulung, and apus bamboo. Then the WA values were improved to 15%, 13%, 12% for particleboards made from 30% citric acid and fine particles of Petung, Wulung, Apus bamboo, respectively. In this study, the citric acid amount varied at 15%, 20%, and 25%, and has not significantly influenced particleboard WA value. The difference of bamboo particles type influenced wettability properties, as mentioned before. Type B bamboo particles which have lower silica content, have superior wettability properties than type A bamboo particles, thus causing the improved bonding then resulted in enhanced dimensional stability.

As demonstrated in Figure 11, the thickness swelling (TS) values of the particleboards bonded with citric acid fulfilled the requirement

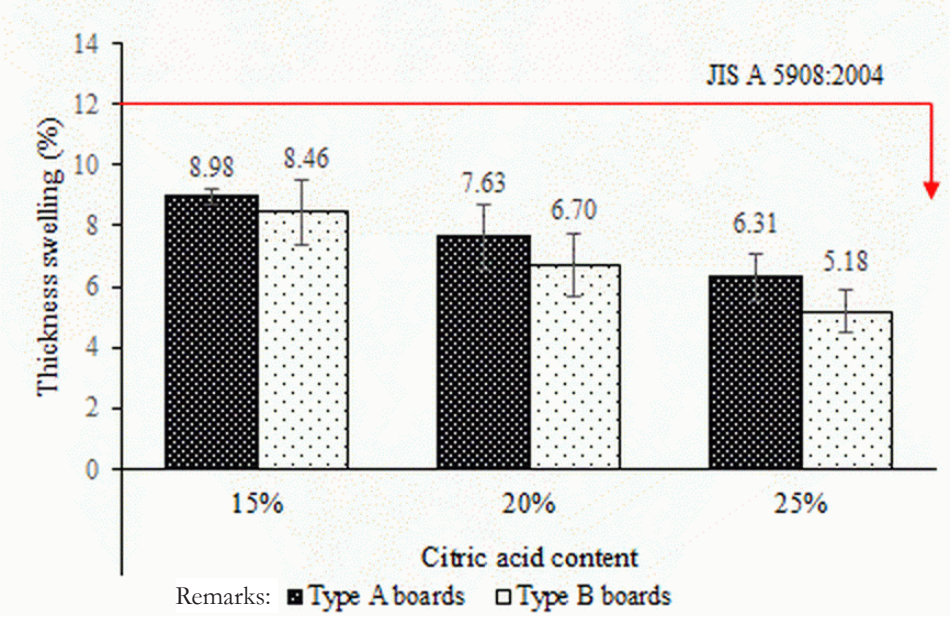

Figure 11. Thickness swelling of particleboards made from type A and type B bamboo particles

Tabel 15. Analysis of variance for particleboard's thickness swelling

Source	DF	SS	MS	F	P
Replication	4	7.987	1.9967	0.90	0.483
Particleboards type	1	5.563	5.5634	2.51	0.129
CA content	2	44.193	22.0965	9.95	0.001
Particleboards type*CA content	2	0.487	0.2436	0.11	0.897
Error	20	44.399	2.2199		
Total	29	102.630			

of JIS A 5908 (max 12 %), demonstrating that bamboo particleboard had good dimensional stability. Analysis of variances due to citric acid content has a value of P<0.01 (Table 15), indicating that citric acid content has a very significant effect on the value of thickness expansion (TS) of particleboard.

Further testing of the effect of citric acid levels using the Tukey comparison method, with 95% confidence level is presented in Table 16, showing that particleboard with 25% citric acid content produces particleboard with a lower thickness expansion value than particleboard with 15% and 20% citric acid content. This shows that the stability of the bamboo particleboard bonded with citric acid at a level of 25% is better than that of the bamboo particleboard bonded with citric acid at a concentration of 15% and 20%.

Tabel 16. Grouping information using the Tukey Method and 95% confidence

CA content	N	Mean	Grouping	
CA 15%	10	8.71781	A	
CA 20%	10	7.16632	A	B
CA 25%	10	5.74580		B

Remarks: *Means that do not share a letter are significantly different.*

The TS value was 8.98% for type A particleboard bonded with 15% citric acid. The TS value was improved to 7.63% and 6.31% by adding 20% and 25% citric acid, respectively (Figure 10). Moreover, the TS value of type B particleboard was also improved when applying higher citric acid content, with a range of TS values of 5.18~8.46%. This occurrence is possible because type B bamboo particles might deliver a more intimate contact area among particles, and in contrast with type A bamboo particles due to the lower concentration of silica in type B bamboo particles, resulting in more intense bonding. The same trend was also found by (Widyorini, Nugraha, et al., 2016). They reported that bamboo-citric acid particleboards have TS value in a range of 7 ~ 9% when bonded with 15% citric acid and 2 ~ 4% when bonded with 30% citric acid.

E. Particleboards Durability Analysis by Cyclic Aging Treatment

The thickness change of particleboards made from type A and type B bamboo particles after cyclic aging treatment are depicted in Figure 12. The thickness change of bamboo particleboards at each phase of the cyclic aging treatment decreased with the increase of citric acid content, regardless of the type of bamboo particles.

The particleboard dimensions have remained stable during all steps of cyclic aging treatment. The results demonstrate that boards with a 25% citric acid content performed better dimensional stability than the boards bonded with 15% or 20% citric acid. The percentage of thickness-change of type A and type B bamboo particleboards bonded with 25% citric acid after being boiled in water for 4 h was 12.15% and 12.31%, respectively. This value of particleboard thickness-change was lower than those bonded with 15% or 20% citric acid. The result suggests that 25% of citric acid effectively produced good dimensional stability particleboard.

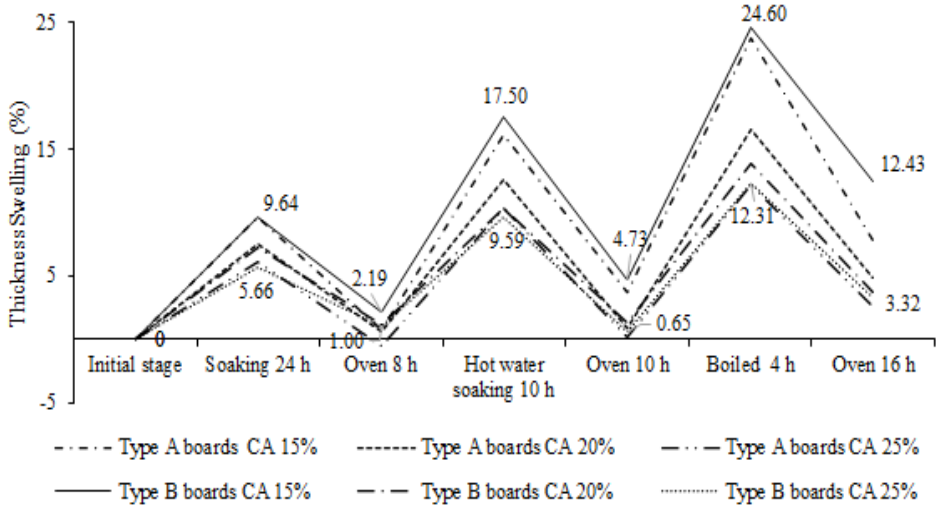

Figure 12. Thickness swelling of bamboo particleboards during cyclic aging treatment

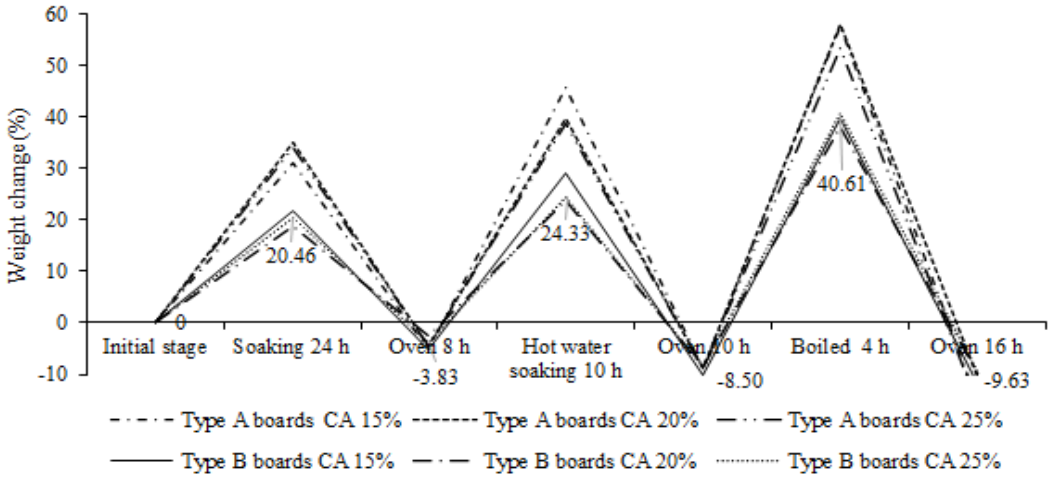

Figure 13. Weight changes of bamboo particleboards during cyclic aging treatment

The change of particleboards weight after cyclic aging treatment is illustrated in Figure 13, indicating that the weight change decreased with the increase of citric acid level.

This outcome demonstrates that the increase of citric acid levels enhances the inhibition of water absorption. The type B bamboo particleboards weight changes due to the following hot-water immersion treatment (24.33%) were higher than those of type A bamboo particleboards after the first phase of water immersion treatment (20.46%). This occurrence is affected by the water resistance of the adhesive decreased due to hot-water immersion treatment, thus enhancing the water infiltration into the boards. The type A bamboo particleboard weight bonded with 25% citric acid changed by approximately −4.61 to −15.74% with the following drying treatment. The scale of type B bamboo particleboard weight change is similar to that of type A bamboo particleboards. Nevertheless, the type B bamboo particleboards weight changes due to each phase of drying treatment were lower, approximately −3.83 to −9.63%. This outcome demonstrates that the bonding between type B

bamboo particles and citric acid was superior to type A bamboo particles, thus more dominant to resist water due to a more intimate contact area among particles with citric acid, by the lower concentration of silica in bamboo skin.

F. Bonding Adhesion of Bamboo Particles and Citric Acid Analysis by FTIR

The bonding mechanisms of bamboo particleboards with various citric acid levels were evaluated using FT-IR spectroscopy. The board infrared (IR) spectra are presented in Figure 14 and Figure 15.

In the FTIR analysis, the peak intensity at approximately 1714 cm^{-1} is typically ascribed to C=O stretching due to carboxyl groups and/or C=O ester groups (Yang et al., 1996; Žagar & Grdadolnik, 2003). Kusumah, Arinana, et al., (2017) and Kusumah, Umemura, et al., (2017a) mentioned that carbonyl groups were represented as ester linkage between hydroxyl groups of sweet sorghum bagasse

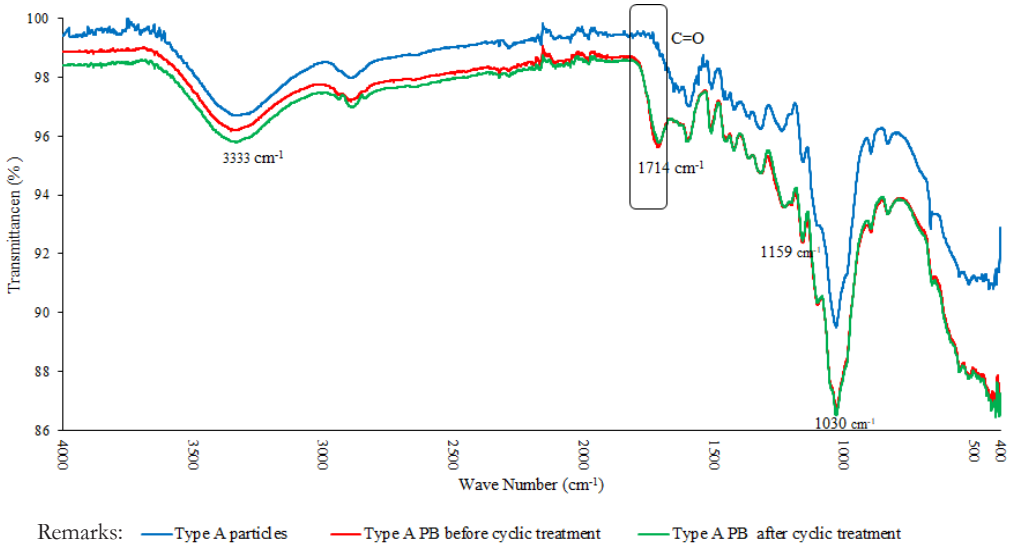

Figure 14. FTIR spectrogram of type A bamboo particles and particleboards made of type A bamboo particles bonded with 25% citric acid before and after cyclic aging treatment

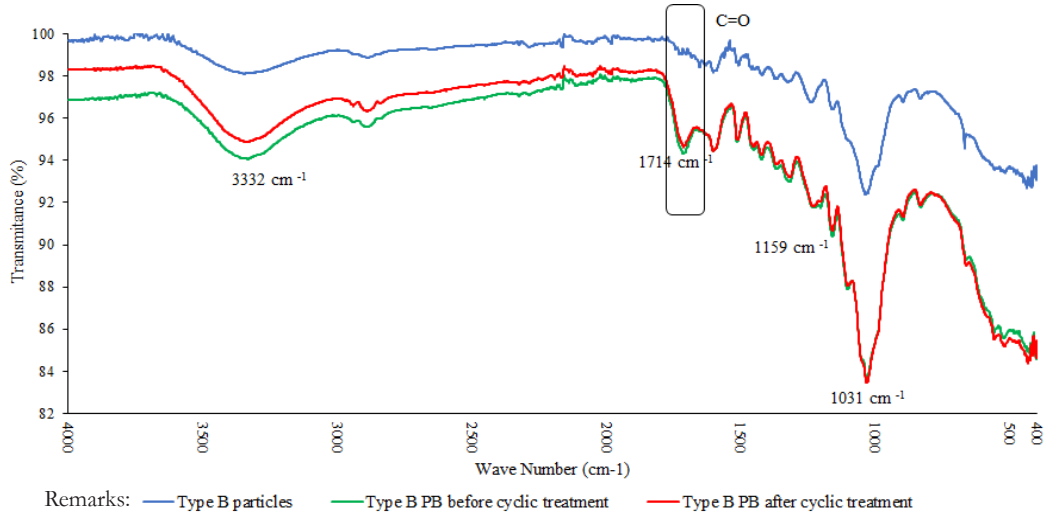

Figure 15. . FTIR spectrogram of type B bamboo particles and particleboards made of type B bamboo particles bonded with 25% citric acid before and after cyclic aging treatment

(lignocellulosic materials) and carboxyl groups of citric acid. As described in Figure 14, FTIR spectra of Type A bamboo particles show no peak at 1713 cm^{-1}. On the other hand, FTIR spectra of particleboard made from type A bamboo particles show a peak at 1713 cm^{-1} before and after cyclic aging treatment. It has proven the forming of ester linkage in particleboards.

According to the results presented in Table 4, band characteristics were changed from type A and type B particleboards before and after cyclic treatment.

The peak at nearly 1714 cm^{-1} was assigned to the C=O stretch in esters. The IR spectra of type B bamboo particleboards exhibit that the intensities of the transmittance peaks at nearly 1714 cm^{-1} representing that carboxyl groups in citric acid reacted with the hydroxyl groups of type B bamboo particles to form ester linkages (Figure 15). The bonding mechanism is very similar to that detected in wood particleboards bonded with citric acid (Umemura et al., 2015). Accordingly, ester linkages formation would cause good adhesiveness and convey superior physical characteristics to the bamboo particleboards.

IV. CONCLUSION

The effects of bamboo particle type and citric acid level on the mechanical and physical properties of Sembilang bamboo particleboards bonded with citric acid were evaluated. The type B particleboards' internal bond (IB), modulus of rupture (MOR), water absorption (WA), and thickness swelling (TS) were superior compared to the type A particleboards. This was influenced by the lower concentration of silica in type B particleboards, which tend to allow an intimate contact area among particles and citric acid then produced better quality particleboards compared to type A particleboards. On the other hand, type A particleboard shows higher quality, in terms of modulus elasticity, due to bamboo outer skin contributing to particleboards' rigidity. Furthermore, the MOR, MOE, and IB values of type B bamboo particleboards satisfied the type 18 requirements of JIS A 5908. Although, the screw holding power of type B bamboo particleboards only satisfied type 8 of JIS A 5908. The physical properties of Sembilang bamboo particleboards were also improved when using type B bamboo particles and bonded with 25% citric acid. Based on the infrared spectra, ester linkages appeared clearly in Sembilang bamboo particleboards manufactured with type B bamboo particles and bonded with 25% citric acid. This means that removing bamboo skin containing silica affected the mechanical and physical properties of Sembilang bamboo particleboards bonded with citric acid.

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ORTHOPTERAN DIVERSITY IN TROPICAL ECOSYSTEMS OF CENTRAL KERALA, INDIA

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ORTHOPTERAN DIVERSITY IN TROPICAL ECOSYSTEMS OF CENTRAL KERALA, INDIA. Orthoptera is a diverse arthropod taxon that includes locusts, grouse locusts, short-horned grasshoppers, long-horned grasshoppers, katydids, crickets and mole crickets. They play crucial roles in food chains, nutrient cycling and pollination. The diversity of orthopterans in agroecosystems and grasslands located in the highlands and lowlands of Central Kerala were studied from December 2019 to March 2020. The study was conducted in Avoly of Ernakulam District and Venmony of Idukki District in Kerala by employing random sampling in 10 x10 m quadrats. A total of 35 species of orthopterans, belonging to two suborders, 10 families, 20 subfamilies, and 33 genera were recorded. Family Acrididae with fourteen species was the most dominant family followed by Tettigoniidae. Two species namely, *Chitaura indica* and *Burrinia burri* are endemic to the state of Kerala. It was found that the ranges of most of the orthopteran genera reported in our study extend all over the South East Asian countries. The highest number of Orthoptera was reported in December in both locations and it decreased towards March. Simpson's diversity index value shows that both regions harbour a highly diverse orthopteran community. The diversity index value of Venmony is comparatively higher which might be due to the proximity of the study site to the natural forest ecosystem and fewer disturbances. More studies on the orthopteran fauna of Kerala are recommended which would help control their pest status and exploit their economic potential as food in animal husbandry.

Keywords: Grasshoppers, locusts, highlands, Western Ghats, ecotone, diversity, Kerala

KEANEKARAGAMAN ORTHOPTERAN PADA EKOSISTEM TROPIS DI CENTRAL KERALA, INDIA. Orthoptera adalah takson arthropoda yang mencakup belalang, belalang belibis, belalang bertanduk pendek, belalang bertanduk panjang, jangkrik semak, jangkrik dan jangkrik mol. Mereka memainkan peran penting dalam rantai makanan, siklus nutrisi dan penyerbukan. Keanekaragaman orthoptera di ekosistem pertanian dan padang rumput yang terletak di dataran tinggi dan rendah Central Kerala dipelajari dari Desember 2019 hingga Maret 2020. Penelitian dilakukan di Avoly, Distrik Ernakulam dan Venmony, Distrik Idukki di Kerala dengan menggunakan random sampling pada kuadrat 10 x10 m. Tercatat sebanyak 35 spesies orthoptera, yang termasuk dalam dua subordo, 10 famili, 20 subfamili, dan 33 genera. Famili Acrididae dengan empat belas spesies merupakan famili yang paling dominan diikuti oleh Tettigoniidae Dua spesies yaitu, Chitaura indica *dan* Burrinia burri *adalah endemik negara bagian Kerala. Ditemukan bahwa kisaran sebagian besar genera orthopteran yang dilaporkan dalam penelitian ini meluas ke seluruh negara-negara Asia Tenggara. Jumlah Orthoptera tertinggi dilaporkan pada bulan Desember di kedua lokasi dan menurun pada bulan Maret. Nilai indeks keanekaragaman Simpson menunjukkan bahwa kedua wilayah memiliki komunitas orthopteran yang sangat beragam. Nilai indeks keanekaragaman Venmony relatif lebih tinggi yang mungkin disebabkan oleh kedekatan lokasi penelitian dengan ekosistem hutan alam dan gangguan yang lebih sedikit. Studi lebih lanjut tentang fauna orthopteran Kerala direkomendasikan yang akan membantu mengendalikan status hama mereka dan memanfaatkan potensi ekonomi mereka sebagai makanan di peternakan.*

Kata kunci: Belalang, belalang, dataran tinggi, West Ghats, ekoton, keanekaragaman, Kerala

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I. INTRODUCTION

Orthopterans are found to be one of the oldest lineages of insects with primitive unspecialized wings. Order Orthoptera belongs to class Insecta and is divided into two suborders namely Ensifera and Caelifera. The word Orthoptera is derived from Greek words 'Ortho' means straight and 'Pteros' means wing (Tandon & Hazra, 1998). They are also known as 'saltatoria' for their saltatorial hind legs which aids in leaping. Caelifera consists of short-horned grasshoppers, grouse locusts and locusts whereas Ensifera includes long-horned grasshoppers, mole crickets, crickets and katydids.

Orthoptera is a diverse arthropod taxon with 28,702 species globally (Cigliano, Braun, Eades, & Otte, 2021). Around 2,000 species are known from South East Asia (Dawwrueng, Tan, Artchawakom, & Waengsothorn, 2017). In India, around 1,093 species belonging to 404 genera and 21 families of Orthoptera were identified (Chandra, Raghunathan, & Rizvi, 2021; Chandra et al., 2020; Chandra & Sheela, 2019; Chandra & Sheela, 2018; Chandra et al., 2017; Chandra et al., 2016; Venkataraman et al., 2015; Venkataraman et al., 2014; Venkataraman, 2013; Shishodia et al., 2010). In Kerala, 13 families, 99 genera and 130 species of Orthoptera from two suborders were reported (Bhaskar, Easa, & Hochkirch, 2018).

Orthoptera is popularly known for their pest status in Kerala but they also perform ecological roles as in nutrient cycling, trophic food chain, pollination and plant growth. They are excellent ecological indicators of the health of the grassland ecosystem (Tan, Choi, & Shankar, 2017). Grasshoppers play a significant role in the food chain as they convert plant tissue into large units of animal material and serve as food for vertebrate animals. Orthopterans are also economically important as pests and food sources (Priya, 2005).

The study of Orthoptera in the Indian sub-continent was initiated in the nineteenth century by Agustin Stahl. Boliviar (1900, 1902, 1917) made major contributions to the orthopteran fauna of India. Monographs by Chopard (1928, 1969) also remain as a major guide to the studies of Indian Orthoptera. Another important contribution to Indian Orthoptera (Caelifera) was the 'Fauna of British India - Orthoptera' (Kirby, 2015). Bhowmik (1985) provided a technical monograph about orthopteran subfamilies especially on Acrididae. Tandon and Hazra (1998) studied the orthopterans distributed throughout the physiographic zones of the Indian subcontinent. Shishodia, Chandra, and Gupta (2010) prepared a preliminary checklist of Orthoptera of India.

Orthopteran diversity in Kerala has been documented by various isolated studies like Shishodia and Hazra (1986), Vasanth (1991), Mathew (2004), Prabakar and Radhakrishnan (2005), Koya et al., (2017), Eldhose et al. (2019) and Kuruvila et al. (2019). A compiled checklist of the Orthoptera of Kerala was prepared by Bhaskar et al. (2018). Nevertheless, orthopteran diversity in Central Kerala has not been well explored. Central Kerala is the broadest part of the state with myriads of ecosystems stretching along an altitudinal gradient from the mangroves along the coast to the sholas in the hills. These ecosystems host a diverse orthopteran fauna which are underexplored till date. The present study attempts a comparison of the orthopteran diversity along the altitudinal gradient in grasslands and the agroecosystems of Central Kerala along with its diversity statistics.

II. MATERIAL AND METHOD

A. Study Site

The selected study sites were Avoly (9°58'14.9"N, 76°36'54.5"E) and Venmony (9°57'35.4"N, 76°52'03.6"E) in Central Kerala, India (Figure 1). Avoly is situated at an altitude of 45 m asl. The average temperature here ranges from 24–36°C and receives monsoon rain. In both areas, the study was conducted in agroecosystems and open grasslands. The agroecosystem selected for the study included monoculture plots of rubber and mixed plots with crops namely, plantain, turmeric, tapioca

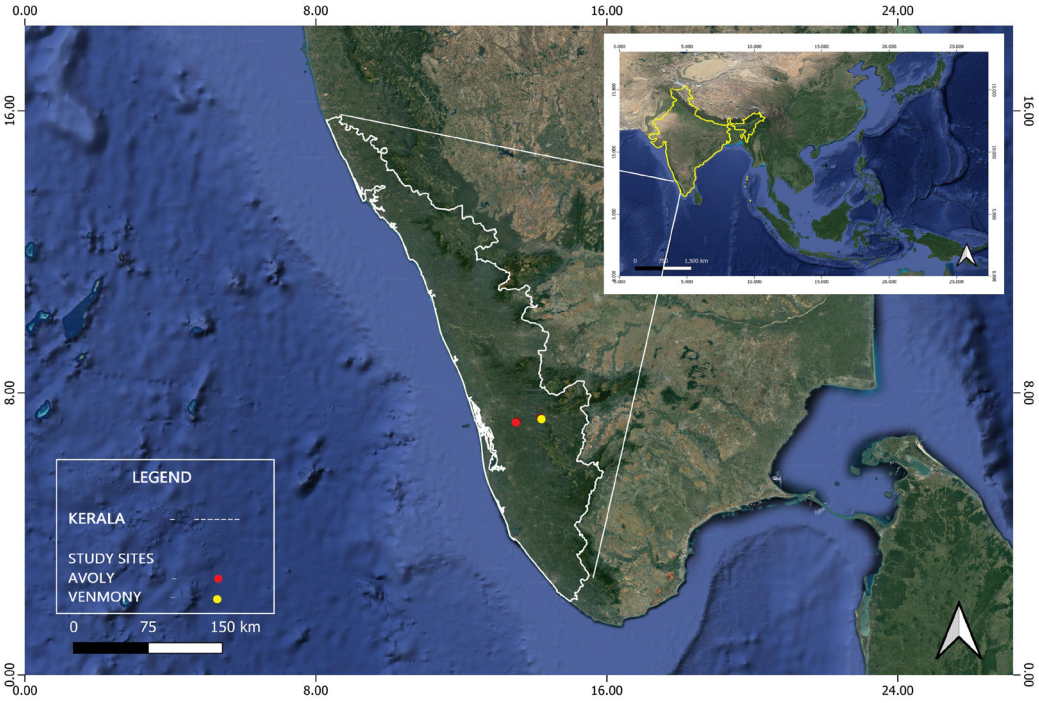

Figure 1. Map showing study site

and vanilla. The study site in Venmony is an ecotone, an immediate periphery of the natural forest area under Mullaringad forest range of the Western Ghats which is situated at an elevation of 540 m asl. Temperature ranges from 20–32°C. The study site was separated from the natural forest by a perennial stream flowing between them. The agroecosystem in Avoly was near human interferences like roads and playgrounds.

B. Methods

The study was carried out from December 2019 to March 2020. Field visits were conducted during the morning [7:00 to 11:30 a.m. IST] and evening [3:30 to 6:00 p.m. IST] hours. Sampling was conducted once every month in both sites. Random sampling was done using the quadrat method. Five quadrats of size 10 x10 m were laid randomly in both locations. Pitfall trap was used to sample the litter dwelling orthopterans. Pitfall trap was made using a cylindrical plastic cup of 10 cm depth and 8 cm diameter. Soap solution was filled upto a height of 3 cm to prevent the trapped insects from escaping. They were employed one per quadrat in monoculture plantations of rubber and grasslands. Insects were collected from quadrats by visual search for 20 min followed by handpicking. Sweep net sampling was used to collect orthopterans from plants inside the quadrat. The sweep net has a 90 cm long handle and a 30 cm ring onto which a white coloured muslin cloth of 60 cm was attached. To ensure that the whole area of the quadrat was swept at least once, five sweeps per quadrat was done. Shaking or beating was also performed five times per quadrat to collect orthopterans from plants. Abrupt shaking of bushes inside the quadrat made the insects fall onto a white cloth spread beneath the plant. Only adult specimens were collected. The collected specimens were photographed using a Samsung A10S mobile with 13 MP rear camera.

After the collection, insects were transferred into specimen bottles containing cotton soaked in ether. The dead insects are preserved in 70% alcohol. Some of the sacrificed insects were pinned by insect pins and dried. Identification has been done mainly by comparing the morphological characters of

specimens with descriptions in taxonomic keys, standard textbooks (Mathew, 2004; Prabakar & Radhakrishnan, 2005; Shishodia et al., 2010; Tandon & Hazra, 1998) and the aid of Orthoptera Species File (Cigliano et al., 2021). Existing literatures were referred to confirm the geographical distribution of the identified species also.

C. Analysis

Diversity of both sites were calculated using Shannon diversity index and Simpson's diversity index. Shannon diversity index takes into account species richness and evenness whereas Simpson's diversity index is a dominance index (Magurran, 2004). The significance of the values obtained were analysed using a simple t-test and ANOVA. Monthly variation of Orthoptera in both sites were analysed by comparing the number of individuals recorded in different months. PAST 4.06b and MS Excel softwares were used for the statistical analysis.

III. RESULT AND DISCUSSION

A. Orthopteran Species Diversity

The study reports 35 different species of orthopterans belonging to two suborders, 10 families, 20 subfamilies and 33 genera (Table 1). A total of 27 species were recorded from Avoly and 25 species from Venmony. This study reveals 27% of the orthopteran fauna was reported from Kerala state (Bhaskar et al., 2018). *Chitaura indica* and *Burrinia burri* was reported in the study to be endemic to Kerala (Chandra & Gupta, 2013).

Most of the orthopteran species reported are native to the tropical belt. *Atractomorpha crenulata*, *Phlaeoba antennata*, *Ducetia* sp. and *Mecopoda* sp. found in the two locations are also reported throughout Southeast Asia (Buzzetti & Devriese, 2008). The following genus reported in our study namely Acrida, Chitaura, Oxya, Atractomorpha also has been reported from Sulawesi, Indonesia (Walton et

Table 1: Orthopteran diversity in Avoly and Venmony of Central Kerala

Sl. No	Family	Subfamily	Genus	Species
SUBORDER -CAELIFERA				
1.	Acrididae	Acridinae	*Phlaeoba*	*antennata* Brunner Von Wattenwyl, 1893
2.				*infumat*a Brunner Von Wattenwyl, 1893
3.				*panteli* Bolivar,1902
4.			*Carliola*	*carinata* Uvarov,1929
5.			*Acrida*	sp.
6.		Catantopinae	*Xenocatantops*	*humilis* Serville,1838
7.			*Diabolocatantops*	*innotabilis* Walker,1870
8.		Eyprepocnemidinae	*Eyprepocnemis*	*alacris* Serville,1838
9.		Oedipodinae	*Ceracris*	*striata Uvarov,1925*
10.			*Dittopternis*	*venusta Walker,1870*
11.			*Trilophidia*	*annulata Thurnberg,1815*
12.		Oxyinae	*Chitaura*	*indica Uvarov,1929*
13.			*Caryanda*	*cachara* Kirby,1914
14.			*Oxya*	*hyla* Serville,1831
15.		Spathosterninae	*Spathosternum*	*prasiniferum* Walker,1871
16.	Chorotypidae	Chorotypinae	*Burrinia*	*burri* Bolivar,1914
17.	Pyrgomorphidae	Orthacridinae	*Neorthacris*	*acuticeps* Bolivar,1902
18.		Pyrgomorphinae	*Atractomorpha*	*crenulata* Fabricius,1793
19.			*Chrotogonus*	sp.

Table 1. Continued

Sl. No	Family	Subfamily	Genus	Species
20.	Tetrigidae	Scelimeninae	*Eucriotettix*	sp.
21.			*Criotettix*	sp.
	SUBORDER – ENSIFERA			
22.	Gryllidae	Gryllinae	*Acheta*	*domesticus* Linnaeus,1758
23.			*Gryllodes*	*sigillatus* Walker,1869
24.			*Cophogryllus*	sp.
25.	Gryllacrididae	Gryllacridinae	*Brachyntheisogryllacris*	*maindroni*, Griffini,1913
26.	Gryllotalpidae	Gryllotalpinae	*Gryllotalpa*	*africana* Beauvois,1805
27.	Myrmecophilidae	Myemecophilinae	*Myrmecophilus*	*albicinctus* Chopard,1924
28.	Tettigoniidae	Conocephalinae	*Conocephalus*	*maculatus* Le Guillou,1841
29.		Mecopodinae	*Mecopoda*	sp.
30.		Hexacentrinae	*Hexacentrus*	sp.
31.		Phaneropterinae	*Ducetia*	sp.
32.		Pseudopyllinae	*Acanthoprion*	*suspectum* Brunner von Wattenwyl,1895
33.			*Phyllozelus*	sp.
34.			*Tegra*	*viridivitta* Walker,1870
35.	Trigonidiidae	Trigonidiinae	*Trigonidium (Trigonidium)*	*cicindeloides* Rambur,1838

al., 1997). The genera *Phlaeoba*, *Xenocatantops*, Diabolocatantops, *Caryanda*, *Oxya*, *Conocephalus*, *Gryllus* and *Spathosternum* are also distributed in the South East Asian countries of Vietnam and Thailand (Dawwrueng et al., 2017; Kim & Pham, 2014).

Acrididae was found to be the largest family with 15 species followed by Tettigoniidae with seven species. Families namely Trigonidiidae, Gryllacrididae, Gryllotalpidae, Myrmecophilidae and Chorotypidae constituted only 3% of the total species composition (Figure 2). Acrididae is a dominant family of grasshoppers widely distributed. Many studies have reported similar results where Acrididae dominated. Our results are in accordance with the study conducted in Nanda Devi Biosphere Reserve and Achanakmar Wildlife Sanctuary which reports Acrididae as the dominant family with six species and 15 spp. respectively followed by Tettigoniidae as the second most abundant family with four species in the former study area (Arya et al., 2015; Gupta & Chandra, 2017). Orthopteran diversity in Anamudi Shola National Park is also dominated by the family Acrididae with six species (Eldhose et al., 2019). A similar study which compares orthopteran fauna of highlands and lowlands of Kerala conducted in Kattapana and Kottayam presents similar results with Acrididae as the dominant family with 10 spp. and Tettigoniidae the second dominant family with three species (Kuruvila et al., 2019). Acrididae was the largest family with 26 spp. in a study conducted at Vaniyamkulam village of Palakkad (Koya et al., 2017). Studies of paddy fields in Uttar Pradesh also have Acrididae as the largest family with 21 spp. (Akhtar & Usmani, 2014).

Families namely Acrididae, Tetrigidae, Gryllidae, Gryllacrididae, Gryllotalpidae and Tettigoniidae are also reported in studies conducted in Borneo islands (Tan & Wahab, 2018). Tetrigidae is widely distributed and occurs in Cambodia, Myanmar, Sumatera in

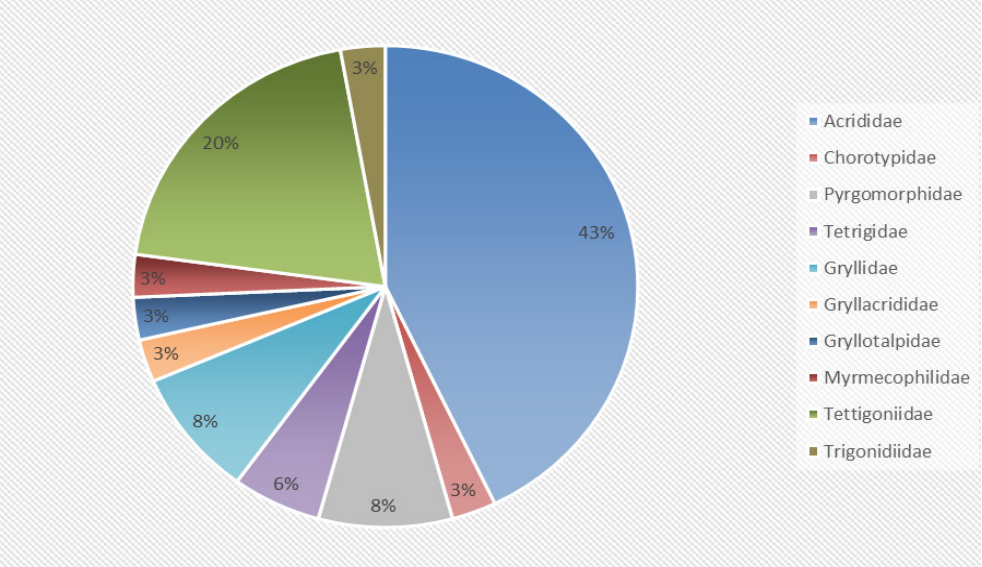

Figure 2. Distribution of orthopteran families in Central Kerala

Indonesia, Vietnam, Thailand, Singapore and Borneo (Dawwrueng et al., 2017; Kim & Pham, 2014; Storozhenko, 2019; Tan et al., 2013; Tan & Wahab, 2018).

Though orthopterans observed in the study area are not considered as serious pests of regional crops, most of these species have been reported as pests of various cereals and vegetables across India. *P. antennata*, *Phlaeoba infum*ata, *Xenocatantops humili*s, *Eyprepocnemis alacri*s, *Dittopternis venusta*, *Trilophidia annulat*a, *Oxya hyl*a, *Spasthosternum prasiniferum*, *Neorthacris acuticep*s, *Atractomorpha crenulata* and *Trigonidium cicindeloide*s have been reported as pests (Garg & Tandon, 1982; Mandal et al., 2007).

Some of the orthopterans reported in the study area have been suggested as future alternative food source and their nutritional potential have been studied. *O. hyla*, *Ducet*ia sp., *Phyllozellu*s sp. and *Gryllus africana* observed in our study were identified as potential nutritional supplement for livestock and humans (Chakravorty et al., 2018; Gahukar, 2018; Magara et al., 2021; Mandal et al., 2007).

B. Species Composition of Orthoptera in the Study Sites

The study revealed that Venmony had a greater number of orthopterans – 578 individuals than the lowland region Avoly with 493 individuals (Table 4). This is in accordance with the findings of (Kuruvila et al., 2019) which recorded a greater number of orthopterans in high-range areas in summer and monsoon seasons when compared to the low-range areas. The study site at Avoly is a lowland region with an altitude of 45 m asl while Venmony is located at 540 m asl which falls in a mid-altitude region with respect to the altitudinal gradient of Kerala. Several studies have shown a similar trend of higher orthopteran diversity in the medium altitudes than in lower and higher altitudes (Azil & Benzehra, 2020; Sirin et al., 2010). Besides, the proximity to natural forest area and less human interferences might be a favourable factor for high orthopteran diversity in Venmony. Avoly is located amidst a semi-urban habitat which is subjected to anthropogenic disturbances. Many studies have reported a lower diversity of orthopterans when ecosystems where disturbed (Baldi & Kisbenedek, 1997; Senthilkumar & Barthakur, 2013).

The species composition of orthopteran diversity in Avoly Panchayat and Venmony shows that 17 out of the 35 species were common to both study sites. The rest were found in any one of the two sites. Ten species were found only in

Avoly Panchayat and eight species were found only in Venmony (Table 2). *E. alacris*, *D. venusta*, *T. annulat*a, *B. burri*, *N. acuticeps*, *Chrotogonus* sp., *Gryllus domesticus*, *Brachyntheisogryllacris maindroni*, *Myrmecophilus albicinctus* and *Tegra viridivitta* were observed only in Avoly in the study. These species are commonly seen in agroecosystems and some are even pestiferous (Mayya et al., 2005; Soundararajan, 2000; Srinivasan & Prabakar, 2013). *E. alacris*, *D. venust*a, *T. annulata*, *N. acuticeps*, *Chrotogonus* sp., *G. domesticus* and *T. viridivitta* were observed in grasslands in the present study as well as (Srinivasan & Prabakar, 2013) *B. burri* and *B. maindroni* were found near vegetable crops. *M. albicinctus* was observed among leaf litter in rubber plantations.

Table 2: Variation in Species Composition of Avoly and Venmony

Sl. No	Species	Avoly	Venmony
1.	*Phlaeoba antennata*	✓	✓
2.	*Phlaeoba panteli*	✓	✓
3.	*Phlaeoba infumata*		✓
4.	*Carliola carinata*		✓
5.	*Ac*rida sp.	✓	✓
6.	*Xenocatantops humilis*	✓	✓
7.	*Diabolocantantops innotabilis*	✓	✓
8.	*Eyprepocnemis alacris*	✓	
9.	*Ceracris striata*		✓
10.	*Dittopternis venusta*	✓	
11.	*Trilophidia annulata*	✓	
12.	*Chitaura indica*	✓	✓
13.	*Caryanda cachara*		✓
14.	*Oxya hyla*	✓	✓
15.	*Spasthosternum prasiniferum*	✓	✓
16.	*Burrinia burri*	✓	
17.	*Neorthacris acuticeps*	✓	
18.	*Atractomorpha crenulata*	✓	✓
19.	*Chrotogonu*s sp.	✓	
20.	*Eucriotettix* sp.	✓	✓
21.	*Criotetti*x sp.	✓	✓
22.	*Gryllus domesticus*	✓	
23.	*Gryllodes sigillatus*	✓	✓
24.	*Cophogrylu*s sp.	✓	✓
25.	*Brachyntheisogryllacris maindroni*	✓	
26.	*Gryllotalpa Africana*	✓	✓
27.	*Myrmecophilus albicinctus*	✓	
28.	*Conocephalus maculatus*	✓	✓
29.	*Mecopoda* sp.	✓	✓
30.	*Hexacentrus* sp.		✓
31.	*Ducetia* sp.		✓
32.	*Acanthoprion suspectu*m		✓
33.	*Phyllozellu*s sp.		✓
34.	*Tegra viridivitta*	✓	
35.	*Trigonidium cicindeloides*	✓	✓

P. infumata, *Carliola carinata*, *Ceracris striata*, *Caryanda cachara*, *Hexacentrus* sp., *Ducetia* sp., *Acanthoprion suspectum* and *Phyllozellus* sp. were reported only in Venmony in the study. *Hexacentrus* sp., *Ducetia* sp., *A. suspectum* and *Phyllozellus* sp. were found around shrubs and crops like Cocoa. A. suspectum prefer shrubs (Yadav & Kumar, 2020). *P. infumata*, *C. carinata* and *C. striata* were observed in monoculture plantations of rubber as well as in open grasslands. The presence of bamboo thickets at the forest edges near the agroecosystem in Venmony and that of *C. striata* are in accordance with the foodplant preference of the species (Srinivasan & Prabakar, 2013). *C. cachara* was observed from grassland in Venmony.

The agroecosystem in Venmony has a perennial stream flowing around its boundaries separating it from the natural forest area, whereas Avoly was comparatively dry. *P. infumata* found only in Venmony prefers moist areas (Srinivasan & Prabakar, 2013) and *Chrotogonus* sp. which prefer places where the amount of water is less in the soil (Mandal et al., 2007) was seen only in Avoly. Thus, the presence and absence of orthopterans in each area is dependent upon various biotic and abiotic environmental factors characteristic to each area.

C. Relative Abundance

O. hyla was found to be the most abundant species in both Avoly and Venmony with abundance values of 21.3 and 17.6 respectively. *O. hyla* has been reported as an abundant species occurring in various parts around the world (Akhtar & Usmani, 2014; Gupta & Chandra, 2017; Itterbeeck et al., 2019). This might be due to its multivoltine and polyphagous nature (Ghosh et al., 2015). *O. hyla* is infamous as a pest of rice in the Indian subcontinent (Das et al., 2012). *A. crenulata* was the second most abundant species in Avoly with an abundance value of 19.9 whereas, *P. antennata* was the second most abundant species in Venmony with abundance value of 16.3 (Table 3). *A. crenulata* is a well-known pest of crops like tobacco and its abundance might be attributed to its nature to breed freely throughout the year (Srivastava, 1957).

Table 3: Relative abundance of species observed in Avoly and Venmony

Avoly		Venmony	
Species	Abundance	Species	Abundance
1. *Phlaeoba antennata*	4.06	1. *Phlaeoba antennata*	16.27
2. *Phlaeoba panteli*	1.62	2. *Phlaeoba panteli*	6.10
3. *Acrida* sp.	2.84	3. *Phlaeoba infumata*	10.00
4. *Xenocatantops humilis*	2.03	4. *Carliola carinata*	6.10
5. *Diabolocantantops innotabilis*	13.39	5. *Acrida* sp.	1.86
6. *Eyprepocnemis alacris*	0.61	6. *Xenocatantops humilis*	1.86
7. *Trilophidia annulata*	2.43	7. *Diabolocantantops innotabilis*	6.95
8. *Dittopternis venusta*	0.61		
9. *Chitaura indica*	4.06	8. *Ceracris striata*	1.53
10. *Oxya hyla*	21.30	9. *Chitaura indica*	2.03
11. *Spasthosternum prasiniferum*	3.04	10. *Caryanda cachara*	2.20
12. *Burrinia burri*	0.41	11. *Oxya hyla*	17.63
13. *Neorthacris acuticeps*	0.61	12. *Spasthosternum prasiniferum*	1.86
14. *Atractomorpha crenulata*	19.88	13. *Atractomorpha crenulata*	4.41
15. *Chrotogonus* sp.	0.61	14. *Eucriotettix* sp.	2.37
16. *Eucriotettix* sp.	1.62	15. *Criotettix* sp.	6.95
17. *Criotettix* sp.	4.26	16. *Gryllodes sigillatus*	4.75

Table 3. Continued

Avoly		Venmony	
Species	Abundance	Species	Abundance
18. *Gryllus domesticus*	1.42	17. *Cophogryllus* sp.	1.69
19. *Gryllodes sigillatus*	3.45	18. *Gryllotalpa africana*	0.85
20. *Cophogryllus* sp.	2.64	19. *Conocephalus maculatus*	0.17
21. *Brachyntheisogryllacris maindroni*	0.41	20. *Mecopoda* sp.	1.86
22. *Gryllotalpa africana*	1.83	21. *Hexacentrus unicolor*	0.17
23. *Myrmecophilus albicinctus*	2.03	22. *Ducetia* sp.	0.34
24. *Conocephalus maculatus*	2.64	23. *Acanthoprion suspectum*	0.17
25. *Mecopoda* sp.	1.22	24. *Phyllozellus* sp.	0.34
26. *Tegra viridivitta*	0.41	25. *Trigonidium cicindeloides*	1.53
27. *Trigonidium cicindeloides*	0.61		

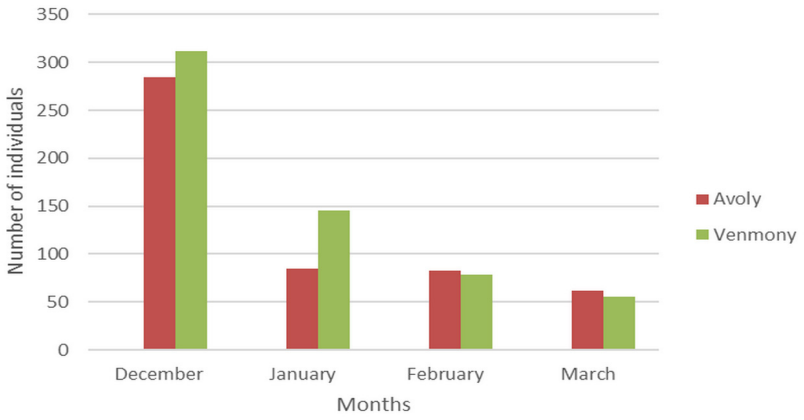

Figure 3. Monthly variation in number of orthopterans between two selected sites

B. burri, *B. maindroni* and *T. viridivitta* were the least abundant species in Avoly with an abundance value of 0.41. In Venmony, *Conocephalus maculatus*, *Hexacentrus* sp. and *A. suspectum* were the least abundant species with an abundance value of 0.17 (Table 3). The vegetation structure and other environmental variables like temperature might be a factor that caused the variations in abundance of orthopterans(Geppert et al., 2021).

D. Monthly Variation in the Occurrence of Orthopterans

In both the study sites, the largest number of orthopterans was observed during the month of December and declined gradually in the following months (Figure 3). The significance of the monthly variation of orthopterans were tested using ANOVA and the P value was found to be less than 0.05 which means the variation is significant. This might be due to the optimum vegetation cover during the post-monsoon months of December (Thakkar et al., 2015; Mayya et al., 2005). Venmony had a slightly greater number of orthopterans than Avoly in the months of December and January. During the dry months of February and March, Avoly had a slightly greater number of species than Venmony. The comparison of monthly data of the two sites using a t-test shows that the variation in numbers of orthopterans between sites is not statistically significant.

Table 4. Diversity statistics of Avoly and Venmony

Sl.No	Diversity indices	Avoly	Venmony
1.	Richness (Taxa)	27	25
2.	Evenness	0.52	0.60
3.	Shannon Index(H)	2.65	2.70
4.	Simpson's Diversity Index (1-D)	0.89	0.91

The slight variations might be attributed to the variations in various environmental factors like temperature, humidity, floral composition and cover that is characteristic of each area (Mayya et al., 2005).

E. Diversity Statistics of Orthoptera in Central Kerala

The number of species in Avoly was 27 and that of Venmony was 25. The evenness value is 0.60 in Venmony, higher than that of Avoly which is 0.52 (Table 4). So Venmony has a more stable community than Avoly. Venmony has a slightly higher biodiversity index value than Avoly. The value of Shannon index of Venmony and Avoly are 2.70 and 2.65 respectively (Table 4). The difference in value of Shannon diversity index between the two sites is not statistically significant since the p value is 0.32. Venmony has a Simpson's diversity index value of 0.91 and Avoly has a value of 0.89; hence the former location is slightly more diverse than the latter (Table 4). The P value for the simple t-test on Simpson's diversity index is 0.01 which means the difference between the two sites is significant. Both sites have high Simpson's diversity index value and hence harbour high orthopteran diversity. Venmony is located near to the natural forest ecosystem which might be a reason for the comparatively high evenness and diversity. Proximity of cultivable lands to forest landscapes increase insect interchanges between ecosystems and hence a higher diversity and stable community of insects are seen in the forest-edge agroecosystems (González et al., 2016).

IV. CONCLUSION

The present study reveals an account of the diverse orthopteran fauna in the central part of Kerala state in South India across the altitudinal gradient. The highlands in Central Kerala are comparatively less disturbed from anthropological interferences and hence harbour more biodiversity than the lowland regions. There is significant seasonal variation in orthopteran fauna and hence they can be adversely affected by the global climate change. Identification of orthopterans of a particular area can also help in monitoring and keeping potential pest species under check and thus protecting crops of the region. A long-term study covering more ecosystems is recommended in the future which would reveal the population dynamics of orthopterans of this region.

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Water is a necessary part of every reasons's diet and of all the nutrient a body needs to function, it requires more water each daya than any other nutrients a body needs to function, it requires more water each day than any other nutrient (Whitney & Rolfes, 2011)

Or

Whitney and Rolfes (2011) state the body requires many nutrients to function but highlight that water is of greater importance than any other nutrient.

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