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Research Article

Relationships Between Butterfly with Feed Plants in Sangihe Islands, North Sulawesi, Indonesia

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Abstract

Background and Objective: Interaction of butterfly with plants is a form of mutualism. Plants need help in pollination and at the same time, butterflies need food in the form of nectar and pollen. This research aimed to observe and analyze relationships between butterflies with feed plants in Sangihe Islands, North Sulawesi, Indonesia. **Materials and Methods:** Observations were conducted from April-August, 2019 by observing the preference of butterflies for flowering plants, the proboscis length of butterflies, the length of corolla tubes, the volume and sugar content of nectar and environmental factors. Data analysis included the relationship between the proboscis length of butterflies and the length of corolla tubes and the relationship of nectar volume and sugar level of nectar with environmental factors. **Results:** The results showed that there were 23 families and 52 species of plants visited by butterflies. The plants were visited by butterflies of 5 families, which included 43 species and 179 individuals. The number of butterflies visiting flowering plants varied. Based on the time of visit, the highest frequency of butterfly visits to flowering plants was obtained in the morning. Then, the frequency began to decline during the day. Meanwhile, the highest volume and sugar content of nectar were found in the morning and tended to decrease during the day. **Conclusion:** Relationships of butterflies with flowering plants was influenced by plant habitus, types of inflorescence, flower color, shape of corolla tube, volume and sugar content of nectar.

Key words: Lepidoptera, mutualism, nectar, flowering plants, proboscis, environmental factors

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

For their life, butterflies interact with host plants by laying their eggs on host plants and using host plants as feed for their larvae. Some butterfly species have specific host plant species. Adult butterflies need plants as a food source in the form of flower nectar¹.

Plants secrete varying amounts of nectar^{2,3}. In addition to drinking nectar, some types of butterflies also eat pollen⁴ and drink the juice of rotting fruit⁵. Butterfly has an elongated sucking mouthpart (proboscis) and a good sense of smell and butterfly is able to detect the color spectrum⁶. Some butterfly species are selective in visiting flowering plants as a source of nectar⁷. Nectar from flowers provides energy and flower pollen provides protein, lipids and vitamins⁸. Nectar is a complex compound produced by plant glands in the form of a sugar solution. The main composition of nectar is glucose, fructose and sucrose. Nectar also contains amino acids and lipids.

Several studies on relationships of butterflies with plants have been carried out including flowering time of butterfly nectar food plants is more sensitive to temperature than the timing of butterfly adult flight⁹. Ecosystem services of lepidoptera to the floral diversity of Mandapam Group of Islands¹. Rusman *et al.*¹⁰ have researched about butterflies (Lepidoptera: Papilionoidea) of Mount Sago, West Sumatra: diversity and flower preference.

Research on relationships of butterflies with feed plants in the Sangihe Islands, North Sulawesi, has never been conducted and reported. Butterfly diversity research is mostly conducted on the mainland of Sulawesi Island. In fact, this information is very important considering that at this time, the habitat of butterflies in the Sangihe Islands has undergone a change and has been turned into a plantation and settlement. In addition, data on butterfly diversity and its relationships with feed plants that are available to date are data taken several years ago and obtained only at certain locations. Meanwhile, current data on the overall distribution and diversity of butterflies in the Sangihe Islands are not yet available. In fact, Sulawesi is an area with a high rate of forest destruction. This research aimed to uncover relationships of butterflies with feed plants through observed and analyzed some variables which included feed preferences, the relationship between butterfly proboscis length with the corolla length and the volume and sugar content of flower nectar in the Sangihe Islands, North Sulawesi, Indonesia.

MATERIALS AND METHODS

Study site: Relationships between butterflies with plants was observed at two sub-districts and four villages in the Sangihe Islands, North Sulawesi. The villages that became the sampling points were Ulung Peliang Village, Kalinda Village (Tamako Sub-district), Kaluwatu Village and Laine Village (South Manganitu Sub-district). Field observations were conducted for 5 months from April-August, 2019 and in one month, 5-day observation was conducted.

Observation of relationships: Observation of butterfly relationships included preference of butterflies for flowering plants, butterfly proboscis length, the corolla tubes length, the volume and sugar flower nectar content and environmental factors. Determination butterfly plants were done by observing, recording, documenting and identifying the plants visited by butterflies. The plants visited were also recorded by family, species, habitus, flower color, type of flower and types of butterflies that visited the plants. The plants that butterflies visited were taken and their specimens were stored on newspaper for identification purposes^{11,12}.

Proboscis length measurement: Measurement of the proboscis length was carried out on five species of butterflies (*Papilio rumanzovia*, *Danaus ismare alba*, *Ideopsis juvena totoliensis*, *Catopsilia pomona* and *Eurema tominia*) and for each species, the proboscises of 4 individuals were measured. Measurement of the proboscis length was conducted by placing a butterfly that had been collected on a paper. The curled proboscises were straightened with the help of needles and tweezers. The base and tip of the proboscis were marked on the paper. The proboscis length was obtained by calculating the distance between the base and the tip of the proboscis that had been marked on paper. The proboscis length was measured using a digital caliper.

Measurement of corolla tubes length: The measurement of corolla tubes length was carried out on 5 species of flowering plants visited by butterflies (*Ixora javanica*, *Oxalis barrelieri*, *Lantana camara*, *Bougainvillea spectabilis* and *Clerodendrum paniculatum*). Corolla length was measured using a digital caliper.

Measurement of sugar and nectar: Further, the measurement of volume and sugar content of flower nectar was conducted on 3 species of plants visited by butterflies, namely,

Ixora javanica, *Hibiscus rosasinensis* and *Calliandra calothyrsus*. Measurements were taken at 07.00-08.00, 09.00-10.00, 11.00-12.00 and 13.00-14.00 Central Indonesian Time (UTC+8). Nectar volume was measured using a 5 µL micropipette, while nectar sugar concentrations were measured using a refractometer with a 0-33% Brix scale range. Nectar volume was measured by inserting the micropipette into nectaries. Meanwhile, nectar sugar contents were measured by placing the nectar on the glass of refractometer and then being directed toward the light¹³. If the measured flower had a small amount of nectar, then the sample could be added³.

Measurement of environmental factors: Environmental factors were also measured at one hour intervals during butterfly observation. Environmental factors measured included air temperature and humidity, which were measured using a thermohygrometer, light intensity, which was measured using a lux meter, wind speed measured using an anemometer and altitude and coordinates, which were measured using global positioning system (GPS).

Statistical analysis: Data analysis included the relationship between the proboscis length of butterflies and the length of corolla tubes and the relationship of volume and sugar content of nectar with environmental factors (temperature, humidity, wind speed and light intensity). The relationship test was performed with the Spearman correlation using¹⁴ the statistical version 6.

RESULTS

Preference of butterflies plants: The observation on the number of flowering plants visited by butterflies showed a result of 23 families and 52 species of plants. The plants were visited by butterflies from 5 families, which included 43 species and 179 individuals. The butterflies that visited plants the most were *Graphium agamemnon*, which visited 14 species of plants and *Papilio polytes* and *Eurema blanda*, each visiting 12 species of plants (Table 1).

The family of plant that was frequently visited by butterflies was Asteraceae with 16 species of plants, followed by Malvaceae, with 4 species of plants. Plant families that were least visited by butterflies were Amaranthaceae, Annonaceae, Apocynaceae, Euphorbiaceae, Lauraceae, Musaceae, Nyctaginaceae, Oleaceae, Orchidaceae,

Oxalidaceae and Melastomaceae, each of which was only one species of plant (Table 1). The plant species that were visited by butterflies the most (14 species) were *Ixora javanica*, followed by *Eupatorium inulifolium*, which was visited by 12 species of butterflies (Table 1).

The types of plant visited by butterflies included shrubs, herbs, trees and lianas. To obtain nectar as a food source, butterflies preferred to visit shrubs (56.98%) than herbs (30.73%), trees (10.61%) and lianas (1.68%) (Fig. 1a).

Butterfly visited frequency: Butterfly visited frequency was varied based on the color plant flowers. The colors of flowers that butterflies frequently visit were white (38.87%) and red (25.14%), while the less visited colors were blue and white-purple, with each frequency of butterfly visits of 1.12% (Fig. 1b).

Types of inflorescences visited by butterflies: There were 7 types of inflorescences visited by butterflies. The most visited inflorescence type was tube (28.49%), then head (27.93%). The least visited type of inflorescence was flag (3.35%) (Fig. 1c).

Families flowers visited by butterflies: The families flowering plants visited by butterflies were as many as 5 families. The butterfly families that visited plants the most were Papilionidae, with a frequency of 36.87% and Nymphalidae (27.93%). Meanwhile, the lowest frequency of visits was from the Hesperidae family (Fig. 1d).

Visiting time: Based on the visiting time, it was found that generally, butterflies visited flowers in the morning. The highest number of butterfly visits occurred at 09.00-10.00 Central Indonesian Time, then between 7.00-08.00 Central Indonesian time. The time of the butterfly visit began to decrease from 11.00-14.00 (Fig. 2).

Butterfly proboscis length of and the corolla tube length: From the measurements of the butterfly proboscis length, it was found that *Papilio rumanzovia* had the longest proboscis, with an average proboscis length of 34.08 mm, when compared to other species. The butterfly that had the shortest proboscis was *Eurema tominia* with an average proboscis length of 5.95 mm (Table 2).

Butterflies from the Papilionidae family tended to visit flowers with an average corolla tube length of 16.43 mm and butterflies from the Nymphalidae family visited flowers with corolla tube lengths of 8.30 and 8.38 mm. Meanwhile, Pieridae visited the flowers with corolla tube lengths of 12.18 and

Table 1: Floral plants characteristics visited by butterfly species at Sangihe Islands

Nectar plants	Plant habits	Flower color	Flower type	Butterfly species
Acanthaceae				
<i>Asystasia gangetica</i>	Herb	White	Funnel	<i>Junonia hedonia</i> , <i>Eurema blanda</i> , <i>Eurema hecabe</i>
<i>Sanchezia speciosa</i>	Shrub	Yellow	Funnel	<i>Junonia hedonia</i> , <i>Crestis acilia</i>
<i>Strobilanthes crispus</i>	Shrub	Yellow	Funnel	<i>Mycalesis horsfieldi</i> , <i>Mycalesis janadarna</i>
Amaranthaceae				
<i>Gomphrena globosa</i> L.	Herb	Purple	Head	<i>Eurema blanda</i>
Annonaceae				
<i>Annona muricata</i> L.	Tree	Yellow	Head	<i>Graphium meyeri</i> , <i>Graphium agememnon</i>
Apocynaceae				
<i>Catharantus roseus</i>	Shrub	Pink	Tube	<i>Papilio polytes</i>
Asteraceae				
<i>Acmella paniculata</i>	Herb	Yellow	Head	<i>Danaus genutia</i>
<i>Ageratum conyzoides</i>	Herb	Purple	Head	<i>Danaus ismare alba</i> , <i>Papilio sataspes</i> , <i>Ypthima loryma</i> , <i>Jamides snelleni</i> , <i>Jamidaes aratus</i> , <i>Jamides celeno</i> , <i>Papilio demolion</i> , <i>Papilio polytes</i> , <i>Eurema tominia</i> , <i>Parthenos sylvia</i>
<i>Caesalpinia pulcherrima</i>	Shrub	Red	Brush	<i>Papilio gigon</i> , <i>Papilio polytes</i>
<i>Cassia obtusifolia</i>	Herb	Yellow	Fascicle	<i>Catopsilia pomona</i> , <i>Hebomia glaucippe celebensis</i>
<i>Chromolaena odorata</i>	Shrub	White	Head	<i>Papilio polytes</i> , <i>Lampides boeticus</i> , <i>Catopsilia pomona</i> , <i>Eurema hecabe</i> , <i>Graphium agememnon</i> , <i>Vindura celebensis</i> , <i>Graphium milon</i> , <i>Papilio gigon</i> , <i>Idiopsis juvena totoliensis</i>
<i>Clibadium surinamensis</i>	Shrub	White	Head	<i>Hypolimnas bolina</i> , <i>Hypolimnas missipus</i>
<i>Commelina benghalensis</i>	Herb	Blue	Funnel	<i>Eurema tominia</i> , <i>Eurema blanda</i>
<i>Elephantopus mollis</i>	Herb	White	Brush	<i>Eurema tominia</i> , <i>Rapala ribbei</i>
<i>Emilia sonchifolia</i>	Herb	Purple	Head	<i>Danaus ismare alba</i> , <i>Jamides snelleni</i> , <i>Eurema tominia</i> , <i>Mycalesis horsfieldi</i>
<i>Eupatorium inulifolium</i>	Shrub	White	Head	<i>Euchrysops cnejus</i> , <i>Hypolimnas bolina</i> , <i>Jamides aratus</i> , <i>Jamides celeno</i> , <i>Junonia hedonia</i> , <i>Papilio helenus</i> , <i>Graphium agememnon</i> , <i>Graphium meyeri</i> , <i>Catopsilia pomona</i> , <i>Eurema tominia</i> , <i>Eurema hecabe</i> , <i>Eurema blanda</i>
<i>Galinsoga parviflora</i>	Herb	Yellow	Head	<i>Mycalesis janadarna</i>
<i>Gynura crepidioides</i>	Herb	White	Head	<i>Eurema blanda</i> , <i>Eurema hecabe</i>
<i>Makania micrantha</i>	Liana	White	Brush	<i>Pithecopis phoenix</i> , <i>Lampides boeticus</i> , <i>Junonia hedonia</i> ,
<i>Sphagneticola trilobata</i>	Herb	Yellow	Head	<i>Danaus genutia leucoglens</i> , <i>Danus ismare alba</i> , <i>Euploea leucostictos</i> , <i>Jamides celeno</i>
<i>Synedrella nodiflora</i>	Herb	Yellow	Head	<i>Eurema blanda</i> , <i>Mycalesis janardana</i>
<i>Veronia altissima</i>	Herb	Purple	Brush	<i>Papilopoytes</i>
Euphorbiaceae				
<i>Euphorbia heterophylla</i>	Herb	White	Brush	<i>Gandaca harina</i> , <i>Eurema blanda</i> , <i>Borbo cinnara</i> , <i>Potanthus fettingi</i>
Fabaceae				
<i>Calliandra calothyrsus</i>	Shrub	Red	Brush	<i>Graphium agememnon</i> , <i>Papilio ascalaphus</i> , <i>Graphium milon</i> , <i>Junonia hedonia intermedia</i> , <i>Graphium meyeri</i> , <i>Papilio sataspes</i>
<i>Casia alata</i>	Herb	Yellow	Flag	<i>Catopsilia pomona</i> , <i>Hebomoia glaucippe</i>
<i>Crotalaria mucronata</i>	Herb	Yellow	Flag	<i>Danaus genutia leucoglens</i> , <i>Borbo cinnara</i> , <i>Ideopsis juvena tontoliensis</i>
Lamiaceae				
<i>Clerodendrum paniculatum</i>	Shrub	Red	Tube	<i>Papilio gigon</i> , <i>Papilio polytes</i> , <i>Junonia hedonia</i> , <i>Graphium agememnon</i> , <i>Catopsilia pomona</i> , <i>Vindura celebensis</i> , <i>Graphium milon</i> , <i>Idiopsis juvena</i> , <i>Eurema hecabe</i>
<i>Orthosiphon spicatus</i>	Shrub	White	Tube	<i>Junonia hedonia intermedia</i> , <i>Mycalesis janardana</i> , <i>Eurema blanda</i>
Lauraceae				
<i>Persea americana</i>	Tree	White	Dish	<i>Hypolimnas bolina</i> , <i>Junonia hedonia</i>
Malvaceae				
<i>Hibiscus rosasinensis</i>	Shrub	Red	Dish	<i>Junonia hedonia</i> , <i>Papilio sataspes</i> , <i>Paclyopta poliponthes</i> , <i>Graphium agememnon</i> , <i>Papilio polithes</i>
<i>Kleinhovia hospita</i>	Tree	Pink	Dish	<i>Hebomia glaucippe celebensis</i>
<i>Sida rhombifolia</i>	Shrub	Yellow	Dish	<i>Eurema tominia</i> , <i>Eurema hecabe</i> , <i>Eurema blanda</i>
<i>Urena lobata</i>	Shrub	Pink	Dish	<i>Eurema blanda</i> , <i>Mycalesis janardana</i>
Melastomataceae				
<i>Clidemia hirta</i>	Shrub	White	Funnel	<i>Mycalesis janardana</i>
<i>Melastoma malabathricum</i>	Shrub	Purple	Funnel	<i>Danaus affinitis fulgarata</i>
Mimosaceae				
<i>Mimosa diplotricha</i>	Herb	Pink	Brush	<i>Jamides snelleni</i>
<i>Mimosa pudica</i>	Herb	Pink	Brush	<i>Jamides aratus</i> , <i>Eurema blanda</i> , <i>Eurema hecabe</i> , <i>Guttula blanda</i>
Musaceae				
<i>Musa paradisiaca</i>	Herb	White	Tube	<i>Hypolimnas bolina</i> , <i>Danaus genutia leucoglens</i>
Myrtaceae				
<i>Eugenia aquea</i>	Tree	White	Brush	<i>Hypolimnas bolina</i> , <i>Graphium agememnon</i> , <i>Papilio ascalaphus</i> , <i>Papilio rumanzovia</i>
<i>Psidium guajava</i>	Shrub	White	Brush	<i>Graphium agememnon</i>

Table 1: Continue

Nectar plants	Plant habits	Flower color	Flower type	Butterfly species
Nyctaginaceae				
<i>Bougainvillea spectabilis</i>	Shrub	Orange	Tube	<i>Papilio gigon</i> , <i>Papilio polytes</i> , <i>Danaus ismare alba</i>
Oleaceae				
<i>Jasminum sambac</i>	Shrub	White	Tube	<i>Papilio polytes</i> , <i>Graphium milon</i>
Orchidaceae				
<i>Spathoglottis plicata</i>	Herb	Purple	Flag	<i>Papilio ascalaphus</i>
Oxalidaceae				
<i>Oxalis barrelieri</i>	Herb	Pink	Tube	<i>Papilio polytes</i> , <i>Eurema blanda</i> , <i>Eurema hecabe</i>
Melastomaceae				
<i>Melastoma malabathricum</i>	Shrub	Purple	Tube	<i>Eurema tominia</i> , <i>Eurema hecabe</i> , <i>Graphium agamemnon</i>
Piperaceae				
<i>Piper betle</i> L.	Shrub	Pink	Fascicle	<i>Graphium agememnon</i>
<i>Piper aduncum</i>	Shrub	White	Fascicle	<i>Graphium meyeri</i> , <i>Papilio rumanzovia</i> , <i>Papilio gigon</i> , <i>Parthenos sylvia</i>
Rubiaceae				
<i>Ixora javanica</i>	Shrub	Red	Tube	<i>Papilio rumanzovia</i> , <i>Graphium meyeri</i> , <i>Papilio agamemnon</i> , <i>Papilio polytes</i> , <i>Papilio polyphontes</i> , <i>Eurema blanda</i> , <i>Eurema hecabe</i> , <i>Hypolimnna bolina</i> , <i>Danaus ismare alba</i> , <i>Catopsilia pomona</i> , <i>Vindule celebensis</i> , <i>Graphium milon</i> , <i>Papilio gigon</i> , <i>Ideopsis juvena</i>
<i>Mussaenda pubescens</i>	Shrub	Yellow	Dish	<i>Graphium agamemnon</i> , <i>Papilio sataspes</i> , <i>Papilio rumanzovia</i>
Rutaceae				
<i>Citrus</i> sp.	Tree	White	Dish	<i>Papilio rumanzovia</i> , <i>Graphium meyeri</i> , <i>Papilio sataspes</i> , <i>Papilio gigon</i> , <i>Papilio polytes</i> , <i>Papilio memmon</i> , <i>Papilio ascalaphus</i> , <i>Graphium agememnon</i> , <i>Papilio demoleus</i> , <i>Eurema hecabe</i>
Verbenaceae				
<i>Lantana camara</i>	Shrub	Red	Tube	<i>Juonina hedonia</i> , <i>Vindule celebensis</i> , <i>Graphium agamemnon</i> , <i>Catopsilia pamona</i> , <i>Graphium milon</i> , <i>Papilio gigon</i> , <i>Ideopsis juvena</i> , <i>Papilio rumanzovia</i> , <i>Erionota thrak</i>
<i>Stachytarpheta jamaicensis</i>	Shrub	White-Purple	Tube	<i>Eurema tominia</i> , <i>Eurema hecabe</i>

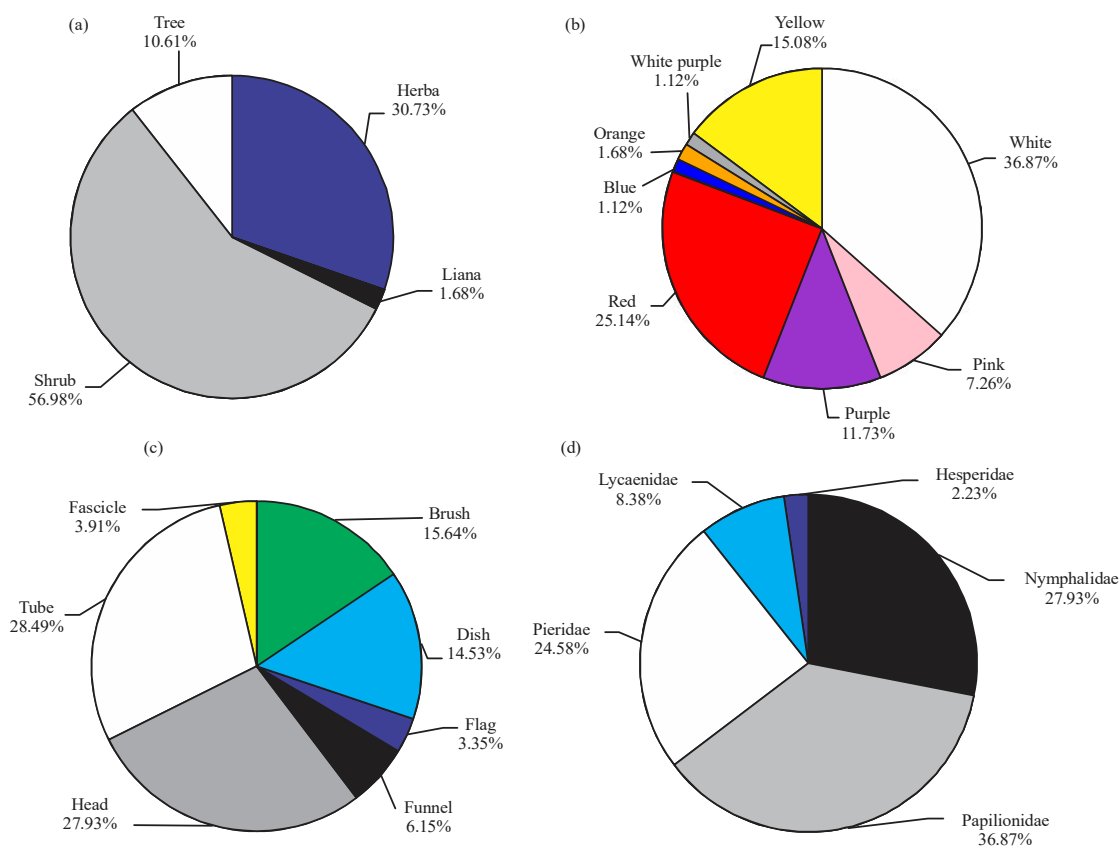


Fig. 1 (a-d): Butterflies visit plants based on (a) Plant habits, (b) Flower color, (c) Flower type and (d) Plants visiting frequency

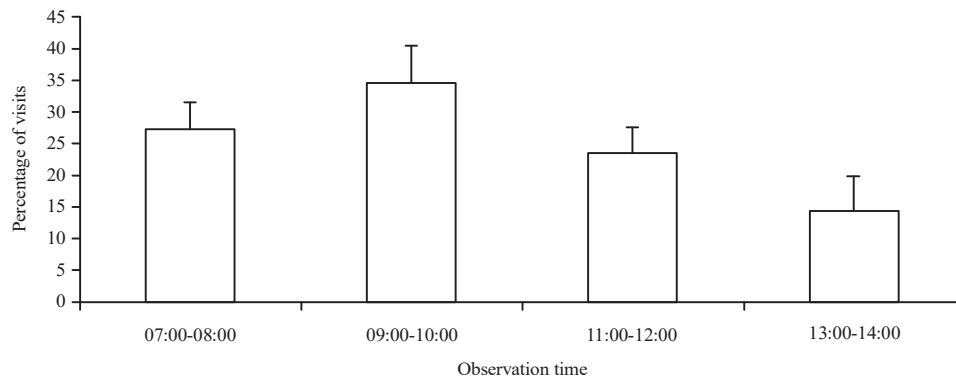


Fig. 2: Butterfly visiting frequency based on the observation time

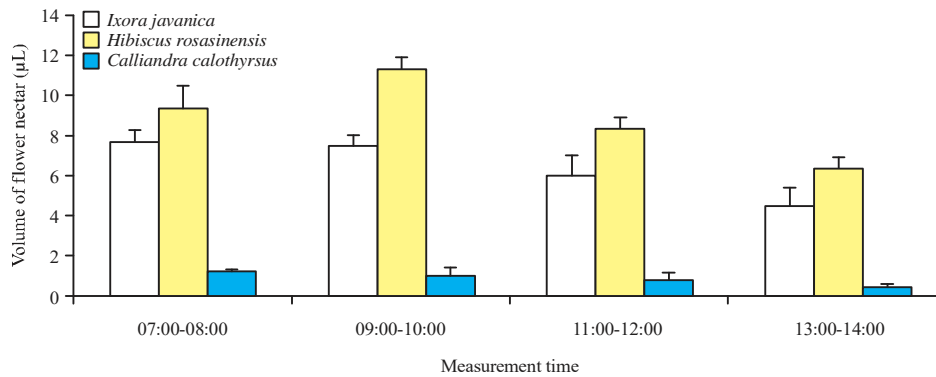


Fig. 3: Nectar volume based on observation time

Table 2: Correlation between butterfly proboscis length and crown flower length

Species	Proboscis length (mm)	Crown flower length (mm)
	Mean ± SD	Mean ± SD
<i>Papilio rumanzovia</i>	34.08 ± 1.28	16.43 ± 8.51
<i>Danaus ismare alba</i>	12.53 ± 1.84	8.30 ± 0.73
<i>Idiopsis juvena totoliensis</i>	10.41 ± 0.74	8.38 ± 0.48
<i>Catopsilia pomona</i>	17.40 ± 0.95	12.18 ± 1.46
<i>Eurema tominia</i>	5.95 ± 1.17	3.64 ± 0.83

$r = 0.72$ (correlations are significant at $p < 0.050$, $n = 20$)

3.64 mm. Based on the correlation analysis, it was found that there was a positive correlation between the proboscis length of the butterfly and the corolla tube length of the flower visited ($r = 0.72$, $p < 0.050$, $n = 20$) (Table 2).

Flower nectar volume and content: Based on measurements, the highest flower nectar volume was found in *Hibiscus rosasinensis* plants, ranging from 6.33-11.33 µL and subsequently *Ixora javanica* (4.50-7.67 µL). The highest flower nectar volume was found in the morning (09.00-10.00 Central Indonesian time) and the volume tended to decrease during the day (Fig. 3).

The sugar content of nectar varied between one flower to another. The highest sugar content of nectar in the morning was found in *Hibiscus rosasinensis* (22-24%) and at noon was found in *Ixora javanica* (17.4-20.71%). Sugar content of flower nectar tends to be high in the morning and tends to decrease during the day (Fig. 4).

Volume and sugar content with environmental factors:

Based on correlation test of nectar volume of three plant species with environmental factors, it was found that the volume of flower nectar was positively correlated with air humidity. The volume of nectar showed a negative correlation with air temperature, wind speed and light intensity (Table 3). This means that if air temperature, wind speed and light intensity were higher, the volume of flower nectar decreased. Correlation test of flower nectar sugar content with air humidity showed positive results. Meanwhile, nectar sugar content showed a negative correlation with air temperature, wind speed and light intensity (Table 4). This means that if air temperature, wind speed and light intensity were higher, sugar content of nectar decreased.

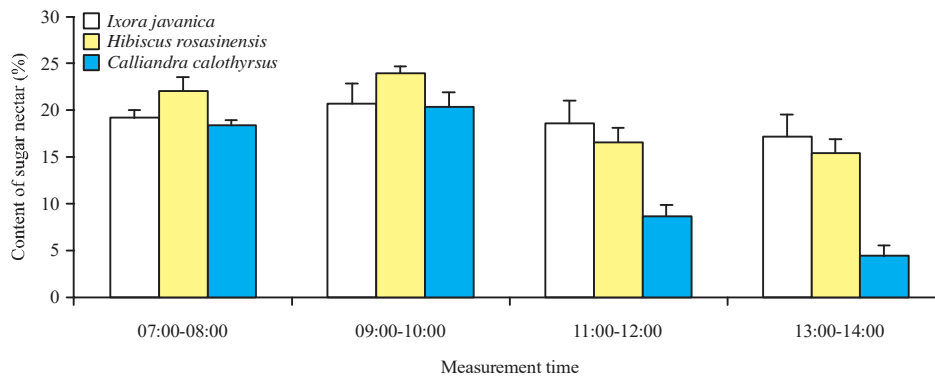


Fig. 4: Sugar content based on the observation time

Table 3: Correlation between nectar volume butterflies plants with environmental factors

Variables	Temperature	Humidity	Wind speed	Light intensity
<i>Ixora javanica</i>	-0.77*	0.88*	-0.52	-0.87*
<i>Hibiscus rosasinensis</i>	-0.33	0.57*	0.00	-0.42
<i>Calliandra calothyrsus</i>	-0.76*	0.76	-0.52*	-0.72*

*Correlations are significant at $p < 0.050$, $n = 12$

Table 4: Correlation between nectar sugar content butterflies plants with environmental factors

Variables	Temperature	Humidity	Wind speed	Light intensity
<i>Ixora javanica</i>	-0.14	0.22	-0.42	-0.30
<i>Hibiscus rosasinensis</i>	-0.41	0.64*	-0.17	-0.59
<i>Calliandra calothyrsus</i>	-0.85*	0.56*	-0.78*	-0.81*

*Correlations are significant at $p < 0.050$, $n = 12$

DISCUSSION

The preference of butterflies for plants varied between plant families and species. Plant family that many butterflies visit during observation was Asteraceae. This was due to the availability of plants from Asteraceae family in the study site. Moreover, the plants of the Asteraceae family flower throughout the season. According to Robson¹⁵, most pollinating insects visited the flowers of the Asteraceae family and the Fabaceae family. The flowers of the Asteraceae plant usually have a small size and a less attractive color, although some have yellow, purple and white colors that attract many types of potential pollinators.

The observations found that the flowers of *Ixora javanica* and *Eupatorium inulifolium* were visited by butterflies the most. The visit of a butterfly to a flower is greatly influenced by the morphological and physiological characteristics of the flower, such as size, shape, color, scent, blooming period and nectar content. According to Tiple *et al.*¹⁶ and Faheem *et al.*¹⁷ several factors influenced the preferences of butterflies for feed plants. Those factors were habitus, lower shape, length of corolla tube and the color of nectar flowers, pollen and other rewards. Gombert *et al.*¹⁸ argued that butterflies would be

interested in visiting flowers as a source of nectar or food based on three characteristics, namely, flower shape, color and flower scent.

Flowers that were often visited by butterflies during observation were flowers that had white and red colors. Some studies reported that butterflies liked red, yellow, orange, blue and purple flowers^{19,20}. According to Abrol⁶, butterflies often visited brightly colored flowers, although sometimes butterflies also visited white flowers. Flowers that have bright colors (white, violet and yellow) can be captured and responded by the butterfly's senses. *Eupatorium inulifolium*, which was visited by many butterflies during observation, is a white flowering shrub of the Asteraceae family.

The type of inflorescences that butterflies often visit was tube. Flowers with inflorescences resembling tubes contain lots of nectar. The shape of the long corolla tube is a protection for plants to store nectar. The nectar can only be reached by certain types of pollinating insects, such as bees and butterflies that have proboscis to reach the nectar. Nimbalkar *et al.*¹⁹ argued that butterflies were more likely to visit flowers that have tubular corolla than flowers that have other shaped corollas.

Proboscis length measurements showed that butterflies with large body sizes, such as those from the Papilionidae family, tended to have a longer proboscis size than butterflies with smaller bodies. This showed that flowers with long corolla tubes tended to be visited by butterflies with long proboscis and vice versa. Thus, there was a correlation between the length of the proboscis and the length of the corolla tube. This is in accordance with the reports of Rusman *et al.*¹⁰ and Tiple *et al.*¹⁶, which showed that the proboscis length of butterfly had a positive correlation with the length of the corolla.

Observation of the frequency of butterflies visiting flowering plants to obtain nectar showed that the highest visit was at 09.00-10.00 Central Indonesian Time. Visits tended to decrease during the day. The same thing happened when measuring the volume and sugar content of flower nectar. The low volume of nectar during the day was probably because the nectar had already been taken by other insects in the morning or had evaporated. This is in accordance with research of Efendi²¹, which stated that there was high nectar secretion in the morning. The research of Fidalgo and Kleinert²² reported that the sugar concentration of nectar was the highest in the morning, when temperatures were relatively low and humidity was high, with the highest peak of sugar concentrations between 9:25 and 9:55 am.

The volume and sugar content of flower nectar varies between plant species. Several studies regarding the volume and sugar concentration of flower nectar have been conducted. The nectar volume of *Lantana camara* ranges from 0.41-0.98 μ L, nectar volume of *Hibiscus rosasinensis* ranges from 5.1-14 μ L and nectar volume of *Coffea canephora* ranges from 0.4-1 μ L²³. Each type of plant secretes nectar content with different amounts and concentrations. The amount of nectar that is secreted is influenced by internal and external factors. Internal factors include the morphology and physiology of flowers. External factors that affect nectar quality are microclimate conditions and soil properties²³⁻²⁵.

External factors that affect the volume and sugar content of nectar, based on the correlation test, were air temperature, air humidity, wind speed and light intensity. High temperatures affected nectar production through changes in nectar volume and sugar concentration. Nectar volume generally increases with increasing temperature, up to the species-specific optimum temperature. The air temperature above the optimum will cause the volume and sugar content of nectar to decrease²⁶.

CONCLUSION

The plant family that was frequently visited by butterflies to obtain nectar was Asteraceae. The relationship between butterflies with flowering plants was strongly influenced by plant habitus, flower color and inflorescence type. The volume and sugar nectar content were the highest in the morning but decreased during the day. This caused many butterflies to visit flowers in the morning as compared during the day. Factors affecting the volume and sugar content of flower nectar were air temperature, humidity, wind speed and light intensity.

SIGNIFICANCE STATEMENT

This study discovers the relationship between butterflies with feed plants was strongly influenced by the morphology of the flower, volume and sugar content of nectar. Asteraceae family was the butterfly plants in the Sangihe Island. The maintenance and management butterfly plants such as Asteraceae is key factor for butterflies conservation in the Sangihe Islands.

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