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THE SELECTION OF ORNAMENTAL PLANT FOR LANDSCAPE DESIGN OF POLLINATION GARDEN AT BOGOR BOTANIC GARDENS

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Abstract. *Bogor Botanic Gardens is one of the outstanding green areas in Bogor City. Thousands of plant species are growing and providing suitable habitats and feed for various pollinators, such as butterflies, bees, and wasps. A well-designed pollination garden will benefit the pollinators and also create an educational facility for the community. This study aimed to select and characterize species of flowering plants that effectively attract pollinators, particularly Lepidoptera and Hymenoptera, in the pollination garden candidate area. The observation had been carried out on 12 ornamental plant species: Pennisetum purpureum, Cosmos sp., Pachystachys lutea, Cuphea hyssopifolia, Orthosiphon aristatus, Lantana camara, Citrus aurantifolia, Buddleja davidii, Ixora javanica, Nerium oleander, Hibiscus rosa-sinensis, and Aglaia odorata. The method for observing pollinators was a standard walking method. Pollinator photos, its number, its visit time, and the plants it visited were recorded. A total of 23 species of Lepidoptera (20 species from 4 families and 3 species were unidentified) and 9 species of Hymenoptera (4 families) were found in the area with the best observation time at 08.30-09.30 (GMT+7). The most visited plants by pollinators were Cuphea hyssopifolia, Lantana camara and Orthosiphon aristatus. Lepidoptera and Hymenoptera preferred blue-purple and bright-orange-yellow flowers. In addition, the flower characters that might influence pollinator visits are also described. The result would be an essential recommendation for plant selection, landscape design, and construction of the pollination garden in Bogor Botanic Gardens.*

Keywords: *botanic gardens, pollination garden, flower characters, landscape design, pollinator*

Citation
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INTRODUCTION

Pollinators are common in the tropics (Ollerton, 2017) and capable of pollinating up to 87% of flowering plants. Therefore they can show the change in land use (Winfree et al., 2011). In an ex-situ conservation area such as botanic gardens, the plant species that are planted may not commonly found naturally in the area. It may influence and change the pre-

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ference of pollinators within the area. Many local and exotic pollinators in botanic gardens have been studied, mainly their behaviour and preference in pollinating local and introduced plants (Webber et al., 2012). Today, the study of pollinators is used to study the evolution of Invasive Alien Species (IAS) to explain the ecological functions and the evolution of pollinators in IAS ecosystems recipient (Vanbergen et al., 2018). Therefore pollinators can play a role as an indicator of plant diversity in an ecosystem, particularly in tropics that have many species of plants.

Bogor Botanic Gardens (Kebun Raya Bogor) is home to thousands of species that provided food and habitat for many pollinators such as birds, bats, squirrels, butterflies, and bees. On the other hand, the existence of pollinators in the area has ecologically benefit for flowering species to regenerate (Kato et al., 2008). Beyond that, this mutualism symbiosis has shown a crucial ecological role in maintaining plant diversity (Ollerton, 2017). Several studies on pollination of living collection by pollinators have been carried out in the garden, namely observing flowering and insect pollination of *Areca vestiaria* (Utami & Kahono, 1989), fruit-eating and nectar-eating bat (Soegiharto & Kartono, 2009), reproductive biology and insect visitors to *Cassine koordersii* (Ardhianto et al., 2009), insect pollination of *Rafflesia patma* flower (Kahono & Mursidawati, 2010), and guidance on butterfly introduction practices at Bogor Botanical Garden (Peggie & Amir, 2006).

The botanic garden is one of green space that plays essential roles, both ecologically and socially. The importance of a botanic garden function in conservation, research, education, tourism and ecosystem services are conveyed in a presidential policy 93/2011 (2011) that regulates botanic garden status and development in Indonesia. The existence of a botanic garden in a city does not only play a role in providing a green space but also in supporting ecosystem balance in a city that is more complex and challenging.

Urban communities demand a green space for social activities such as gathering, casual sports, hobbies and educational activities, provided by a botanic garden. Educational activities in a botanic garden can be an appropriate approach to deliver the mission of the botanic garden in increasing public awareness of botanical and environmental issues. The importance of the pollination issue can be delivered through developing a thematic garden, namely "pollination garden". The pollination garden should be able to provide public experience seeing the natural pollination process in nature, an example and recommendation of gardening practices and to stimulate communities in supporting and helping pollinator fitness. Well-planning landscape design of a pollination garden is not only appropriate for the local area but also has a scientific base and references, which will improve the ability to attract pollinators.

This study aims to evaluate and select the efficacy of some local ornamental plants which have the potential to attract Lepidoptera (butterflies), and Hymenoptera (bees and wasps) in the candidate area of pollination garden in Bogor Botanic Gardens (later called as pollination garden), along with characterizing the flower and the pollinators. The result will be part of recommendations that benefit the process of plant selection, landscape design and construction of pollination garden in Bogor Botanic Gardens.

MATERIALS AND METHODS

Study Area and Data Collection

This research is an experimental study conducted in August-December 2018 at

Bogor Botanic Gardens, Bogor City, West Java, Indonesia. Twelve local ornamental plants were tested in three plots, 5 m^2 each, located in the candidate area of pollination garden (Figure 1). They were *Pennisetum purpureum*, *Cosmos* sp., *Pachystachys lutea*, *Cuphea hyssopifolia*, *Orthosiphon aristatus*, *Lantana camara*, *Citrus aurantifolia*, *Buddleja davidii*, *Ixora javanica*, *Nerium oleander*, *Hibiscus rosa-sinensis* and *Aglaia odorata*. Those species were chosen and justified based on the family of species, the role of species as a host plant and food plant (Subahar & Yuliana, 2010) and personal communication.

The area of the pollination garden covered about 8776.94 m^2 and is located in the southeast of Bogor Botanic Garden (Figure 1). It is laid on the section XIX.K, XIX.N and XIX.M. The temperature was around 22-32°C, 78.30% in relative humidity, 7 hours of photoperiodicity, and the average wind speed was 2 m/s (Indonesian Meteorology, Climatology, and Geophysics Center, 2018). The surrounding area is heavily shaded by canopy trees, while most of the central area in the day time was fully exposed by the sun, with some part was shaded by small trees. A big pond in the middle of the area that acted as a water source and insect attractor.

The observation was used the standard walking method (Pollard & Yates, 1993; Tati-Subahar et al., 2007) in each plot and started at 08.00 – 11.00 (GMT+7) as the most active period for butterfly (Kunte, 1997). Each butterfly and bee species have found from the plot were recorded and taken photographs, for identification of butterflies "Practical Guide to the Butterfly on the Bogor Botanic Garden" (Peggie & Amir, 2006) was used along with expert discussion and consultation. In addition, we consulted "Plant Identification Terminology: An Illustrated Glossary" (Harris & Harris, 2004) for identification of the floral character of plant species we used. The factors which were observed included flower characters, butterflies and bee species, and frequency of pollinator visit.

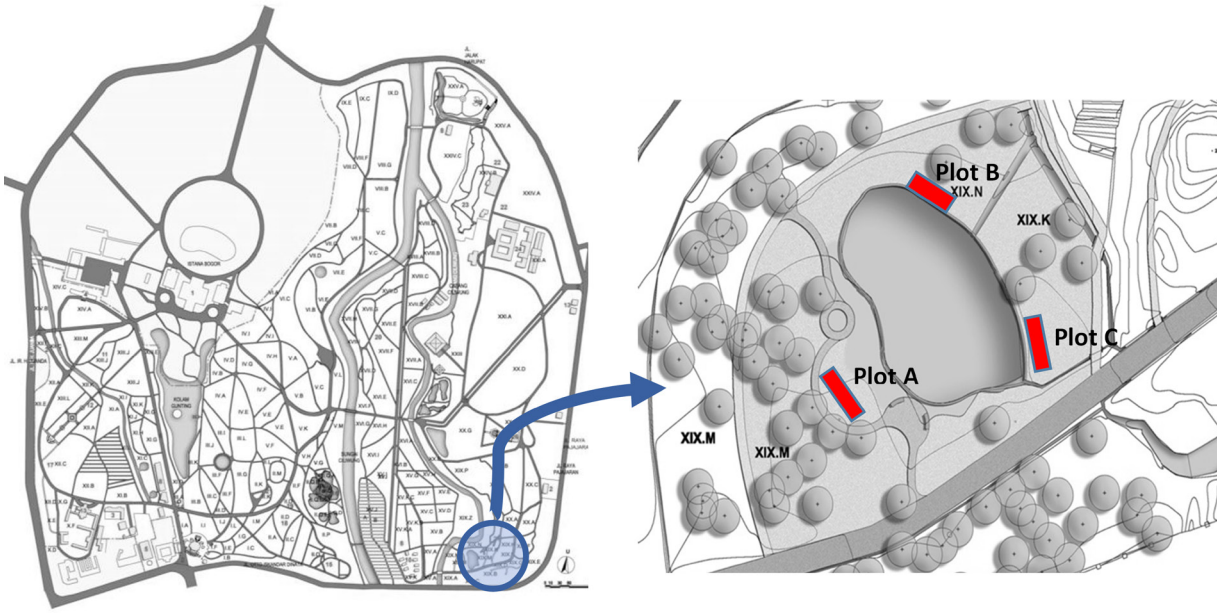

Figure 1. Ornamental plant observation plots for attracting pollinators at the candidate location Pollination Gardens, located on the Vak. XIX.K, XIX.N, and XIX.M in Bogor Botanic Garden.

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Data Analysis

Lepidoptera is the largest plant-feeding order of insects that has an ecological function as pollinators and prey. Lepidoptera has more than 43 superfamilies, one of which is Papilionoidea as the largest clade consisting of butterfly relatives (Mitter et al., 2017). Another largest insect order is Hymenoptera, which is consisting of sawflies, wasps, ants, and bees (Peters et al., 2017). The presence of Lepidoptera and Hymenoptera could be analyzed and figured out by comparing the number of species richness, species diversity, and species evenness. Data analysis was carried out to determine the diversity of pollinators in the pollination garden using the Margalef index (R), Shannon-Wiener diversity index (H'), and Evenness index (E). Margalef Index is a richness index where S is the number of species observed, and n is the total number of individuals of species in plots, and ln is a natural log, so the richness index formula is $R = (S-1)/\ln n$. Richness index explaining that $3,5<R<5,0$ shows moderate species richness and $R>5,0$ shows high species richness.

Furthermore, Shannon-Wienner diversity index was used to determine diversity, which can be calculated by the proportion of the first species in the total sample (Pi) multiplied by the natural log (ln) of the proportion of the i species in the total plot. The formula of a diversity index is $H' = Pi \times \ln Pi$. The diversity index divides into three criteria, namely $H'<2$ shows low category, $2<H'<3$ shows medium category, and $H'>3$ shows high category. The evenness index aims to determine the level of species distribution. The formula of an evenness index is $E = H'/\ln S$. Magurran (1988) has stated that the value of Evenness index is close to the values of 1 that mean there are no dominant species in the area. There are parameters index still relevant to Hymenoptera and Lepidoptera biodiversity analysis (Kwatrina et al., 2018; Budiadi et al., 2020). Principal Component Analysis (PCA) using XLStat 2014 was used to analyze the relationship between the pollinator interests in the plant species.

RESULTS AND DISCUSSION

Floral Characters

Twelve species of flowering ornamental plants from different families show diverse flower characters (Table 1). Five species of flowering plants throughout the observation produced many flowers multiple times, namely *Cosmos* sp., *Pachystachys lutea*, *Cuphea hyssopifolia*, *Orthosiphon aristatus*, and *Lantana camara*. Meanwhile, the other species have infrequent and short flowering period. They are perennial plants with bright colors, some do not have a scent while others have a strong scent.

Diversity and Abundance of Pollinators

There were 23 species of Lepidoptera (20 species from 4 families and 3 species were unidentified), and 9 species of Hymenoptera (4 families) recorded during this study. The relative abundance of insect pollination also varied (Table 2). In Lepidoptera, species with a high abundance were *Junonia atlites* and *Eurema* sp., while in Hymenoptera, the highest abundance was *Amegilla* sp.

Table 1. Floral characters

Family	Plant Species	Flower fertilizations	Perianth Form	Flower Symmetry	Flower colors	Inflorescence types	Floral nectaries	Life cycle	Flower scents
Poaceae	*Pennisetum purpureum*	Cross-pollination	Lodicules	Zygomorphic	Magenta	Panicle	Absent	Perrenial	No scent
Asteraceae	*Cosmos* sp.	Cross-pollination	Ligulate/ Liguliform	Zygomorphic, inflorescene actinomorphic	Yellow	Head	At apex of ovary	Annual	Light
Acanthaceae	*Pachystachys lutea*	Self-pollination	Labiate/ bilabiate	Zygomorphic	White	Raceme	At base of ovary	Perrenial	Light
Lythraceae	*Cuphea hyssopifolia*	Cross-pollination	Salverform/ Hypocrateriform	Actinomorphic	Purple	single / solitary	At base of ovary	Perrenial	No scent
Lamiaceae	*Orthosiphon aristatus*	Self and cross	Labiate/ bilabiate	Zygomorphic	Purple and White	Raceme	The depth of the tubular part of the corolla	Perrenial	Light
Verbenaceae	*Lantana camara*	Self and cross	Salverform/ Hypocrateriform	Zygomorphic, inflorescene actinomorphic	Yellow, Orange, Pink and White	Umbel	The depth of the tubular part of the corolla	Perrenial	Strong
Rutaceae	*Citrus aurantifolia*	Self-pollination	Funnelform	Actinomorphic	White	single / solitary or cyme	At base of ovary	Perrenial	Strong
Scrophulariaceae	*Buddleja davidii*	Cross-pollination	Salverform/ Hypocrateriform	Actinomorphic	White	Panicle/ Thyrse	At base of ovary	Perrenial	Strong
Rubiaceae	*Ixora javanica*	Cross-pollination	Salverform/ Hypocrateriform	Actinomorphic	Red	Compound Corymb	The depth of the tubular part of the corolla	Perrenial	Light
Apocynaceae	*Nerium oleander*	Self-pollination	Funnelform	Actinomorphic	Pink	Compound Corymb	At base of ovary	Perrenial	Medium
Malvaceae	*Hibiscus rosa-sinensis*	Cross-pollination	Funnelform	Actinomorphic	Red	single / solitary	Adaxial surface of calyx	Perrenial	No scent
Meliaceae	*Aglaia odorata*	Cross-pollination	Urceolate	Actinomorphic	Yellow	Panicle	Surface secretion	Perrenial	Strong

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Table 2. List of species and the relative abundance of pollinator insects at Pollination Gardens

Ordo	Family	Species	Relative abundance (%)
Lepidoptera	Nymphalidae	*Doleschallia bisaltide*	0.29
		Euploea sp.	0.58
		Hipolimnas bolina	1.45
		Junonia atlites	28.90
		Junonia erigone	11.27
		Junonia hedonia	6.07
		Neptis hylas	2.89
		Ypthima sp.	8.38
	Papilioninae	*Graphium agamemnon*	0.58
		Papilio demolion	0.58
		Papilio demoleius	0.29
		Papilio polytes	1.16
	Pieridae	*Appias lyncida*	0.58
		Appias nero	8.67
		Appias olferna	2.02
		Eurema sp.	15.32
		Leptosia nina	5.20
	Lycaenidae	Lycaenidae 1	1.16
		Lycaenidae 2	2.60
		Lycaenidae 3	0.58
	-	Sp. 1*	0.58
		Sp. 2*	0.58
		Sp. 3*	0.29
Hymenoptera	Apidae	*Amegilla* sp.	36.29
		Apis cerana	4.84
		Tetragonula sp.	2.42
		Thyreus sp.	11.29
		Trigona sp.	6.45
	Megachilidae	*Megachile* sp.	1.61
	Scoliidae	*Campsomeris* sp.	11.29
	Vespidae	*Phimenes* sp.	10.48
		Polistes sp.	15.32

Butterflies that belong to Nymphalidae family were most commonly found in the pollination garden. They have polyphagic properties that allow them to have more than one type of food/ host (Priyono & Abdullah, 2013). Also, the environmental conditions of the pollination garden, which were slightly open with good airflow supported the species of *Junonia atlites* (28.90%), *Junonia erigone* (11.27%) and *Junonia hedonia* (6.07%) to have a relatively high abundance (Indriani et al., 2010) reported that *Junonia atlites* in Tanjung Puting National Park are often found in open bushland. This type of butterflies likely live in open habitat with high ambient temperatures.

The highest relative abundance of Hymenoptera was *Amegilla* sp. (36.29%) with blue-banded body details showing that this species likes to fly in an open area exposed to sunlight under the canopy (Kato et al., 2008). In addition, this species also has long glossa (a tongue-like structure in the labium of an insect's mount parts), so it tends to visit flowers with deep tubes and brightly colored flowers such as blue-white. In general, (Miller et al., 2011) described that bees (bee-pollinated) generally attracted to blue and yellow flowers. Besides that, flowers that have nectar guide can increase pollinators visit flowers because it helps bees finding the nectar (Hansen et al., 2012; Leonard et al., 2013). Other relative abundances were *Polistes* sp. (15.32%), *Campsomeris* sp. (11.29%), and *Phimenes* sp. (10.48%), which live solitary and predatory. These species often visit flowers to look for prey, namely caterpillars and small bees. Nevertheless, the presence of *Polistes* sp., *Phimenes* sp., and *Campsomeris* sp. who visit these flowers are also useful in the pollination process (Parikesit et al., 2018; Prakash Gautam & Kumar, 2018).

The biodiversity values of Lepidoptera was higher than Hymenoptera (Table 3). The index of species diversity (H') of Lepidoptera in the pollination garden was classified as moderate (2.34), while Hymenoptera was classified as low (1.86). It was directly proportional to the value of the two species of pollinators. Meanwhile, the index of species evenness of pollinator species showed low value (E <0.1). It shows that in pollination garden could be found individual species domination, while other species were part of subdominant or not dominant.

Table 3. Diversity parameters of pollinators

Parameter	Lepidoptera	Hymenoptera
Richness index (R)	3.76 (moderate)	1.66 (low)
Diversity index (H')	2.34 (moderate)	1.86 (low)
Evenness index (E)	0.10 (low)	0.21 (low)

The best time to observe pollinating insects in the pollination garden was at 08.30-09.30 GMT+7 (Figure 2). It was in line with (Priyono & Abdullah, 2013), who stated that butterflies would be active and fly well when the sunlight intensity increases as butterflies need heat to help them fly. Insects which were mostly found during the best observe times were *Eurema* sp., *Junonia atlites*, *Junonia erigone*, *Appias nero*, *Ypthima* sp., *Amegilla* sp., and *Phimenes* sp.

Potential Pollination Garden

The pollination garden candidate area at Bogor Botanic Gardens has considerable potential to bring pollinating insects, such as butterflies and bees. It will undoubtedly become one of the new alternative gatherings and educational places at the Bogor Botanic Gardens which is full of information and knowledge for visitors. Based on the observation, the five most-visited plants by pollinators were *Cuphea hyssoppifolia*, *Lantana camara*, *Orthosiphon aristatus*, *Cosmos* sp., and *Pachystachys lutea* (Figure 3). *Cuphea hyssoppifolia* has nectaries at the base of long corolla tube so that advantages for Hymenoptera and Lepidoptera to reach it with their more extended proboscis (Safriya & Karunaratne, 2011).

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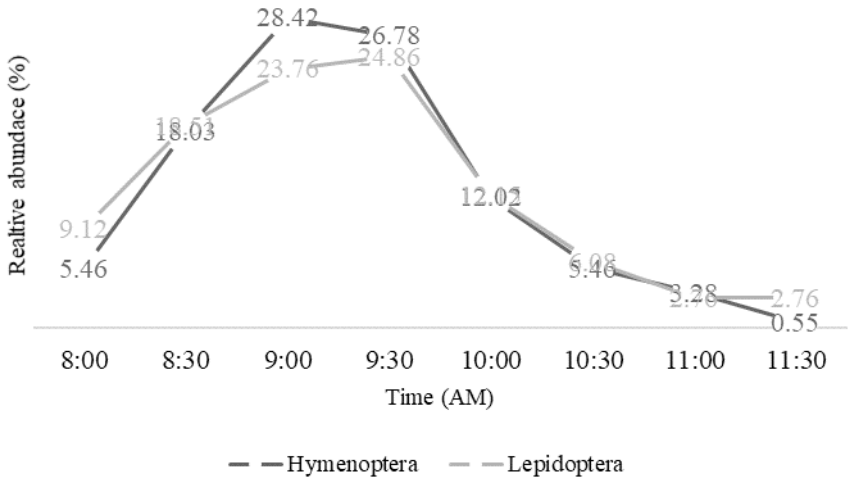

Figure 2. Insects visited the flowers

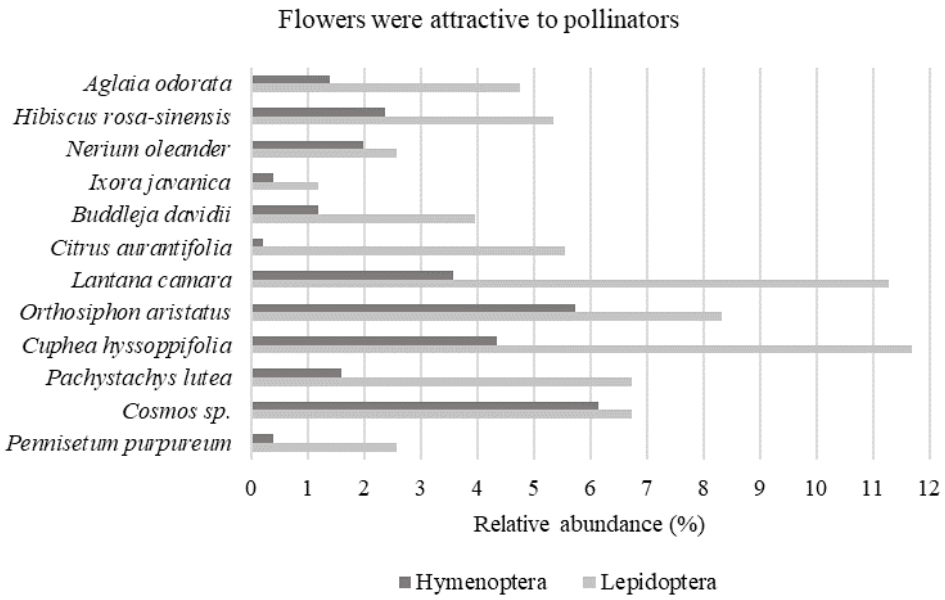

Figure 3. Plant visited by pollinators

Most of the selected plant has a diverse flower characteristic to attract Hymenoptera and Lepidoptera. *Cuphea hyssoppifolia* was the most commonly visited by insects because the flowers emerge in the terminal and have a lot of numbers and perianth with the form of Hypocrateriform, which is a purple tube and small in size. It allows Hymenoptera and Lepidoptera to take nectar at the bottom of the ovary of the flower with the proboscis (Safriya & Karunaratne, 2011).

The second most commonly visited species was *Lantana camara*, which has an umbel type inflorescence in terminals. Thus allowed insects to visit at the same time. Moreover, the corolla color, which changes from yellow in the opening, then changes to orange and gradually changes to reddish-orange, acts as the

indicator of pollen maturity and nectar content (Barrows, 1976; Priyanka & Joshi, 2013). Therefore, *Lantana camara* is visually appealing for pollinators.

Orthosiphon aristatus was one of the most visited species by bees because of the variety of flower colors, including purple, intermediate (purple-white), and white (Febjislami et al., 2019). It is also has a raceme inflorescence and blooms from the bottom to the top. The flowering period was quite long, which was around 2-3 weeks. Therefore, it allowed the pollinator to visit the inflorescence in a longer period multiple times.

However, some plant species were not preferable to pollinators due to some characters. For instance, *Ixora javanica* and *Hibiscus rosa-sinensis* had fewer visitors, Lepidoptera and Hymenoptera, because of the red flowers. Flowers with brightly colored characters such as red are generally more attractive to birds than bees (Hails & Kavanagh, 2013). Bees learn rapidly the association of colour, rewards, and its costs (Chittka & Wells, 2004), somehow the topic of bee vision and colour preference still has a long argument. *Pennisetum purpureum* was not a type of insect-pollinated plant, but the leaves were commonly used by butterflies to perch or to lay butter eggs. The pollination of *Pennisetum purpureum* is assisted by wind, and the spikelet color not flashy (colorful), making it less attractive to pollinating insects in the morning. *Citrus aurantifolia* and *Aglaia odorata* are also species of plants with a strong scent with an inconspicuous color and flower shape, so both species of plants are widely used by butterflies to perch and lay their eggs.

Ornamental Plant for Landscape Design of Pollination Garden

The principal component analysis was used to determine the plant species that can attract pollinating insects from the relatives of Lepidoptera and Hymenoptera. Based on the insect group found shows that the relatives of Lepidoptera are divided into three groups (Figure 4), namely the group that has the highest relative frequency and relative abundance consisting of just one species, namely *Junonia atlites*. The second group of butterflies is common and has a medium frequency of visits. This group of butterflies has similar plant species preferences: zygomorphic flower type, perianth flower in the form of labiate and umbel, white, yellow, and purple, and has a medium aroma. In contrast, the third group is the butterfly group that has a low relative abundance of species. Generally, these species come to visit the pollination garden only occasionally to sunbath and perch on plants. However, the presence of this third butterfly group can increase the diversity value of butterflies in the pollination garden, especially if the plant characters fit the group preferences. In addition, there is one species of butterfly that is an outlier, *Neptis hylas*, which has a living preference in the shaded area or under the canopy (Saikia, 2014). Thus, in compiling the pollination garden landscape design, the habitat and feed conditions should be adjusted to the preferences of the second and third groups so that the potential for butterflies that come is higher.

Furthermore, the analysis of the main components in the Hymenoptera is divided into two large groups and additional outliers of two species (Figure 5), namely the *Amegilla* sp. and *Polistes* sp. Both of these species have a big difference in habitat and food preferences. *Amegilla* sp. is a solitary honey bee that prefers areas that are not exposed to direct sunlight and flowers that provide lots of nectar and pollen, such as the type of *Cuphea hyssopifolia*, *Cosmos* sp., and *Orthosiphon aristatus*. While *Polistes* sp. is a predatory wasp that

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visited many species of plants, especially in the areas that are open and exposed to direct sunlight. The most visited plant by Polistes sp. was *Cuphea hypssopifolia* because this plant is commonly visited by *Apis cerana*, *Amegilla* sp. and *Trigona* sp., which is a prey of *Polistes* sp.. The first group consisted of three species of predators that have relatively high abundance in the pollination garden, namely *Thyreus* sp., *Campsomeris* sp. and *Phimenes* sp. These three species of predators may be one of the factors making other species of pollinators relatively low. A second group is a group of common pollinating bee species from Apidae family who prefer yellow, orange, pink, white to magenta flowers with a type of inflorescence of the form of a head and medium and light floral scent.

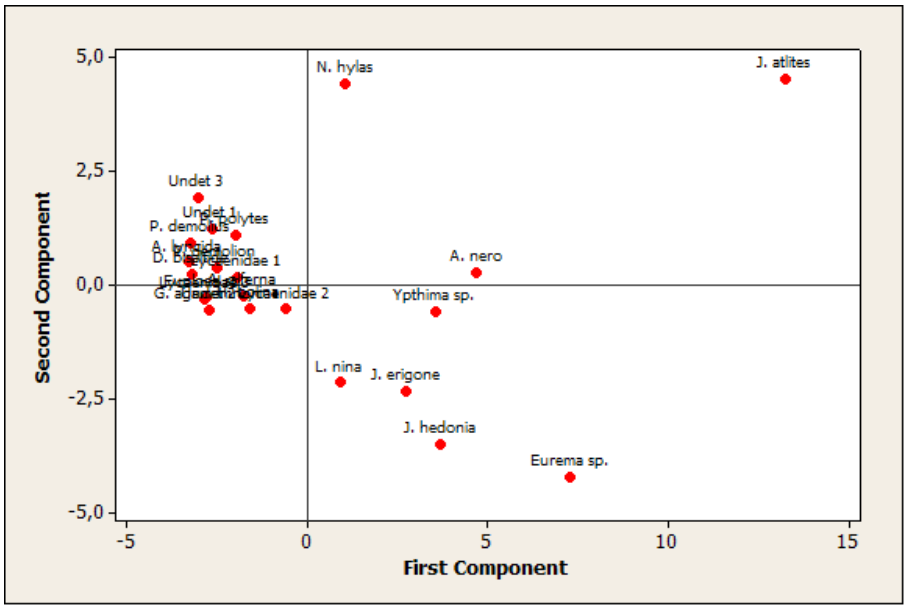

Figure 4. Principal Component Analysis of Lepidoptera

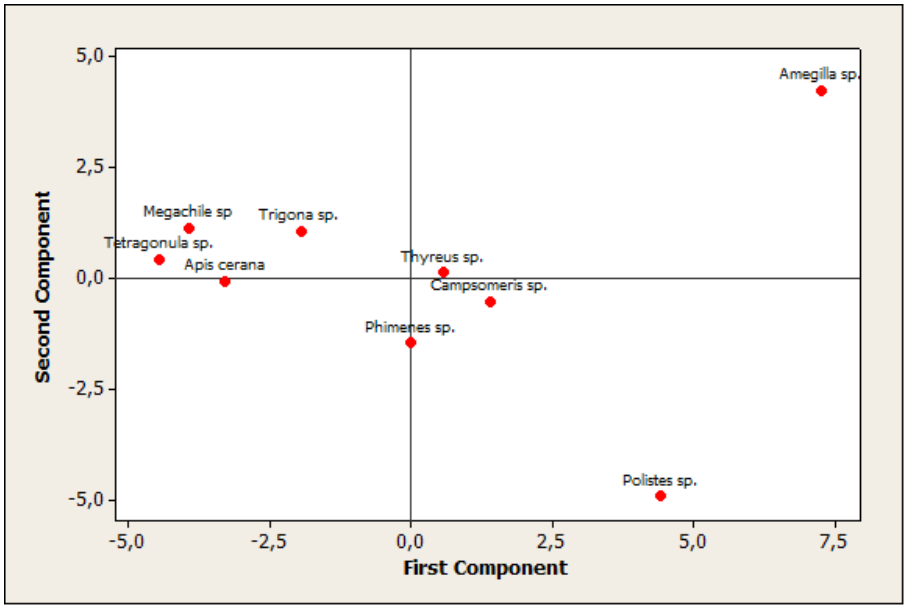

Figure 5. Principal Component Analysis of Hymenoptera

The constituent plants which are suggested to attract Lepidoptera and Hymenoptera in the pollination garden are species that have white, yellow, or purple to magenta flowers with less scent. The preferable forms of the inflorescence are head, raceme, umbel, and the shape of the flower crown in the form of labiate and hypocrateriform. In addition, it is important to provide suitable plant species to feed the pollinators larvas, which is not only providing space for insects to breed but also providing a platform to lay eggs such as the *Citrus aurantifolia* and *Aglaia odorata*.

Pollinators from Lepidoptera (butterflies order) and Hymenoptera (bees order) preferred plants with particular flower characters in color, flower symmetry, inflorescent, and scent. Lepidoptera and Hymenoptera preferred blue-purple and bright-orange-yellow flowers or inflorescence. Lepidoptera preferred zygomorphic flowers in the form of labiate and umbel inflorescences. In contrast, Hymenoptera liked flowers that have a flower pad for them to perch as in the inflorescence of the head, shape, umbel. Both groups had a preference for light to medium scented flowers. The plant species that are highly recommended to be included in the garden design are *Cuphea hyssopifolia*, *Lantana camara*, and *Orthosiphon aristatus*, or any other local plants with similar flower characters.

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