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RESEARCH PAPER

Plant Dispersal Mode at Different Urbanization Levels in Ipoh City Council, Perak

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Abstract

Urbanization is rapidly expanding, and many forests are being cleared. The loss of crucial ecological functions, including dispersal and pollination, in urban settings can have detrimental effects on individual species and the sustainability of entire ecosystems. Nevertheless, how urbanization affects seed dispersal is still largely unexplored. Hence, this study aimed to investigate the association between plant dispersal mode and urbanization intensity in Ipoh City Council, Perak. The percentage of built-up area within a 1km^2 area was measured using ArcGIS software to establish the urbanization gradient. To reflect distinct urbanization, a total of 12 sampling plots, with the sized of 1km^2 for each plot were designed. 40 subplots were randomly selected in each plot to create a complete sampling site of 0.1 hectare, and any plants discovered in the subplots were identified at the species level. To characterize the mode of dispersion for each plant species recorded, a few reports from literature have been used as a guideline. Endo-zoochory and hemerochory were more prevalent in urban settings than in other study areas. Significant abundance of zoochory-dependent plants in this study area, it shows urbanization does not always reduce the nature conservation value of places in Ipoh. In the future, policymakers, and town planners could use the findings of this study to help them continuously improve urban development and generate more sustainable urban expansion.

Keywords: Dispersal mode, ecological services, Geographical Information Systems (GIS), Ipoh, urbanization gradient.

INTRODUCTION

As the cities expand, many people have relocated to cities. Urbanization is anticipated to reach 65 percent of the world population in the next 40 years (Ali, Bakhsh & Yasin, 2019). There appear to be a range of positive outcomes to urbanization, including better quality of life and greater opportunities for social connection (Zhao, Shi & Niu, 2014). In order to meet the needs of the increasing urban population, cities need to expand, and this leads to more forest destruction. Such anthropogenic activities could also bring risks to ecological processes. For instance, in order for forest plants to regenerate, the ability of seeds to disperse into the disturbed urban environment is essential (Wang & Smith, 2002). Nevertheless, how urbanization affects seed dispersal is still largely unexplored (Stanley & Arceo-Gómez, 2020). If urbanization alters the frequency, identity, and performance of interactions between plants and their mutualistic partners, functioning processes involving seed dispersal may be affected (Markl et al., 2012). The loss of crucial ecological functions (e.g., dispersal and pollination) in urban settings can have detrimental effects on individual species and the sustainability of entire ecosystems (Valiente-Banuet et al., 2015).

Furthermore, seed dispersal has significant interaction with the key drivers of biodiversity changes in the twenty-first century, including habitat degradation, biological challenge, and climate change (McConkey et al., 2012). Prior studies have demonstrated that urbanization may impair seed dispersal in terms of the distance and direction of dispersal due to habitat fragmentation that consequently interrupts gene flow of plant species across populations (Gelmi-Candusso & Hämäläinen, 2019). For instance, habitat fragmentation reduces the number of animals that act as seed dispersers and disrupts their movement (Markl et al., 2012; Westcott & Graham, 2000). With the interruption of gene flow, it is likely that zoochorous plant populations would become isolated in urban areas (Johnson & Munshi-South, 2017). Ultimately, the ecosystem’s ability to operate may be jeopardized because changes in seed dispersal can have a massive effect on ecological processes and sustainability (Terborgh, 2013). After all, the ability of plants to migrate and develop new populations determine their potential to spread and thrive across landscapes (Rogers et al., 2019).

Although evidence from the previous studies showed how urbanization could influence seed dispersal negatively, the need for urbanization to support human social and economic development cannot be neglected. Therefore, this study aimed to determine how plant dispersal mode responds to changes along the urbanization gradient in Ipoh, Perak. To accomplish this goal, we conducted research in Ipoh City Council which is located in Perak state of Peninsular Malaysia. Ipoh City Council was chosen because it serves as the state's core urban centre (van Grunsven & Benson, 2020). Aside from that, human activities in Perak have resulted in substantial landscape transformations and sudden shifts in land usage (Wan Mohd Jaafar et al., 2020). For comparison purposes, within the last 29 years, the state of Perak has lost approximately 16 percent (189,423 ha) of its forested land (Wan Mohd Jaafar et al., 2020). Furthermore, Ipoh City Council is regarded as a phytogeographical distinct region that contains three distinct elements, including limestone flora (Wong, 1998), the Perak sub-province that influences the Sumatran flora (Ashton, 1992), and the Seasonal Asiatic Intrusion that is enclave invasion by Burmese-Thai floristic elements (Wong, 1998). Therefore, Ipoh City Council is an excellent location for investigating the effects of urbanization on ecological processes, particularly those involving dispersal mode.

Our research findings will offer conservation measures for recovering potential biodiversity losses and a new paradigm for sustainable urban design for Malaysian cities. In a rapidly urbanizing world, understanding ecological reactions to urbanization is critical to ensure that cities are designed for the well-being of humans and nature (Niemelä, 2017).

MATERIALS AND METHODS

Study area

This study was conducted in four distinct urban settings, i.e., wild land, rural, suburban, and urban areas in Ipoh City Council in the Perak state of Peninsular Malaysia (101° 3' 57.118747" - 101° 3' 57.118747"E, 4° 28' 26.148383" - 4° 28' 26.148383"N, Figure 1). Ipoh is positioned between Kuala Lumpur and Penang, making it a vital transit centre for west Malaysia. Limestone hills surround the city of Ipoh, can be found throughout the northeast, east, and southeast of suburban areas. Moreover, rainforest-like conditions can also be found in Ipoh. The temperatures range from 20.7°C to 30.6°C throughout the year, with monthly variations in relative humidity. With an average of 200 mm (7.9 in) of rain per month and 2,427.9 mm (95.59 in) of rain annually, Ipoh receives a lot of rain throughout the year. In Ipoh City, October is the wettest month of the year, with rain falling at an average of 297.2 mm (11.70 in). Besides that, the driest month is January, with an average of 132.3 mm (5.21 in) of rainfall.

Urbanization intensity quantification

The percentage of the built-up area within a 1km^2 region determined the urbanization intensity of sampling locations. The built-up percentage is a helpful indicator for urbanization intensity since it can be measured in any urban area regardless of geographical, cultural, or historical variance. The urbanization intensity quantification was performed using ArcGIS software using the Ipoh land use map issued by Malaysia's Federal Department of Town and Country Planning. The map has 12 separate land use attributes, and these features were divided into green regions and built-up areas. The built-up areas consisted of seven features, such as manufacturing, service and infrastructure, commercial, institutional, mixed construction, transport or mobility, and residential or housing areas. On the other hand, forests, parks, recreation centres, undeveloped land, and farming areas made up the green areas. However, the water body was exempted from all categories. Wild land (0-2% built-up percentage), rural (5-20%), suburban (30-50%), and urban areas (>50%) were designated as the four categories of urbanization intensity based on the built-up percentage of the 1km plots (Marzluff, Bowman & Donnelly, 2001). A total of 12 sampling plots were constructed by replicating each category twice.

Site Selection and Sampling Design

A total of twelve sampling plots that sized 1km^2 were randomly built to reflect an urbanization gradient (Figure 1). For plant study, it was suggested that a rectangular plot of 0.05-0.1 ha with a minimum aspect ratio of 1:20 should be used (Yang, Lam & Su, 2019). In this study, 40 subplots with a size of 1m x 25m were used and it yielded a cumulative collecting area of 0.1 hectare per plot. Any plants in the subplot with a diameter at breast height (DBH), measured at 1.3 meter above the ground, of 5 cm or more were considered as samples. Plant taxonomist from Forest Research Institute Malaysia (FRIM) helped to identify every sample.

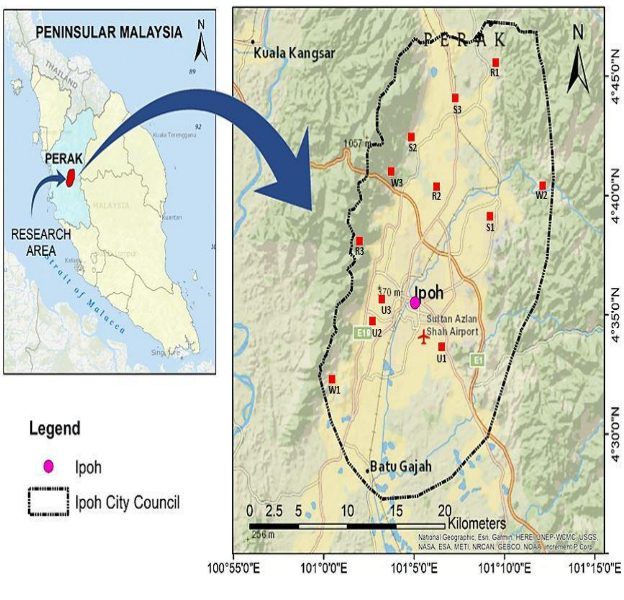

Figure 1. Study area in Ipoh City Council, Perak where 12 sampling plots represented an urbanization gradient (W: wild land; S: suburban; R: rural; U: urban).

Dispersal Mode

The mode of dispersal for each plant was identified through the previous report by Cornelissen et al. (2003) and Pérez-Harguindeguy et al. (2013; 2016). According to the literature, several types of dispersal have been listed, for example, anemochory (wind dispersal), endo-zoochory (internal animal transport), exo-zoochory (external animal transport), dispersal by hoarding, myrmecochory (ant dispersal), hydrochory (water dispersal), ballistichory (dispersal by launching, and bristle contraction). On the other hand, hemerochory was included in this study because humans may be able to help the seed to disperse, especially in urban areas. The percentage of dispersal modes that made up each of the urbanization categories (wild land, rural, urban, and suburban) was determined and compared.

RESULTS AND DISCUSSION

Findings for dispersal mode along the urbanization gradient are summarised in Figure 2, which shows that urban plots only have five different types of dispersal modes, namely the endo-zoochory (71%), myrmechory (35%), hemerochory (35%), exo-zoochory (7%) and ballistichory (7%). Endo-zoochory was found to be the most common mode of dispersal in urban areas. Exo-zoochory and ballistichory, on the other hand, accounted for the lowest percentage of urban dispersal modes. For suburban areas, the findings have clearly shown that endo-zoochory (82%) was found to be the most common dispersal modes in suburban regions, and followed by myrmechory (30%), exo-zoochory (21%), hemerochory (21%), anemochory (17%), and hydrochory (8%). Endo-zoochory was shown to have the highest percentage of dispersal modes in the suburban area meanwhile, hydrochory, on the other hand, was the least.

In this study, rural locations offer a wide range of dispersal modes compared to urban, suburban, and wild land settings. It was shown that in rural areas, the most prevalent mode of dispersal was endo-zoochory (88%), followed by hemerochory (23%), myrmechory (15%), anemochory (11%), and ballistichory (7%). Meanwhile, 3% of the total was accounted by hydrochory and exo-zoochory. In the wild land, endo-zoochory (85%) was the most important dispersal mode, and this result was followed by myrmechory (19%), exo-zoochory (16%), hydrochory (4%), anemochory (2%), and ballistichory (1%).

Land-use change alters the spatial organization of tropical landscapes, but how it affects vital biological processes like seed dispersion is unknown (San-José, Arroyo-Rodríguez & Meave, 2020). Dispersal is a vital ecological function that influences plant community structure and distribution [3]. Furthermore, dispersion perturbations may impair ecosystem efficiency and persistence (Terborgh, 2013). Dispersal mode was the focus of this investigation to examine how urbanization affects it. Endo-zoochory was shown to be the most common method of dispersal in urban areas based on the findings of this investigation in different urban settings (urban, suburban, rural, and wild land). Plant species that found in urban areas with endo-zoochory method were *Terminalia mantaly*, *Morinda citrifolia*, *Mangifera indica*, *Syzygium aqueum*, *Adenanthera pavonina*, *Azadirachta indica*, *Moringa oleifera*, *Aidia densiflora*, *Samanea saman* and *Carica papaya*. This result was supported by Albrecht & Haider (2013) which stated that seeds spread inadvertently through metropolitan areas, primarily via zoochory, due to the introduction of few non-native species. However, this result contradicted to Gelmi-Candusso & Hämäläinen (2019), which clarified that the dispersal processes of plants that rely on animal-mediated dispersal (zoochory) may be disproportionately affected by urbanization, as many animals prevent or limit their activities in urban areas. Initial discoveries have also noted evidence that human-induced disturbances, such as habitat fragmentation, habitat loss, and hunting have also been shown to alter seed dispersal by animals (zoochory). For instance, reduced availability of animal dispersers can affect seed removal rates, particularly in metropolitan environments (Markl et al., 2012) and human activity and fragmentation can lead to changes in disperser movement patterns (Ciuti et al., 2012; Gaynor et al., 2018). Seed distribution can be affected by these kinds of changes (Westcott & Graham, 2000). As a result, small populations of zoochorous plants may be isolated due to disturbed seed dispersion in urban settings (Johnson & Munshi-South 2017), which might impact the general functioning of the ecosystem.

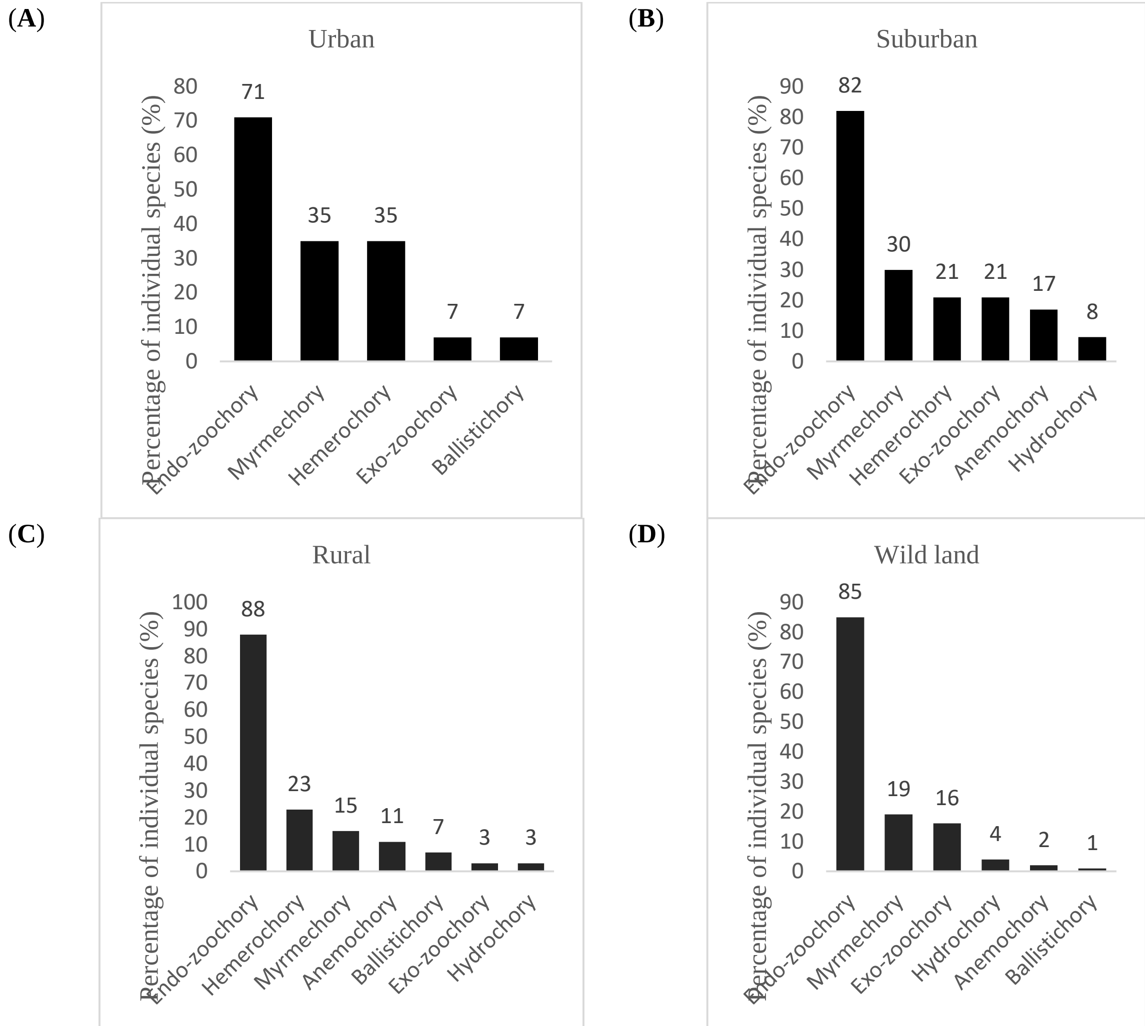

Figure 2. Dispersal mode along the urbanization gradient in Ipoh City Council, Perak where (**A**) urban (**B**) suburban (**C**) rural (**D**) wild land.

Nonetheless, the study found that urban plots had a more significant percentage of plants with endo-zoochory seed distribution, indicating that herbivorous birds or mammals have a good diet in the area (Albrecht & Haider, 2013). A similar correlation was found at the scale of entire cities by Knapp et al. (2008), and this finding confirms their findings. It also suggests that the nature conservation value of these areas in Ipoh is not always reduced because of urbanization and that taxa that conduct critical ecosystem functions may benefit from this as well. Endo-zoochory dispersion was able to take advantage of the new urban habitat environments. Animal-dispersed plants may also be less likely to become extirpated in more urbanized habitats, which may help explain the overall frequency of zoochory-dependent plants (Williams et al., 2005) since animal seed dispersers play an essential role in the conservation or alteration of plant ecosystems in urban environments (Gelmi-Candusso & Hämäläinen, 2019). It was also discovered that the dispersal techniques of myrmechory (dispersed by ants) and hemerochory (dispersed by humans) were quite common in metropolitan environments.

Because of urbanization, there are many roadsides opened, and as research has demonstrated, these roadsides might function as new primary habitats or dispersal corridors in fragmented landscapes. According to Bernes et al. (2016), roadsides, especially sandy that are exposed to the sun, provide habitat not only for plants but also for a broad range of ants and insects. The research indicated that metropolitan areas in Ipoh, Perak were more likely to distribute seeds by humans than other study locations. Seed dispersal by humans has been examined in detail (Bullock et al., 2018), especially in urban areas (von der Lippe et al., 2013; von der Lippe & Kowarik, 2008). Recent studies have shown that most non-native species were brought to urban areas on purpose (e.g., in gardens, residents' areas) by humans.

In this study, Ipoh is also home to a wide variety of non-native and ornamental plants that may be used for both landscaping and decoration. In addition, Mango species in this study area were predominantly moved and dispersed by people, mainly due to the commercialization and consumption of their fruits. According to Orwa et al. (2009), since their fruits are eaten and distributed by bats, hornbills, monkeys, elephants, and porcupines, the Mango species is likely to have survived in cultivation and established itself in natural areas in almost every location where it was introduced and constantly relocated by humans for decades. Flies, ants, beetles, and bats may also pollinate *Mangifera indica* flowers; however, bees tend to be the most efficient pollinators, according to research (Orwa, 2009). These non-native species populations in urban areas, particularly those distributed by birds (Gaggini, Rusterholz & Baur, 2017), serve as seed sources for nearby woodlands, resulting in ecological consequences extending beyond the urban context. Furthermore, the spread of non-native species to nearby pristine ecosystems might be expedited due to the complex interactions of numerous dispersers (Gelmi-Candusso & Hämäläinen, 2019). Even while habitat fragmentation and land destruction remain a worry, higher percentages of species with endo-zoochory dispersal in Ipoh areas indicate better survival conditions for most animal groups.

CONCLUSION

To summarise, urbanization does not always lower the nature conservation value of regions in Ipoh, and taxa that perform key ecosystem processes may also benefit. The new urban habitat conditions allowed endo-zoochory dispersion to thrive. Animal-dispersed plants might be less likely to become extinct in an urban setting, which could explain the high prevalence of zoochory-dependent plants in this study area. However, in a selected region for urban, suburban, and rural, the human aspect is critical for plant species establishment. Humans cultivated plants for landscape and beauty purposes, especially in metropolitan areas. In addition, most cultivated plants can be found in residential neighbourhoods.

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Supplementary material:

Family	Plant species	Presence at urbanization level				Dispersal mode							References
		U	S	R	W	A	En	Ex	M	Hy	B	Hu	
Anacardiaceae	*Buchanania arborescens*				√		√						Lee et al., 2002
	Mangifera indica	√	√	√	√		√		√			√	Magloire et al., 2018 Lee et al., 2002 Lemmens et al., 1995
	Swintonia floribunda				√	√	√	√		√			Kochummen et al., 1996
Annonaceae	*Monocarpia marginalis*				√		√						Lee et al., 2002 Hanum, 1999
	Polyaltia cauliflora				√		√						Lee et al., 2002
Apocynaceae	*Alstonia angustiloba*		√			√	√						Shono et al., 2006
	Alstonia spathulata				√	√							Corlett, 1991
	Plumeria alba	√							√			√	Staples & Elevitch, 2006
Araliaceae	*Arthrophyllum diversifolium*				√		√						Lee et al., 2002
Asteraceae	*Chromolaena odorata*		√			√		√					Blackmore, 1998
Bignoniaceae	*Tabebuia rosea*	√			√	√							Croat, 1978
Calophyllaceae	*Mesua ferrea*				√		√	√					Lee et al., 2002
Cannabaceae	*Trema tomentosa*				√	√	√		√				Moran, 2007 Soepadmo, 1974
Caricaceae	*Carica papaya*	√	√				√					√	Magloire et al., 2018 Staples & Elevitch, 2006
Celastraceae	*Salacia maingayi*				√		√						Kitamura et al., 2002
Combretaceae	*Terminalia mantaly*	√	√				√						Magloire et al., 2018
Family	**Plant species**	**Presence at urbanization level**				**Dispersal mode**							**References**
		U	S	R	W	A	En	Ex	M	Hy	B	Hu	
Dipterocarpaceae	*Dipterocarpus oblongifolius*				√	√			√				Hosaka et al., 2009
	Shorea bracteolata				√	√	√		√				Hosaka et al., 2009
	Shorea hopeifolia				√	√	√		√				Hosaka et al., 2009
	Shorea multiflora			√		√			√				Hosaka et al., 2009
Euphorbiaceae	*Hura crepitans*	√		√							√		Deegan, 2012
	Hevea brasiliensis			√	√		√				√		Magloire et al., 2018
	Macaranga denticulata		√				√						Lee et al., 2002
	Macaranga tanarius		√	√	√		√						Moran, 2007

	Mallotus muticus		√	√		√	√		√				Yamasaki et al., 2013
Fabaceae	*Acacia auriculiformis*		√	√	√			√	√	√			Brown et al., 2012
	Acacia mangium		√		√			√	√	√			Brown et al., 2012 Butcher et al., 2004
	Adenanthera pavonina	√	√				√						Sosef, 1998
	Aganope thyrsiflora				√	√	√	√					Parthasarathy et al., 2015
	Bauhinia purpurea			√			√						Lim et al., 2018
	Caesalpinia sappan	√							√				Roubik, 1995
	Milletia pinnata				√				√				Arpiwi et al., 2014
	Parkia speciosa		√				√	√	√				Lee et al., 2002
Family	**Plant species**	**Presence at urbanization level**				**Dispersal mode**							**References**
		U	S	R	W	A	En	Ex	M	Hy	B	Hu	
	Samanea saman	√					√		√			√	Staples & Elevitch, 2006
Guttiferae	*Garcinia mangostana*			√	√		√					√	Staples & Elevitch, 2006
Hypericaceae	*Cratoxylum formosum*				√	√	√	√					Blackham et al., 2014
	Cratoxylum maingayi				√	√							Blackham et al., 2014
	Ficus benjamina		√		√		√						Kitamura et al., 2002
	Ficus elastica			√			√						Lim et al., 2018
	Ficus hispida			√	√		√						Kitamura et al., 2002
	Ficus magnoliifolia				√		√						Lee et al., 2002
	Ficus racemosa				√		√						Lim et al., 2018
	Ficus religiosa			√	√		√						Lim et al., 2018
	Ficus sinuata				√		√						Kitamura et al., 2002
	Streblus elongatus				√		√						Sosef, 1998
Moringaceae	*Moringa oleifera*	√					√	√					Jyotri et al., 1990
Muntingiaceae	*Muntingia calabura*		√	√			√						Kitamura et al., 2002
Myrtaceae	*Syzygium aqueum*	√			√		√					√	Lim et al., 2018
	Syzygium grande			√	√		√						Lim et al., 2018
Family	**Plant species**	**Presence at urbanization level**				**Dispersal mode**							**References**
		U	S	R	W	A	En	Ex	M	Hy	B	Hu	
	Syzygium myrtifolium				√		√						Blackham et al., 2014
	Syzygium valdevenosum				√		√						Tarszisz et al., 2018
	Syzygium zeylanicum			√			√						Corlett, 2017
Olacaceae	*Ochanostachys amentacea*				√		√						Lemmens et al., 1995
Opiliaceae	*Champereia manillana*				√		√						Hanum, 1999

Ochnaceae	*Ochna kirkii*		√				√						Teo et al, 2011
Oxalidaceae	*Sarchotheca griffithii*				√		√						Sosef, 1998
Pandaceae	*Microdesmis caseariifolia*				√		√	√					Clark et al., 2001
Passifloraceae	*Paropsia vareciformis*				√				√				Fiala et al., 1995
Pentaphylacaceae	*Eurya acuminata*				√		√						Kitamura et al., 2002
Phyllanthaceae	*Antidesma cuspidatum*				√		√						Lee et al., 2002
	Aporosa penangensis				√		√						Schot, 2004
	Aporosa symplocoides				√		√		√				Schot, 2004
	Baccaurea parviflora				√		√						Lucas et al., 1998
Polygalaceae	*Xantophyllum affine*				√		√		√				Lee et al., 2002
Family	Plant species	Presence at urbanization level				Dispersal mode							References
		U	S	R	W	A	En	Ex	M	Hy	B	Hu	
Rhamnaceae	*Ziziphus mauritiana*			√			√						Sosef, 1998
Rhizophoraceae	*Pellacalyx saccardianus*				√		√						Hodgkison et al., 2003
Rubiaceae	*Aidia densiflora*	√					√						Hanum, 1999
	Morinda citrifolia	√		√	√		√						Lee et al., 2002
	Morinda elliptica				√		√						Lee et al., 2002
	Pertusadina eurhyncha				√	√		√					Sosef 1998
Sapindaceae	*Nephelium lappaceum*		√	√			√					√	Staples & Elevitch, 2006
	Pometia pinnata				√		√		√				Lee et al., 2002
Sapotaceae	*Mimusops elengi*				√	√	√						Lim et al., 2018
	Palaquium gutta				√		√						Lim et al., 2018
Symplocaceae	*Symplocos cochinchinensis*				√		√						Sosef, 1998
Ulmaceae	*Gironniera nervosa*				√	√	√						Sosef, 1998

NOTE: U=Urban, S=Suburban, R=Rural, W=Wild land; Dispersal mode of plant species in Ipoh, Perak. NOTE: A= Anemochory, En= Endo-zoochory, Ex= Exo-zoochory, M= Myrmecochory, Hy= Hydrochory, B= Ballistichory, Hu= Hemerochory