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Mistletoe abundance, distribution and associations with trees along roadsides in Penang, Malaysia

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Abstract: Despite their devastating effects on trees and, therefore, conservation importance, little is known about mistletoe distribution and associations with trees. The study was conducted to determine mistletoe abundance, distribution and their associations with trees in Penang, Malaysia. Mistletoes and their hosts were sampled at two main sites, roadside and an adjacent interior site. A total of 1431 mistletoe shrubs belonging to five species, four genera and two families were identified. These were found on 29 tree species belonging to 24 genera and 13 families. The most abundant mistletoe species was *Scurrula ferruginia* (718 individuals) followed by *Dendrophthoe pentandra* (585 individuals). Mistletoe abundance differed significantly between the species ($P < 0.001$) although it was similar between the roadside and interior sites ($P = 0.565$). *Dendrophthoe pentandra* infested 93 % of the recorded host species. *Tabebuia pallida* was the most frequently parasitised. Mistletoe abundance depended significantly on host diameter, height and crown shape. The mistletoes were non-randomly distributed between host species, and while some mistletoes preferred certain hosts, others were not found to have specific preferences. *D. pentandra* and *S. ferruginia* showed positive and negative associations, respectively with more tree species in the study.

Resumen: A pesar de susefectos de vastadores sobrelos árboles y su consiguiente importancia para la conservación, se sabe poco sobre la distribución de los muérdagos y sus asociaciones con losárboles. Elestudio se realizó con el fin de determinar la abundancia y la distribución del muérdago y sus asociaciones con árbolesen Penang, Malasia. Los muérdagos y sus hospederos fueron muestreadosen dos sitios principales, borde de camino y un sitio adyacente del interior del bosque. En total se registraron 1431 arbustos de muérdago pertenecientes a cinco especies, cuatro génerosy dos familias. Éstos fueron encontrados sobre 29 especies de árboles pertenecientes a 24 génerosy 13 familias. La especie de muérdago más abundante fue *Scurrula ferruginia* (718 individuos), seguida de *Dendrophthoe pentandra* (585 individuos). La abundancia de los muérdagos difirió significativamente entreespecies ($P < 0.001$), aunque fue similar entre los sitios de borde de camino y del interior ($P = 0.565$). *Dendrophthoe pentandra* infestó 93 % de las especies registradas de hospederos. *Tabebuia pallida* fue la especie parasitada con mayor frecuencia. La abundancia del muérdago dependió significativamente del diámetro, la altura y la forma de la copa del hospedero. Los muérdagos no se distribuyeron al azar entre las especies hospederas, y mientras que algunos muérdagos prefirieron ciertos hospederos, para otras no se encontraron preferencias específicas. *D. pentandra* y *S. ferruginia* mostraron asociaciones positivasy negativas, respectivamente, con más especies arbóreas en elestudio.

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Resumo: Apesar de seus efeitos devastadores sobre as árvores e, portanto, a sua importância para a conservação, pouco se sabe sobre a distribuição do visco e sua associaçãocom árvores. O estudo foi realizado para determinar a abundância do visco, a distribuição e as suas associações com as árvores em Penang, Malásia. O visco e os seus hospedeiros foram coletados em dois locais principais, à beira de estradas e num local interior, adjacente. Foram identificados um total de 1.431 arbustos de visco pertencentes a cinco espécies, quatro géneros e duas famílias. Estes foram encontrados em 29 espécies arbóreas, pertencentes a 24 géneros e 13 famílias. As espécies mais abundantes de viscoforam a *Scurrula ferruginia* (718 indivíduos), seguida por *Dendrophthoe pentandra* (585 indivíduos). A abundância de viscos diferiu significativamente entre as espécies (P < 0,001), embora tenha sido semelhante entre os locais na beira da estrada e interior (P = 0,565). A Dendrophthoe pentandra infestava 93 % das espécies hospedeiras registadas. A *Tabebuia pallida* foi a espécie mais frequentemente parasitada. A abundância dos viscos dependia significativamente do diâmetro do anfitrião, altura e forma do copado dos hospedeiros. Os viscosencontravam-se distribuídos de forma não aleatória entre as espécies hospedeiras, e enquanto alguns viscos preferiam certos hospedeiros, outros não mostraram ter preferências específicas. Neste estudo, a *D. pentandra* e a *S. ferruginia* mostraram associações positivas e negativas, respectivamente, com mais espécies de árvores.

Key words: Abundance, distribution, host specificity, mistletoes, mistletoe-tree associations, host.

Introduction

Mistletoes of the family Loranthaceae are hemiparasitic shrubs that take water and nutrients from host plants, but are able to photosynthesise. They are reported to show host specificity (Norton & Carpenter 1998), although many species occur on a wide range of hosts from many ecosystems, especially forests and woodlands (Calder 1983; Hawksworth 1983). Most Asian mistletoes have obligate relationship with certain families of birds such as the sunbirds and flower-peckers that pollinate the flowers and disperse the seeds (Bishop 2010; Davidar 1980, 1983; Kuijt 1969). Like other parasitic organisms, mistletoes may show specialisation on host species due to a number of factors. A number of mistletoe species are specialised in living on different hosts due to frequent encounters between mistletoe seeds and commonest plants (Fadini 2011). Some studies have indicated that non-random perch preferences of seed dispersers are important for determining host specificity (Monteiro *et al.* 1992). This may result in concentration of mistletoe seeds on either the most abundant trees or the less abundant ones (Fadini 2011).

To control mistletoes, that tend to destroy host trees, an understanding of the factors regulating their abundance and distribution is needed (Norton & Reid 1997). The importance of tree availability in regulating mistletoe distribution has been reported (de Lange *et al.* 1997; Norton 1997). Additionally, the effects of forest fragmentation on mistletoe abundance and distribution have been studied (Norton *et al.* 1995). However, only little is known about the distribution patterns of mistletoes on tree species. Furthermore, there is limited information concerning the association between mistletoes and their host species. Though roadside survey of mistletoes has been reported to be effective, only a limited number of studies have used this approach (Merrill & Hawksworth 1985; Mathiasen *et al.* 1996). The aim of the study was to determine the abundance and distribution of mistletoes, and their association with trees. It was hypothesised that mistletoe abundance may differ among tree species, and between roadside and interior site. Furthermore, it was hypothesised that mistletoes are randomly distributed on host trees and will show associations with tree species.

Materials and methods

The study was conducted along the Sungai Dua road in Penang Malaysia (5° 24′00″ N and 100° 14′20″ E), where many avenue trees have been planted. The climate of the area is tropical with an average annual rainfall of about 2670 mm.

Table 1. Abundance of mistletoe species identified in the study area.

Species	Family	Abundance
Dendrophthoe pentandra (L.) Miq.	Loranthaceae	588
Scurrula ferruginia (Roxb. ex Jack) Danser	Loranthaceae	727
Macrosolen cochinchinensis (Lour.) Tiegh.	Loranthaceae	29
Viscum ovalifolium DC.	Santalaceae	76
Viscum articulatum Burm. f.	Santalaceae	11

The daily temperature ranges from 24° to 32 °C and relative humidity ranges from 70 to 90 %. The mean altitude of the study area is 67 m a.s.l. (range: 65 - 110 m a.s.l.).

Sampling

The sampling method used in this study followed the road side survey approach reported by Merrill & Hawksworth (1985) and Mathiasen *et al.* (1996). Four transects (1 km long and 20 m wide) were demarcated along the Sungai Dua roadside in Penang. Each transect was about 5 m from the edge of the road. A similar number of transects was also located in the interior of the road (100 m from the road) for comparison with the roadside transects. Within each transect, all trees with dbh ≥ 10 cm were examined for the presence of mistletoes. In addition, diameter, height and crown shape of host species were determined.

Data analyses

The observed distribution of mistletoes among trees was tested against the expected distribution under the null hypothesis of random mistletoe distribution among trees (Rist *et al.* 2011). This analysis was conducted with chi square goodness of fit test. Two way non-parameteric multivariate analysis of variance (NPMANOVA) was performed to examine the effects of host species, site, and interaction between them on mistletoe abundance using Bray-Curtis distances (Anderson 2001). Simple linear regression was conducted to determine the relationship between mistletoe abundance and the host characteristics such as: diameter, height, canopy shape. Normality of the data was checked with probability plots whereas homogeneity of variance was verified with residual plots. No transformation of data was done as the data passed normality and homogeneity tests.

To determine single species association of mistletoes with trees, the Monte Carlo test of randomisation, which compared observed and expected abundance of mistletoes on trees, was conducted (Webb & Peart 2000). The randomisation test comprised of 1000 repetitions of shuffling trees that hosted mistletoes. In each case, the observed abundance of each species was compared to the expected abundance generated by randomly shuffling the trees. A mistletoe species was statistically associated with a habitat if its observed abundance was more extreme than at least 97.5 % of the expected abundance. An association was positive or negative when the observed abundance was greater or less respectively, than the expected abundance for more than 97.5 % of the randomisations. All analyses were run at a significance level of 5 % using the SAS version 8 (SAS Institute) except for the NPMANOVA which was run with PAST programme.

Results

A total of 480 trees representing 39 species, 32 genera and 15 families were identified in the study area, of which 29 species (79 %) belonging to 24 genera and 13 families hosted mistletoes (Table 3). Fabaceae was the most dominant host family (8 species), followed by Myrtaceae (4 species), Moraceae (3 species), Apocynaceae (3 species), Rubiaceae (3 species) and Sapindaceae (3 species). *Swietenia macrophylla* and *Tabebuia pallida* were the most abundant tree species in the study area. Accordingly, these species had more of their individuals hosting mistletoes than any other tree species. Mistletoe abundance related significantly with tree dbh, height and crown shape (r^2 = 49, $P < 0.001$; r^2 = 39, $P = 0.001$; r^2 = 34, $P = 0.003$, respectively).

Mistletoe distribution and abundance on trees

A total of 1431 mistletoes representing five species, four genera and two families were identified in the study area (Table 1). *Scurrula ferruginia* was the most abundant species (727 individuals) followed by *Dendrophthoe pentandra* (588 individuals). Mistletoe abundance differed significantly among host species ($P < 0.001$) although it remained the same between roadside and interior site ($P = 0.565$). The interaction between host species and site was significant ($P < 0.001$). *D. pentandra* was the most common species,

Table 2. Mistletoe species load on host tree species in the study area.

Tree species	Number of visible infected spots of mistletoe species on trees				
	D. pentandra	*S. ferruginea*	*M. cochinchinensis*	*V. ovalifolium*	*V. articulatum*
Acacia auriculiformis	7	-	-	-	-
Alstonia angustiloba	24	-	-	-	10
Artocarpus incisus	2	-	-	-	-
Artocarpus heterophyllus	26	5	15	-	-
Azadirachta indica	11	-	-	-	-
Bauhinia purpurea	3	1	-	-	-
Cinnamomum iners	4	-	-	-	-
Erioglossum rubiginosum	17	11	2	76	-
Ficus fruiticosa	1	12	-	-	-
Filicium decipiens	12	-	-	-	-
Gardenia carinata	2	1	-	-	-
Kopsia arborea	14	-	-	-	-
Lagerstroemia speciosa	-	58	-	-	-
Mangifera foetida	4	-	-	-	-
Mangifera indica	16	6	3	-	-
Manilkara zapota	1	2	1	-	-
Mimusops elengi	1	10	-	-	-
Nephelium lappaceum	14	12	-	-	-
Peltophorum pterocarpum	23	-	-	-	-
Punica granatum	-	2	-	-	-
Samanea saman	61	51	-	-	-
Swietenia macrophylla	196	4	-	-	-
Syzygium aqueum	42	7	-	-	-
Syzygium cumini	14	17	-	-	-
Syzygium jambos	7	8	-	-	-
Syzygium malaccense	3	-	-	-	-
Tabebuia pallida	1	510	-	-	-
Terminalia calamansanai	48	1	5	-	1
Terminalia catappa	31	-	-	-	-

infesting more host species (99.5 %) than any of the other species (Table 2). This was followed by *S. ferruginia*, which infested 28 % of the host species. The remaining species occurred on only a few tree species. *Erioglossum rubiginosum* was infested by higher number of mistletoe species (four out of the five mistletoe species) than other tree species. *T. pallida* was infested most by *S. ferruginia* (510 individuals) whereas *S. macrophylla* was infested most (196 individuals) by *D. pentandra*. Mistletoe distribution on trees was non-random in the studied plots (χ^2 = 1145.94, df = 28, P = 0.001).

Mistletoe-tree associations

All the mistletoe species showed significant associations with one tree species or the other (Table 4). *D. pentandra* showed associations with 19 of the tree species in the study. This consisted of 13 positive and seven negative associations with the host species. *S. ferruginia* had associations with 21 tree species out of which 4 were positive and 17 were negative. The rest of the mistletoe species showed positive association with a few of the tree species; most of the associations were negative. *Terminalia calamansanai* was the only

Table 3. Tree species abundance and number hosting mistletoe species in the study area.

Tree species	Family	No. of trees	No. of trees hosting mistletoes
Acacia auriculiformis A. Cunn.	Fabaceae	1	1
Alstonia angustiloba Miq.	Apocynaceae	1	1
Artocarpus incisus (Thunb.) L.	Moraceae	4	1
Artocarpus heterophyllus L.	Moraceae	17	10
Azadirachta indica A. Juss.	Meliaceae	13	4
Bauhinia purpurea L.	Fabaceae	7	3
Cinnamomum iners Reinw. ex Blume	Lauraceae	1	1
Erioglossum rubiginosum (Roxb.) Blume	Sapindaceae	5	3
Ficus fruiticosa Roxb.	Moraceae	7	5
Filicium decipiens (Wt. & Arn.) Thw.	Sapindaceae	9	5
Gardenia carinata Wall. ex Roxb.	Rubiaceae	2	2
Kopsia arborea Blume	Apocynaceae	11	8
Lagerstroemia speciosa (L.) Pers.	Lythraceae	4	4
Mangifera foetida Lour.	Anacardiaceae	2	3
Mangifera indica L.	Anacardiaceae	11	7
Manilkara zapota (L.) van Royen	Sapotaceae	1	1
Mimusops elengi L.	Sapotaceae	12	1
Nephelium lappaceum L.	Sapindaceae	18	10
Peltophorum pterocarpum (DC.) Backer ex Heyne	Fabaceae	21	7
Punica granatum L.	Fabaceae	1	1
Samanea saman F. Muell.	Lythraceae	12	12
Swietenia macrophylla King	Meliaceae	107	83
Syzygium aqueum (Burm.f.) Alsto	Myrtaceae	12	10
Syzygium cumini (L.) Skeels	Myrtaceae	1	1
Syzygium jambos Alston	Myrtaceae	1	1
Syzygium malaccense (L.) Merr. & Perry	Myrtaceae	3	2
Tabebuia pallida (Lindl.) Miers.	Bignoniaceae	103	58
Terminalia calamansanai (Blanco) Rolfe	Combretaceae	11	5
Terminalia catappa L.	Combretaceae	21	5

tree species which had positive association with more than one mistletoe species.

Discussion

Mistletoe abundance varied significantly between host species in the study, with species such as *Alstonia angustiloba*, *Artocarpus heterophyllus*, *Syzygium cumini* and *E. rubiginosum* carrying significantly more mistletoe numbers than all the other host species. This phenomenon may be due to a number of factors including host selection by birds (Buen & Ornelas 1999), ability of mistletoe seeds to become established more success-fully on some tree species than others (Reid *et al.* 1995), and variation in the persistence level of adult mistletoes among tree species (Hoffmann *et al.* 1986). It has been hypothesised that roads modify hydrology and nutrient patterns, thereby providing better habitat for mistletoe to thrive (cf. Norton & Smith 2009). However, mistletoe abundance remained the same between the roadside and interior host species. This finding is contrary to the work of Norton & Smith (2009) in which mistletoes were significantly more abundant in roadsides than interior sites. The lack of significant difference in mistletoe abundance between roadside and interior site in this study could be

Table 4. The associations between mistletoe and tree species in the study area (mistletoe species names are coded with their shortened forms). Positive association is indicated by a positive sign (+) whereas negative association is indicated by a negative sign (-).

Tree species	Mistletoe association				
	D. pentandra	*S. ferruginea*	*M. cochinchinensis*	*V. ovalifolium*	*V. articulatum*
Acacia auriculiformis	+	–	–	–	–
Alstonia angustiloba	+	–	–	–	+
Artocarpus incisus		–	–	–	–
Artocarpus heterophyllus	+	–	+	–	–
Azadirachta indica	+	–	–	–	–
Bauhinia purpurea			–	–	–
Cinnamomum iners		–	–	–	–
Erioglossum rubiginosum	–	–		+	–
Ficus fruiticosa	–	+	–	–	–
Filicium decipiens	+	–	–	–	–
Gardenia carinata			–	–	–
Kopsia arborea	+	–	–	–	–
Lagerstroemia speciosa	–	+	–	–	–
Mangifera foetida		–	+	–	–
Mangifera indica	+	–		–	–
Manilkara zapota			–	–	–
Mimusops elengi	–		–	–	–
Nephelium lappaceum			–	–	–
Peltophorum pterocarpum	+	–	–	–	–
Punica granatum	–		–	–	–
Samanea saman	+		–	–	–
Swietenia macrophylla	+	–	–	–	–
Syzygium aqueum	+	–	–	–	–
Syzygium cumini			–	–	–
Syzygium jambos			–	–	–
Syzygium malaccense		–	–	–	–
Tabebuia pallida	–	+	–	–	–
Terminalia calamansanai	+	–	+	–	
Terminalia catappa	+	–	–	–	–

attributed to the lower host species abundance that occurred along the roadside. Therefore, the roadside might have provided a better habitat but due to the limited number of hosts, mistletoe abundance along the roadside could not surpass that of the interior site. The significant interaction between host species and site suggests that differences between host species were not the same in all the sites.

Mistletoe abundance was influenced by a number of factors related to host characteristics. Tree height was an important host feature that controlled mistletoe distribution and abundance in the study. Generally, taller trees hosted more mistletoes than shorter trees. It has been suggested that tall trees tend to attract more dispersers of mistletoes compared to shorter trees (Buen *et al*. 2002), which explains why taller trees hosted more mistletoes in this study. Diameter of host trees was also another characteristic which influenced mistletoe abundance on host species. This finding is at variance with the work of Buen *et al*. (2002) in which there was no significant influence of host diameter on mistletoe abundance. The positive relationship between mistletoe abundance and tree diameter in this study could be due to the fact that larger trees received more mistletoe seeds as they served as better perches for birds (Overton 1994). Trees with conical crown shape hosted more mistletoe individuals compared with trees with non-conical crown shape. Conical crowns are known to create large gaps at the top of the canopy, thereby allowing greater sunlight penetration (Smith & Brewer 1994). This condition probably favoured the growth and development of mistletoe species.

All the mistletoe species showed strong associations with one host species or another in the study. These associations differed from species to species, with *D. pentandra* and *S. ferruginea* showing associations with more tree species than other mistletoes in the study. Whereas most of the associations were positive for *D. pentandra*, majority of the associations between *S. ferruginea* and the host species were negative. These findings demonstrate that different species of mistletoes specialise with different host species in different forms. For some of the mistletoe species (*D. pentandra*, *S. ferruginea* and *Macrosolen cochinchinensis*) host specificity with trees did not depend on host abundance as they showed positive association with both abundant and less abundant tree species. This shows that mistletoe specialisation on trees was not as a result of frequent encounter of mistletoe seeds and host trees. Rather, the pattern may be explained by non-random perch preferences of dispersal birds (Monteiro *et al.* 1992) which might have resulted in the concentration of seeds on both most abundant and less abundant tress (Buen & Ornelas 1999; Roxburgh & Nicolson 2005). Mistletoes were non-randomly distributed on host trees, confirming the findings of some previous studies (Norton *et al.* 1997; Rist *et al.* 2011). The distribution of mistletoes on host species varied between the mistletoe species. Whereas *V. ovalifolium* and *V. articulatum* infested only one and two tree species respectively, the rest of the mistletoe species were found on many more tree species. Furthermore, these mistletoe species exhibited positive association with only one species each, showing narrow host specificity. These findings demonstrate that *V. ovalifolium* and *V. articulatum* may have restricted host ranges.

Conclusions

Mistletoe abundance and distribution were influenced by host species and their characteristics (diameter, height and canopy shape). Roadside mistletoe abundance did not differ significantly from the interior site abundance. Mistletoes showed non-random distribution on their hosts. All the mistletoe species showed associations with different tree species. The general patterns of mistletoe abundance and distribution as well as mistletoe-tree associations observed in this study could be useful in the management of mistletoes in Malaysia and beyond.

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