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Original article

Infestation and host specificity of mistletoe parasitic plants in Purwodadi Botanic Garden

Solikin Solikin

Research Center for Ecology and Ethnobiology, National Research and Innovation Agency, Jl. Raya Jakarta-Bogor Km 46, Cibinong, Bogor West Java 16911, Indonesia.

Abstract

Mistletoes are hemiparasitic aerial plant that invade and parasitize wild and cultivated plants. Depending on the diversity of their host plants, they can be classified as generalists and specialists. The Shannon index of the host plants diversity can be used to determine host specificity of mistletoes. This study aimed investigate the evolution of misletoes and temporal variation of host plants and or their specificity in Purwodadi Botanic Garden during 2013-2021. Observational data were collected using exploratory and descriptive methods, i.e., species and number of mistletoe and their hosts. The mistletoes species was identified using binoculars in the garden and further identified by constructing herbarium specimens and photographs. The results showed that five mistletoes species infested 142 species, 82 genera, and 36 families. A significant relationship was found between the number of mistletoe species and the number of host plants infested. The number of host plants infested tended to decrease between 2013 and 2021. *Scurrula atropurpurea* was the most specialized mistletoe with a Shannon index of 0.16±0.09. In short, it is necessary to increase the control of mistletoe population and mistletoe infestation on crop plants.

Keywords: host specificity, parasitic plant, Purwodadi Botanic Garden

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Introduction

Globally, there are an estimated 4200 species of parasitic plants distributed in 18 families and 274 genera (Nickrent, 2002). These plants grow as aerial parasites on stems or as terrestrial parasites on roots of other plants as their hosts. Parasitic aerial plants commonly referred to as mistletoes (Nickrent, 2002; Ntoukakis and Gimenze-Ibanez, 2016) have been frequently discovered as parasites in crop plants, such as the mistletoe *Dendrophtoe pentandra* on *Dillenia philippensis*, *Cassia garrettiana, Ficus fistulosa*, and *Hydnocarpus sumatranus* in Purwodadi Botanic Garden (Solikin, 2016), *Annona reticulata, Annona squamosa,* and *Psidium guajava* in Bangkalan Madura (Solikin, 2020). Mistletoe adheres to its host plants with a specialized organ, the haustorium (Yoshida et al., 2016), and is directly dependent on host plants for mineral nutrition, including nitrogen (Daryaei and Moghadam, 2012; Teodoro et al., 2013; Griebel et al., 2017), affecting host plants growth. Bediako et al. (2013) reported that parasitization and infestation of mistletoe in central Ghana caused growth retardation, mortality, and yield reductions in citrus (65%, 55%, and 95%, respectively). Lech et al. (2020) showed that European mistletoe (*V. album*) has emerged as an important pest of forest trees in Central Europe, resulting in defoliation of tree crowns. Mistletoe infestation on teak clonal seed orchards (CSO) caused a significant decline in fruit yields of many mother trees (Muttaqin et al., 2016). Mistletoe *D. pentandra* infestation caused death of most branches and twigs of *C. fistula* in Purwodadi Botanic Garden (Solikin, 2021).

Some mistletoes are classified as "specialists" due to the fact that they are only found on a few host plants, while others associated with multiple host plants are classified as "generalists" (Norton and Carpenter, 1998; Norton and De Lange, 1999; Fadini, 2011). The benefits of adapting to a common host may favor parasites with host specificity (Norton and Carpenter, 1998). Generalists such as mistletoe *D. falcata* and *S. pulverulenta* infest 401 species (Hawksworth et al., 1993) and 81 species (Pundir, 1995) of host plants, respectively, when host populations are unpredictable and short-lived (Okubamichael et al., 2016). The specialist mistletoe, such as *Plicosepalus kalachariensis* and P. *undulate*s, are found only on Acacia species (Norton and de Lange, 1999). Mistletoes could function as host generalists or specialists, depending on several inherent and external factors, including host plant characteristics (abundance, diversity, height, age, diameter, and compatibility), season, pathogen, and dispersal patterns (Isikhuemen et al., 2020). Information on the level of host specificity is critical to further understanding the ecology of structurally dependent plants such as parasitic plants. It is also essential to investigate host specificity at the family, genus, and species levels since available species that can be parasitized at each level vary and not all species in a genus can be parasitized in the same way by specialized mistletoes (Okubamichael et al., 2016)

Purwodadi Botanic Garden, as an ex situ conservation area, has cultivated and conserved many plant species from relatively dry grasslands area in Indonesia. Mistletoe has been observed parasitizing a

* Corresponding Author:
Solikin Solikin
Research Center for Ecology and Ethnoecology, National Research and Innovation Agency, Purwodadi Botanic Garden, Jl. Raya Surabaya-Malang km 65, Purwodadi, Pasuruan East Java 67163, Indonesia.
Phone: 081334522748 Fax: -
E-mail: solikin@brin.go.id/lipisolikin@gmail.com

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variety of tree and shrub species in the garden. Solikin (2016) reported that five mistletoes were found in Purwodadi Botanical Garden,, namely *D. pentandra, M. tetragonus, S. atropurpurea, V. articulatum, and V. ovalifolium*. No such studies have been conducted on the distribution and specificity of mistletoe in the Purwodadi Botanical Garden. Thus, it is important to obtain information on plant species potentially parasitized by mistletoe and on the dominance, generalization and specificity of mistletoe in the garden. This study aimed to explore the development of misletoes and temporal variation of host plants and or specificity in Purwodadi Botanic Garden during 2013-2021. This study is essential for managing plant collections to control the population of parasitic plants.

Methods

Time and location

The studies were conducted in Purwodadi Botanic Garden at an altitude of about 300 m in an area of 85 ha, located in Purwodadi District, Pasuruan Regency, East Java Province, Indonesia (Figure 1B). This location was bordered by Taman Wisata Alam Gunung Baung and Welang River (East), Kertosari Village (North), Purwodadi Village (South), and Malang – Surabaya highway (West). Meteorological data, including precipitation (2232 mm per year), rainy day (152 days per year), relative air humidity (RH) (74.33%), minimum and maximum temperature (20.37ºC and 30.82ºC), were obtained from climate station in Purwodadi Botanic Garden during 2014 – 2019 (Solikin 2021). Rainy season was occured in November-April, while dry season in May-October. The plants collection are planted in blocks according to their families and themes. The blocks are bordered by footpaths and roads (Figure 1).

Data collection and analysis

The observed data were collected using exploratory and descriptive-based methods every four years from 2013 to 2021 (2013, 2017, 2021) by observing species and numbers of mistletoe and their hosts. Binoculars were exploited to facilitate observation and identification of species and numbers of mistletoe in plant canopies. A hand counter was utilized to enumerate the number of mistletoe attached to each host plant. Identification of mistletoe species and their host plants was achieved directly in the garden. Herbarium specimens were constructed and photographed for further identification of mistletoe and their hosts. The level of host specificity of mistletoe was determined by measuring the Shannon index (Norton and de Lange, 1999; Maqurran, 2004):

$$H' = -\sum Pi \ln Pi$$

Where Pi is the proportion of records found on the i-th host species. Mistletoes with low diversity scores are the most host-specific and parasitize a small number of hosts with one host, while those with high diversity scores are the least host-specific and parasitize many hosts without any one host dominating. An ANOVA analysis was performed to determine the difference between mistletoe species and number of host plants infested.

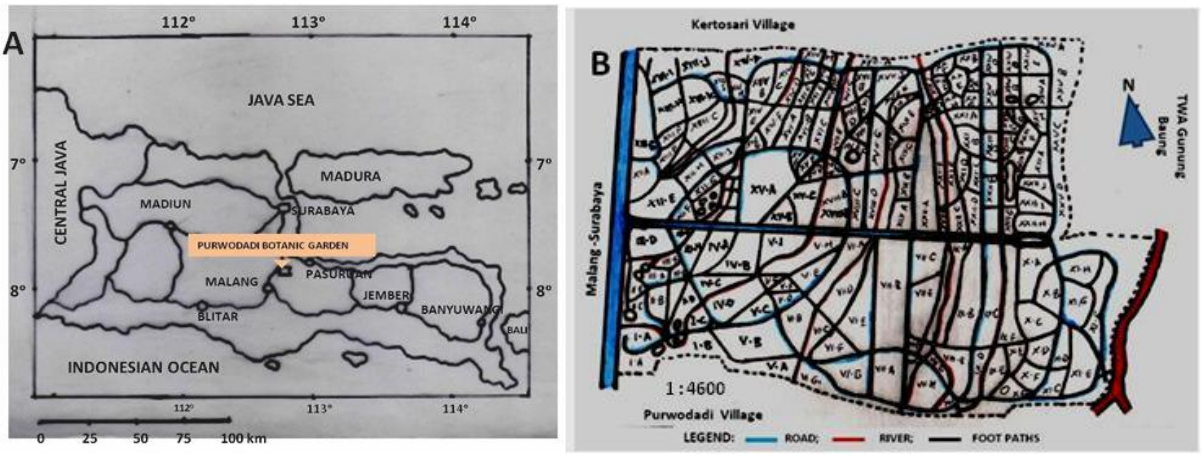

Figure 1. Maps : A.Location of Purwodadi Botanic Garden, East Java, Indonesia; B. Garden and blocks of plants collection in Purwodadi Botanic Garden

Results

Species of mistletoes ond host plants

Five mistletoe species, including *D. pentandra, M. tetragonus, S. atropurpurea, V. articulatum, and V. ovalifolium,* were observed as parasites on collected plants in Purwodadi Botanic Garden during 2013 -2021 (Figure 2), and were classified as aerial hemiparasites. They parasized different species, genus and family of cultivated plants in the gardens. Table 1 showed that 142 species, 82 genera and 36 families of host plants were infested by mistletoe in Purwodadi Botanic Garden during 2013-2021. They are categorized as trees, shrubs, and woody plants with species number of 110, 30, and 2, respectively (Table1). A significant difference was found between mistletoe species and the number of species, genera, and families of host plants parasitized by mistletoe ($p<0.05$). *D. pentandra* parasitized the most species (71.33), genus (53.00) and family (26.33) of the host plants (Table 2).

Specificity of mistletoes on host plants

The level of host specificity of mistletoe parasites can be assessed using the Shannon index (H'). The H' values of mistletoe species infesting host plants were significantly different (P<0.05) (Table 3). The highest H' value was obtained by *D. pentandra* with an H' value of 2.20±0.10, and the lowest H' value was obtained by *S. atropurpurea* with an H' value of 0.16±0.09 (Table 3)

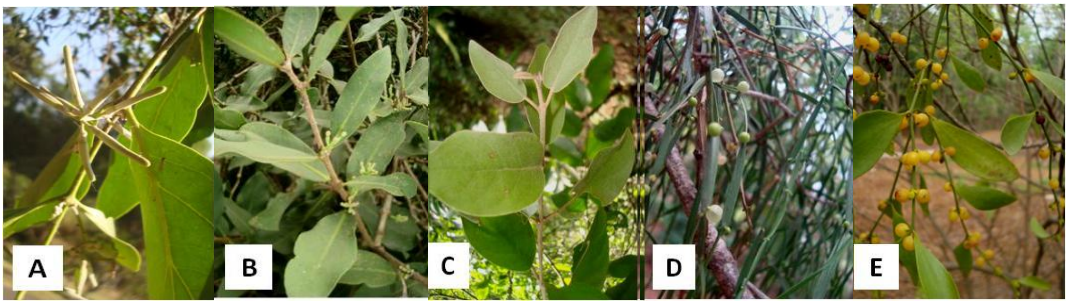

Figure 2. Species of mistletoes found in Purwodadi Botanic Garden A= D. pentandra, B= M. tetragonus, C= S. atropurpurea, D= V. articulatum, E= V.ovalifolium

Table 1. The species presence of host plants parasitizied by mistletoes in Purwodadi Botanic Garden during 2013-2021

Species	Family	Habit	Dp	Mt	Sa	Vo	Va	Species	Family	Habit	Dp	Mt	Sa	Vo	Va
Acacia auriculiformis	Leguminosae	T	+	-	-	-	-	*Glochidion sp2*	Euphorbiaceae	T	+	-	-	-	-
A. oraria	Leguminosae	T	+	-	-	-	-	*Glochidion sp3*	Euphorbiaceae	T	+	+	-	+	-
Acacia sp	Leguminosae	T	+	-	-	-	-	*Glochidion sp4*	Euphorbiaceae	T	0	-	+	+	-
Acacia leucoploea	Leguminosae	T	+	+	-	-	-	*Glochidion sp5*	Euphorbiaceae	T	+	-	-	-	-
Acronychia sp	Rutaceae	T	+	-	-	-	-	*Glycosmis cochinchinensis*	Rutaceae	S	+	-	+	+	-
Aglaia odorata	Meliaceae	S	+	-	-	-	-	*Glycosmis gracilis*	Rutaceae	S	0	-	+	+	-
Aglaia sp.	Meliaceae	T	+	-	-	-	-	*Glycosmis pentaphylla*	Rutaceae	S	+	-	-	+	+*
Albizia chinensis	Leguminosae	T	0	-	+	+	-	*Glycosmis sp+*	Rutaceae	S	+	-	-	-	+*
Albizia lebbekoides	Leguminosae	T	0	-	+	+	-	*Glycosmis sp2*	Rutaceae	T	+	-	-	-	-
Albizia procera	Leguminosae	T	+	-	+	+	-	*Glycosmis sp3*	Rutaceae	S	0	-	-	+	
Annona muricata	Annonaceae	T	+	-	-	-	-	*Glycosmis triphylla*	Rutaceae	S	+	-	+	+	-
Antiaris toxicaria	Moraceae	T	0	+	-	-	-	*Gonocaryum litorale*	Icacinaceae	T	0	-	+	-	-
Antidesma bunius	Euphorbiaceae	T	+	-	-	-	-	*Graptophyllum pictum*	Acanthaceae	S	+	-	-	-	-
Antidesma montanum	Euphorbiaceae	S	+	-	-	-	-	*Guioa sp*	Sapindaceae	T	+	-	-	-	-
Antidesma pentadrum	Euphorbiaceae	S	+	-	-	-	-	*Holarrhena floribunda*	Apocynaceae	T	+	+	-	-	-
Arytera littoralis	Sapindaceae	T	+	-	-	-	-	*Holoptelea*	Urticaceae	T	+	-	-	-	-

									integrifolia								
Averrhoa carambola	Averrhoaceae	T	+	-	-	-	+ *	*Hydnocarpus sumatranus*	Flacourtiaceae	T	+	-	-	-	+ *
Barringtonia asiatica	Lecythidaceae	T	+	-	-	-	-	*Ixora javanica*	Rubiaceae	S	+	-	-	-	-
Blumeodendron sp.	Euphorbiaceae	T	+	-	-	-	-	*Jatropa curcas*	Euphorbiaceae	S	+	-	-	-	-
Bombax ceiba	Malvaceae	T	+	-	-	-	-	*Jatropha gossypifolia*	Euphorbiaceae	S	0	+	-	-	-
Brownea ariza	Leguminosae	T	+	+	-	-	-	*Kopsia arborea*	Apocynaceae	T	+	-	-	-	+ *
Calliandra guildingii	Leguminosae	S	+	-	-	-	-	*Lagerstoemia thorelii*	Lytheraceae	T	+	-	-	-	+ *
Calotropis gigantea	Asclepiadaceae	S	+	-	-	-	-	*Lagerstroemia loudoni*	Lytheraceae	T	+	-	-	-	-
Cassia sp	Leguminosae	T	+	-	-	-	-	*Lansium parasiticum*	Meliaceae	T	+	-	-	-	-
Cassia fistula	Leguminosae	T	+	-	-	-	+	*Limonia acidissima*	Rutaceae	T	+	-	-	-	-
Cassia grandis	Leguminosae	T	+	-	-	-	-	*Macaranga sp*	Euphorbiaceae	T	+	-	-	-	-
Casuarina junghuhniana	Casuarinaceae	T	0	+	-	-	-	*Mallothus sp*	Euphorbiaceae	T	0	+	-	-	-
Cedrella odorata	Meliaceae	T	+	-	-	-	+ *	*Malphigia glabra*	Malpighiaceae	S	+	-	-	-	-
Ceiba pentandra	Malvaceae	T	+	-	-	-	+ *	*Mangifera indica*	Anacardiaceae	T	+	+	-	-	+ *
Citrus hystrix	Rutaceae	S	0	-	-	-	-	*Mangifera longipes*	Anacardiaceae	T	+	-	-	-	-
Citrus maxima	Rutaceae	T	0	-	-	-	-	*Manilkara kauki*	Sapotaceae	T	+	-	-	-	-
Citrus microcarpa	Rutaceae	S	+	-	-	-	-	*Melia azedarach*	Meliaceae	T	+	-	-	-	-
Citrus sp	Rutaceae	S	+	-	-	-	-	*Miliusa macropoda*	Annonaceae	T	+	-	-	-	+ *
Codeaeum variegatum	Euphorbiaceae	S	+	-	-	-	-	*Mischocarpus fuscescens*	Sapindaceae	T	+	-	-	-	-
Croton cascorlaides	Euphorbiaceae	T	0	-	-	+	-	*Morinda citrifolia*	Rubiaceae	T	+	-	-	-	-
Croton sp	Euphorbiaceae	T	+	-	-	-	-	*Morus alba*	Moraceae	T	+	+	-	-	-
Croton triglium	Euphorbiaceae	S	+	-	-	-	-	*Murraya paniculata*	Rutaceae	S	+	-	-	-	-
Cryptocarya densiflora	Lauraceae	T	+	-	-	-	-	*Musaenda flava*	Rubiaceae	S	+	-	+	-	-
Dillenia pentagyna	Dilleniaceae	T	+	-	-	-	+ *	*Nerium oleander*	Apocynaceae	S	0	+	-	-	-
Dillenia philippensis	Dilleniaceae	T	+	-	-	-	-	*Osmanthus fragrans*	Oleaceae	T	+	+	+	+	+ *

Diospyros discolor	Ebenaceae	T	+	-	-	-	-	*Parkia timoriana*	Leguminosae	T	+	-	-	-	-
Diospyros malabarica	Ebenaceae	T	+	-	-	-	+*	*Persea americana*	Lauraceae	T	+	-	-	-	-
Diospyros sp	Ebenaceae	T	+	-	-	-	-	*Pithecellobium dulce*	Leguminosae	T	+	-	-	-	+*
Dysoxylum sp1	Meliaceae	T	+	-	-	-	-	*Pleiogynium timoriense*	Anacardiaceae	T	+	-	-	-	-
Dysoxylum sp2	Meliaceae	T	+	-	-	-	-	*Plumeria alba*	Apocynaceae	T	+	+	-	-	+*
Dysoxylum sp3	Meliaceae	T	+	-	-	-	-	*Plumeria rubra*	Apocynaceae	T	0	-	-	-	-
Dysoxylum sp4	Meliaceae	T	+	-	-	-	-	*Pterocarpus indicus*	Leguminosae	T	+	-	-	-	-
Ehretia microphylla	Boraginaceae	S	+	-	-	-	-	*Salix tetrasperma*	Salicaceae	T	+	-	+	-	-
Eugenia uniflora	Myrtaceae	T	+	-	-	-	-	*Sandoricum koetjape*	Meliaceae	T	+	-	-	-	-
Euodia latifolia	Rutaceae	T	+	-	-	-	-	*Saraca declinata*	Leguminosae	T	+	-	-	-	-
Euodia macrophylla	Rutaceae	T	+	-	-	+	+*	*Saraca thaipengensis*	Leguminosae	T	+	+	-	-	+*
Excoecaria cochinchinensis	Euphorbiaceae	S	+	-	-	-	-	*Schinus terebinthifolia*	Anacardiaceae	S	+	-	-	-	-
F. pisocarpa	Moraceae	T	+	+	-	-	-	*Scolopia spinosa*	Flacourtiaceae	T	+	-	-	-	+*
Falcataria moluccana	Leguminosae	T	0	-	+	+	-	*Senna alata*	Leguminosae	S	+	-	-	-	-
Feronella lucida	Rutaceae	T	+	-	-	-	-	*Senna garretiana*	Leguminosae	T	+	-	-	-	+*
Ficus hispida	Moraceae	T	0	+	-	-	-	*Senna siamea*	Leguminosae	T	+	+	-	-	-
Ficus benjamina	Moraceae	T	0	+	-	-	-	*Solanum torvum*	Solanaceae	S	+	-	-	-	-
Ficus callosa	Moraceae	T	+	+	-	-	-	*Spondias mombin*	Anacardiaceae	T	+	-	-	-	-
Ficus racemosa	Moraceae	T	0	+	-	-	-	*Stelechocarpus burahol*	Annonaceae	T	+	+	-	-	+*
Ficus religiosa	Moraceae	T	+	+	-	-	+x	*Streblus asper*	Moraceae	T	+	+	-	-	-
Ficus rumphii	Moraceae	T	0	-	-	-	-	*Syzigium cumini*	Myrtaceae	T	+	-	-	-	-
Ficus superba	Moraceae	T	0	-	-	-	-	*Syzygium polyanthum*	Myrtaceae	T	+	-	-	-	-
Ficus variegata	Moraceae	T	+	+	-	-	+*	*Syzygium samarangense*	Myrtaceae	T	+	-	-	-	-
Ficus villosa	Moraceae	T	+	-	-	-	-	*Taxodium huegelii*	Taxodiaceae	T	+	-	-	-	-
Firmiana malayana	Sterculiaceae	T	+	+	-	-	-	*Tectona grandis*	Verbenaceae	T	+	-	-	-	+*

Garcinia celebica	Clusiaceae	T	+	-	-	-	-	*Terminalia catappa*	Combretaceae	T	+	-	-	-	-
Garcinia dulcis	Clusiaceae	T	+	-	-	-	+*	*Triphasia trifolia*	Rutaceae	S	+	-	-	-	-
Garcinia macrophylla	Clusiaceae	T	+	-	-	-	+*	*Vitex pinnata*	Verbenaceae	T	+	-	-	-	-
Gliricidia sepium	Leguminosae	T	+	-	-	-	-	*Wetria insignis*	Euphorbiaceae	T	+				
Glochidion sp	Euphorbiaceae	T	+	-	-	+	-	*Zanthoxylum scandens*	Rutaceae	Cl	+	-	-	-	+*
Glochidion sp+	Euphorbiaceae	T	0	-	-	+	-	*Ziziphus oenophyla*	Rhamnaceae	Cl	0	+	-	-	-

Note : 1 = Found - = Not found ; Dp = *D. pentandra*, Mt = *M. tetragonus*, Sa= *S. atropurpurea*, Vo= *V.ovalifolium*, Va= *V. articulatum*; 1* = hyperparasite on *D. pentandra;* 1x = hyperparasite on *M. tetragonus*

Table 2.. Effects of mistletoe species on number of species, genus, and family of infested host plants in Purwodadi Botanic Garden during 2013-2021

Species of mistletoe	Number of host plants (per year)			Number of parasite (individual)
	Species	Genus	Family	
Dendrophthoe pentandra	71.33 ± 15.50[a]	53.00 ± 11.36[a]	26.33 ± 3.79 [a]	383.33 ± 170.25[a]
Macrosolen tetragonus	22.00 ± 3.61[b]	14.67 ± 4.04[b]	9.00 ± 2.65 [bc]	249.33 ± 130.35[ab]
Viscum articulatum	15.00 ± 1.73[b]	14.33 ± 1.53[b]	10.67 ± 2.31 [b]	64.67 ± 9.50[b]
Viscum ovalifolium	6.67 ± 4.04[b]	4.33 ± 2.52[b]	3.67 ± 1.53 [c]	30.00 ± 16.70[b]
Scurrula atropurpurea	6.00 ± 1,00[b]	4.33 ± 1.53[b]	3.33 ± 1.53 [c]	26.00 ± 2.79[b]

Note : numbers followed by same alphabetic in the same coloum was not different significanly by Tukey 95% Simultaneous Confidence Intervals

Table 3. Shannon index of mistletoe species (H') in Purwodadi Botanic Garden during 2013-2021

Species of mistletoe	**Family**	**Shannon index (H')**
Dendrophthoe pentandra	Loranthaceae	2.20±0.10[a]
Macrosolen tetragonus	Loranthaceae	0.58±0.24[b]
Viscum articulatum	Santalaceae	0.33±0.12[bc]
Viscum ovalifolium	Santalaceae	0.20±0.10[bc]
Scurrula atropurpurea	Loranthaceae	0.16±0.09[c]

Note: numbers followed by same alphabetic in the same coloum was not different significanly by Tukey 95% Simultaneous Confidence Intervals

Discussion

Species of host plants and mistletoes

Trees are the predominant host plants of mistletoe species. This is related to the characteristic of birds that prefer to establish in tall plants and higher branches, and thus the parasites are more commonly found in the top of larger or taller trees (Kolodziejek et al., 2013). Kolodziejek et al. (2013) reported that the density of *V. album* mistletoe was higher on tall trees than those on medium or small trees. In addition, host tree diameter was another characteristic that influenced mistletoe density on host species (Rahmad et al., 2014). Birds that spread mistletoe often perch in the tops of larger trees and lay mistletoe on these trees.

The number of host plant species is dynamic. Table 4 illustrates that the number of host plants generally increased between 2013 and 2017, for example, the number of host plants of *D. pentandra* decreased from 71 species, 48 genera, and 28 families in 2013 to 87 species, 66 genera, and 29 families in 2017 and then to 56 species, 45 genera, and 22 families in 2021. It is favorable effect of mistletoe control by trimming and removing branches or twigs infested with mistletoe. This measure is often implemented by farmers and is effective in reducing mistletoe spread, dispersal, and population. Bediako et al.

(2013) reported that all farmers in the central region of Ghana mechanically removed mistletoe on citrus trees by trimming the branches. Removal of mistletoe in trees eliminates mistletoe seeds, serving as a source of new mistletoe that are dispersed by birds. Birds play an important role in mistletoe spread, about 70% of mistletoe in citrus orchards in central Ghana is distributed by birds (Bediako et al., 2013). In short, birds feed on mistletoe seeds and excrete them with their droppings. The seeds contain a sticky substance (vascin) (Lech et al. 2020) that is undigested in the birds' stomachs. They can adhere to stem bark, germinate, and grow into new mistletoe when secreted by birds. Pest control for new plants from scouting or other sources was applied in nurseries before planting them in the collection garden. Pests such as fungi, insects, bacteria, and parasitic plants were controlled in nurseries ensuring that new plants planted in the garden were free of these pests.

The increase in infested host species was attributed to the increasing activity of birds spreading mistletoe to new plant taxa as hosts, while the decline in host plants in 2021 was driven by the death of mistletoe on the branches and twigs of host plants or the falling of trees on which mistletoe is attached (Solikin 2016, 2021). Practical pest management measures such as trimming and removing mistletoe from host plants also cause a reduction in mistletoe population and infested host plants.

When new trees or shrubs are planted in the garden, the number of host plants infested by mistletoe may increase. Norton and Carpenter (1998) reported that the establishment of a large number of trees by the Eopea settlement in New Zealand many years ago resulted in a large number of host plants of the mistletoe parasite *Lleostylus micranthus* and *Tupeia antarctica*, such as the tree *Chamaecytisus palmensis*, becoming the main host in several parts of New Zealand. The plant collection at Purwodadi Botanic Garden increased from 1925 species and 11748 specimens in 2013 to 2157 species and 12644 specimens in 2020 (Solikin, 2021). The increase in the plant collection in the garden was mainly due to floral explorations in Java and other islands in Indonesia such as Sulawesi, Kalimantan and Papua. Several newly collected plants such as *Glochidion* spp., *Glycosmis* spp. and *Dysoxylum* spp. were infested with mistletoe, thus increasing the species number of host plants and mistletoe population in the garden. The Leguminosae, Euphorbiaceae, and Rutaceae families were the most important host plants for mistletoe during 2013-2021, with species numbers of 22, 21, and 19, respectively (Table 1).

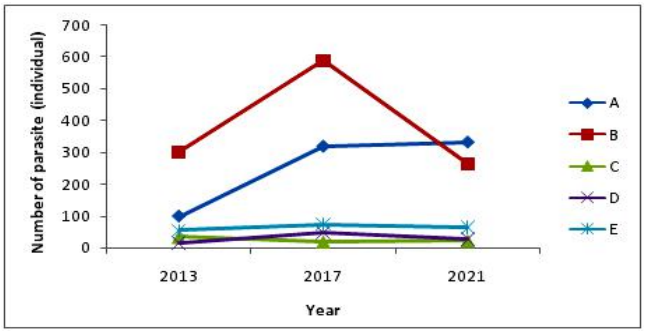

Figure 3. The population number of mistletoe species in Purwodadi Botanic Garden During 2013 – 2021. A= *M. tetragonus*; B= D. *pentandra*, C=*S. atropurpurea*, D= *V. ovalifolium*, and E= *V.articulatum*

Mistletoe infection is a dynamic process that continuously shifts stand dynamics through time (Griebel1 et al. 2017). Mistletoe populations at Purwodadi Botanic Garden increased consistently from 2013 to 2017 and then decreased until 2021 (Figure 3). *D. pentandra* had the highest population among the other mistletoes and increased consistently from 2013 to 2017. This was due to the accumulation of this parasite in hosts during several years during this period. However, the population declined after 2017, while the population of *M. tetragonus* remained increasing until 2021. The high population of *M. tetragonus* in 2021 was mainly sustained by *Ficus* spp. hosts, especially *F. religiosa,* which reached 331 individuals from 7 host plants (Table 5).

Biotic and abiotic factors influence the population dynamics of mistletoe. Competition for water, mineral nutrients, and photosynthesis is an important factor in the growth and population dynamics of mistletoe. Solikin (2021) reported that the long dry season in 2015, strong competition between mistletoe and hosts, between mistletoe in hosts, and between hosts caused high mortality of *D. pentandra* and *V. articulatum* on *C. fistula* after this period until 2019. This trend persisted until 2021, when *V. articulatum* was no longer found on *D. pentandra* in *C. fistula* on the same plants. Monica et al. (2017) also reported that population growth of mistletoe *Arceuthobium globosum* was reduced by competition for resources such as water, mineral nutrients, and photosynthate. Competition among host trees negatively affects mistletoe occurrence since trees that outcompete their neighbors generally have better access to resources and have more resources available for mistletoe than suppressed trees (Matula et al., 2015). Increasing competition among host trees causes a decrease in tree size and a decrease in the number of mistletoe-infested trees (Matula et al., 2015).

Table 4. Number of species, genus, family of host plants by mistletoe species during 2013-2021

Species of Mistletoe	Number of host plant								
	Species			Genus			Family		
	2013	2017	2021	2013	2017	2021	2013	2017	2021
Dendrophthoe pentandra	71	87	56	48	66	45	28	29	22

Macrosolen tetragonus	25	23	18	17	17	10	10	11	6
Scurrula atropurpurea	7	6	5	6	3	4	5	2	3
Viscum ovalifolium	3	11	6	2	7	4	2	5	4
Viscum articulatum	13	16	16	13	14	16	8	12	12

Note : numbers followed by same alphabetic in the same coloum was not different significanly by Tukey 95% Simultaneous Confidence Intervals

Host specificity of mistletoes

Kent and Paddy (1992) classified plant diversity as low (H'<1), moderate (1<H'<2), and high (H'>2). The highest Shannon index (H') for *D. pentandra* (H'= 2.20±0.10) indicates that this parasite is the highest generalist or the lowest host plant specialist, while the lowest H' for *S. atropurpurea* (0.16±0.09) indicates that this species is the lowest generalist or the highest host plant specialist at the local level in Purwodadi Botanic Garden. The highest generalization of *D. pentandra* not only affects the number of species, genera and families of host plants parasitized by this mistletoe (Table 1), but also the number of parasites (Table 2). In 2017, it infested 87 species, 66 genera, and 27 families of host plants (Table 4) with an average population number of 383.33 ± 170.25 individuals (Table 2). Xiao and Pu (1988) also reported that this parasite affected 360 species of host plants in Xishuangbanna, Yunnan, China. In contrast, *S. atropupurea* was the lowest generalist or most specific to host plants in Purwodadi Botanic Garden. It parasitized 3.33 families with 6.00 species and 4.33 genera with 26.00 ± 2.79 individuals (Table 2).

Table 5. Population of M. *tetragonus* on F. *religiosa* on several stem diameter in several blocks in 2021

Host	Location(Block)	Number of parasite (Individual)
1	IV B.	30
2	IV B.	14
3	IV B.	13
4	IV B.	33
5	XII.F	95
6	XV.F	72
7	XV.F	74
	Total	331

An additional intriguing aspect of mistletoe host specificity is the propensity of mistletoes to parasitize other mistletoes known as hyperparasite, which are frequently from Loranthaceae, Viscaceae, and Santalaceae families (Nickrent, 2002). Solikin (2016) reported that *V. articulatum* (Santalaceae) was found as hyperparasite on *D. pentandra* (Loranthaceae). Table 1 showes that twenty-seven hyperparasitism of *V. articulatum* were found on *D. pentandra* in twenty six host plant species (96.3%), while there was only one hyperparasite (3.7%) on *M. tetragonus* in *F. religiosa*.

In plant communities with high species diversity and few dominant species, mistletoes tend to be generalists (Luo et al., 2016), as in Purwodadi Botanic Garden. The generalization of mistletoe in Purwodadi Botanic Garden is related to the plant species diversity in the garden. About 179 families, 997 genera and 2157 species of plants were collected in the garden (Solikin, 2021). The generalisation of the mistletoe species is widespread, which comparable with the previous study (Polhill and Wiens, 1998), reporting that about 70% of the mistletoes species in Africa to be generalist to host plants.

The high plant diversity favors birds as mistletoe dispersers to spread mistletoe to many tree plant species. Therefore, the mistletoes can infest many plant species. Table 1 and Table 2 showed that *D. pentandra* infested the most plant species, genus and family. This species was predominant mistletoe infested several species of fruit plants in Bangkalan, Madura, East Java with and Important Value Index of 162.51 and infested several species of fruit plants (Solikin, 2020).

Overall, it can be concluded that host specificity and generalization of mistletoe species significantly differ among mistletoe species in Purwodadi Botanical Garden. *D. pentandra* is the most generalist or the least specilialist mistletoe, infecting 119 host plant species with an H' value of 2.20, while *S. atropurpurea* was the least generalist or the most specialist mistletoe in Purwodadi Botanic Garden, infesting of 12 host plant species. In 2013-2021, 142 species from 82 genera and 37 families of host plant species were infested by mistletoe. Population of *D. pentandra* is the most with parasite number of 383.33 individuals per year, while *S. artopurpurea* has the least dominant with parasite number of 26.00 individuals per year.

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