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# Population study of *Peristylus goodyeroides* (Orchidaceae) in five habitats and implication for its conservation

**SITI NURFADILAH**
Purwodadi Botanic Garden, Indonesian Institute of Sciences. Jl. Surabaya-Malang Km. 65, Purwodadi, Pasuruan 67163, East Java, Indonesia.
Tel./fax.: +62-343-615033, email: siti.nurfadilah@lipi.go.id; fadilahzr@gmail.com

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**Abstract.** *Nurfadilah S. 2017. Population study of* Peristylus goodyeroides (*Orchidaceae) in five habitats and implication for its conservation. Biodiversitas 18: 1084-1091.* Many orchids have experienced population decline because of natural and anthropogenic disturbances and the remaining populations occur in fragmented habitats. The present study aimed to investigate (i) population of a terrestrial orchid, *Peristylus goodyeroides* (D. Don) Lindl., in terms of its demography, population size, and plant size, and (ii) characteristics of vegetation surrounding *P. goodyeroides* and its effect on the population size of *P. goodyeroides* (iii) environmental factors (litter thickness and soil pH) and their effects on the plant size of *P. goodyeroides* in five habitats. Number of individuals, plant height and leaf area of *P. goodyeroides*, surrounding vegetation, litter thickness, and soil pH were recorded in each habitat. The results showed that there was variation in the demographic structure of the population of *P. goodyeroides* in five habitats. Furthermore, three habitats of *P. goodyeroides* had small population size and small plant size compared to the other two habitats that had relatively larger population size and plant size. Small population size was correlated with taller vegetation surrounding *P. goodyeroides* reducing light availability for *P. goodyeroides*, while small plant size was related to sparse and thin litter cover causing low soil moisture and lacking nutrient availability for *P. goodyeroides*. Soil pH between habitats was similar and did not affect *P. Goodyeroides* plant size. The present study has implication on the conservation of *P. goodyeroides* for the improvement of population performance for the increase in population size and plant size for the species survival.

**Keywords:** Conservation, habitat, population, plant size, *Peristylus goodyeroides*

## INTRODUCTION

Orchidaceae is one of the biggest plant families containing approximately 25,000 species occurring in a wide range of natural habitats, such as mountainous areas, grasslands, forests, and rocks (Dressler 1993; Arditti 1991). Orchids are known to be vulnerable to habitat alteration impacted by natural and anthropogenic disturbances leading to the disappearing of orchids in disturbed habitats (Swarts and Dixon 2009; Rewicz et al. 2015; Tamn 1972). Deforestation and conversion of orchid habitats into housings, buildings, main roads, industries, and agricultural landscapes causing deterioration and loss of orchid habitats have impacted on the orchid population (Carey 1999; Drayton and Primack 1996; IUCN 1996; Taylor and Roberts 2011). Many orchids have been reported to experience sharp decline of population and change of patterns of orchid distribution because of the land use change and habitat fragmentation, with the remaining population is isolated and occur in ecologically marginal habitats (Wotavova et al. 2004; Jacquemyn et al. 2005;Kull and Hutchings 2006; Silvertown et al. 1994; Romero-Calcerrada and Perry 2004). Their future survival and persistence rely on the strategy of management of orchid conservation (Carey 1999; Sletvold et al. 2010; Wotavova et al. 2004; Janeckova et al. 2006).

Understanding of orchid population in terms of the demographic structure and population performance is required in the management of orchid conservation. Demographic information showing the population dynamics, whether the populations are declining, increasing, or stable is important in the species recovery and conservation (Schemske et al. 1994). Demographic structure of a population can be classified into four life history stages based on age and life stage (seedlings, juveniles, vegetative adults, and flowering adults) (Jacquemyn et al. 2003). The life history stages that have the greatest effects on the population growth and species persistence need to be considered (Schemske et al. 1994). In the establishment and development of orchid population, flowering individuals with their ability to produce seeds is vital for seedling recruitments to increase population size for the future orchid persistence (Willems 1982). Willems (1982) reported the development of population of *Orchis simia* from only one individual of a flowering plant producing seeds important for seedling recruitments and the establishment of the population.

Furthermore, assessment of the performance of orchid population based on the population size (extinct, small, medium, large, very large) is important in the management of orchid conservation (Light and MacConaill 2005; Mehrhoff 1989; Wotavova et al. 2004), with extinct and small population size correlated with minimum viable population are the priority and need high attention in the conservation for the future survival of orchids (IUCN 1996; Ackerman 1998). Moreover, the performance of orchid population can also be based on the plant size as plant size can influence survival and is one of determinant factors of the ability of plants to flower for reproduction, thus, affected population size (Calvo 1990; Gregg and Kery 2006; Jacquemyn et al. 2010; Mehrhoff 1989; Tremblay 2006; Wesselingh et al. 1997; Willems 1982).

*Peristylus goodyeroides*, a terrestrial orchid was reported formerly a very common plant in grassland, teak forests, from near sea level to 1,750 m asl (Comber 1990). However, increased human population, rapid development of housings, buildings, roads, expansion of agricultural areas has impacts on orchid habitats causing loss and deterioration of many habitats of orchids and on the orchid population decline, including *Peristylus goodyeroides*.

The present study investigated the occurrence of the population of *Peristylus* goodyeroides in fragmented habitats within agricultural landscapes in Purwodadi District, Pasuruan Regency, East Java, in five extant habitats (bamboo forest, cananga woodland, Capang woodland, Gajah Rejo woodland, and Pucang Sari woodland). The aim of the present study was to investigate (i) population of *P. goodyeroides* in terms of its demography, population size and plant size in five habitats (ii) characteristics of vegetation surrounding *P. goodyeroides* and its effect on the population size of *P. goodyeroides* (iii) environmental factors (litter thickness and soil pH) and their effects on the plant size of *P. goodyeroides* in five habitats.

The present study supports for the conservation of orchids, many of which have suffered from habitat pressure, loss, and deterioration, as well as population decline. An understanding performance of the population of orchids in the extant habitats is important in the management of orchid conservation to formulate conservation for the improvement of population performance of orchids for their future and long-term survival.

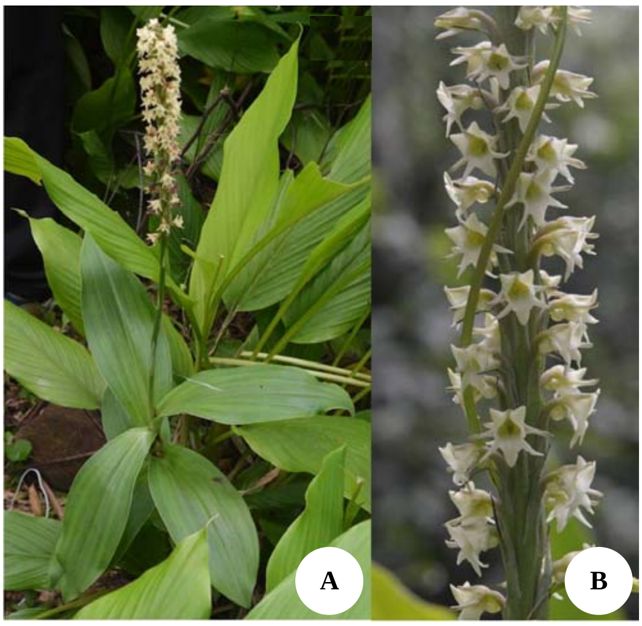


**Figure 1.** A. Flowering plant of *Peristylus goodyeroides,* B. Flowers of *Peristylus goodyeroides*

## MATERIALS AND METHODS

### Study area

*Peristylus goodyeroides*, a terrestrial orchid in the present study occurred in five habitats within agricultural landscapes in Purwodadi District, Pasuruan Regency, East Java, Indonesia. The five habitats were bamboo forest, cananga woodland, Capang woodland, Gajah Rejo woodland, and Pucang Sari woodland. The size of the five habitats varied. The size of the bamboo forest, cananga woodland, Capang woodland; Gajah Rejo woodland, and Pucang Sari woodland were approximately 30 m x 40 m; 40 m x 50 m; 100 m x 150 m; 75 m x 75 m; 80 m x 100 m, respectively. The distance between populations ranged from 70 m to 2 km (Figure 2).

The dominant vegetation in the bamboo forest were *Bambusa blumeana*, *Ceiba pentandra,* and *Swietenia macrophylla*, while cananga woodland was dominated by *Cananga odorata* and *Gigantochloa apus*. The dominant vegetation in Capang woodland were *Albizia procera, B. blumeana, C. pentandra, Syzygium javanicum,* and *S. picnanthum*. Gajah Rejo woodland were dominated by *Bambusa vulgaris, C. odorata, C. pentandra, Dendrocalamus asper, Gigantochloa atter, S. macrophylla, Syzygium pycnanthum,* and *Tamarindus indica,* while the dominant vegetation in Pucang Sari woodland were *Albizia lebbeck, C. pentandra, D. asper, G. apus, G. atter,* and *S. macrophylla*.

### Procedures

The present study investigated the population of *P. goodyeroides* in terms of its demography, population size, and plant size, surrounding vegetation and environmental factors in five habitats of *P. goodyeroides*. Plots of 2 m x 2 m were established at each site. The number of individuals of *P. goodyeroides* was counted, plant height, leaf number, leaf length and width of *P. goodyeroides* were also measured in each plot. Vegetation surrounding *P. goodyeroides* was characterized, the plant species was identified, and the number of individuals of each plant species in each plot was counted. Litter thickness and soil pH in each plot were also measured.

*Demography of population of* Peristylus goodyeroides

To investigate the demography of population of *P. goodyeroides* in five habitats, individuals of *P. goodyeroides* were classified based on the life history stages (age stages (seedlings, juveniles, and adults) and life stages (flowering and non-flowering (vegetative) (Kery and Gregg 2004). Therefore, there were four classifications in the demography of *P. goodyeroides* population (i) seedlings, (ii) juveniles, (iii) vegetative adults, and (iv) flowering adults. The classification of stages was based on the plant height of *P. goodyeroides*; seedlings ( < 15 cm); juveniles (15 cm-30 cm), vegetative adults (>30 cm without flowers), and flowering adults (>30 cm with flowers).

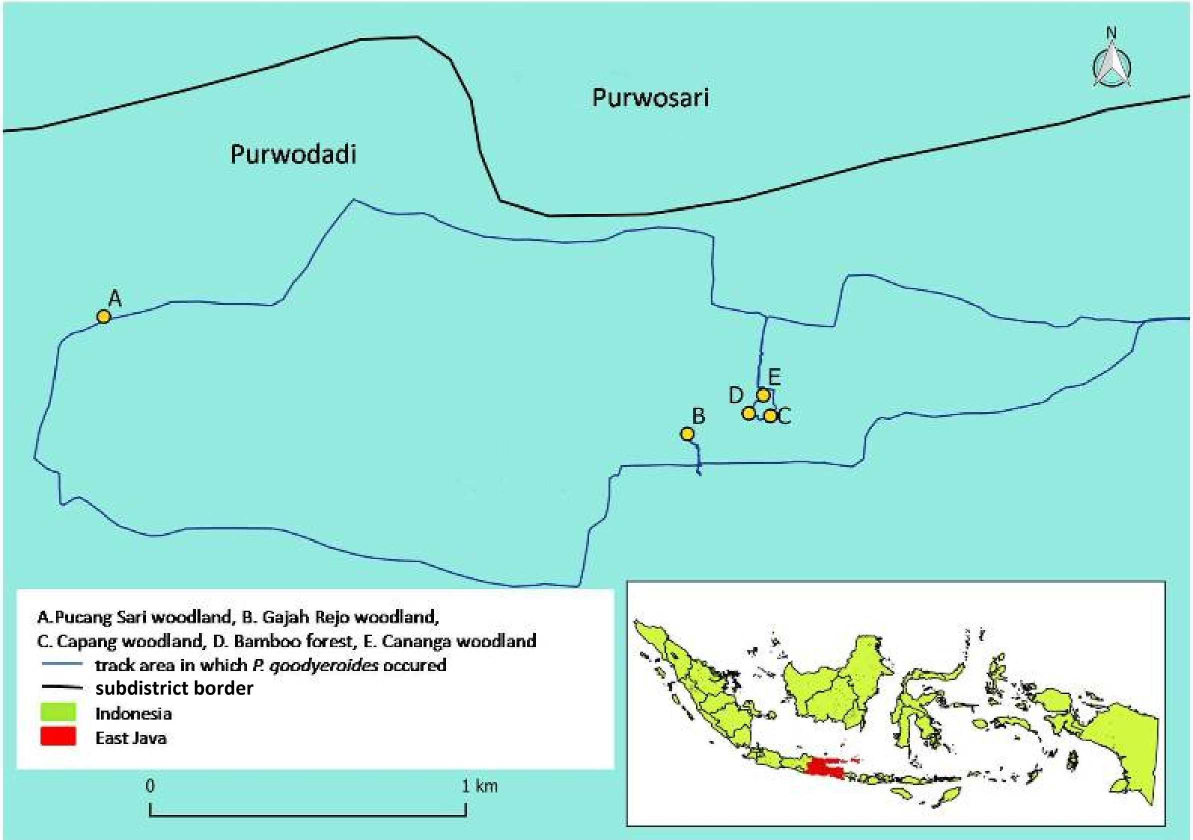


**Figure 2.** Map of area of five populations of *P. goodyeroides* in Purwodadi District, Pasuruan Regency, East Java, Indonesia

**Table 1.** Key state of population size of *Peristylus goodyeroides* in Purwodadi District, Pasuruan Regency (modified from Wotavova et al. 2004)

| State of populations | Number of individuals (flowering) |
|---|---|
| Small population | 1-10 |
| Medium population | 10-100 |
| Large population | 100-1000 |
| Very large population | >1000 |

*Correlation between population size and characteristics of surrounding vegetation*

The population size of *P. goodyeroides* (measured as number of flowering individuals) was correlated to the characteristics of surrounding vegetation. To investigate the correlation between population size of *P. goodyeroides* and characteristics of surrounding vegetation in five habitats, CANOCO with direct redundancy analysis RDA was used. Direct gradient analysis is a method to find the directions of variability in vegetation community data, which correlate with the state of population size of *P. goodyeroides* for each habitat (Table 1) (Wotavova et al. 2004).

*Correlation between plant size and environmental factors*

Parameters of plant size including plant height and leaf area of flowering adult individuals of *P. goodyeroides* in five habitats were analyzed using ANOVA with MINITAB 14.0. Leaf area was estimated by calculating leaf length and width in an elliptic area (Cleavitt et al. 2017). Leaf area = $\pi$ ($^1/_2$ x leaf length) x $^1/_2$ x leaf width). Environmental factors (litter thickness and soil pH) in five habitats were also analyzed using ANOVA with MINITAB 14.0. The correlation between plant size and environmental factors (litter thickness and soil pH) was analyzed using Regression with MINITAB 14.0.

## RESULTS AND DISCUSSION

The present study has shown the population of *Peristylus goodyeroides* regarding its demography, population size and plant size in the five habitats impacted by anthropogenic disturbances, within agricultural landscapes. Also, the study revealed comparable data of the demography, population size and plant size of *P. goodyeroides* across five habitats (bamboo forest, cananga woodland, Capang woodland, Gajah Rejo woodland, and Pucang Sari woodland) in Purwodadi District, Pasuruan Regency. The correlation between population size of *P. goodyeroides* and the characteristics of surrounding vegetation, and the correlation between plant size of *P. goodyeroides* and the environmental factors also have been shown in the present study.

**Demography of population *Peristylus goodyeroides***

There was variation in the population demographic structure of *P. goodyeroides* across five habitats. The population demographic structure in Capang woodland and Pucang Sari woodland consisted of seedlings, juveniles, and adults; bamboo forest consisted of seedlings and adults; while Gajah Rejo woodland and cananga woodland only consisted of adult individuals (Figure 3). The proportion of each stage across five habitats was also various. Bamboo forest had a proportion of seedlings larger than vegetative and flowering adults, cananga woodland only consisted of one flowering individual, Capang woodland had a proportion of seedlings larger than that of juveniles and flowering adults (Figure 3). Gajah Rejo woodland only consisted of adults with the proportion of flowering adults was higher than that of vegetative adults, while Pucang Sari woodland had a proportion of flowering adults larger than that of seedlings, juveniles, and vegetative adults. Other studies also demonstrated variation in the population demographic structure of other orchids, such as *Liparis loeselii* (Oostermeijer and Hartman 2014).

Flowering adults are one of determinant factors in the development of population as they can produce fruits and seeds that are important for seedling recruitment (Willems 1982). The larger proportion of flowering adults, the larger probability for the development of population and the increase of the population size.

**Correlation between population size and characteristics of surrounding vegetation**

The results of the present study also showed that population size of *P. goodyeroides* (measured as number of flowering individuals) varied among habitats. The population size of *P. goodyeroides* in the bamboo forest, cananga woodland, and Capang woodland could be categorized as a small population, while the population of Gajah Rejo woodland and Pucang Sari could be categorized as medium population (Table 1; Table 2). A number of flowering individuals in the bamboo forest, cananga woodland, Capang woodland, Gajah Rejo woodland, and Pucang Sari woodland were 1;1;3; 16; and 37, respectively (Table 2).

Other studies also demonstrated similar results on the variation of the population size of orchids occurring in different habitats. *Spiranthes sinensis* had various population size among habitats from the small to medium population size, with a number of reproductive individuals in the habitats ranged from 3 to 98 individuals (Sun 1996). *Spiranthes hongkongensis* also had variation in population size in different habitats with a number of reproductive individuals ranged from 1 to 79 individuals (Sun 1996).The size of the population of *Dactylorhiza majalis* also varied between habitats, from less than 10 to more than 100 flowering individuals (Wotavova et al. 2004).

Results of RDA analysis showed that bamboo forest, cananga woodland, and Capang woodland that had small population was correlated with taller vegetation (surrounding vegetation that are taller than the orchid, i.e., *Boesenbergia rotunda* and *Curcuma purpurascens*) (Table 2; Figure 4), while Gajah Rejo woodland and Pucang Sari woodland that had medium population were correlated with short vegetation (Table 2; Figure 2). Taller vegetation limited access of *P. goodyeroides* for light resulting in the low number of individuals persisted in the habitats with taller vegetation surrounding the orchid. Short vegetation near *P. goodyeroides* provided a wide access for light which is essential for photosynthesis, growth, development, and survival, leading to the relatively higher number of individuals in the habitats of the orchid with short vegetation. Light is an important factor limiting growth and reproduction that affect population size of orchids (Jacquemyn et al. 2010; Whigham 2004).

Other studies also showed similar results that population size of orchids was correlated with characteristics of surrounding vegetation cover. Wells (1967) reported that scarce and absent of *Spiranthes spiralis* was associated with taller vegetation surrounding the orchid. Surrounding vegetation has been widely reported to affect the abundance and population size of orchids in some ways (i) tall vegetation reduced light availability for the orchids (ii) fast-growing surrounding vegetation overgrew the orchids, such as grasses (Wells 1967; Tamn 1972; Wotavova et al. 2004). Wells (1967) reported that when *Bromus erectus* (taller vegetation surrounding *Spiranthes spiralis*) dominated the habitats, the orchid was scarce and absent. Furthermore, Wotavova et al. (2004) also reported that a low number of *Dactylorhiza majalis* in the habitats was related to the characteristics of surrounding vegetation that was dominated by grass overgrowing the orchid.

Orchids have been widely reported to occur in vegetation community composed of several herb species forming vegetation cover (Curtis 1943; Wells 1967; Janeckova et al. 2006; Wotavova et al. 2004). Vegetation cover is important to maintain moisture. However, characteristics of vegetation cover are known to determine the abundance of orchids. Orchids are present in low number or absence in (i) tall vegetation community (Wells 1967; Jersakova et al. 2002) or (ii) grasses that usually inhibited orchids (Wotavova et al. 2004; Coates et al. 2006).

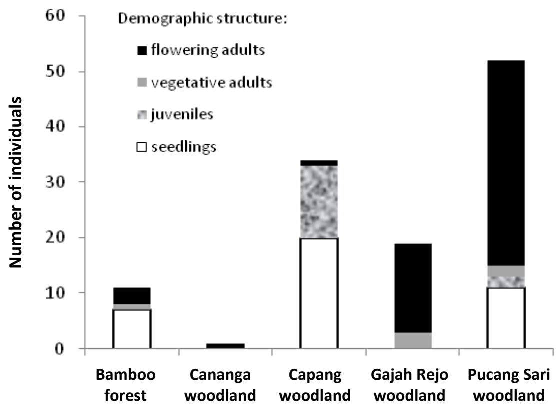


**Figure 3.** Demographic structure of population of *Peristylus goodyeroides* across five habitats

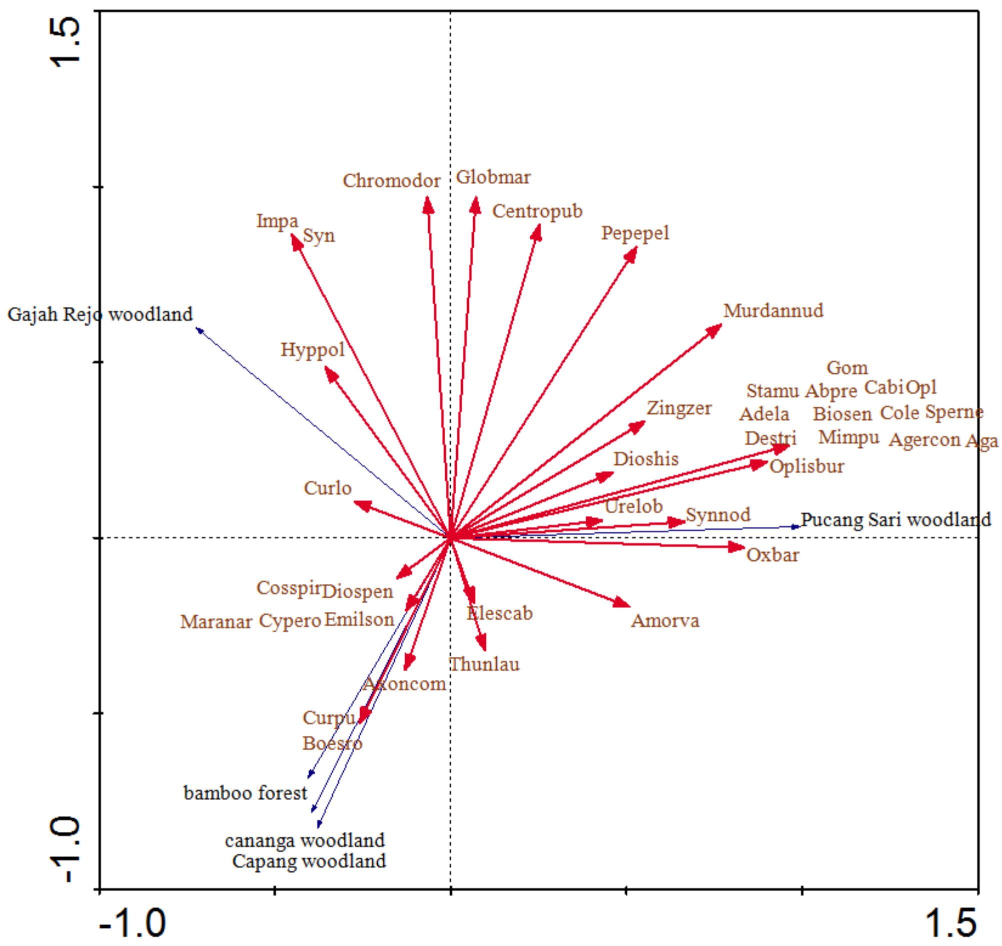


**Figure 4.** Results of RDA of five habitats of *Peristylus goodyeroides.* Legend: Bamboo forest, cananga woodland, and Capang woodland had a low number of individuals of *Peristylus goodyeroides* (1-3 individuals), Gajah Rejo woodland had a medium number of individuals (16 individuals), Pucang Sari woodland had the largest number of individuals (37 individuals). Abpre (*Abrus precatorius*), Adela (*Adenostemma lavenia*), Aga (*Agave* sp.), Agercon (*Ageratum conyzoides*), Amorva (*Amorphophallus variabilis*), Axoncom (*Axonopus compressus*), Boesro (*Boesenbergia rotunda*), Biosen (*Biophytum sensitivum*), Cabi (*Caladium bicolor*), Centropub (*Centrosema pubescens*), Cole (*Coleus* sp.), Cosspir (*Costus spiralis*), Curlo (*Curcuma longa*), Curpu (*Curcuma purpurascens*), Cypero (*Cyperus rotundus*), Chromodor (*Chromolaena odorata*), Destri (*Desmodium triflorum*), Dioshis (*Dioscorea hispida*), Diospen (*Dioscorea pentaphylla*), Emilson (*Emilia sonchifolia*), Elescab (*Elephantopus scaber*), Globmar (*Globba marantina*), Gom (*Gomphostemma* sp.), Hyppol (*Hypoestes polythyrsa*), Impa (*Impatiens* sp.), Maranar (*Maranta arundinacea*), Mimpu (*Mimosa pudica*), Murdannud (*Murdannia nudiflora*), Oplisbur (*Oplismenus burmanni*), Opl (*Oplismenus* sp.), Oxbar (*Oxalis barrelieri*), Pepepel (*Peperomia pellucida*), Sperne (*Spermacoce neohispida*), Stamu (*Stachytarpheta mutabilis*), Synnod (*Synedrella nodiflora*), Syn (*Synedrella* sp.), Thunlau (*Thunbergia laurifolia*), Urelob (*Urena lobata*), Zingzer (*Zingiber zerumbet*)

**Table 2.** Number of flowering individuals and key state of population size of *Peristylus goodyeroides* in five extant habitats

| Habitats of *Peristylus goodyeroides* | Number of flowering individuals | State of population size |
|---|---|---|
| Bamboo forest | 3 | Small population |
| Cananga woodland | 1 | Small population |
| Capang woodland | 1 | Small population |
| Gajah Rejo woodland | 16 | Medium population |
| Pucang Sari woodland | 37 | Medium population |

### Correlation between plant size of *Peristylus goodyeroides* and environmental factors

The results showed that plant size of *P. goodyeroides* (plant height and leaf area) varied and was significantly different between habitats. Mean plant height of *P. goodyeroides* in the bamboo forest, cananga woodland, and Capang woodland was 31.33 cm; 29.2 cm; and 30 cm, respectively. Pucang Sari woodland had taller individuals of *P. goodyeroides* (44.1 cm) than bamboo forest, cananga woodland, and Capang woodland. Gajah Rejo woodland had the tallest individuals of *P. goodyeroides* compared to other habitats (57.99 cm) (Figure 5).

Leaf area of *P. goodyeroides* also showed variation between habitats with a similar trend as plant height. Mean leaf area of *P. goodyeroides* in the bamboo forest, cananga woodland, and Capang woodland was 39.74 $cm^2$; 47.1 $cm^2$; and 48.08 $cm^2$, respectively. Pucang Sari woodland had larger leaf area (81.35 $cm^2$) than bamboo forest, cananga woodland, and Capang woodland. Gajah Rejo woodland had the largest leaf area compared to other habitats (112.07 $cm^2$) (Figure 5). The taller individuals and larger leaf area of *P. goodyeroides* in Pucang Sari woodland and Gajah Rejo woodland than in bamboo forest, cananga woodland, and Capang woodland is related to litter thickness. Pucang Sari and Gajah Rejo woodland had thicker litter than bamboo forest, cananga woodland, and Capang woodland (Figure 6). Previous studies have shown that litter is important to maintain high soil moisture level and also as the source of organic matter on which mycorrhizal fungi depend (Garrett 1956). Mycorrhizal fungi have the capability to absorb a wide range of nutrients available in soils provided by leaf litter and organic matter and transfer a proportion of nutrients to the orchid, which are essential for orchid growth, development, and survival (Kononova 1961; Nurfadilah et al. 2013; Smith and Read 1997).

Analysis of correlation between plant size and litter thickness using Regression confirmed that plant height and leaf area of *P. goodyeroides* was positively associated with litter thickness ($r$= 0.39; df=1; P = 0.03; for regression of litter thickness and plant height) and ($r$= 0,59; df=1; P =0.001 ; for regression of litter thickness and leaf area) (Figure 6). Thicker litter tended to support the increase of plant height and leaf area of *P. goodyeroides* (Figure 7). This indicates that litter is important for growth and development of *P. goodyeroides.* Other studies also showed the importance of litter for growth and development, as well as for reproduction of other orchids, such as *Platanthera praeclara* (Sieg and King 1995) and *Caladenia flava* subsp *flava* (Newman et al. 2013).

Mean soil pH recorded across five habitats of *P. goodyeroides* ranged between 5-5.95 (Figure 6). ANOVA showed that soil pH in the five habitats of *P. goodyeroides* was not significantly different) (P> 0.05) (Figure 6). This indicates the similarity of soil pH in the five habitats did not affect the variation in plant size of *P. goodyeroides*. Regression analysis confirmed that soil pH was not correlated with plant size ($r$=0.20; df=1; P =0.268; for interaction between plant height and soil pH) and ($r$=0.316; df=1; P =0.084; for interaction between leaf area and soil pH) (Figure 8). Other studies also showed that soil pH did not differ among habitats and was not significantly correlated with growth and development of other orchids, such as *Platanthera praeclara* (Sieg and King 1995).

### Implication for conservation

The present study showed the different performance of *P. goodyeroides* regarding its population and plant size correlated with environmental factors in the five extant habitats (bamboo forest, cananga woodland, Capang woodland, Gajah Rejo woodland, and Pucang Sari woodland). Population and plant sizes are one of determinant factors for a long term and future survival of orchids as they can affect growth and reproduction of orchids (Jacquemyn et al. 2010; Tremblay 2006; Gregg and Kery 2006). Large population size and plant size have been exhibited to have higher survival of orchids compared to small population and small plant size (Gregg and Kery 2006; Shaffer 1987).

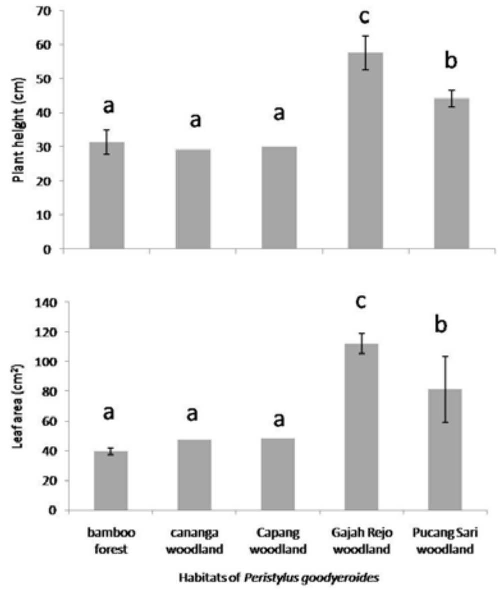


**Figure 5.** Plant height and leaf area (± SE) of *Peristylus goodyeroides* in five habitats. Different letters above column indicate significantly different (P < 0.05).

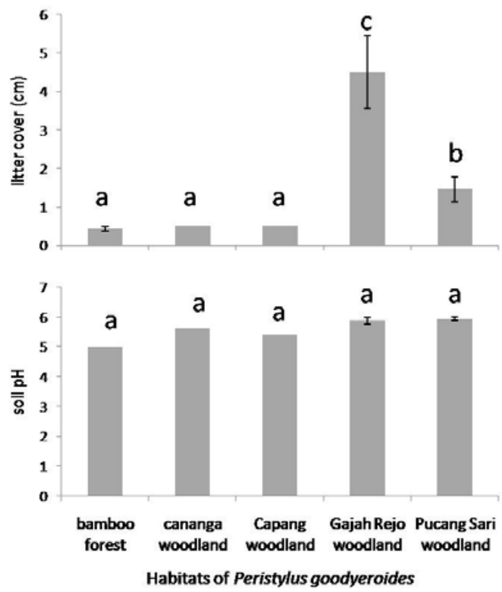


**Figure 6.** Environmental factors; abundance of vegetation surrounding *P. goodyeroides*, litter cover, and soil pH (± SE) in five habitats of *P. goodyeroides.* Different letters above column indicate significantly different (P < 0.05), while same letters above column indicate not significantly different (P > 0.05)

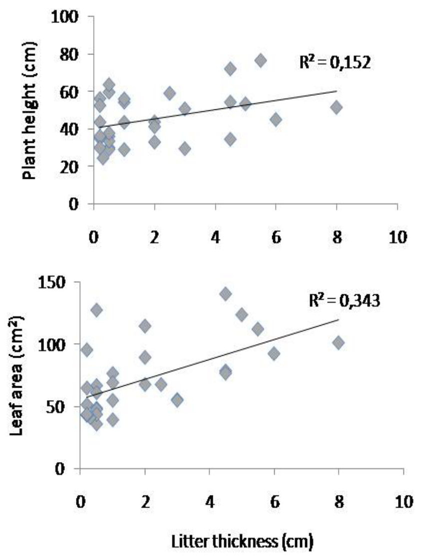


**Figure 7.** Positive correlation between plant size and litter thickness in plots across five habitats of *P. goodyeroides*. Correlation between plant height and litter thickness (*top*). P < 0.05 (P=0.012); leaf area interaction with litter thickness (*bottom*); P < 0.05 (P=0.011)

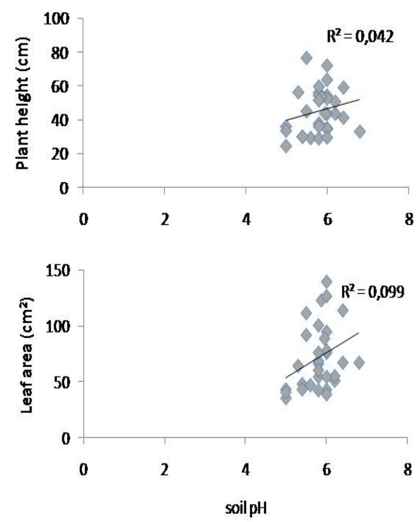


**Figure 8.** The interaction between plant size and soil pH in plots across five habitats of *P. goodyeroides*. Soil pH did not affect plant height (*top*) and leaf area (*bottom*)

The present study has implications for the improvement of population performance of orchids that had small size population and relatively small size plants in the bamboo forest, cananga woodland, and Capang woodland for the increase of population size and plant size in these three habitats. To increase population size and plant size of *P. goodyeroides* in these three habitats can be conducted by coppicing or mowing tall vegetation surrounding the orchid and increase litter cover for the optimal thickness of litter cover.

Coppicing is known to be useful to provide more access to light for plants grown with taller plants. Light is known as a limiting factor in the growth and development of plants including orchids. Field experiment of coppicing or mowing surrounding tall vegetation of another orchid, *Ophrys insectifera* has been demonstrated to be positively related to plant performance and population fitness of *O. insectifera* through the increase of plant size and flowering production and the ability to flower in consecutive years. Field experiments on the effect of coppicing or mowing tall vegetation surrounding *P. goodyeroides* are required. Moreover, field experiments of adding litter for sparse and thin litter cover in a bamboo forest, cananga woodland, and Capang woodland for the optimal thickness of litter cover that can increase plant size of *P. goodyeroides* are also required to increase the performance of *P. goodyeroides* population. Leaf litter accumulation can maintain soil moisture and is a potential source for organic matter, one of important substance to ensure the survival of mycorrhizal fungi; thus for the survival of the orchids as orchids highly rely on the mycorrhizal fungi for their survival (Garrett 1956; Batty et al. 2001). Some orchids, such as *Gastrodia confusa, Cymbidium sinense* growing in bamboo forests are known to form a symbiotic association with several species of litter decomposer *Mycena* fungi (Ogura-Tsujita 2009; Fan et al. 1996). Apart from the use of litter for the growth of orchids, leaf litter is also important for seedling recruitment (Batty et al. 2001).

Management of conservation of *P. goodyeroides* needs to consider the establishment and preservation of large population and large plant for the survival of orchids (Dorland and Willems 2002; Gregg and Kery 2006). A small population of *P. goodyeroides* in the bamboo forest, cananga woodland, and Capang woodland is the priority and needs high attention to be enhanced for the enlargement of the population for future and a long-term survival of *P. goodyeroides* that have experienced population decline. Field experiments on the effects of coppicing or mowing tall vegetation and the optimal thickness of litter cover on population and plant size are recommended for better performance of population and survival of *P. goodyeroides*.

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