Tropical Natural History 17(1): 1-10, April 2017

The Relationships between Host Tree Characteristics and Liana Climbing Success at Mo Singto Forest Dynamics Plot, Khao Yai National Park, Thailand

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Received: 11 September 2016; Accepted: 6 February 2017

Abstract.– Variations in climbing strategies of liana ramets allow them to successfully ascend to forest canopies. These diverse climbing strategies also depend on variations in sizes and bark textures of host trees. Characteristics of lianas and host trees at the Mo Singto Forest Dynamics Plot in the Khao Yai National Park in Thailand were examined. The total 1,560 ramets were randomly selected. Their sizes were positively correlated with host tree sizes. However, this relationship varied with liana climbing strategies. Most twiner, hook and tendril climbers tended to use small host trees while adventious root climbers used large host tree. The scrambler and the combination of twiner and scrambler ramets appeared to be independent of host tree sizes. Host trees with slightly rough bark texture showed high association with most ramets regardless of sizes and climbing strategies except the adventitious root climbers that were often found on trees with rough bark texture.

KEY WORDS: **Liana, Climbing Strategy, Host Tree Characteristics, Khao Yai National Park**

INTRODUCTION

Lianas are woody climbing plants commonly found in tropical forests (Addo-Fordjour et al., 2009; Chittibabu and Parthasarathy, 2001; Putz ,1984; Schnitzer, 2005; Schnitzer and Bongers, 2002; Senbeta et al., 2005). Most lianas require suitable host trees to move upward. Because there are variations in these structural supports, liana stems or ramets exhibit different climbing strategies to reach forest canopy. Certain characteristics of host trees, especially bark textures and sizes, have also been reported to be important in determining liana climbing success, which influence the presence of certain climbing strategies of lianas and may also be related to liana diversity, abundance, and forest dynamics (Chittibabu and Parthasarathy, 2001; Nabe-Nielsen, 2001; Putz, 1984; Senbeta et al., 2005).

Areas of biodiversity hotspots such as tropical forests in Thailand are also rich in liana diversity. The Mo Singto Forest Dynamics Plot, which is a network of the Center for Tropical Forest Science (CTFS), shows great liana diversity consisting of 52 common species which were defined as species with at least 1 individual per hectare. These species exhibited six climbing strategies (Khiewbanyang et al., 2014). The relationship between liana and their limiting factors has previously been studied by Lertpanich and Brockelman (2003). This study suggested that environmental factors did not much determine the overall density and diversity of lianas in this plot. Furthermore, this study also found that host trees with the diameter at breast height (dbh) less than 70 cm were highly colonized by many liana ramets from different species, and those that had slightly rough bark texture were often used by ramets of various climbing strategies. It is possible that biotic factors such as the availability of host trees and their characteristics could influence liana climbing success but these factors had yet been investigated. Since liana climbing strategies are unique to these plants and greatly influence forest dynamics, it is necessary to examine characteristics of lianas and their relationships with hosts. The objectives of the study were to determine the relationships of different liana climbing strategies on different sizes and bark textures of host trees at the Mo Singto Forest Dynamics Plot.

MATERIALS AND METHODS

Study site

The study was conducted between April and December 2013 at the Mo Singto Forest Dynamics Plot, located in Khao Yai National Park, Thailand. The park is at the western end of the Panom Dongrak Mountain which lies along the southern edge of northeastern Thailand. The geographic coordinates of the plot are 101°22′E, 14°26′N. The elevation ranges from 725-815 m above sea level. According to the rainfall data obtained from the national park for the period 1994-2007, the rainy season started from May to October with mean annual rainfall of 2,220 mm. The dry season began in November to April. The mean annual maximum and minimum temperatures were 29°C and 19°C. The study site composes of the lowland area near the eastern edge, several ridges, and two valleys with brooks and two permanent springs. A 30.5 hectares (ha) forest dynamics plot was situated in a seasonal evergreen forest and divided into 762 quadrats of 20 m x 20 m (see also Brockelman et al., 2011).

Liana database and sampling

The 2011 liana and tree census data used in this study was obtained from the Ecology Laboratory of the National Center for Genetic Engineering and Biotechnology (BIOTEC), under the National Science and Technology Development Agency (NSTDA). All ramets whose diameters at breast height (dbh) were greater than or equal to 3 cm with their host trees were assigned specific tagging numbers. Lianas that could not confidently be identified to species were excluded from the analyses. Thirty ramets per species of 52 common species making up a total of 1,560 ramets were selected (Khiewbanyang et al., 2014). Host trees with dbh greater than or equal to 10 cm being attached by the selected ramets were examined. Host trees that were associated with ramets whose dbh smaller than 10 cm were excluded from the analyses.

The relationships between ramet and host tree characteristics

Two characteristics of ramets, which were sizes and climbing strategies, were chosen for this study. Sizes of these ramets were divided into three groups. Small size was defined as having dbh of 3-5.9 cm while the medium and large sizes were those having dbh of 6-8.9 cm and ≥ 9 cm, respectively. Kheiwbanyang et al. (2014)

recorded six climbing strategies, including twiners, scramblers, the combination of twiner and scrambler, tendrils, adventitious roots, and hooks, from these 1,560 ramets.

Two characteristics of host trees, which were sizes and bark textures, were examined. Sizes of host trees were also divided into three groups: small (dbh of 10-39.9 cm), medium (dbh of 40-69.9 cm) and large (dbh of ≥ 70 cm). Bark texture varied from rough to smooth, as a result of the number of lenticels, branch scars, and wound present on host trees. Lichens and mosses were not considered as parts of bark texture. Bark texture of host trees associated with liana ramets were classified into smooth, slightly rough, and rough (Campbell and Newbery 1993, van der Heijden et al. 2008). Bark texture of all host trees were photographed for confirmation. Smooth bark or unbroken bark was defined as the surface being smooth and glossy to dull area. This type of bark texture generally exhibited a very thin outer bark and flat. Slightly rough bark was the surface being any combination of small dimples, shallow fissures and lenticels visible. Rough bark was the surface with scales or plates, deeply fissures or cracks, deeply furrows or ridges, and vertical strips.

Data analyses

Correlation analysis was performed in order to clarify the relationships between host tree and ramet characteristics. The preference of hosts with particular bark texture was tested by using the chi-square test (χ^2) based on the availability of hosts. The Pearson correlation coefficient (ρ) and χ^2 were analyzed by the PASW Statistics for Windows, Version 18.0. Chicago: SPSS Inc. USA. All syntheses were test with statistically significant relationships ($p < 0.05$).

RESULTS

There were proportional differences between the three groups of ramet sizes regardless of their climbing strategies (Table 1). Most ramets were small (74.62%), followed by medium (19.55%) and large (5.83%). Among six climbing strategies, the majority were the twiners (30.77%) followed by the combination of the twiners and scramblers (26.92%), scramblers (21.15%), tendrils (9.62%), hooks (7.69%), and the least common adventitious roots (3.85%).

TABLE 1. The number of ramets in three size classes according to their climbing strategies The three groups of host tree sizes which were divided into small (3-5.9 cm dbh), medium (6-8.9 cm dbh) and large (≥ 9 cm dbh).

Ramet climbing strategy	Twiners	Scramblers	Twiners and Scramblers	Tendril	Adventitious roots	Hooks	Total
Small size	347	238	323	118	44	94	1,164
Medium	102	72	72	26	13	20	305
Large	31	20	25	6	3	6	91
Total	480	330	420	150	60	120	1,560

TABLE 2. The number of host trees in three size classes according to their bark textures. The three groups of host tree sizes which were divided into small (10-39.9 cm dbh), medium (40-69.9 cm dbh) and large (≥ 70 cm dbh).

Host tree characteristics	Smooth bark texture (S)	Slightly rough bark texture (SR)	Rough bark texture (R)	Total
Small size	56	771	308	1135
Medium	27	157	122	306
Large	14	32	73	119
Total	97	960	503	1560

Host trees also varied in size (Table 2). The majority of host trees were categorized in a small group (76.57%) followed by the medium size (17.66%) and large size trees (5.78%). Host tree were also grouped based on their bark textures. The majority of them had slightly rough bark texture (61.54%) followed by rough bark texture (32.24%) and smooth bark texture (6.22%).

The relationships between host tree and ramet sizes

A general trend showed a significantly positive correlation between ramet sizes of all climbing strategies and host tree sizes ($p < 0.05$) (Fig. 1). Small host trees were generally associated with small ramets. On the other hand, large host trees could actually support all sizes of ramets. It was

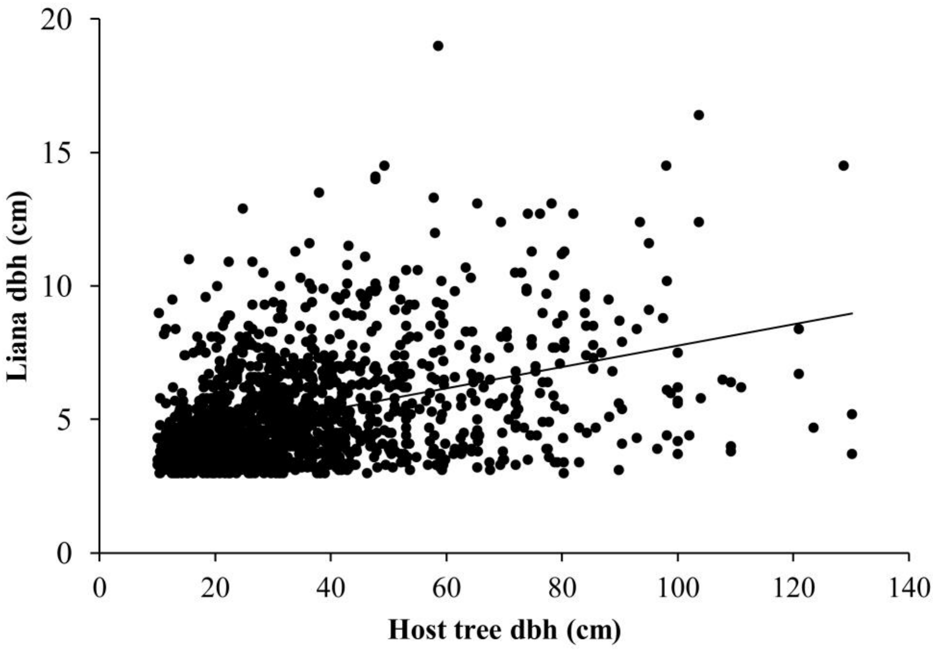

FIGURE 1. The relationship between host tree and liana sizes ($\rho = 0.683$, $p < 0.05$).

recorded that a tree with dbh of ≥ 70 cm supported ramets with dbh as small as 3 cm and as large as 16.4 cm.

The relationships between host tree size and ramet climbing strategies

The results showed that ramets using different climbing strategies appeared to use certain sizes of host trees (Fig. 2). Ramets employing the twiner strategy not only showed a significant association with host tree sizes but also showed more frequent use of small hosts than expected ($\chi^2 = 15.27$, df = 2, $p < 0.05$).

A positive correlation between ramets using the adventitious root strategy and host tree sizes was found. Ramets with this climbing strategy were mostly medium in size. The majority of these ramets tended to use medium host trees. Data showed that the adventitious root climbers appeared to use hosts of medium size ($\chi^2 = 82.70$, df = 2, $p < 0.05$).

In contrast, both the scramblers and ramets using the combination of twiner and scrambler showed a weak correlation with host tree sizes, and these ramets appeared to

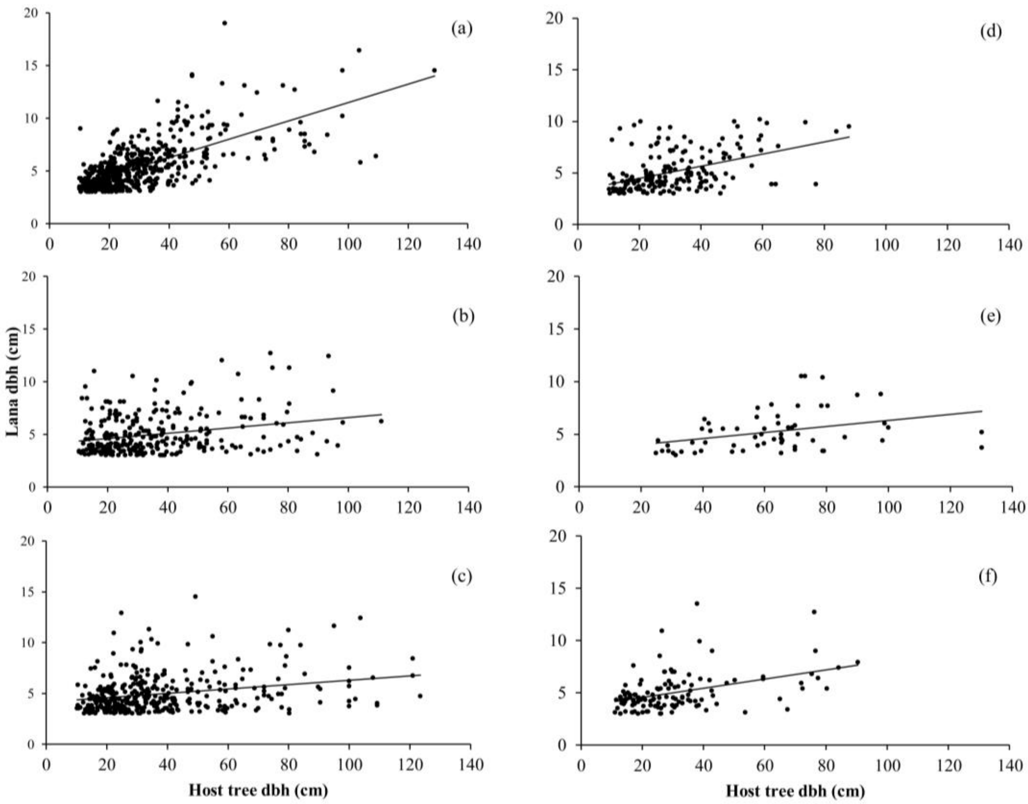

FIGURE 2. The relationship between host tree size liana size with Pearson correlation coefficient: a) twiner strategy ($\rho = 0.878$, $p < 0.05$), (b) scrambler strategy ($\rho = 0.263$, $p < 0.05$), (c) the combination of twiner and scrambler strategy ($\rho = 0.259$, $p < 0.05$), (d) tendril strategy ($\rho = 0.457$, $p < 0.05$), (e) adventitious root strategy ($\rho = 0.349$, $p < 0.05$), (f) hook strategy ($\rho = 0.419$, $p < 0.05$).

be independent of host tree sizes (scrambler ramets: χ^2 = 11.48, df = 2, p = > 0.05; ramets using the combination of twiner and scrambler: χ^2 = 3.23, df = 2, p > 0.05).

Similarly, ramets that employed the hook strategy were found to use small host trees as most of them were small but not more frequently than other host tree sizes. (χ^2 = 5.57, df = 2, p > 0.05). Ramets employing the tendril strategy were also independent of host tree sizes (χ^2=2.926, df = 2, p > 0.05). Even though small ramets tended to be found on small host trees, larger ramets could use host of any sizes.

The relationships between host tree bark texture and ramet sizes

The proportion of host trees with slightly rough bark texture was the greatest (Table 2). Ramets tended to use hosts with slightly rough bark more than expected (χ^2 = 6.36, df = 2, p = 0.041) (Fig. 3). Host with slightly rough bark texture were used by small ramets. Larger ramets though using the hosts had a tendency to use hosts with rough bark texture as well.

The relationships between host tree bark texture and ramet climbing strategies

Some ramet climbing strategies appeared to be dependent on host tree bark texture (Fig. 4). Hook climbers used host trees with slightly rough bark texture more often than expected (χ^2=11.52, df = 2, p < 0.05). On the other hand, adventitious root climbers required host trees with rough bark (χ^2= 8.32, df = 2, p < 0.05). Ramets employing the other climbing strategies were independent of host tree bark textures (p > 0.05).

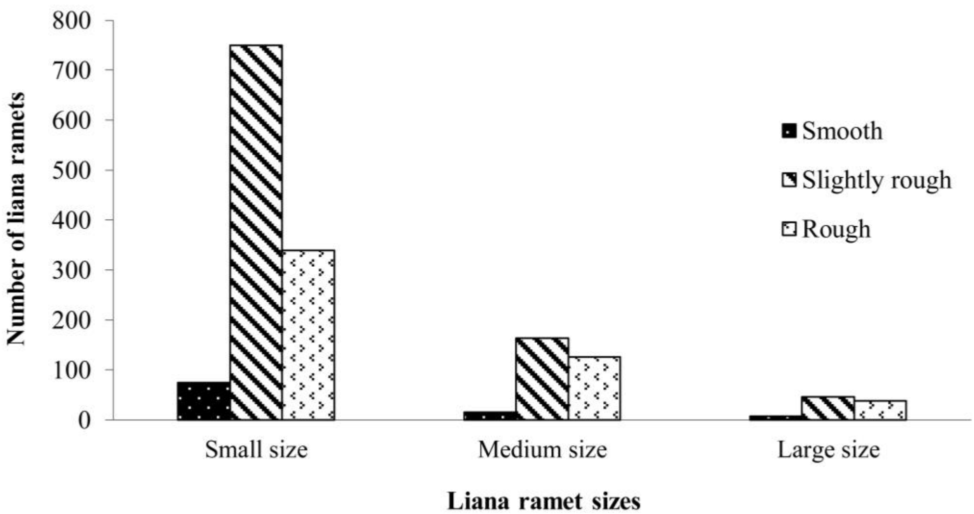

FIGURE 3. The host tree bark texture used by liana ramets of ≥3 cm dbh at Mo Singto Forest Dynamics plot, Khao Yai National Park Thailand.

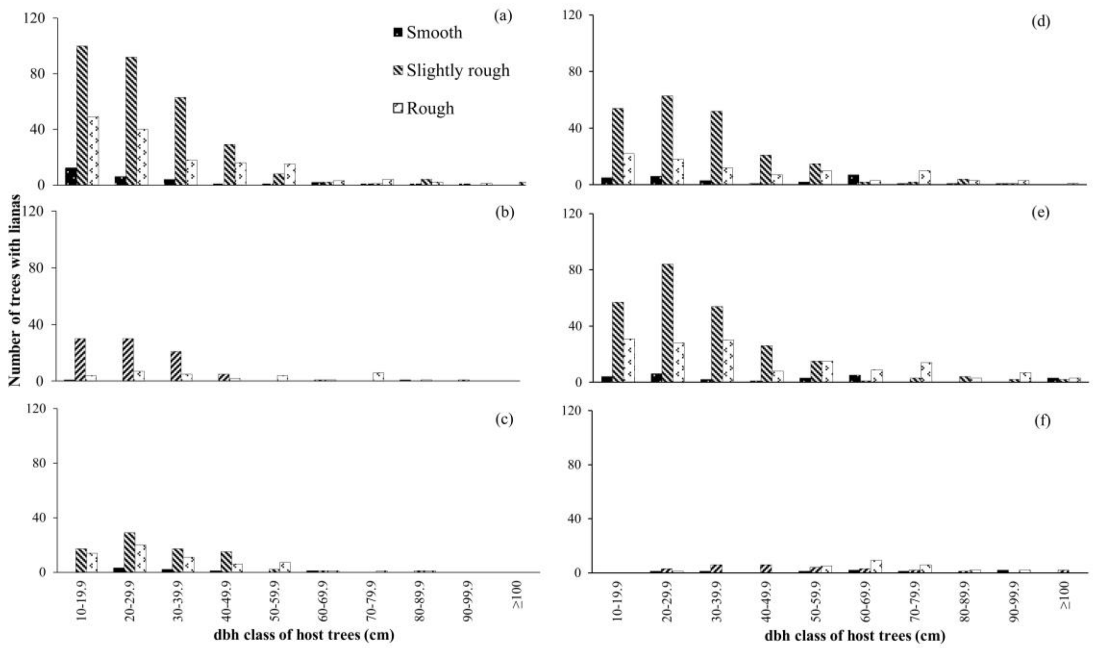

FIGURE 4. The host tree diameter size ≥10 cm dbh used by liana ramets of ≥3 cm dbh at Mo Singto Forest Dynamics plot, Khao Yai National Park Thailand: (a) ramets showing the twiner strategy, (b) the hook strategy, and (c) the tendril strategy (d) ramets showing the scrambler strategy, (e) the combination of twiner and scrambler strategy, and (f) the adventitious root strategy.

DISCUSSION

The Mo Singto Forest Dynamic Plot harbors high diversity of lianas. This diversity not only includes the number of species but also the diverse liana climbing habits as well as their associated host trees, which influence liana climbing success. Trees with small dbh and slightly rough bark texture dominated the study plot and served as the most abundant hosts available for liana ramets. Despite the abundance of this type of host trees, ramets with certain characteristics showed preferences toward certain characteristics of host tree.

The relationships between host tree size and liana climbing success

The relationships between liana and their host tree sizes were not random. This was particularly true for large ramets because small hosts were not able to support their weight. Although small ramets could use host trees of any sizes, they were found to climb small trees more often than larger trees. It is possible that small trees were more abundant in the area than larger trees and available for the young ramets to climb. Some studies suggested that some of these small ramets were capable of growing under the low light environment and could only use small host trees (Nabe-Nielsen, 2001).

The twiner ramets appeared to be associated with host trees with dbh < 50 cm (Nabe-Nielsen, 2001; Senbeta et al., 2005). However, this type of ramets may be found on large host trees as reported in DeWalt et al. (2000) in that the relative abundance of stem twiners in an old growth tropical forest increased with trunk diameter. It was because these twiners had attached to and grown on their hosts, and as their hosts became larger, the ramets also got larger.

Most adventitious root climbers were medium and large and also found to often use medium and large host trees, which were also observed in other areas (Carrasco-Urra and Gianoli, 2009). Because adventitious root climbers directly attached themselves to trunk, large host trees provided more space for attachment (Tally et al., 1996).

Some individual ramets could grow greater than 2 m tall before requiring any supports that were large enough to support their weight (Putz, 1984). These ramets usually exhibited certain climbing strategies, especially the scrambler and the combination of twiner and scrambler strategies. They were independent of host tree sizes as indicated by a weak correlation between these types of climbing strategies and host sizes. Thus, sizes of hosts might not be as important as other factors. This supported the suggestion that scramblers may depend on the density of supports and climb trees more successfully in young forests (Campanello et al., 2007). Scramblers in this study were found to climb not only their host trees but also other lianas. Similarly, the combination of twiner and scrambler strategy also showed a weak correlation with host tree sizes. Small host tree trunk was often used by twiners in the ascending state but scrambling ramets allowed the lianas to extend into the upper canopy on branches of their host trees. The combination of twiner and scrambler ramets would be more prevalent in younger forests and this trend was also observed in this study. Therefore, small host trees provided better support for the combination of twiner and scrambler ramets than less abundant and large host trees.

The hook climbers could use host trees of any sizes and this result was consistent with Putz (1984). It was probable that some hook climbers only required the presence of either branches or trunks of their hosts. As long as host trees offered areas for attachment, they would be suitable for hook climbers.

Tendril climbers used sensitive organs to attach to their supports and were also independent of host tree sizes probably because they only require surface areas for holding on to their hosts. Nevertheless, this result was contradictory to previous findings (Leicht-Young et al., 2010; Putz 1984) that found tendrils to use mostly small host trees. They argued that large host trees were likely too large for direct climbing because a tendril must wrap itself around the supports. On the other hand, as long as there are surface areas for these ramets to hold, sizes of host trees should not be relevant. Most host trees at the Mo Singto Forest Dynamic Plot were small yet the number of tendril ramets examined in this study still showed no particular use of certain size of host trees. Other factors may influence the successful climbing of this type of ramets rather sizes of host trees.

The relationships between host tree bark textures and liana climbing success

Bark textures were also important to climbing success of lianas. Although the frequent use of hosts with slightly rough bark texture by small ramets was observed, it was as expected since most available host trees had slightly rough bark texture.

Some climbing strategies of the ramets appeared to show some associations with host tree bark texture. Preference of particular bark texture of host trees was also obvious in ramets using hooks (host trees with slightly rough bark texture) and adventitious roots (host trees with rough bark texture). This situation has been reported in other studies (Tally et al. 1996). Slight differences were suggested that host trees with strongly peeling bark would be difficult for lianas to colonize using adventitious roots because rough bark was not stable surfaces for root attachment (Jiménez-Castillo and Lusk, 2009). This could be due to the degree of roughness assigned to trees. Despite all these, bark texture poses the importance for successful climbing of ramets.

The twiners, scramblers, ramets using the combination of climbing strategies, and tendrils appeared to be independent of host tree bark texture. The selection of host trees of stem twiners were likely influenced by host tree sizes rather than bark textures. On the other hand, the scramblers and ramets using multiple climbing strategies only required any types of leaning supports regardless of specific characteristics of hosts. Similarly, it was observed that the tendril ramets did not show any statistically significant relationships with two host tree characteristics examined in this study since they only required surface areas for holding.

Differences in liana and host tree relationships observed in this study added to the evidence that the suitability and availability of host trees with various characteristics influence liana climbing success. Host tree size was an obvious important factor for ramets with certain climbing strategies. On the other hand, some ramtes did not depend on particular sizes or bark textures of hosts for colonization. The unique and diverse morphology and climbing habits of lianas could explain liana distribution patterns that may be correlated with forest succession stages but there is still unclear and requires further investigation.

ACKNOWLEDGEMENTS

We gratefully thank Warren Y. Brockelman and Wirong Chanthorn for their advice. We would like to thank Department of National Parks, Wildlife and Plant Conservation for permission to collect information in Khao Yai National Park. This thesis work is supported by Thailand Graduate Institute of Science and Technology (TGIST), TGIST-01-55-020 under National Science and Technology Development Agency (NSTDA).

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