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TRAIT-BASED STUDIES ON THE ABUNDANCE AND CANOPY SHADE PREFERENCES OF ASTERACEAE SPECIES IN CIBODAS BOTANICAL GARDEN

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ABSTRACT

Knowledge of community structures and capacity to differentiate invasive from non-invasive species are essential for invasive species management. Specific Leaf Area (SLA) is a potential proxy to differentiate invasive from non-invasive species. This study aims to identify the relationship between Important Value Index (IVI) with SLA of Asteraceae species, and predict Asteraceae habitat preference based on shade characteristics at the Cibodas Botanical Garden. There is a positive correlation between SLA and IVI value of Asteraceae species in shaded habitat. The Asteraceae species that prefer shaded habitat tend to have larger SLA relative to species in open area (odds ratio = 2.754). This study showed that SLA is a potential proxy to indicate plant abundance and an informative proxy to predict habitat preferences in CBG ecosystem. These traits information is crucial for invasive exotic plant species management in CBG particularly and tropical botanic gardens in general.

Keyword: *invasive species, exotic species, SLA, logistic regression, trait*

PENDAHULUAN

Invasive species is a species that occurs outside their natural distribution ranges and causing significant negative impact to native ecosystems and human activities. The development of invasive species can be harmful to native species due to negative ecological relationships such as predation and resources competition (Indrawan, Primack, & Supriatna 2012). One of special attributes that support the biological invasion of invasive species is the allelopathic capacity, which is the ability to produce secondary metabolites that can inhibit neighboring native plants growth (Funk et al., 2005; Orr et al. 2005).

Asteraceae is one of the biggest plant families with more than 1600 genus and around 25000 species globally. Asteraceae inhabit variety of habitat types such as lowland, coastal, arid, semi-arid, up to highland and mountainous ecosystems (Nikolic & Stevovic 2015). The life-form of Asteraceae also varied from annual herbs, perennial herbs, to shrubs and trees. Even though Asteraceae are widely distributed, but this taxon mainly occur in open areas rather than closed canopy tropical forests (Funk et al. 2005). Moreover, characteristics of Asteraceae, such as numerous seed production, long seed dispersal ability, wide tolerance to environmental condition, and high rate of offspring, causing Asteraceae to become a potential invasive species (Solfiyeni et al. 2013; Adriadi, Chairul, & Solfiyeni 2012). Many Asteraceae species also produce secondary metabolites that can become allelopathic to support their competition ability with their neighboring plants (Funk et al. 2009).

Asteraceae species are major problems in Indonesian invasive species. According to Tjitrosoedirdjo (2005), there are 53 Asteraceae species out of 339 invasive species in Indonesia. Among these 53 species, there are noxious invasive Asteraceae species including *Chromolaena odorata*, *Mikania micrantha*, and *Sphagneticola trilobata*. A study conducted by Adriadi, Chairul, & Solfiyeni (2012) showed that weeds in palm oil agriculture land in Batang Hari area are dominated by 13 Asteraceae species.

Invasion successfulness associated with exotic species characteristics that can support invasion processes. These characteristics include long distance dispersal, high reproduction and growth rate, vegetative reproduction ability, and high tolerance to abiotic conditions such as temperature, humidity, and soil type (Velde et al. 2006). Those characteristics are example of plant functional traits, which is plant functional characteristics that are affect plant fitness through plant growth, reproduction, and life history (Violle et al. 2007). According to van Kleunen, Weber, & Fischer (2010), invasive plant species have higher traits values than non-invasive plants. One of these traits is specific leaf area (SLA). Even though leaf mass per area (LMA) is clearly different between shaded and open leaves (Lambers, Chapin III, & Pons 1998), specific leaf area used in this study as proxy for invasion capacity due to SLA as indication for invasiveness (Van Kleunen, Weber, & Fischer 2010)

SLA stated as traits that associated with carbon assimilation and its allocation in plants. SLA indicated the invasiveness of an exotic species because it positively correlates with growth rate and light intensity (Dawson, Burslem, & Hulme 2011). Several studies indicated that invasive species have higher SLA values than non-invasive species in tropical rainforests (Pattison, Goldstein, & Ares 1998), Mediterranian islands (Gulias et al. 2003), and tallgrass prairie vegetation (Smith & Knapp, 2001).

Abiotic conditions also play important roles in plant invasion successfulness. A study by Junaedi & Dodo (2014) showed that even though *Austroeupatorium inulifolium* have the highest invasion risk score, but the existence of canopy shade that reduced light intensity become limiting factor for this exotic species in Halimun Salak corridor. Master, Tjitrosoedirdjo, & Qayim (2016) also showed that biological invasion of *Merremia peltata* in Bukit Barisan Selatan National Park is negatively correlated with canopy shade. The existence of canopy shade in an ecosystem can limit plant access to light resources. Area without canopy shade receive higher light intensity that consequently causing exotic plants in these areas have higher SLA values, higher growth rates, and become successful invaders (Yansen et al. 2015).

One of plant invasion pathway in Indonesia is plant exchange and introduction via botanical gardens. For example, the dispersal of *Mikania micrantha* in Indonesia is the result of plant introduction from Paraguay through Bogor Botanical Garden. Other invasive species that introduced via botanical gardens are *Mimosa pigra* and *Eicchornia crassipes* (Tjitrosoedirjo, 2005). Cibodas Botanical Gardens (CBG) is one of Indonesian botanical garden that conserved tropical highland plant species (Surya et al. 2013). The fragmented forests in CBG area are prone to exotic plant invasion due to edge effect phenomena. There are several detected naturalized exotic species from CBG to adjacent forests such as *Austroeupatorium inulaefolium*, *Chimonobambusa quadrangularis*, and *Strobilanthes hamiltoniana* (Mutaqien, Tresnanovia, & Zuhri, 2011). There are 15 exotic species detected in CBG remnant forests and four of these exotics are Asteraceae species (Mutaqien, Tresnanovia, & Zuhri, 2011). Furthermore, Tjitrosoedirdjo (2002) stated that the amount of Asteraceae genus in Java (107 genus) is larger than Sumatra (74 genus). This is because botanical gardens were contributed to Asteraceae introductions in the past.

The occurrence of Asteraceae species in CBG may become a potential threat to native plant biodiversity in CBG and its adjacent native forests. Knowledge about Asteraceae community structure in CBG is needed as a basic information for exotic invasive plant species management in CBG. Prevention is the best management approach for exotic invasive species. Therefore, capacity to differentiate exotic invasive form non-invasive exotic plant species is essential for management purposes. This differentiation can be conducted using plant functional traits as proxies (Kleunen, Weber, & Fischer 2010).

Exotic species studies on detection (Junaedi 2014), vegetation structure (Mutaqien & Zuhri 2011), and species dispersal (Mutaqien, Tresnanovia, & Zuhri 2011; Kudo et al. 2014) has been conducted in CBG. However, there are no studies about exotic species differentiation based on plant traits and traits relation with exotic plant community structure yet. There is no published information about Asteraceae community structure in CBG reported yet. Therefore, traits – plant community correlation studies need to be conducted in CBG, particularly for exotic species in CBG. The aims of this study are: (1) to examine the community structure of Asteraceae species in CBG; (2) to examine the correlation between Specific Leaf Area (selected plant trait) with their important value index (IVI, as a proxy of community structure) of Asteraceae species in CBG, and (3) predicting canopy cover preferences of Asteraceae species in CBG based on their SLA value. This study may provide basic information for exotic invasive species management and provide a reference and example of SLA-based ecological prediction.

METHODS

Study Location and Time

This study conducted in CBG area (6 44’ 30’’ S, 107 0’ 19’’ E) from March to April 2018. CBG located at 1100-1450 m above sea level. Air temperature in CBG ranged from 19$_o$ C to 30$_o$ C with daily average temperature equal to 22.61$_o$ C. Air humidity ranged from 65% to 82% with daily average 74.14%. Light intensity range in CBG is from 300 to 13650 lux. Abiotic data from all compartments presented in Table 1.

TABLE 1. Measurement results (average) of abiotic parameters in CBG sampling sites. Measurement conducted from March to April 2018.

	Compartments							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Altitude (m above sea level)	1344	1355	1353	1394	1360	1384	1397	1310
Air temperature ($_o$C)	23	22	22	23	24	22	21	21
Air humidity (%)	72	73	73	65	80	74	82	79
Soil humidity (%)	78	61	54	58	52	61	51	57
Light intensity (x 100 lux)	1152	992	777	579	228	206	251	192

Procedures

Specific Leaf Area (SLA) and Habitat

Specific Leaf Area (SLA) data collected based on manual in Perez-Harguindeguy et al. (2013). Sampled leaves are healthy leaves that are not too old and too young, not folded, no sign of herbivore destruction, and directly exposed to sunlight. We collected 5 leaves for every species we detect in a plot. If a species is very abundant in a plot, then we collected two leaves from five individuals in a plot. Leaf area measured from leaves photo data captured by using Canon D60 camera, using software ImageJ (Schneider et al. 2012). Dry leaf mass data measured after leaf samples dry-ovened in MEMMERT IN 55 oven for 3 days (72 hours) in constant temperature of 70oC on OHAUS digital balance. SLA calculated as the ratio between leaf area and dry leaf mass.

We collected data from natural Asteraceae population only and did not include Asteraceae of CBG garden collections. We also limited the sampling to herbs and omitted the other growth-form (such as liana/climber, shrub, and trees) because of two main reasons. Firstly, herb is dominant growth-form in Asteraceae (van Steenis 2006). Secondly, SLA is a sensitive trait relative to leaf position from the ground. Therefore, by limiting the sampling to herbs only, we assume that the effect of leaf position relatively minor in this study (Perez-Harguindeguy et al. 2013).

To collect shading preference data, we divided compartments into two types: opened area (full sunlight exposure) (compartment 1 to 4) without any shading from canopies, and shaded area (compartment 5 to 8) with shading from canopies. Shaded compartment and plots placed next to fragmented forests in CBG area (Mutaqien & Zuhri, 2011).

Data Analysis

The Correlation between Important Value Index (IVI) and Specific Leaf Area (SLA)

Linear regression analysis conducted to examine the correlation between IVI and SLA value. We conducted three regression analysis for total data, open compartment only, and shaded compartment only, based on:

IVIi = a0 + ß1SLAi + εi ……………………..e1)

where IVIi is important value index of species i, SLAi is specific leaf area value of species i, and εi is normally distributed error (εi ~ N (0, σ)). Bayesian statistical analysis conducted in R using rjags to call JAGS in R.

Shading Preferences Based on SLA Value

Logistic regression analysis conducted to examine the shading preferences of Asteraceae species habitat based on SLA value, using following formula:

pi = e (gi)⁄(1+e(gi)) ……………………………e2)

where pi is probability of an Asteraceae species i prefer shaded habitat and gi = a0 + ß1SLAi + εi. Dependent variable in the previous logistic regression equation coded as 1 if the species occurred in shaded compartments and 0 if the species occurred in opened habitat. Bayesian statistical analysis conducted in R using rjags to call JAGS in R.

RESULTS AND DISCUSSIONS

We detected 20 Asteraceae species in total, with twelve species were found in either shaded or open compartments. There were four species that occur exclusively in shaded compartments (*Mikania micrantha, Bidens biternata, Clibadium surinamense,* and *Synedrella nodiflor*a) and four species only detected in open compartments (*Sonchus arvensis, Sonchus asper, Porophyllum ruderale,* and *Eclipta prostata*) (Table 2). This study did not include all detected Asteraceae species in CBG ecosystem because included Asteraceae species that were grow naturally (not CBG garden collection), Asteraceae with herbaceous growth-form, and possible to be measured and recorded. For instance, we did not include *Tithonia diversifolia, Austroeupatorium inofolium,* and *Chromolaena odorata* because they were on cliffs that are difficult to access. We also omitted *Cosmos caudatus* and *Cosmos sulphureus* because these two species are CBG garden collections.

TABLE 2**.** Detected Asteraceae species in this study. Four species only exist in shaded compartments and four species only occur in open compartments

Species	**Occurence**	
	Open compartment	**Shaded compartment**
Acmella uliginosa	V	V
Ageratum conyzoides	V	V
Ageratum houstoniaum	V	V
Bidens biternata	-	V
Bidens pilosa	V	V
Clibadium surinamense	-	V
Crassocephalum crepidioides	V	V
Dicrocephala bicolor	V	V
Emilia sonchifolia	V	V
Erigeron sumatrensis	V	V
Galinsoga parviflora	V	V
Mikania micrantha	-	V
Sonchus arvensis	V	-
Sonchus asper	V	-
Eclipta prostrata	V	-
Porophyllum ruderale	V	-
Sphagneticola trilobata	V	V
Synedrella nodiflora	-	V
Taraxacum officinale	V	V
Youngia japonica	V	V

In general, *Emilia sonchifolia* is the most dominant Asteraceae species with IVI value equal to 26.85%. This species occurs in both compartment types: shaded and open. Dominant species have high biomass productivity and indicate that abiotic condition in studied ecosystem supports the development and growth of dominant species (Odum 1993).

Specific leaf area (SLA) calculated by dividing average leaf area with average dry leaf mass for every species in every plot. Most of SLA values of Asteraceae species in shaded compartment are higher than species in open compartments, except for *Sphagneticola trilobata* (Figure 2). The existence of shading decreased the amount of sun light received by plants (irradiation). Sitompul & Purnomo

(2005) stated that the absence of canopy shade increase irradiation value up to 61 % relative to shaded area. SLA is trait that is useful as indicator for plant shade tolerance capacity. Higher SLA value may indicate plant adaptation to increase leaf area index to maximize light radiation acceptance for photosynthesis under shaded condition (Suwarto 2013).

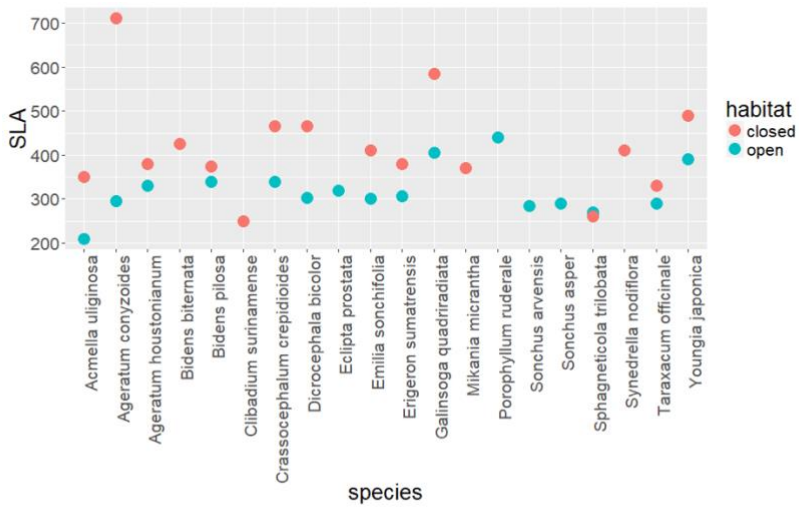

FIGURE 2. Mean Specific leaf area (SLA) value of measured Asteraceae species in closed compartment (orange) and open compartment (blue).

Based on equation e1, linear regression result between IVI and SLA value in shaded compartment give the largest and most significant correlation value (adjusted r-squared = 0.147, p = 0.07). Linear regression result (IVI-SLA correlation) for open compartment give negative values. There are other factors that somehow contribute to this negative correlation between SLA and IVI. We speculate that Asteraceae species in open compartments are frequently managed (cutted) by CBG staff because most of these CBG open areas are popular destination for CBG visitors (Table 3). Correlation between IVI and SLA for total data (open and shaded data combined) is positive, but the magnitude and significance are smaller than shaded compartment only data (Figure 3). For every unit increase in log(IVI), we predict there will be 0.0015 increase unit of SLA value.

TABLE 3. Linear regression result based on eq1 for shaded compartment data only, open compartment data only, and total data (shaded and open compartment data combined).

Model	Regression equation	Adjusted r square	P value
Shaded compartment only	Log(IVI) = 0.333 + 0.002*SLA	0.147	0.071
Open compartment only	Log(IVI) = 2.237 – 0.514*SLA	-0.062	0.725
Shaded + Open compartment	Log(IVI) = 0.185 + 0.0018*SLA	0.021	0.249

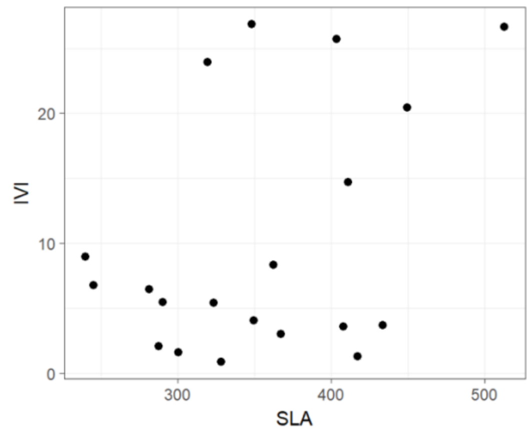

FIGURE 3. Scatter plot of specific leaf area (SLA) versus important value index (IVI) values of Asteraceae species from open and closed habitat in total

High SLA value may indicate high growth rate. Richardson & Pysek (2007) stated that species capacity to reach high growth rate depends on resources availability. The finding in this study is contradictive with a study result by Cornwell & Ackerly (2010), which showed that abundant species have smaller SLA values. However, the study did not consider native-exotic in their species categorization. Species abundance and occurrence in an ecosystem correlated with ecological processes and related with 1) morphological and physiological characteristics, 2) relative abundance of resources and 3) supported abiotic conditions for plant optimum growth (Grime 2006; Cornwell & Ackerly 2010). Therefore, apart from SLA, there are many factors may possibly correlate with plant abundance in an ecosystem. On the other hand, SLA value also correlates with other factors such as leaf thickness. Finally, SLA may become a useful proxy to indicate or predict the abundance of Asteraceae species, but need to be complemented with other traits to gain more accurate prediction.

Based on eq2 (logistic regression), analysis result showed that larger SLA values tend to occur in shaded compartment. In contrast, smaller SLA values tend to exist in open compartments (Figure 4). Odds ratio value from analysis result is equal to exp(1.013) = 2.754. From this figure, we can conclude that based on SLA values, Asteraceae species prefer shaded habitat nearly 3 times than open habitat.

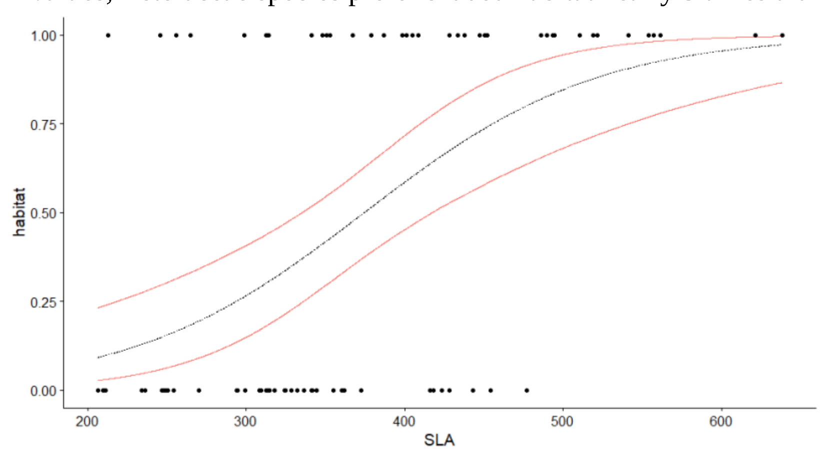

FIGURE 4. Logistic regression prediction of Asteraceae habitat preferences between shaded (1) and open (0) compartments. Red lines are lower (2.5%) and higher (97.5%) credible interval

According to Keddy (1992: 160), traits may indicate species successfulness in a specific ecosystem. The habitat preference of Asteraceae species may be indicated by SLA. Wilson, Thompson, & Hodgson (1999: 156) stated that SLA may represent resources gain by plants. Plant with high SLA value tend to be productive but short-lived and prone to herbivore, while plant with smaller SLA value tend to work better in limited resources environment. Paired t-test results of SLA values of the same Asteraceae species in different habitat did not reveal significant differences though. The logistic regression result showed that Asteraceae species with higher SLA values tend to prefer shaded environment with low light irradiance. This result in concordance with a study by Shipley & Almeida-Cortez (2003: 77) in Asteraceae species (*Achillea millefolium, Arctium minus, Chrysanthemum leucanthemum, Cichorium intybus*, *Matricaria matricarioides*, and *Rudbeckia hirta*) that showed that SLA negatively correlated with light irradiance. Alternatively, high SLA value indicate the maximisation of leaf area to capture light under limited light resources in shaded habitat (Lambers et al 1998, p. 330). Thus, SLA may explain the capacity of exotic species to cope with low light conditions.

CONCLUSIONS

There are 20 Asteraceae herb species recorded in Cibodas Botanic Gardens (CBG) with *Emilia sonchifolia* as the most dominant species. There is a positive correlation between SLA and IVI value of Asteraceae species in shaded environment. Finally, Asteraceae species with higher SLA value tend to prefer shaded habitat than open habitat. This study showed that SLA is a potential proxy to indicate plant abundance and an informative proxy to predict habitat preferences in CBG ecosystem. This study also demonstrated that informative prediction for invasive species risk assessment, such as predicting habitat suitability, may be established based on simple traits information such as SLA. These traits information are crucial for invasive exotic plant species management in CBG particularly and tropical botanic gardens in general.

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