INVASIVE WEEDS IN BOGOR BOTANIC GARDENS, INDONESIA AND ITS IMPLICATION ON SURROUNDING LANDSCAPES

Gulma Invasif di Kebun Raya Bogor, Indonesia dan Implikasinya pada Lansekap di Sekitarnya

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Abstrak

Areal konservasi yang didedikasikan untuk koleksi dan pertukaran bahan tanaman disinyalir menjadi sumber gulma bagi wilayah di sekitarnya. Tujuan dari penelitian ini adalah mengindentifikasi dan mengevaluasi gulma ruderal invasif di Kebun Raya Bogor (KRB). Observasi dilakukan untuk mengidentifikasi spesies gulma, menentukan tingkat invasif, dominasi gulma, dan penyebarannya di dalam KRB. Gulma diamati pada setiap vak (petak) termasuk asosiasinya dengan tanaman koleksi. Data pengendalian gulma dan kematian tanaman koleksi dianalisis kaitannya dengan keberadaan gulma. Penyebaran gulma di luar areal KRB diamati secara transek mengikuti alur sungai dan jalan raya. Hasil menunjukkan bahwa terdapat tujuh gulma invasif yaitu *Cecropia adenopus* (Cecropiaceae), *Cissus nodosa* Blume (Vitaceae), *Cissus sicyoides* Blume (Vitaceae), *Dioscorea bulbifera* L. (Dioscoreaceae), *Ficus elastica* Roxb. (Moraceae), *Mikania micrantha* H.B.K. (Asteraceae) dan *Paraserianthes falcataria* (L.) Nielsen (Fabaceae). Ketujuh gulma tersebut menginvasi pada 41 famili dari total 215 famili yang ada di KRB. Enam spesies yaitu *C. adenopus*, *C. nodosa* Blume., *C. sicyoides* Blume., *D. bulbifera* L., *M. micrantha* H.B.K. dan *P. falcataria* (L.) Nielsen pada awalnya adalah koleksi introduksi di KRB sedangkan *F. elastica* Roxb. merupakan spesies asli setempat. Ada dugaan kuat bahwa penyebaran gulma invasif di KRB karena pengaruh angin, burung, kelelawar, pengunjung dan aliran air. Semua gulma yang ada, juga ditemukan di luar areal KRB. Mengingat pengaruh gulma tersebut terhadap tanaman koleksi di KRB cukup merugikan, oleh karena itu, perlu ada langkah pengendalian jangka panjang yang komprehensif terhadap gulma tersebut baik di dalam maupun di luar kawasan KRB dengan melibatkan otoritas setempat.

Kata kunci: Areal konservasi, gulma ruderal, pengendalian gulma, penyebaran gulma, weed bank

Abstract

Conservation areas with the objective for collection and exchange plant materials have been speculated as weed bank for surrounding areas. Objective of this study was to identify and characterize ruderal invasive weeds in the Bogor Botanic Gardens (BBG). Observations were conducted in all vak (collection blocks) in the BBG in order to identify the weeds species, determine their invasiveness, dominance and distribution. Weeds associations with host plants were observed. Current weed control program and data of dead trees collection were analyzed in relevant to weed. Distribution of weeds outside BBG was observed by transects method following river and road directions. Results showed that there were seven invasive weeds, i.e., *Cecropia adenopus* (Cecropiaceae), *Cissus nodosa* Blume (Vitaceae), *Cissus sicyoides* Blume (Vitaceae), *Dioscorea bulbifera* L. (Dioscoreaceae), *Ficus elastica* Roxb. (Moraceae), *Mikania micrantha* H.B.K. (Asteraceae) and *Paraserianthes falcataria* (L.) Nielsen (Fabaceae). These seven weeds species invaded 41 out of 215 plant families in BBG. Six species of weeds, i.e., *C. adenopus, C. nodosa* Blume., *C. sicyoides* Blume., *D. bulbifera* L., *M. micrantha* H.B.K. and *P. falcataria* (L.) Nielsen*,* were introduced as BBG collections for the first time while the *F. elastica* Roxb was considered as native. It is most likely that the weeds dispersal agents are the wind, birds, bats, visitors, and waters. All of these weeds existed in surrounding areas outside BBG. Given the detrimental impact of invasive weeds on the plant collection in BBG, it is necessary to develop long–term comprehensive control measures both inside and neighboring areas by involving other government authorities beyond BBG.

Keywords: Conservation area, ruderal weed, weed bank, weed control, weed dispersal

INTRODUCTION

Invasive weeds spread extensively to cultivated lands and other disturbed areas and cause vegetation changes (Mashhadi and Radosevich, 2004). Campbell (2005) stated that invasive weeds have high negative impact on economy, environment, and human health and caused a noticeable problem in many countries (Weber and Gut, 2004; Grimsrud *et al*., 2008; Ou *et al*., 2008; van Wilgen *et al*., 2008; Dawson *et al*., 2009; Moser *et al*., 2009; Klepeis, 2009).

Although Botanical Gardens function as a conservation area for flora and fauna (Oldfield, 2009), many invasive weed species are believed to spread out from the conservation areas (Hulme, 2011; Webber *et al*., 2011; Zuhri and Mutaqien, 2013). Sastroutomo (1990) states that weed can destroy crops by competing for light, water, and nutrients. Furthermore, weeds are detrimental for crop production because crop diseases and pests harbor on weeds and removing weeds is troublesome and costly. In the conservation area, however, the presence of invasive weeds is sometimes debatable because invasiveness is a matter of subjective judgement (Sastroutomo, 1990), and studies of invasive weeds in the botanical gardens in Indonesia become important concern (Roemantyo and Purwantoro, 1990; Webber *et al*., 2011; Conn *et al*., 2012).

Until 2009, Indonesia has twenty botanical gardens extending across six bioregions (five in Java, one in Bali, one in Nusa Tenggara, five in Sumatra, four in Kalimantan, and four in Sulawesi) (LIPI, 2009). Four botanical gardens, i.e., Bogor, Cibodas, Purwodadi, and Bali, are gazetted as *ex situ* conservation centers. Until recently, the Indonesian government has already planned develop to a total of 47 botanical gardens where the 21 new botanical gardens are also located in six main bioregions exhibiting unique characteristic of climatic and edaphic conditions, i.e., three in Java, one in Nusa Tenggara, five in Sumatra, one in Lampung, five in Kalimantan, five in Sulawesi and one in Wamena, Papua (LIPI, 2011). The ability of weeds to become invasive is determined by the characteristics of the plants and environmental factors (Mashhadi and Radosevich, 2004), and in general, invasive plants are able to develop root formation rapidly and the presence of many kinds of local pollinators permit the propagation of invasive plants (Tjitrosemito, 2004). Tjitrosoedirdjo (2010) revealed that invasive plants are able to form a dense canopy, and lack of potential natural enemies which attack them and he further presumed that a non–native species which find an optimum new ecosystem may evolved into invasive weed. According to Shi *et al*. (2010), rainfall and temperature greatly affect the success of invasion. Therefore, dominant invasive weeds maybe different among regions (Weber and Gut, 2004; Hulme, 2011).

Identification of invasive weeds in the botanical gardens is important issue because the intensity of plant materials exchanges among botanical gardens are relatively high, both nationally and internationally (Radosevich *et al*., 2007). This may lead to the escape of seeds and propagules of invasive weeds from botanical gardens into surrounding areas. The aim of this study was to identify invasive weeds in the Bogor Botanic Gardens and surrounding landscapes.

METHODS

This study was conducted at the Center for Plant Conservation Botanic Gardens–LIPI (6°36'14"S and 106°47'50"E), West Java, Indonesia (260 m above sea level) in January to May 2011. Observation outside BBG was conducted from June 2011 to December 2013.

BBG is the oldest botanical gardens in Indonesia and the 13th oldest in the world. BBG covers 87 hectares and is located about 60 km south of Jakarta. The soil of BBG is latosols, with reddish brown color and flat topography (slope 3–15%). The annual rainfall varies between 3000–5000 mm, with more than 240 rainy days, and the daily temperature between 21.4°–30.2 °C. BBG nestles between two rivers: Ciliwung and Cibalok. According to Subarna (2002), Cibalok river was a source of water for irrigation for BBG. BBG had a major collection of living plants consisting of 3,423 species which were displayed in 192 plots called *vak*. In this collection of plants, 54% of species were native and 46% were introduced plants. More than 56 species of birds and bats were recorded in BBG (Subarna, 2002).

Invasive weeds were observed in the entire plots (100% of BBG area) of living germplasm collection (vak) in the garden and classified according to Tjitrosoedirdjo (2010), such as dicots and monocots, excluding aquatic and grass weeds. All observed weeds were kept as herbarium specimen in Bogor Agriculture University. Distribution, coverage, mode of reproduction, and invasiveness of weeds were investigated. Official site of particular plant in BBG was determined as center point of its dispersal, and judged by interviews with staffs of BBG. Canopy width was measured by the canopy projection areas which were visually outlined on the ground. Area of weed cover was estimated by using ARC GIS 3.3 program. Reproduction method was determined based on either existence of propagule or available literature.

Sum of dominance ratio (SDR) was calculated from all plots according to the method of Moenandir (1993) with a slight modification. For SDR calculation, dry mass of weed was excluded due to technical difficulties, thus SDR was estimated by the average of relative frequency and relative density of a weed. Relative frequency was calculated by dividing the absolute frequency of a weed by the number of plots where any species of weeds were detected. Relative density was calculated by dividing the number of sites inhabited by a particular species of weed by the number of sites inhabited by any species of weeds. Scoring invasiveness followed the procedures proposed by Hiebert and Stubbendieck (1993) and Tjitrosoedirdjo (2010), in which 20 characters were scored from zero to five (Table 1). Weed had score more than 50 are classified as important weeds from agronomy and ecological point of views.

Weeds outside BBG were traced follow river and follow main and residential roads where accessible by car, up to ca 9.5 km apart from BBG. Total 18 sites were observed (Figure 1). In each site, a square area of about 100 m x 100 m (if applicable) or

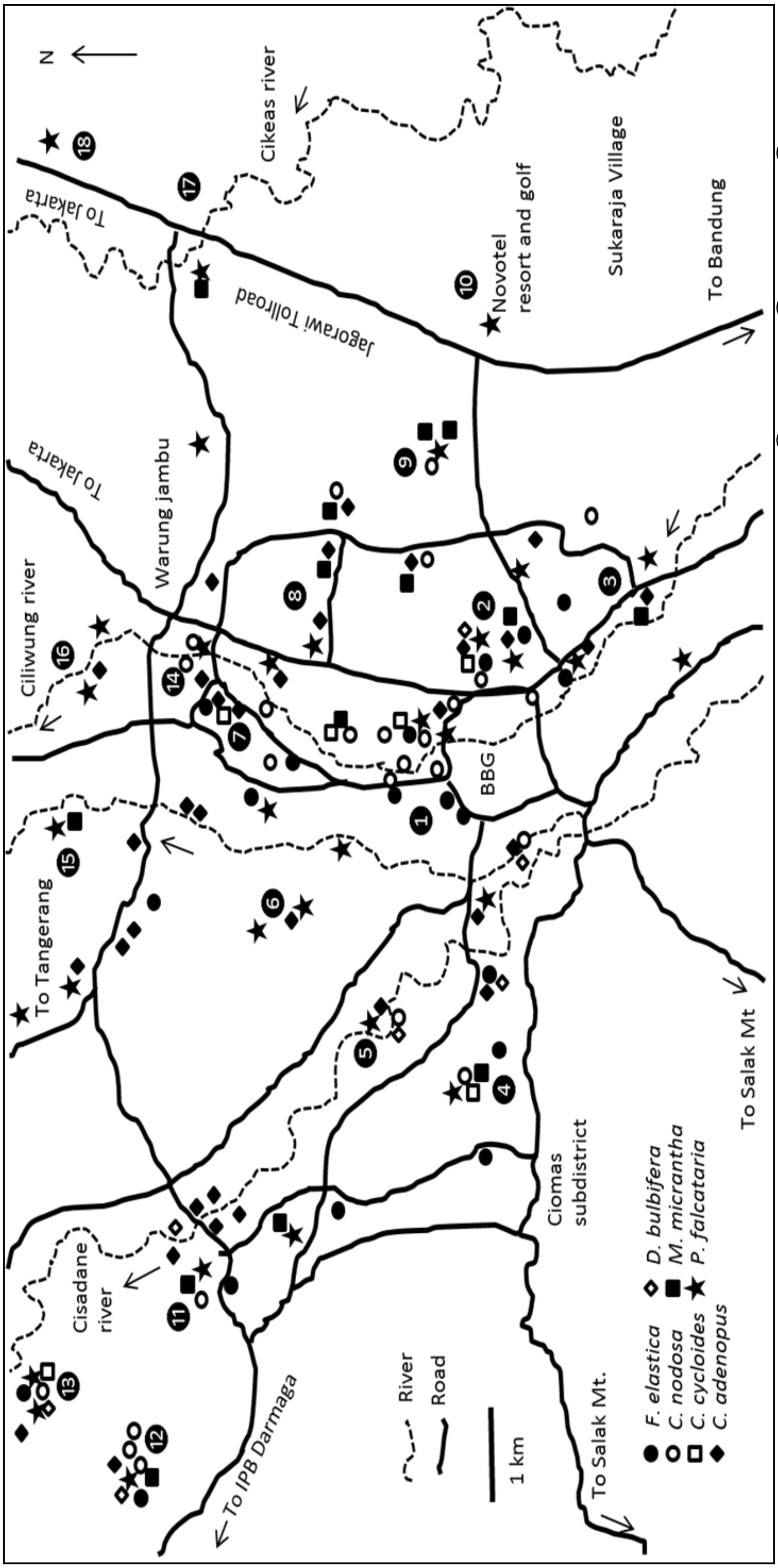

Figure 1. Weeds distribution outside Bogor Botanical Gardens (BBG). Number represented site name, i.e., ① Sempur, ② IPB Bogor, ③ Bogor Baru, ④ Ciomas, ⑤ Cilendek, ⑥ Cimanggu, ⑦ Stadion Bogor, ⑧ Bantarjati, ⑨ Cimahpar, ⑩ Novotel Hotel, ⑪ Bubulak, ⑫ IPB Darmaga, ⑬ CIFOR Forest, ⑭ Warungjambu, ⑮ Kedungbadak, ⑯ Karadenan, ⑰ Sentul Selatan, and ⑱ Sentul rest area.

one hectare was studied. Weeds were identified by morphological characters, only mature weeds were considered. Since the weeds in some places were regularly cleaned, in that case, interview with people in targeted-areas was conducted. Interview was also conducted to determine weed origin (cultivated or natural one).

RESULTS AND DISCUSSIONS

Weed Species

Seven invasive weed species were detected in BBG; six of them, i.e., *Cecropia adenopus* Mart. ex Miq, *Cissus sicyoides* Blume., *Cissus nodosa* Blume, *Dioscorea bulbifera* L., *Mikania micrantha* HBK and *Paraserianthes falcataria* (L.) Nielsen, were originally collected by BBG as living collections. One weed, i.e., *Ficus elastica* Roxb invaded BBG. Among seven weeds, *Mikania micrantha* had the highest invasive score of 78 points, followed by *C. sicyoides* (75 point score), *D. bulbifera* (69 point score), *C. nodosa* (67 point score), and *F. elastica* (56 point score) (Table 1). *P. falcataria* and *C. adenopus* were less harmful than the other five invasive weeds. Woody climbers, i.e., *D. bulbifera*, *C. sicyoides*, *C. nodosa* and *M. micrantha*, had a significant impact on the ecological stability in BBG because their invasiveness scored 50 or more.

Dioscorea bulbifera (*huwi* in Sundanese or *gembili* in Javanese) plant climbed up rapidly a host tree and covered branches and twigs, reducing photosynthetic activity of a host plant. It distributed through seeds and aerial bulbils. The *D. bulbifera* invaded 26 families on 5 plots on the southeast side of BBG, i.e., XI.D, XII.B, XII.C, XVII.G and XX.B (Table 2); these plots were close to the plot XV.B where *D. bulbifera* was introduced to the BBG for the first time.

Mikania micrantha is a common creeping weed in agriculture fields in Indonesia (Nasution, 1986). This plant which is native to central and south America was introduced from Paraguay to Indonesia through BBG in 1949 and used as a ground cover in the rubber plantation in 1965, and later spread throughout Indonesia (Watehouse, 1994; Weber, 2003). In BBG, it grew thickly in the landfill areas, pool sides, river sides and along the fence lines, where *Cissus* species were also found. In II.O plot, *M. micrantha* invaded *Agave vivipara* L. collection (Table 2) and disturbed the growth of *Agave* as well as the beauty of the garden. The weed could reproduce from seeds or regenerate from stem fragments. Nasution (1986) stated that *M. micrantha* sprouting and seed germination rate were higher than 95% and 60%, respectively. *M. micrantha* spreads to plot II.Q, II.O, XVII.B, XXIV.A and XXV.A in BBG.

Cecropia adenopus is woody weed and pioneer plant grows on ruderal area close to fences, small rivers and walk ways. Genus *Cecropia* is considered as invasive weed (Webber *et al*., 2011). *C. adenopus* synonim *C. pachystachya* was introduced to BBG from Argentina in around 1921 (Conn *et al*., 2012). According to Conn *et al*. (2012) beside *C. adenopus*, in BBG also maintained *C. peltata* introduced from American tropics in 1897 and *C. palmata* introduced from Brazil in 1904. In this study, we determined *Cecropia* complex as *C. adenopus*. This weed was distributed almost throughout BBG (Table 2) and disturbed the sight and beauty of BBG. Some plants alived on the bridges in BBG that will weaken it. According to Lemmens and Bunyapraphatsara (2003) undisturbed 3- to 20-year-old weeds could produce seeds. Beside man that has apparently been the main agent of the plants species' spreading, seed dispersal was also assisted by wind, bats and birds.

Ficus elastica (Moraceae) was hemi epiphytes, and initially grown on a niche (holes) on the host tree. Aerial roots of *F. elastica* gradually grow down toward the ground, and then strangle the host trees (Sastrapradja and Afriastini, 1984). Once the roots had reached the ground, the weed grew quickly and blocked sunshine, resulting in the death of the host plant. The weed was distributed almost throughout the plots in BBG (Table 2), particularly in the collection areas of trees over 10 m in height. In BBG *F. elastica* seeds are disseminated by birds and bats (Sastrapradja and Afriastini, 1984).

Table 1. Invasive weed scoring in Bogor Botanical Garden according to Hiebert and Stubbendieck (1993) and Tjitrosoedirdjo (2010)

Criteria	Score	Invasive species z						
		Mm	Cs	Db	Cn	Fe	Pf	Ca
1. Populated area (ha)	< 0.5 ha (score 2); 0.5 – 1 ha (score 4) and>1 ha (score 5)	2	2	4	2	2	2	2
2. Level of abundance of the population	narrowly (1); evenly(3); and widely and densely (5) distributed	1	1	3	1	3	1	3
3. Level of visual impact on landscape	no impact (0); slight impact (2); large impact (4); and very large impact (5)	2	4	4	4	0	2	2
4. Vegetative regeneration	no succession after weeding (0); regrowth from roots or bulbs (3) and regrowth from some parts of plants (5)	5	5	3	5	3	0	0
5. Ability to complete reproduction cycle	no (0); and able to complete (5)	5	5	5	5	5	5	5
6. Method of reproductive	vegetative(1); seed (3) and both vegetative and seed (5) propagation	5	5	5	5	3	3	3
7. Vegetative reproduction	no (0); maintenance of population (1); the increase in population (3); and rapid increase of population (5)	3	5	3	5	0	0	0
8. Sexual reproduction frequency	almost never (0); once in every 5 years or more (1); every year (3); once or twice a year (5)	5	5	5	5	5	5	5
9. Number of seed/plant	1–10 seeds (1); 11–1000 seeds (3); and larger than 1000 seeds (5)	3	3	3	3	5	5	3
10. Dispersal agent of seeds	no agent (0); one agent (3); more than one agent (5)	5	5	0	5	5	5	5
11. Dispersal ability	little ability (0); high ability (5) for long–distance dispersal	3	0	3	0	3	3	3
12. Propagule abundance in nearby areas	no propagule source (0); present some propagule sources with low dispersal ability (1); present some propagule sources with high dispersal ability (3); present many propagule sources (5)	3	3	3	3	3	3	0
13. Competitive ability	less competitive (0); competitive (3); highly competitive (5)	5	5	5	5	3	3	3
14. Germination condition	germination in plowed area (0); under canopy with specific soil condition (3); under canopy at any condition (5)	5	5	5	5	3	3	3
15. Allelopathic compound	few(0); a small amount (3); a large amount of allelopathic compound (5)	3	0	0	0	0	0	0
16. Biological controls	completely controlled (0); partly controlled (3); not controlled (5)	5	3	3	3	3	3	3
17. Shading form (canopy)	formation of sparse canopy (0); moderately–dense canopy (3); dense canopy (5).	3	5	5	3	0	0	0
18. Effect to native plant species	Little or no effect (0); attacking and deforming native plants (3); attacking and replacing native plant (5).	5	5	5	5	5	0	0
19. Possible impact to other site	No impact to remote areas (0); moderate impact to remote areas with the same ecological conditions (1); moderate impact to remote areas with different ecological conditions (3); strong impact to remote areas with different ecological conditions.	5	4	0	0	0	0	0
20. Number of weedings frequency	once a year (manual or chemical) (0); two or three times a year (manual or chemical) (3); many times (5).	5	5	5	5	5	5	5
	Total	78	75	69	67	56	48	45

[z]Mm–*Mikania micrantha* H.B.K, Cs–*Cissus sicyoides* L., Db–*Dioscorea bulbifera* L., Cn–*Cissus nodosa* L., Fe–*Ficus elastica* Roxb ., Pf–*Paraserianthes falcataria,* and Ca–*Cecropia adenopus*

Paraserianthes falcataria (Fabaceae) was initially planted in II.C plot, then spread to plot II.O and II.D plots (Table 2) where Cycadaceae and Pandanaceae were collected, respectively. This tree had fragile and bole branches, and also fallen branches caused serious damage to trees in the collection. The classification of *P. falcataria* as weed was debatable because its timber had much economic value and its litter improved soil fertility.

Cissus sicyoides and *C. nodosa* (Vitaceae) are climbing weeds that easily damaged the weed–mantled plant by reducing the amount of transmitted light for photosynthesis (Agustin, 2005). These weeds were initially living collection in plots XVII.F and XI.B, respectively, then occupying II.O, II.P, II.F, XVII.I, XX.B and XXIV.B plots (Table 2). *C. sicyoides*, which is native to Africa (Heyne, 1987), was introduced to Bogor and then spread to Bali and Sulawesi Islands. *Cissus sp*. could be reproduced by seeds, stems and aerial roots. Roemantyo and Purwantoro (1990) reported *C. sicyoides* disturbed 117 tree species from 38 families in BBG, or about 3 % of the living collection.

Weed Distribution and Dominance

Dioscorea bulbifera was the most dominant weeds, followed by *F. elastica* and *C. sicyoides* (Table 3). Invasive scores are indicative of potential weed ability to spread into new areas, while SDR is indicative of actual floristic variation. Thus, invasiveness scores were not necessarily related with SDR although weeds with invasiveness scores above 50 generally had SDR higher than 10% except for *M. micrantha* (7.27%) (Tables 1 and 3). It is likely that the number of individuals of an invasive weed was limited at first if the weed were not native ones. Invasive weeds could spread and invade host plants even the initial number of individuals of invasive weeds was very low. Tjitrosoedirdjo (2010) explained that invasive weeds have high ability to develop viable population in a generation, vigorous in growth and superior reproduction, and absent of pest and diseases.

D. bulbifera interestingly had the largest distribution and coverage in BBG (Table 3). Coverage capability of a weed was determined by its habitat and canopy form, while the distribution of a weed was determined by its characteristics and type of dispersal agents. *C. adenopus* dispersed longer distances than *M. micrantha*, thus *C. adenopus* having higher total coverage areas (Table 3) than *M. micrantha*, although, the coverage area per site was larger in *M. micrantha*.

F. elastica, *C. adenopus,* and *P. falcataria* distributed randomly in BBG, as a result by the action of various dispersal agents such as the wind, birds and bats. Observation in outside BBG, many *F. elastica* and *C. adenopus* trees could be seen by the road side and on residential gardens and city parks (Figure 1). Tirtaningtyas (2004) reported 56 species of birds from 46 genera in BBG, each species consisting of 10–50 individuals. Furthermore, Tirtaningtyas (2004) pointed out that a *Ficus sp*. tree provided eating, nesting, playing, mating and twittering places for 5.2, 5.9, 5.2, 4.5 and 22.8% of birds, respectively. On *Paraserianthes falcataria*, only 4.5% of birds did mate and twitter there. According to Rukmana (2003), Kapauk bats (*Pteropus vampyrus*) roosted in 13 trees of seven species including *F. elastica* in BBG. On a *F. elastica* tree, 269 bats existed in the morning and 284 fed on fruits in the evening. Thus, birds and bats probably spread seeds of *F. elastica* both inside and outside BBG.

Visitors to BBG were suspected to play an important role in the spread of weeds all over BBG and also outside BBG, as reported by Nurisjah *et al*. (1995) in the case study of Monas Park in Jakarta. According to the management report of BBG during 2003–2010, an annual number of visitors to BBG was 0.8 to 1.1 million. From field observation, visitors in BBG, particularly kids, were interested to pick aerial bulbil of *D. bulbifera* L., the stem of *M. micrantha* and colorful of aerial roots of *C. sicyoides* and *C. nodosa* Blume. They hold those for a couple of minutes and then discarded the propagules at random places, leading to the dispersal of plants. Therefore, it is important for BBG authority to move the visitors to take action against invasive weeds in BBG.

Table 2. List of dead families, official potential cause of the dead plant collection in Bogor Botanical Gardens in 2011 and its association as weed host

Family	Potential cause[Z]					Hosted weed[Y]	Family	Potential cause					Hosted weed[Y]
	B	T	C	K	L			B	T	C	K	L	
Acanthaceae						B,D	Meliaceae						B,C,D,E
Acrostichaceae					√		Menispermaceae					√	
Agavaceae						A,B,D	Mimosaceae		√		√	√	
Anacardiaceae				√		C,E	Monimiaceae	√					
Annonaceae		√			√	B,C,D	Moraceae					√	C,E
Apocynaceae					√	B,C,D	Myrtaceae	√				√	B,C,D,E
Araceae					√	A,B,D,E	Nymphaeaceae	√		√	√	√	
Araliaceae	√				√		Ochnaceae				√		
Arecaceae	√		√	√	√	B,D	Oleaceae			√		√	
Aspidiaceae					√		Ophioglossaceae					√	
Aspleniaceae					√		Palmaceae						B,D
Asteraceae					√		Pandanaceae						B,D,F
Bignoniaceae	√						Papilionaceae	√	√			√	B,C,D
Blechnaceae					√		Pittosporaceae		√				
Burseraceae					√	C,E	Poaceae						B,D
Cactaceae						B,D	Podocarpaceae	√					
Caesalpiniaceae	√	√		√	√	B,C,D	Polygonaceae		√				
Celastraceae						C	Polypodiaceae					√	
Clusiaceae					√	B,D	Proteaceae						C,E
Combretaceae		√			√		Rhamnaceae					√	C
Connaraceae					√		Rhizophoraceae	√					
Cyatheaceae					√		Rubiaceae	√			√	√	C
Cycadaceae						A,F	Rutaceae					√	B,D
Davaliaceae					√		Sabiaceae					√	E
Dennstaedtiaceae					√		Salvadoraceae					√	
Dipterocarpaceae						B,C,D	Sapindaceae					√	C,E
Dryopteridaceae					√		Sapotaceae						C,E
Ebenaceae	√					B,C,D	Schizaeaceae					√	
Euphorbiaceae	√			√	√	B,C,D	Selaginellaceae					√	
Fabaceae						B,D,E	Sterculiaceae				√		C
Gentianaceae				√	√		Taenitidaceae					√	
Icacinaceae						B,D	Thelypheridaceae					√	
Lauraceae		√		√	√	B,C,D,E	Thymelaeaceae	√					
Lecythidaceae						B,C, D	Ulmaceae						C
Loganiaceae	√						Urticaceae						C
Magnoliaceae						C	Verbenaceae						B,C,D
Malpighiaceae					√		Vitaceae					√	
Maranthaceae					√		Woodsiaceae					√	

Note: [Z] B–Rotten, T–Collapse, C–Fungi, K–Dry, L–Not identified (Source: Document of Bogor Botanical Garden 2011), [Y]Host of weeds : A–*Mikania micrantha,* B–*Cissus sicyoides,* C–*Dioscorea bulbifera,* D–*Cissus nodosa,* E–*Ficus elastica,* F–*Paraserianthes falcataria*. *Cecropia adenopus* invaded all plots, thus specific effect on particular family was not presented.

Table 3. Distribution, coverage and sum dominance ratio (SDR) of invasive weeds in Bogor Botanical Garden, Indonesia, in 2011

Weeds spesies	Distribution		Coverage		SDR^Z (%)
	∑ weedy block	$Frequency^X$ (%)	Individual Number	$Area^Y (m^2)$	
Dioscorea bulbifera L.	44	22.91	138	5641.0	27.66
Ficus elastica Roxb.	28	14.58	94	2585.0	18.23
Cecropia adenopus Mart. ex Miq.	26	13.54	53	1457.5	13.45
Cissus sicyoides Blume.	25	13.02	94	2154.0	17.30
Cissus nodosa Blume.	18	9.37	68	873.1	12.48
Mikania micrantha H.B.K.	13	6.77	32	1642.5	7.27
Paraserianthes falcataria	7	3.64	14	385.0	3.59

[X] Absolute frequency = $\frac{\sum \text{block of particular spesies}}{\sum \text{block in BBG (192)}}$

[Y] Coverage was estimated from canopy projection

[Z] Sum of Dominance ratio

Cissus sp. were found to be abundant along the Ciliwung river, especially around the Sempur square and Warung Jambu areas (approximately 0.5–3 kilometers from the BBG) and in Jakarta (ca 50 km from BBG) (Figure 1). Rivers probably contributed the distribution of *Cissus sp*. in the down stream areas, because vines of *Cissus sp*. hung over the Ciliwung and Cilabok rivers in some places in BBG. Moreover, the connected canopy of trees along the border of BBG became bridges for *Cissus sp*. to spread outside BBG areas directly. During the study, along Salak and Juanda streets at least three points of canopy bridges were observed, i.e., in front of Sempur Square, at corner of the entrance gate of Bogor President Palace, and around Bogor Post Office. The dispersal of *Cissus sp*. to trees outside BBG enhanced by an existence of cables of electrical and telephones that connect trees.

All weeds observed in BBG were also observed in outside areas (Figure 1). Many weeds found in abandoned areas, conservation forest, roadsides, riversides and residential areas forming weed banks (Table 4). According to interview with local residences, all these ruderal weeds were not cultivated ones. Considering that some of the weeds previously elite collection and introduced to BBG from other sites, we speculated that observed weeds in the outside areas were originally come from BBG. In case of *C. peltata*, Conn *et al*. (2012) has speculated that current plants in BBG are as spontaneous re–introductions from naturalized populations in the surrounding area; and the populations outside garden may have originally escaped from the garden. Figure 2 showed that number of weed species increased in area near to BBG. However, frequent weeding residential areas might reduce number of weed. Therefore, it needs a further investigation through genetic markers to ensure the weeds origin outside BBG.

P. falcataria found in all observation sites outside BBG, followed by *C. adenopus* (72% of sites), *C. nodosa* (67%) and *M. micrantha* (62%). *C. cycloides* and *D. bulbifera* became the least found in outside BBG, e.g., 28%. According to interview, people maintained *P. falcataria* tree because they could utilize the wood for making house or furniture. In a limited number of the respondent, they notified that their neighbor sometime used wood of *C. adenopus* for cooking wood and the young leaves for goat feed.

Weed Control and Management

BBG had developed daily, weekly and annual weed control programs. Daily weed control program was implemented in targetted plots by 4–8 workers at intervals of 14 days. Weekly control program was implemented every Friday mainly for densely weedy. Annual control program was done once a year in August to commemorate the Independence Day of the Republic of Indonesia. Although numbers of workers had involved in weed control programs, more intensive weeding program was necessary.

Table 4. Distribution of weed outside Bogor Botanical Gardens 2011–2013

Site	Distance[Z] (km)	Habitat	Number of Weed[Y]							Total species
			CA**	CC*	CN*	DB*	FE***	MM*	PF**	
1. Sempur area	0.3	Road side and river side	1	1	6	0	4	0	2	5
2. IPB Bogor	0.2	Abandoned land	1	1	1	1	2	1	2	7
3. Bogor Baru	1.8	Residential	2	0	1	0	1	1	2	5
4. Ciomas	2.5	Abandoned land, roadside, residential	0	1	1	0	1	1	1	5
5. Cilendek	2.9	Abandoned land, river side	2	0	1	1	0	1	1	5
6. Cimanggu	3.1	Experimental farm, residential	1	0	0	0	0	1	2	3
7. Stadion Bogor	3.0	Residential area, road side	2	1	2	0	3	0	1	5
8. Bantarjati	2.2	Residential area	3	0	1	0	0	2	1	4
9. Cimahpar	3.0	Farm, village	0	0	1	0	0	2	1	3
10. Novotel Bogor	4.3	Roadside	0	0	0	0	0	2	1	2
11. Bubulak	7.0	Farm, roadside	5	0	1	1	1	0	1	5
12. IPB Darmaga	9.5	Park, roadside, abandoned land	1	0	3	1	1	1	1	6
13. CIFOR Forest	8.7	Conservation forest	1	1	1	1	1	0	2	6
14. Warung Jambu	4.5	Riverside, abandoned land	2	0	2	0	0	0	1	3
15. Kedung badak	5.0	Riverside, residential	3	0	0	0	0	2	1	3
16. Karadenan	5.4	Farm, roadside	1	0	0	0	0	0	2	2
17. Sentul Selatan	6.0	Roadside, residential	0	0	0	0	0	2	1	2
18. Sentul rest area	9.0	Farm, dry land	0	0	0	0	0	0	1	1
Total			25	5	21	5	14	16	24	-

[Z] Approximately linier distance measured by projection on map to BBG

[Y] Calculated from mature weeds with flower or fruits in area about 100 m x 100 m in each site; CA-*C.adenopus*, CC-*C.cycloides*, CN-*C. nodosa*, DB-*D. bulbifera*, FE-*F. Elastica*, MM-*M. micrantha*, and PF-*P. falcataria*; * one weed represented one host plant; ** weed height larger than 3 meter; *** stem diameter at 1 meter above soil surface larger than 50 cm.

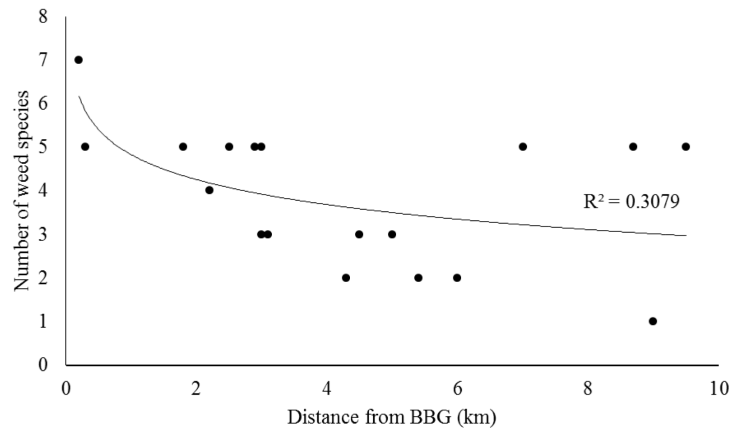

Figure 2. Correlation between total number of species in particular area and distance from Bogor Botanical Gardens (BBG), detail as presented in Table 4.

In case of *Dioscorea bulbifera* L., it is necessary to dig out tubers and collect all aerial bulbils before burning. In vegetatively propagated plants such as *Mikania micrantha* H.B.K. and *Cissus sp*., chopped stem tissues should be cleaned properly from the ground because it could generate a new individual. Weeding of woody epiphytes, *Ficus elastica* Roxb. and *Cecropia adenopus,* were more cumbersome. Weeding of *Ficus elastica* Roxb. required heavy equipments such as crane, truck, climber, and chain for climbing the host trees; three days with 4–5 workers were necessary for removing an old *Ficus elastica* Roxb. tree. In some cases, the host plant died if *Ficus elastica* Roxb. was removed without due care.

Economic losses due to invasive weeds have not been quantified properly in BBG, because the degradation of plant collection proceeds gradually. Therefore, the impact of invasive weeds should be monitored over the long term. During the study, we notified some specific weeds such as *Ficus benjamina* grew on the bridges. However, due to small coverage in the garden, they were excluded from the analysis. Number of collection lost in BBG was marked. In 2011, about 240 plants consisting of 58 families died, and tree death of 17 families were directly associated with the presence of weeds (Table 2). Although the immediate cause of plant death remained to be clarified, it is possible that the death of some plants were as a result of long–term weed invasion.

In Cibodas Botanical Garden (CBG), Zuhri and Mutaqien (2013) revealed that many species including *Cinchona pubescens*, *Calliandra calothyrsus,* and *C. aurantiacum* escaped from CBG to natural forest of Mt. Gede Pangrango. Although botanical garden existence might not as a single source of invasive species in surrounding landscape, however, risk posed by garden collection to escape into other habitat should be considered. Present study indicates that it is important to conduct risk assessment of introduced plants even inside the garden. Lack of risk assessment may cause plant invades to the neighboring areas, similar to as those reported by Zuhri and Mutaqien (2013) in CBG.

This study implies that invasive weeds should be controlled using proper manpower and equipments since weeds had invaded 41 plant families of the 215 families in the BBG collection. Less amount of man power and restrictions on herbicide use might increase the need to adopt the integrated weed management system in BBG. Incorporating visitors in to invasive weed control should be considered in the near future.

Since it was possible that weeds from outside BBG come into BBG and *vice versa*, therefore, in order to increase the effectiveness of weed control in BBG it is necessary to control weeds in outside BBG. Integrated action for weed control among authorities is important. Bogor City Administrative may responsible to control ruderal weeds mainly in Sempur square, Stadion Bogor and other areas including residential as shown in Figure 2. For BBG, actions such as to educate visitor, and to reform border trees will minimize weed dispersal. Other authorities take action on reconstruction cabling and telephones along BBG border, in IPB areas and along rivers. Those integrated actions will increase control of invasive weeds in BBG as well as in the city.

CONCLUSION

There are at least seven invasive weeds from six families were found in BBG, i.e., *Cecropia adenopus*, *Cissus nodosa*, *Cissus sicyoides*, *Dioscorea bulbifera*, *Ficus elastica*, *Mikania micrantha* and *Paraserianthes falcataria*. All weeds, except *Ficus elastica*, were introduced into BBG as exotic plant collection at first, and then were distributed in BBG as invasive weeds. These seven weeds invaded 41 plant families of 215 families in BBG. Weeds spread all around and outside BBG probably by the action of the wind, birds, bats, humans (visitors) and flow of water. This study suggests the importance of implementing integrated action on weed control programs, including the weeds around BBG. Involving all relevant stakeholders in order to minimize the risk of weed invasion from outside BBG come into BBG and *vice versa*, is important.

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