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Floristic analysis of alien invasive plant species at some conservation areas in tropical forest of West Sumatra

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ABSTRACT

An assessment of alien plant invasive and is very important to control the them at protected areas of tropical forest. Sixty-four alien invasive plant species belong to twenty-three families were recorded at six conservation areas of West Sumatra. The species composition of invasive plant were different among those six conservation areas. Kebun Raya Solok had the highest number of species and genera (41 and 39, respectively) and G. Talamau had the lowest one, with ten species and ten genera. Increasing the number of species and genus of invasive plant concordance to disturbance of the studied areas. More than 50% of invasive plant species in School forest for biological research and education, Limau Manis, were similar to those invasive plant species in Kebun Raya Solok, West Sumatra. In contrast, only 13% of invasive plant species from Kebun Raya Solok were similar to G. Talamau. It is very important to note that three invasive tree species (Acacia auriculiformis, Acacia mangium & Arenga obtusifolia) were detected in three conservation areas and the latest one was dominantly distributed in Lembah Anai and Rimbo Panti Natural Reserve. The existance of these invasive species: Imperata cylindrica, Clydemia hirta, Lantana camara, Leucaena leucocephala, Mikania micrantha and Mimosa pigra into conservation areas in West Sumatra have to be warned cause of the severe effect to the biodiversity. The invasive species from family Asteraceae (except Ageratum conyzoides), Leguminosae and Graminae tend to had the xenogamy breeding system that implied the high level of genetic diversity and well adapted various habitats.

Keywords: alien plant invasive species, breeding system, conservation diversity, similarity, conservation area

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INTRODUCTION

Indonesia is one country with a rich diversity of flora. Biodiversity in Indonesia included within the category of the highest in the world, much higher than the bio-diversity in America and tropical Africa, especially when compared to temperate and cold regions. The species diversity in Indonesia is estimated around` 25,000 species or more than 10 % of flora in the world [1]. For sustainable utilization of Indonesia bidiversity, the conservation efforts are needed not only by *in situ* but also *ex situ* programs. The existence of protected area such natural park, Botanical gardens and traditional protected forest are important to support the conservation biodiversity program. The number of protected areas for conservation biodiversity in Indonesia is enough much distributed throughout all the regions of Indonesia. Until year 2016, the government through the Ministry of Environment and Forests has approved the document related to 124 of conservation area. However, In fact, there are 521 conservation area in Indonesia [2].

Related to cause the loss biodiversity, Land-use change and habitat fragmentation and destruction, pollution, climate change and invasive alien species were the direct threats to biodiversity. Invasive species have been mentioned as being the second most important threat to global biodiversity loss, after land use change [3] Invasive alien species [IAS] and climate change, with land use change and changes in the nitrogen and carbon cycles, are identified as the top four drivers of global biodiversity loss.

In general, cause of entry and invade of alien species in protected areas due to human activity for their life. Increased imports of food and other plants to give the opportunity to enter propagules of invasive species into new habitats. Increasing the globalization of trade and tourism lead to biodiversity loss [4, 5]. The opening of roads for ecotourism in protected areas also lead to the invasion of alien species **[**6**].** Today, there is no place in the world which has not been affected by alien species, especially by invasive species [7]. Environmental and economic problems caused by alien species invasion are recognized as important issues worldwide [8]. The most need attention associated with invasive plants is their domination in the habitat and replaced more than 50% natural biodiversity, and half of them are the rare and endangered species [9]. The climate change can induce stress in ecosystem that will facilitate invasive pathways and lead to new introduce plants become invasive [10, 5]. These species can dominate a wide range of habitats, where they change the function, structure, and composition of these habitats, often with serious consequences.

The invasion of alien species in a make economically problem and environmentally degraded in a ecosystems and that is not easy to rehabilitate them. The UN Convention on biodiversity or the Convention on Biological Diversity [CBD], which was declared in 1992 has been ratified by the Government of Indonesia in 1994. Today, not only causing a considerable loss of agricultural weeds, degrading catchment and freshwater ecosystems, alien invasive alien is one of the leading threats to natural ecosystems and biodiversity [11]. To control and management alien species in invaded areas is difficult, and often thus costly and difficult to do. Even the US government issued 100 million dollars annually for the budget control invasive species [12]. Therefore, the most effective way to minimize impact of invasive plants is through preventive measures [13]. An understanding of how and where the invasive plant species introduced very important to control. Information about the origin of invasive species population and the level of genetic variation will determine the success of invasive species controlled habitats [14].

Invasion of alien plant species lead to ecological problems in some conservation areas in Indonesia, such as in Gunung Gede Pangrango National Park [15], in Bogor Botanical Garden [16] in the Bukit Halimun National Park [17]. Recently, the biodiversity of Sumatran forest is threatened due to interference by humans or natural disaster. Invasion of alien plants species [invasive plants] into the forest can reduce the diversity of forest plants, because invasive plants can change the native vegetation in the forest. Studies of invasive species introductions in the past revealed that the impacts of their invasion are complex and can permanently alter the structure and function of communities, cause local extinctions and changes in ecosystem processes. The increased interfere of invasion around the world poses a major threat to indigenous biological diversity [18]. Although most of the scientific literature described the serious negative impacts of invasive alien species, and urges policy-makers and land managers to take appropriate steps to prevent or contain these invasions. However, some invasive alien species also have benefit value. Several species of commercially important trees that are used in plantation forestry are also invasive [19]. Other species was cultivated as agricultural crop and ornamental plants [20].

Tropical forests of Sumatra is an important area for the conservation and sustain-able utilization of plant diversity. Recently, Sumatran forest and its diversity will be disappeared due to human disturbances and natural disasters. Invasion of alien invasive plants species in forests can decrease plant diversity even they can displace native plants in the habitat. Invasive alien plant species has been reported in a variety of ecological problems in the National Park as a conservation area in Indonesia. Although today, it has been known that more than 100 invasive plant species [25 % of them is very dangerous] can lead to the decline of biodiversity of tropical forests. However, their potential threat in the tropical forests of Sumatra has not been fully understood. Assessments of alien invasive plant species and their level of invasiveness is very important to control the invasive plants species, so that the negative effects of reduced diversity can be overcome. This study is very important and strategic for understanding the invasive plants species and prioritizing the species and areas [21] to control of invasive plants and conservation of biodiversity of the forests of Sumatra.

MATERIALS AND METHODS

The research have been Conducted during March to November 2015. Some protected areas in West Sumatra (see Figure 1)., especially tropical Forest (HPPB, Lembah Anai, Batang Palupuh, Solok Bot. Garden and Rimbo Panti) and Herbarium Univ. Andalas (ANDA) & Laboratory Plant Taxonomy, Dept Biology, Fac. of Sci. Andalas University Padang.

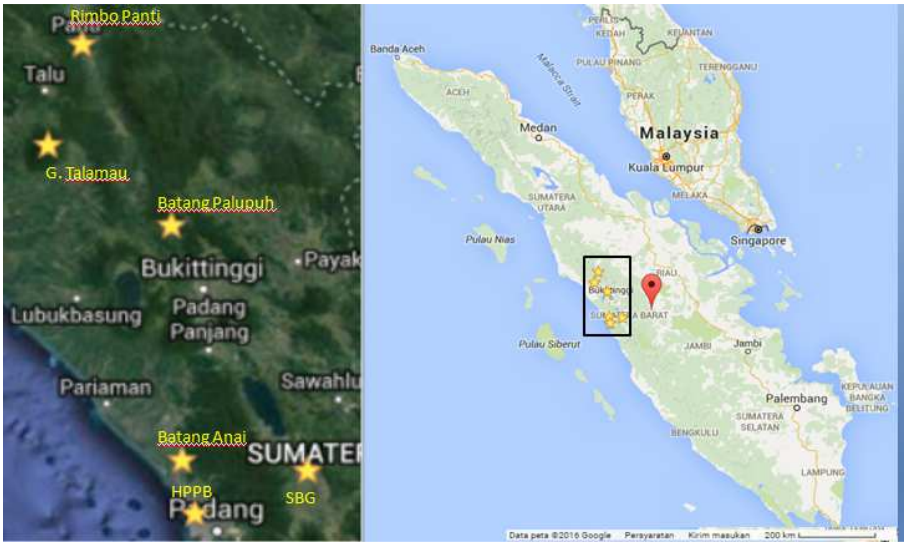

Figure 1. Collection site of six protected areas in West Sumatra (HPPB), Lembah Anai, Batang Palupuh, Solok Botanical Garden (SBG) and Rimbo Panti

Tabel 1. Classification of gradient disturbance of six areas based on modification from Shelton (2011)(22)

Name of area	Type area	Distance to facilities	Spreading Corridors	Habitat type	Canopy dis turbance	Level Disturbance
Kebun Raya Solok	New Botani-cal garden	Surrounded by people settle-ments, crop plantation and roads	Many tracking way to enter secondary forest with many opened areas	Land used for crop plantation, Most areas opened and many non native plants found	Very high	Level I
HPPB	School Forest	One side close to University Cam-pus and other side with Bari-san Range Forest	A few tracking way to enter secondary forest	Secondary Forest, some sites opened with the pioneer and native plants	High	Level II
Batang Palupuh	Natural reser-ve, especially for *Rafflesia* plants	Surrounded by settlements, crop plantations and close to village roads	Many tracking way to enter the primary forest	Primary forest and secondary forest with the pioneer and native plants	Low	Level III
Rimbo Panti	Natural reserve	Very close to main road through primary forest	A few tracking way to enter the primary forest	Primary forest with native plants	Low	Level IV
Lembah Anai	Natural reserve	Main road through primary forest	A few tracking way to enter the primary forest	Primary forest with native plants	Low	Level V
G. Talamau	Natural reserve	No main road & settlements	A few tracking way to enter the primary forest	Primary forest with native plants	Low	Level VI

The floristic study carried out with exploring technique that normally used for flora expedition (Samples invasive plants were collected by exploring the studied areas via routes from the outside into the forest or conservation areas. The samples with generative organs of Angiosperms that putative non-native plants of those areas were collected and processed to herbarium specimens (23) and the voucher specimens were deposited at Herbarium Universitas Andalas Herbarium (ANDA).

Identification of species referred to herbarium specimen, key identification, comparison to the illustration of the related references especially flora of Sumatra. The precise and accepted nomenclature referred to Plant list (2013) (24). A species checklist of vascular plants invasive collected at the six sites was made and the occurrence of the species in the conservation areas was recorded as + (positive) mark and the absence with – (negative). Based on checklist, qualitative data were scored to binary data for further similarity analysis. the Index of Similarity (ISj) was used to clarify differences/similarities among the six conservation areas. ISj = c × 100 (a + b + c) where "c" is the number of common species, "a" is the number of species unique to site #1, and "b" is the number of species unique to site #2. Jaccard's similarity index was analyzed using PAST Version 3.4 (25) to know level difference of species composition between six protected areas. Clarification the alien invasive species referred to Global Invasive Data Based (26) and Indonesia Invasive Data in various related references (e.g.: Tjitrosoedirdjo, 2005). For additional data, the breeding system of invasive species from family with high number of species were estimated using P/O ratio technique (27) to indirectly predict ability adaptation due to high genetic diversity for xenogamy

breeding system (28, 29).

RESULTS AND DISCUSSION

Assessments of alien invasive plant species and is very important to control the invasive plants species at protected areas of tropical forest, West Sumatra. Fifty-nine alien invasive plant species belong to 23 families were recorded at six protected area West Sumatra (Table 1). Family Asteraceae had twelve invasive species, followed by Family Fabaceae eleven invasive species, Graminae had six invasive species, Verbenaceae had three invasive species, Each of Family Convolvulaceae, Malvaceae, Melastomataceae, Piperaceae, Rosaceae, Rubiaceae had two invasive species. In case of each other Family (Acanthaceae, Amaranthaceae, Combretaceae, Commelinaceae, Costaceae, Euphorbiaceae, Labiatae, Myrtaceae, Oxalidaceae, Palmae, Passifloraceae, Polygalaceae, Solanaceae and Vitaceae) had one invasive species.

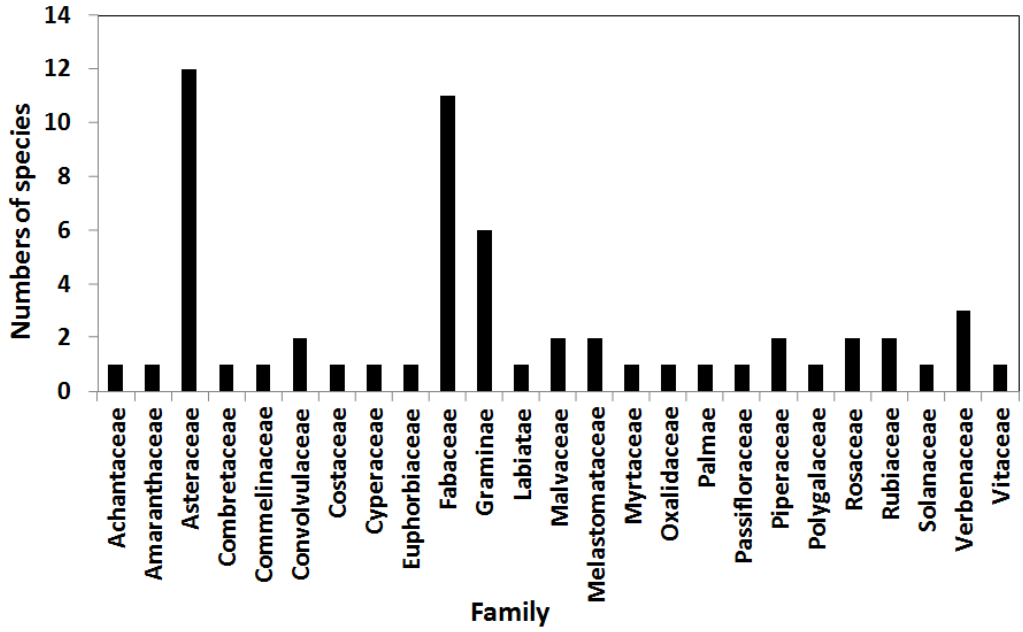

Figure 2. Twenty-five families of invasive species recorded in six protected areas

There were differences of species composition among those six protected areas. The highest number of invasive species were recorded in Kebun Raya Solok, followed by Rimbo Panti with thirty-three invasive species, HPPB with twenty eight invasive species, Batang palupuh with twenty invasive species, Lembah Anai with eleven invasive species, and the lowest one was G. Talamau with ten invasive species (Figure 1).

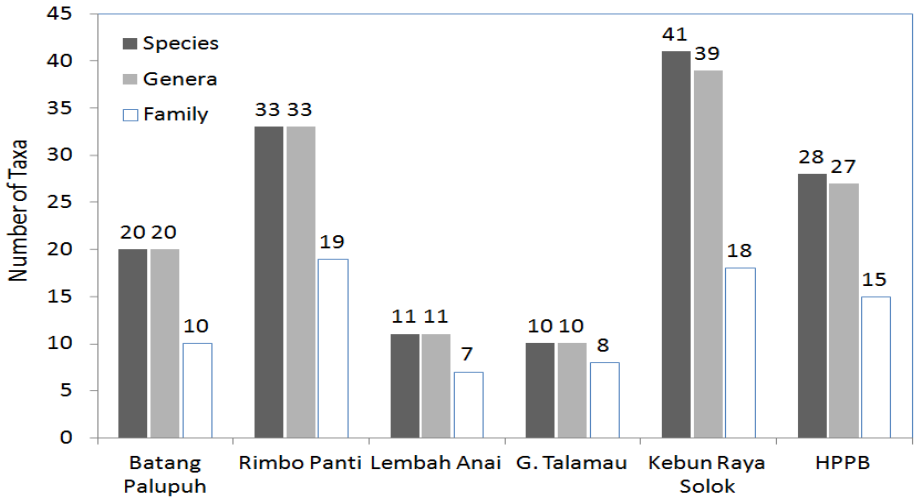

Fig. 1. The different species, genera and family numbers in six conservation area in West Sumatra

Tabel 2. Comparison of species number among six conservation areas of West Sumatra, Indonesia.

No	Species	Conservation Areas					
		Batang Palupuh	Rimbo Panti	Lembah Anai	G. Tala-mau	Kebun Raya Solok	HPPB*
1	*Asystasia gangetica* (L.) T. Anderson	-	+	+	-	+	+
2	*Acacia auriculiformis* Benth.	-	-	-	-	+	+
3	*Acacia mangium* Willd.	-	-	-	-	+	-
4	*Acmella paniculata* (Wall. ex DC.) R. K. Jansen	+	+	-	-	-	+
5	*Ageratum cinyzoides* (L.) L.	+	+	+	-	+	+
6	*Arenga obtusifolia* Blumme ex. Mart.	-	+	+	-	-	-
7	*Austroeupatorium inulaefolium* (Kunth) R. M. King & H. Rob.	+	+	-	-	+	+
8	*Axonopus compressus* (Sw.) P. Beauv	+	+	-	-	-	-
9	*Bidens pilosa* L.	+	-	-	-	+	
10	*Borreria laevis* (Lamk.) Griseb.	+	+	+	-	+	+
11	*Calliandra calothrysus* Meisn.	-	-	-	-	+	+
12	*Camaecrista nictitans* (L) Moench	-	-	-	-	+	+
13	*Centotheca latifolia* Trin.	-	+	-	-	-	-
14	*Centrosema virginianum*	-	-	-	-	+	+
15	*Cheilocostus speciosus*	-	+	-	-	+	+
16	*Chromolaena odorata* (L.) R.M. King & H. Rob.	-	-	-	-	+	-
17	*Cissus hastata* Miq.	-	-	-	+	+	+
18	*Clibadium surinamense* L.	+	+	-	+	+	+
19	*Clidemia hirta* (L.) D. Don	+	+	+	+	-	+
20	*Coffea rubusta* L.	+	-	-	-	+	-
21	*Commelina diffusa* F	+	+	-	-	+	-
22	*Crassocepalum crepidiodes* (Benth.) S. Moore	+	+	+	+	+	-
23	*Crotalaria pallida* Aiton	-	-	-	-	+	-
24	*Cyathula prostrata* (Linn.) Blume.	-	+	-	-	-	-
25	*Cyperus brevifolius* Rottb.	-	+	-	-	-	-
26	*Elephantopus mollis* L.	+	+	-	-	-	-
27	*Elephantopus scaber* L.	-	-	-	-	+	-
28	*Hyptis capitata* Jacq.	+	+	-	-	+	+
29	*Imperata cylindrica* (L.) Raeusch.	-	-	-	-	+	+
30	*Ipomea fistulosa*	-	+	-	-	-	-
31	*Ipomoea cairica* L.Sweet	-	-	-	-	+	-
32	*Lantana camara* L.	+	+	+	-	+	+
33	*Leucana leucocephala* (Lam.) De Wit	-	-	-	-	-	+
34	*Melastoma malabathricum* L.	-	+	+	+	+	+
35	*Mikania micrantha* Kunth	+	+	+	+	+	-
36	*Mimosa diplotrica* Sauvalle	-	+	-	-	+	-
37	*Mimosa pigra* L.	-	+	-	-	+	+
38	*Mimosa pudica* L	+	+	-	-	+	+
39	*Oxalis barrelieri* L.	-	+	-	-	+	+
40	*Panicum maximum*Jacq.	-	-	-	+	-	-
41	*Passiflora foetida* L.	-	-	-	+	-	-
42	*Pennisetum polystachion* (L.) Schut.	-	-	-	+	-	-
43	*Phylanthus amarus* Schum. & Thonn	-	+	-	-	-	-
44	*Piper aduncum* L.	+	+	+	+	+	+
45	*Piperomia pellucida*L.	-	+	-	-	-	-
46	*Polygala paniculata*L.	-	+	-	-	-	-
47	*Rhodomyrtus tomentosa* (Aiton). Hassk.	-	-	-	-	+	+
48	*Rubus buergeri* Miq.	-	-	-	-	+	-
49	*Rubus moluccanus* Anet.	-	-	-	-	+	+
50	*Senna optusifolia* (L.) Roxb.	-	-	-	-	+	-
51	*Sida acuta* Burm.	+	+	-	-	+	+
52	*Sida rhombifolia* L.	-	+	-	-	+	-
53	*Solanum torvum* Sw.	-	-	-	-	+	-
54	*Spagneticola trilobata* (L.C.Rich) Pruski	-	-	-	-	+	+
55	*Stachytarpeta jamaicensis* (L) Vah	+	+	+	-	+	+
56	*Stachytarpheta indica* (L.) Vah	-	-	-	-	+	-
57	*Terminalia catappa* L.	-	-	-	-	+	-
58	*Themeda gigantea* (Cav.) Hac	-	-	-	-	-	+
59	*Tridax procumbens* L.	+	+	-	-	-	-
	Number of species	20	33	11	10	41	28

Furthermore, there was difference composition of invasive species in each conservation areas. Only one invasive species, *Piper aduncum* was recorded at all six conservation areas. Other species that found at five areas as followed: *Ageratum cinyzoides*, *Borreria laevis*, *Clidemia hirta*, *Crassocepalum crepidiodes*, *Lantana camara*, *Melastoma malabathricum*, *Mikania micrantha* and *Stachytarpeta jamaicensis*. Then, there was invasive species that

distributed only at one conservation area, such as: *Centotheca latifolia* and *Phylanthus amarus* in Rimbo Panti, *Chromolaena odorata*, *Crotalaria pallid*, *Rubus buergeri*, *Solanum torvum*, *Stachytarpheta indica* and *Terminalia catappa* in Kebun Raya Solok, *Cyathula prostrata*, *Cyperus brevifolius*, *Ipomea fistulosa*, *Piperomia pellucida*, and *Polygala paniculata* in Rimbo Panti, *Leucana leucocephala* and *Themeda gigantea* in HPPB, *Panicum maximum*, *Passiflora foetida*, and *Pennisetum polystachion* in G. Talamau (see Table 1).

The results of analysis similarity based on the species composition of six conservation area revealed that HPPB vs Kebun Raya Solok and Rimbo Panti vs Batang Palupuh have the high value of similarity index (I=0.533 and I=0.514, repectively). The lowest similarity was detected between G. Talamau and HPPB, I= 0.152) The highest similarity between those two localities due to they were more closer distance than other localities, and their level of human disturbance to habitat. In contrast, very different ecological factors and long distant between Solok Botanical Gardens and G. Talamau resulted in lowest similarity between them.

Table 3. The matrix similarity between invasive plant species in six conservation areas in West Sumatra

Conservation Areas	Batang Palupuh	Rimbo Panti	Lembah Anai	G. Talamau	Kebun Raya Solok	HPPB
Batang Palupuh	1.000					
Rimbo Panti	0.514	1.000				
Lembah Anai	0.348	0.333	1.000			
G. Talamau	0.200	0.162	0.313	1.000		
Kebun Raya Solok	0.298	0.321	0.209	0.133	1.000	
HPPB	0.333	0.386	0.258	0.152	0.533	1.000

Furthermore, the breeding system invasive plant species belong to family Asteraceae, Leguminoceae and Graminae were analyzed. The results indicated that almost all species from those three families have the breeding system tend to xenogamy, except to *Ageratum conyzoides* with facultative autogamy breeding system. Three species (*Acasia auriculiformis*, *Mimosa pigra and Leucaena leucocepala*) had the facultative xenogamy breeding system.

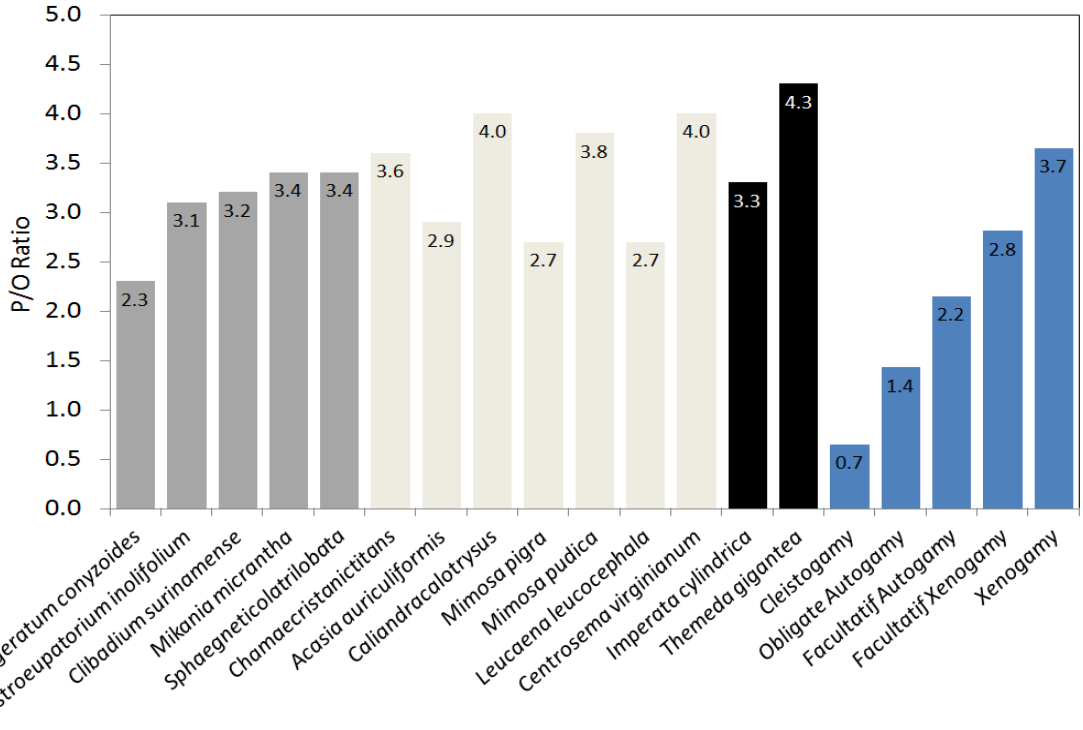

Figure 3. Breeding system of some species belonging to three family with the high number of invasive species compared to breeding system according Cruden (1977) (27)

Generally there is no a habitat of terrestrial and aquatic plants in the world escape from invasing the alien plant species. Although it has been understood that weeds have been occupied on agricultural land in Indonesia, but not much information about alien plant species that invade natural habitats in the forests especially in conservation area tropical forests. Based on information from references and herbarium study, Tjitrosoedirdjo (2005) reported 335 alien plants species Indonesia and most of them recorded were cultivated and the ornamental plants (63%) followed by weed species 17.5% (11). More than half of the cultivated plants are ornamental plants. Some of the alien species were naturalized and escaped from cultivation to become wild. There are 81 species whose benefits are unknown. From the recorded alien plants species, the family Three families have more than 100 species: Asteraceae 162

species, Poaceae 120 species, and Papillionaceae 103 species. In case of results from this study revealed similar trend which those three species recorded with the higher number invasive plants species in six conservation areas in West Sumatra. Similar results were recorded in Shandong region in China (30) and the three families were dominantly occupied due to human activity. The characteristic reproductive such as produced the huge number of propagules and well adapted at various habitats and dispersal seed by wind lead to these invasive plants species were widely distribution and dominated the habitat.

Although huge number alien plant species were already identified, but the inform-ation related the alien plant species as invader to occupy in conservation areas in tropical forest were still unclear. Alien plants species entered in Indonesia (11) by contaminating imported cultivated and ornamental plants (20) and cultivated non native plants in Botanical Gardens (31). Some of the species are naturalized or escaped from cultivation and become wild and invasive due to well adapted and lead to problem invasion.

Commonly, invasion of alien plant species into conservation areas related to intensity of disturbance due to anthropogenic activities (30). In this study, Kebun Raya Solok has the highest number of invasive plant (fourty-one species) compared to other areas. This area was known as the highest disturbance compared to other areas (see Table 1) due to many trail and opened area. Beside that this area has just designated as a Botanical Garden for ex situ conservation. Rimbo Panti area has thirty-three invasive plant species. Although this area is nature reserve area with covered by primary forest, frequently visited by visitors for their hot springs lead to promote high number plant invasive species. Furthermore HPPB area has 28 invasive plant species. This area near the campus of Andalas University and some parts of this area was relatively opened area with secondary that dominated by pioneer plants. Then, Batang Palupuh was a natural reserve but overcome disturbance cause of many visitors for ecotourism of *Rafflesia arnoldii* and *Rizanthes* spp. Lembah Anai and G. Talamau areas has less than other study area. Although Lembah Anai was frequently visited due to tourism of Lembah Anai, but the very steep topography resulted in inhibiting distribution and invasion the invasive plant species. In case of G. Talamau, this area was relatively less visited with lowest the number of plant invasive species. So, we supported that increasing the number of invasive plant species in the conservation areas tend to related to increasing the gradient of disturbance the areas.

Furthermore, the results of this floristic study already revealed the existence of many invasive plant species in six conservation areas, however to control the invasive plant species is required observations and further research on their invasiveness of based on characteristics morphology, ecology, genetics and physiology. Information about the biology of invasive species and their behaviors in new places was essential for predictions and for control high-impact of invaders (32). Related this statements, it was important to distinguish between invasive species because their effects on diversity and composition of resident vegetation differ largely (36), tree invaders have a strong impact on the community scale is associated with reduction in species diversity at higher scales, invaders with a high impact represent a serious hazard to the landscape. Three species of invasive plants tree species were recorded in area study have to be paid attention, namely: *Acasia auriculiformis* in HPPB and Kebun Raya Solok, *Acasia mangium* in Kebun Raya Solok and *Arenga obtusifolia* in Rimbo Panti and Lembah Anai areas. Especially for the last invasive species, serious attention have to be paid by decision markers to conserve biodiversity, because of it dominantly invaded those two conservation areas resulted in severe impact on biodiversity.

It is very important to note that some of alien invasive plant species such as *Imperata cylindrica*, *Clydemia hirta, Lantana camara*, *Leucaena leucocephala*, *Mikania micrantha* and *Mimosa pigra* have been invaded to conservation areas in West Sumatra. Those species have identified as the worst invasive species in the world (33). The occurrences of those plant invaders in conservation areas are danger for plant conservation due to their effect to decrease biodiversity (33, 26).

Moreover, the results of these floristic studies implied the understanding of invasive plant species that have entered the tropical forests of Sumatra especially central Sumatra. However, to overcome the problems of invasive plants is need to study more detailed about biological characteristics (32) and the development of techniques to control them (22). Detailed analysis of the invasiveness is very important to control and manage the invasive plant species. Understanding on the ability adaptation of the invasive plant species is also very crucial. Therefore, analysis genetic diversity and population structure and the level of gene flow in populations of invasive plants are required for the detailed management and control them in the future (14; 8; 34; 35) because the magnitude of the genetic parameters is in line with level of adaptation ability and their success as invader. Results of breeding system analysis indicated some invasive species from family Asteraceae (except *Ageratum conyzoides*), Leguminosae and Graminae tend to manage the xenogamous breeding system. This fact implied the high level of genetic diversity and well adapted various habitats.

CONCLUSION

the results of these floristic studies obtained the understanding of the invasive plant species that have distributed into the tropical forests of Sumatra especially central Sumatra. The various numbers of invasive plant species and genera in conservation areas were concordance to increasing the gradient of disturbance the areas. Results of breeding system analysis indicated the invasive plant species from family *Asteraceae* (except *Ageratum conyzoides*), *Leguminosae* and *Graminae* tend to posses the xenogamy breeding system that implied the high level of genetic diversity and their well adaptation at various habitats. In the future, analysis of genetic diversity, population structure and the level of gene flow in populations of invasive plants are required for the detailed management and control them in the future.

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