Volcano Eruption and Invasion of *Acacia decurrens* (Wendl.) wild. in Mount Merapi National Park

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ABSTRACT

Mount Merapi located in Mount Merapi National Park is one of the major active volcanoes on the Island of Java. The type of eruption is characterized by the collapse of lava dome at the summit generating a huge pyroclastic flows. The last eruption occurred in 2010 and caused severe damage to the surrounding vegetation. After the eruption, *Acacia decurens* grew to dominate in all areas affected by the eruption. The purpose of this research was to investigate the influence of Mt Merapi eruption on the density and distribution of *A. decurrens*. The study was conducted at three locations: Cangkringan and Kemalang which were affected by the eruption and Selo as a comparison because it was not affected by the eruption. The -result showed that the population of *A. decurrens* in Cangkringan was higher than in Selo. The important value indexes (IVI) showed that *A. decurrens* are more dominant in Cangkringan and Kemalang than Selo. Based on Morisita index, at Cangkringan and Kemalang *A. decurrens* saplings was distributed in a clump while at Selo in a random pattern. The high density of *A. decurrens* indicated that the erruption of Mt. Merapi affects invasion of *A. decurrens*.
Key words: *Acacia decurrens*, density, eruption, invasive, Morisita.

INTRODUCTION

Mount Merapi Volcano, located within heavily populated Central Java, is one of the most active and feared volcanoes in the world. Almost eighty-three historical eruptions are reported where the eruption was accompanied by pyroclastic flows. About a dozen pyroclastic flows have caused fatalities to the environment near the Mt. Merapi (Voight 2000). Pyroclastic flows are incandescent mixtures of gas and solids produced by explosive eruptions. Its move rapidly along the ground (>100 km hr^{-1}). Pyroclastic flows commonly include a wide variety of solid materials, dominated by pulverized rocks as well as small particles like sand and dust (del Moral & Grishin 1999; Jekins 2013; Newhall 2000).

The great eruption of Mount Merapi on October 26, 2010 caused damage to the vegetation of Mount Merapi National Park (MMNP). The damage of the vegetation was classified into severely damaged; moderately damaged; lightly damaged and intact (not affected). Generally, in the areas of severe damage the vegetation was thoroughly burned by the pyroclastic flow. In the moderately damaged area, the trees were still standing but almost the entire crown was burned, with broken branches, but some trees still can sprout. In the areas with light damage, the vegetation was still green but there was some damage of trees and plants underneath. While at the area which was not affected by pyroclastic flow, the vegetation was still relatively intact and undamaged (MMNP 2011).

Plants species in the Mt. Merapi National Park (MMNP) vegetation not only consist of native species, but also include alien plant species that began to dominate certain zones in several regions of MMNP. A nonnative or alien species plant is a species which was brought into a natural ecosystem, by intentional or accidental introduction through human activities (Richardson & Pysek 2013). Invasive species, which may be native species or not, are species that have enormous reproductive capacity, so that they spread in a very large area (Richardson & Pysek 2013). Invasive alien plant species found in MMNP is *Acacia decurrens* (Wendl.) Willd. This plant has very rapid spread through seeds and roots. *A. decurrens* is able to dominate an area quickly and decrease the presence of native plants -. The purpose of this research was to investigate the influence of the 2010 Mt Merapi eruption on the density and distribution of *A. Decurrens* and to document the role of pyroclastic flows in the spread of an invasive alien species.

MATERIALS AND METHODS

Time and Location

The research was conducted from March 2014 until December 2014. The location of the research is at Mount Merapi National Park, which is located at 07 ° 22'33 "- 07 ° 52'30" latitude and 110 ° 15'00 "- 110 ° 37'30 " longitude. The study was performed at three different vegetation zones, the upper (1400-1700 m above sea level), middle (1100-1400 m above sea level) and lower zone (800-1100 m ASL). Vegetation data were collected from three sites. The first is Cangkringan site, the second is Kemalang site were affected by pyroclastic flow, and Selo that not affected by pyroclastic flow.

Analysis of Vegetation

Vegetation analysis was performed using a systematic sampling of parallel lines (Cropper 1993; Krebs 2002). There were a number of plots along the transect lines. The plots were designed into nested plots for each vegetation phase. The sizes of the plots were classified into sapling plots 5 × 5 m; and pole plots 10 × 10 m. The composition of vegetation in MMNP was determined by using the parameters: 1) Importance Value Index (IVI); 2) Morisita Dispersion Index (ID). Stand data (diameter and height) of *A. decurrens* were collected from the vegetation plots and the results were grouped by trunk height and branch free diameter size class (saplings and pole sized plants).

The abundance value of *A. decurrens* was transformed using PAST software to get a similarity matrix based on the ' Bray Curtis' similarity index (Clarke 2005). Furthermore, advanced Cluster analysis was carried out for each sub-plot on similarities per row with different heights based on this matrix. Cluster analysis is a multivariate method which aims to classify a sample of subjects (or objects) on the basis of a set of measured variables into a number of different groups such that similar subjects are placed in the same group.

RESULTS AND DISCUSSIONS

Acacia decurrens is endemic to New South Wales, mainly on the coast and tablelands from Hunter Valley south to the Australian Capital Territory. Distribution is spread over a large area, but not far from the eastern coast. *A. decurrens* has been widely cultivated as an ornamental plant and has naturalized in many areas, both in Australia and overseas. Tindale & Kodela (2001) provide maps of both the natural and naturalized distributions. *A. decurrens* grows in open forest or woodland, on hillsides or gullies, on clays and clay loams usually derived from shale. CAB International (2015), based on records of the Australian Tree Seed Centre, CSIRO, Forestry and Forestry Products listed that *A. decurrens* has been grown in the following countries: Argentina, Bolivia, Brazil, Chile, China, Colombia, Congo, Ecuador, Ethiopia, Haiti, Honduras, India, Indonesia, Japan, and Kenya. The species has also been trialed in Australia, e.g. near Canberra and southwest Western Australia.

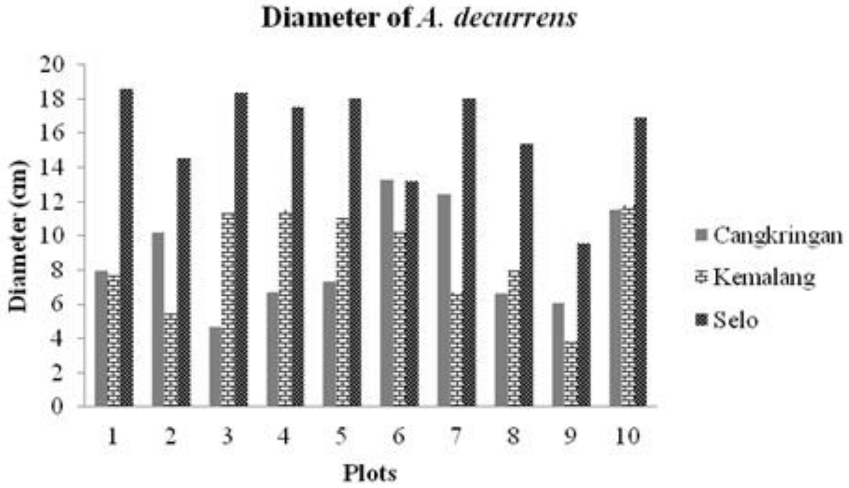

Figure 1. The diameter of *A. decurrens* in three different locations.

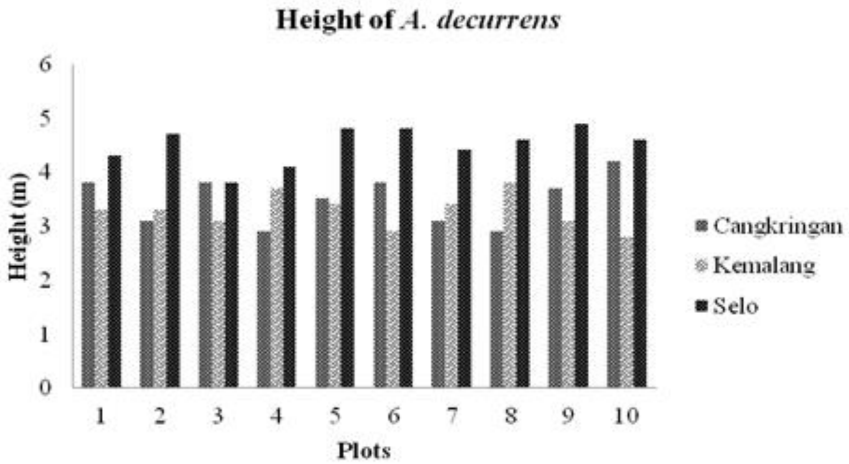

Figure 2. The height of *A. decurrens* in three different locations.

The size of the largest diameters found in Selo indicate that these plants existed before the eruption and the location was not affected by pyroclastic flow. *A. decurrens* tend to be distributed in clusters and thus the density value between individuals is very high. Higher density suggests greater inter-individual competition. This is supported by the research data of trunk diameter (Figure 1) which shows that the invaded locations had small trunk diameters but had relatively tall heights (Figure 2). These results indicate that the diameter of *A. decurrens* in Cangkringan and Kemalang were relatively similar in diameter (Figure 1). Average height of *A. decurrens* plants in Selo was also greater than in Cangkringan and Kemalang. Morphological conditions were probably affected by the process of interspecific competition or adaptation to the high individual density values. The difference between stem diameter and height of trees is part of the invasion process. The invasive plant such as acacia species has a higher size and larger basal leaf area than the noninvasive species (Gallagher 2014). The different sizes of diameter and weight of Acacia tree was occurred because of the high density, tree's age and competition between the individuals.

The differences in diameter and height of *A. decurrens* trees was caused by the pyroclastic flows that damaged the forest at Cangkringan and Kemalang. At these two location, *A.decurrens* growing grew after the eruption and the age of the trees was approximately 3-4 years. While at Selo *A. decurrens* grew as a mixture of new plants and old plants so that the average diameter and height of the tree were higher than in the two other locations. The diameters of the *A. decurrens* were inversely proportional to the density value (Suryanto et al. 2010). the higher density would lead to an intraspecific competition in obtaining resources from the environment.

The cluster analysis showed that there were no affects from elevation on average pole size. The differences in average pole size were influenced by the pyroclastic flows (Figure 3 and 4). Cangkringan zone 2 and 3 had the highest similarity, while the lowest similarity value was at Cangkringan zone 1. The sapling and pole vegetation in the locations that were affected by the eruption were almost uniformly dominated by the species *A. decurrens*.

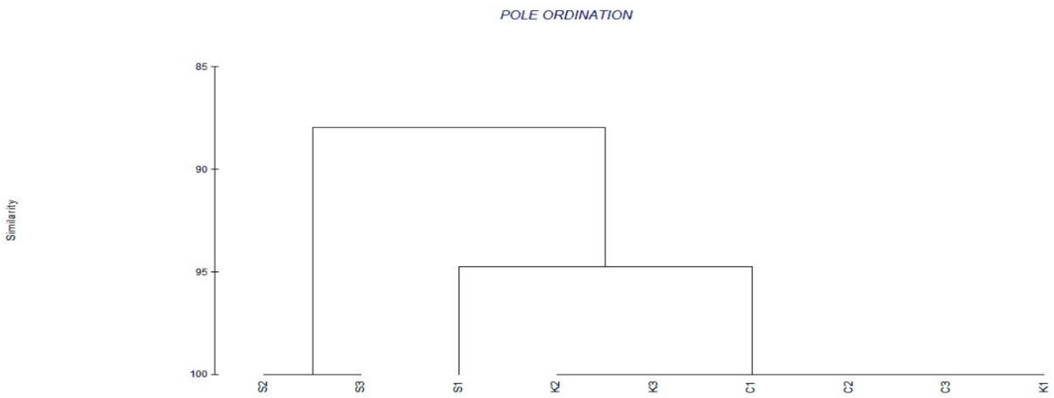

Figure 3. The cluster analysis of the *A. decurrens* pole phase. (Site = C: Cangkringan; K: Kemalang; S: Selo; Elevation zone = 1: Lower; 2: Middle; 3: Upper).

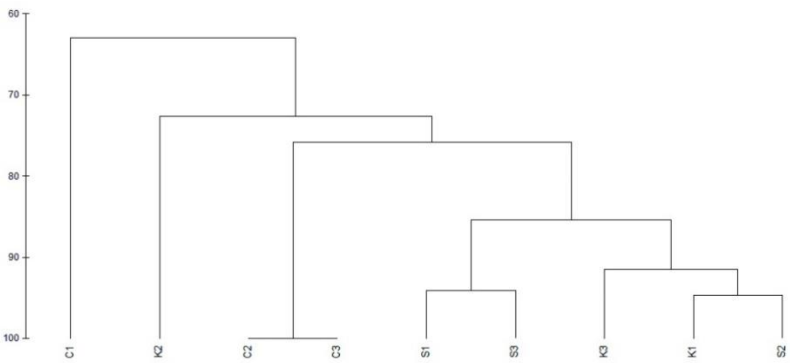

Figure 4. The cluster analysis of the *A. decurrens* sapling phase. (Site = C: Cangkringan; K: Kemalang; S: Selo; Elevation zone = 1: Lower; 2: Middle; 3: Upper).

The species was present before the eruption, but still at low levels. The *A. decurrens* population explosion after the eruption is related to its ability to survive in extreme conditions and rapid growth in the affected region. The high *A. decurrens* population affects the plant species under the invaded locations. High density and relatively high frequency causes a dense canopy closure so that only plants that can tolerate low light conditions can survive. Abundance of individuals of *A. decurrens* also increases the chances of intraspecific and interspecific competition in the invaded plant communities.

The results showed that the sites affected by pyroclastic flows (Cangkringan and Kemalang) were dominated by *A. decurrens*. The Morisita Index shows that the pole categories of *A. deccurens* at Selo were distributed in clumped pattern in zone 1 and 2, while in zone 3 was random distributed (Table 1). The pole distribution pattern in Selo was different with the sapling distribution which the *A. decurrens* was distributed with random pattern. In the area that affected by pyroclastic flow there a various type of distribution pattern based on Morisita Index. The pole categories of *A. decurrens* in Cangkringan also distributed in clump (Zone 2 and 3) but in Kemalang it was distributed in random. The patterns of species distribution based on Morisita index generally showed that the vegetation of plants distributed in groups (Table 1 & 2).

Table 1. The Pole categories of *A. decurrens* in three different locations with three different elevation zones.

Location	Importance Value Index			Morisita Index		
	Zone 1	Zone 2	Zone 3	Zone 1	Zone 2	Zone 3
Cangkringan	157,68	158,68	146,09	R	C	C
Kemalang	107,54	158,78	174,26	C	R	R
Selo	41,94	45,94	107,38	C	C	R

Zone 1 (800 – 1100 m asl); Zone 2 (1100 – 1400 m asl); Zone 3 (1400 – 1700 m asl); Morisita Index: C: Clump; R: Random

Table 2. The Sapling categories of *A. decurrens* in three different locations with three different elevation zones.

Location	Importance Value Index			Morisita Index		
	Zone 1	Zone 2	Zone 3	Zone 1	Zone 2	Zone 3
Cangkringan	80,84	81,84	84	C	C	C
Kemalang	118,46	114,04	153,73	R	C	C
Selo	33,67	42,51	58,67	R	R	R

Zone 1 (800 – 1100 m asl); Zone 2 (1100 – 1400 m asl); Zone 3 (1400 – 1700 m asl); Morisita Index: C: Clump; R: Random

Plants are commonly distributed in clumped patterns that correlate with environmental factors and plant competition to absorb resources from the environment. In the landscape, distribution of plants species in a population is rarely found in a random pattern, but instead trees and tropical shrubs are commonly found in clumped patterns (Call & Nilsen 2003). Clumped distribution patterns are caused by plants reproducing by seeds that it falls close to the mature plant or by plant with rhizomes producing new stems near the parent. Environmental conditions, climate, soil nutrients, and the area size affect the patterns of plant species distributions.

Invasive alien plant traits of high rate of spread, fast growth, and tolerance to habitat disturbance are primary factors allowing them to invade new habitat. *A. decurrens* was the pioneer plant of the succession in the vegetation of Mount Merapi after the eruption. *A. decurrens* has seeds that are resistant to high temperature (Valde et al. 2006; McDonald et al. 2012). The pyroclastic flow was primary factor with its high temperature that stimulated the germination of the *A. decurrens* seed. This phenomenon can be attributed to the invasive plant trait of producing many seeds with long viability in the soil seed bank. Plants have a number of ways to survive a fire, seeds, underground roots, stems and tubers that are insulated by soil, from which plants can regenerate. *A. decurrens* have seeds protected by a thick capsule that are stimulated to germinate after the pyroclastic flow passes. Fires often lead to increased availability of nutrients in an environment in which more light is available and competition is reduced, allowing the seedlings to grow quickly. After fire many plants regenerate very quickly from their seed bank (Smith & Tunison 1992; Wright & Zuur 2014).

A. decurrens easily propagates from seed but nevertheless should be given an additional treatment to induce germination. The best method is to boil the beans at 100 °C for 1 minute in a relatively large volume of water. The seed should be allowed to cool and absorb water for 24 hours; seeds that float to the surface are usually not viable and should be discarded; viable seeds should be swollen and sink. Seeds can also be given a mechanical treatment that breaks the seed coat and optimum germination temperature (Wrigley & Fagg 1996). The recommended temperature for optimal germination is 25 °C; germination starts after five days and all viable seeds usually germinate within 25 days. To manage the invasion of *A decurrens* is not recommended by using mechanical treatment such as burning down the vegetation, because the high temperatures can be trigger the germination of *A. decurrens* seed.

The eruption of Merapi volcanoes was been accompanied by hot pyroclastic flows that burned down all of the vegetation changing the area into open land. *A. decurrens* take an advantage from the degraded area that it has high opportunity to invaded the area. The high temperature of the pyroclastic flows broke the dormancy of the *A. decurrens* seed bank. *A. decurrens* has a hard seed that can survive dormant in certain conditions. The research showed that the high temperature is a stimulant that can increase the ability of *A. decurrens* seeds germination. Seed germination is a critical stage in the life cycle of plants, and often controls the population dynamics. To evaluate the effect of termperature on germination rate, the study was peformed to break dormancy and enhance germination of *A. decurrens* seeds. Soaking, heating, using chemicals, and growth hormones are effective treatments to breaking the dormancy of *A. decurrens* seeds. Temperature was the most important factor for *A. decurrens* seed germination (Sunardi 2016).

CONCLUSION

The eruption of Mount Merapi affected the spread of *A. decurrens* in Mount Merapi National Park. Important Value Index results show that the level of invasion of *A. decurrens* in Cangkringan and Kemalang was greater than in Selo. *Acacia.decurrens* distribution patterns were affected by habitat conditions after the eruption of Mount Merapi, Distribution pattern of saplings in Cangkringan and Kemalang occurred in clumped pattern while in Selo they occurred randomly. The main factor affecting the invasion are high temperature pyroclastic flows that break seed dormancy and trigger the simultaneous germination of large numbers of *A decurrens.*

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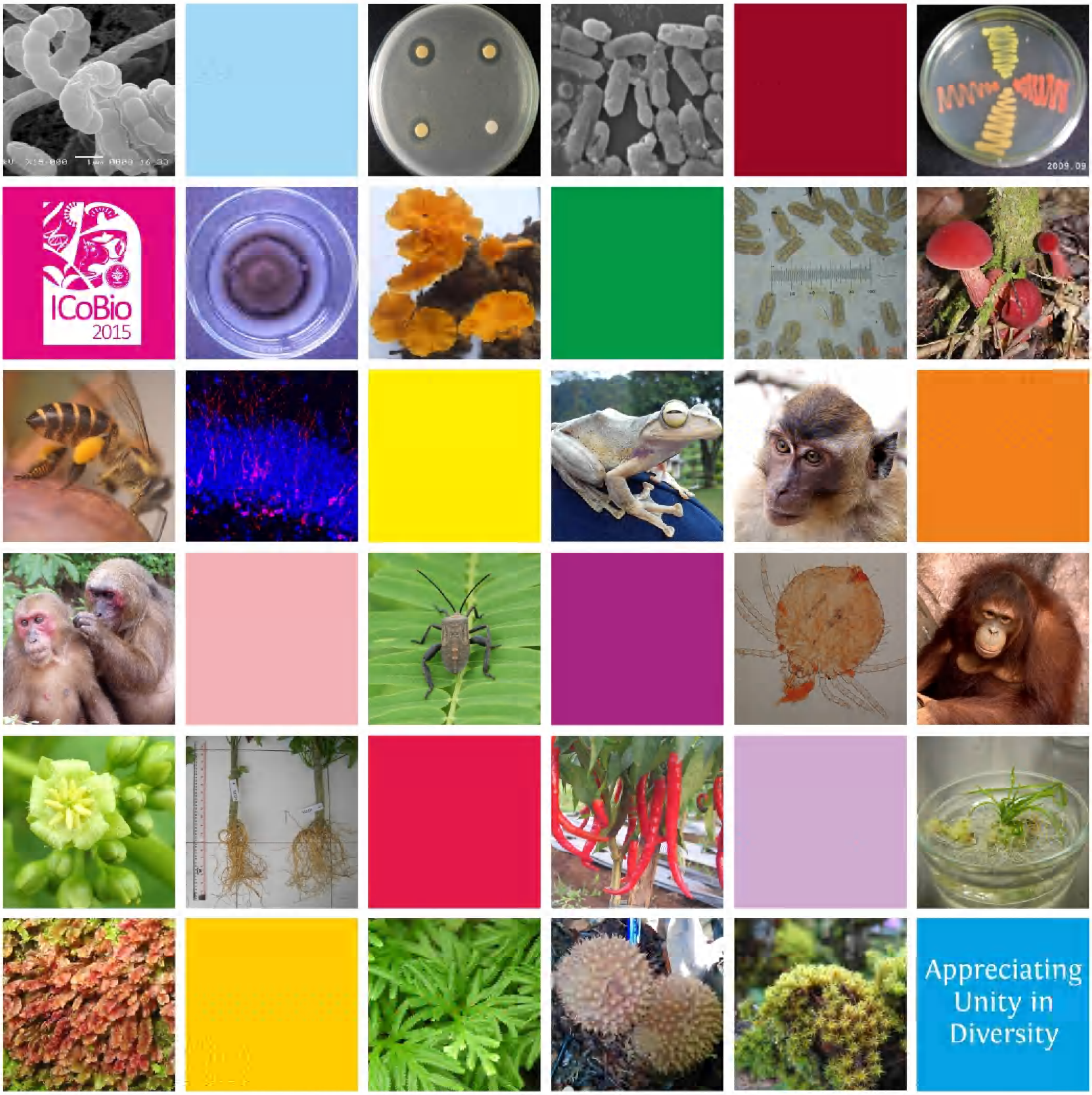

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Foreword

International Conference on Biosciences, ICoBio 2015, took place in Bogor, Indonesia, on August 5-7, 2015. The ICoBio 2015 have the theme of "Appreciating Unity in Diversity". This conference is intended to gain insight into current trends in research and teaching related to biology, such as interdisciplinary approaches that are important for understanding the biology and its applications. Moreover, to encourage the formation of networks between biologists and relevant stakeholders to accelerate our efforts to understand the biological phenomena and their applications.

The ICoBio 2015 is attended by more than 200 participants from several countries including Japan, Malaysia, India, Pakistan, Germany, Thailand, and Indonesia. The conference is the first international conference organized by the Department of Biology, Faculty of Mathematics and Natural Sciences, Bogor Agricultural University, Indonesia and is expected to serve as an initial step to be held continuously every two years (bianually). This activity is also the first step in the framework of collaboration between the Faculty of Mathematics and Natural Sciences (especially Department of Biology) Bogor Agricultural University, Indonesia with the Faculty of Science, Kasetsart University, Thailand.

One of the activities in this conference is the preparation of the proceeding. We received 9 keynote papers and more than hundred papers from oral presentations, workshops, and poster presentations. To collect paper we communicate with the authors and reviewers. One paper was reviewed by a competent reviewer. Reviewers provide comments and further authors revise his/her paper and return it to the editor of this proceeding. Therefore we highly indebted and appreciated to the reviewers who have taken the time, energy, and experience to review the papers.

Finally, there are the 16 accepted papers from oral presentations published in this book. Their topics cover a wide range of biosciences. In the conference, they presented the papers in the main four groups focusing on Biodiversity, ecology, and evolution (group 1); physiological, developmental, and behavioral sciences (group 2); Molecular biology, biotechnology, and omic technology (group 3); and Applied and interdisciplinary biology (group 4).

We do hope that this proceeding will provide you, the reader, the opportunity to get acquainted in greater detail with the ideas and results of the conference participants and also, perhaps, to recall some of the friendly and inspiring atmosphere of ICoBio 2015.

Bogor-Indonesia, August 24, 2015

Prof. Aris Tri Wahyudi
Conference Chairperson

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