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The Dynamics of Annonaceae Plants Collection and Its Conservation Efforts in Purwodadi Botanic Garden

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Abstract. Plant species of Annonaceae family were collected in Purwodadi Botanic Garden (PBG) needs *ex-situ* conservation efforts to prevent threat of extinction. Annonaceae plants collection in PBG have experienced dynamics over the past of 12 years which affect to diversity and conservation efforts. This study aimed to determine the dynamics or development of Annonaceae plant collections in PBG for the past of 12 years and how their conservation efforts. The methods were used are primary and secondary data collections from Registration Unit, measurement of stem diameter, plant height, branch-free stem height (BFS) of Annonaceae plant collections and microclimatic data (temperature, humidity, soil pH and light intensity) in each block of Annonaceae plant collections. Data were analyzed descriptively and by Principal Component Analysis using the statistical program PAST 4.0. The Annonaceae plant collections in PBG have fluctuated in the number of plants, genera, species, specimens and unidentified species with the addition of 28, 10, 6, 58, and 7 plants respectively. There were also 81 times of species identity changes. Annonaceae plant collections in PBG was able to well adapt and develop based on the average of stem diameter and BFS, with humidity and light intensity became the most influential environmental factors for plant growth. The management of Annonaceae plant collections in PBG consisted of the maintenance activities and studies to support the conservation. By regulating and manipulating of humidity and light intensity in Annonaceae plant collections, plant growth will increase and well maintenance. Management efforts can be planned and developed properly by knowing the dynamics of plant collections.

Key words: Annonaceae; Conservation; Dynamics; Plant; Purwodadi Botanic Garden

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INTRODUCTION

Annonaceae is one of the primitive families from Angiosperms that plays an ecological role in species diversity, especially in tropical lowland rainforest ecosystems, namely Paleotropic and Neotropic. Annonaceae consists of 120-130 genera and 2100-2300 species with habitus of tree, shrub and woody climber (Van Heusden, 1992; Couvreur et al., 2012). Plant species from Annonaceae require *ex-situ* conservation to avoid threat of extinction. The forms of threat are the lost of native habitat in the forest, the high rate of exploitation of potentially Annonaceae plant species and the existence of historical values from certain species such as many species of Annonaceae were endemic in certain region (Handayani, 2018). One of the *ex-situ* conservation institutions that conserve Annonaceae plant species is Purwodadi Botanic Garden (PBG).

Plant species of Annonaceae collections were conserved at PBG have experienced of dynamics over the past of 12 years. The dynamics of Annonaceae plant collections were influenced by the survival rate of collections, unidentified species and the potential of species that have not been much explored. Plant as a living collection needs to be supported by a management system that provides a periodic monitoring and an integrated data collection system. Plant collections in a botanic garden were *ex-situ* conserved for the needs of education, culture, research and conservation itself (Cibrian-Jaramillo et al., 2013). The diversity of plants in the world can be identified through grouping the plant collections, identity of species, ecological potential and aspects of its usefulness. The collection of plants in the botanic garden were described as the diversity of plants in the world which is maintained in greenhouses or open gardens, accompanied by historical documentation. *Ex-situ* conservation plays a role in providing reserves of threatened plant populations in the nature, providing plant materials for reintroduction, restoration and giving advice for plant collections management policies (Jardin Botanique de Montreal, 2007).

Periodic monitoring carried out in the management of plant collections is not only to provide information about plant maintenance, but also the latest information about the physiological conditions of the plants collected. This information includes details of plant characteristics, natural conditions during blooming, ecological factors that influence the plant collections growth, evaluation records, propagation, herbarium information and seed collections (Denver Botanic Gardens, 2017). Periodic monitoring can only be done if the condition of plants was maintained. The dynam-

ics of plant collections condition would experienced problems in its maintenance of management. These collection dynamics affect the diversity and conservation efforts, especially for Annonaceae plants species in PBG. This study aimed to determine the dynamics or development of Annonaceae plants in PBG over the past of 12 years and how their conservation efforts. By knowing the dynamics of Annonaceae plant collections in PBG, management efforts of collection can be planned and developed properly. So that, plant collections can be well maintained, healthy and survive.

METHODS

Inventory of Annonaceae data collections

Primary data collections was carried out through inventory and inspection activities of Annonaceae plant collections located in block XVIII.C., XVIII.D., XVIII.E., XIX.B.I. and the other block with Annonaceae plants. The primary data collections were carried out at the end of 2007, 2010, 2012, 2015 and 2018. Secondary data collections were carried out through track record of collections from the catalog book (for collection data of 2007), garden books and collection of plant material books at Registration Unit, PBG. Data for conservation efforts was obtained through interviews with plant technicians in PBG and literature studies.

Measurements of Annonaceae plant collections condition

The condition of Annonaceae plants was observed based on their sustainability and adaptation from the beginning of planting to the present through measurement of stem diameter, plant height and branch-free stem height (BFS). Measurement of stem diameter was carried out at a distance of 20 cm from the soil. The three parameters of observation were measured using a roll-meter (Alday et al., 2016). Microclimatic data in each block was measured using a pH meter (for soil pH), thermohygrometer (for temperature and humidity), and light meter (for light intensity). Each block was 5 replications of measurement.

Data analysis

Primary data was processed and analyzed using Microsoft Excel, while secondary data was analyzed descriptively. Primary data was processed in the form of the number of genera, species, specimens, unidentified species, gendub (only identified at family level) and the origin of collections. The condition of Annonaceae plant collection was analyzed using Principal Component Analysis (PCA) with the PAST statistical program ver. 4.0.

RESULTS AND DISCUSSION

The dynamics of Annonaceae plant collections in PBG

Collections of Annonaceae in PBG have experienced many changes over the past 12 years with an increase in the number of genera, species and specimens. The number of unidentified species has fluctuated, while the number of gendub has increased from 2010 to 2012 and decreased significantly until 2018 due to species identity changes (Figure 1). The dynamics of Annonaceae plant collections were caused by the addition of specimens through exploration activities from various regions of Indonesia, the change in identity of plant from unidentified species, and the death of several of collections. The death of several Annonaceae plants collections in PBG was minimal, but requires further investigation for the cause of death. Some of the causes included the incompatibility of microclimate around the plants to support their growth, maintenance of plants (weeding, fertilizing, watering, etc.), and the presence of certain pests and diseases. For example of death species are *Annona reticulata*, *A. squamosa*, *Cyathocalyx sumatranus*, and *Artabotrys celebica*. The low mortality rate of Annonaceae plant collections in PBG indicates that the plant collections were able to adapt, grow and develop well outside their natural habitat.

The addition of plants and changes of species identity will give a major influence on the conservation of Annonaceae plant species in PBG. Through the addition of plants from exploration activities, it will enrich the species and genetics diversity from Annonaceae plant collections. Annonaceae plants species that were successfully collected and conserved in PBG were originated from various regions in Indonesia including Java, Kalimantan, Sulawesi, Moluccas, Sumba, Sumatra, Papua and East Nusa Tenggara. The origin of most collections comes from East Kalimantan, East Java and South Kalimantan (Figure 2). Over the past of 12 years, there have been 28 numbers of plant collection additions, 10 genera, 6 species, 58 specimens and 7 numbers of unidentified species.

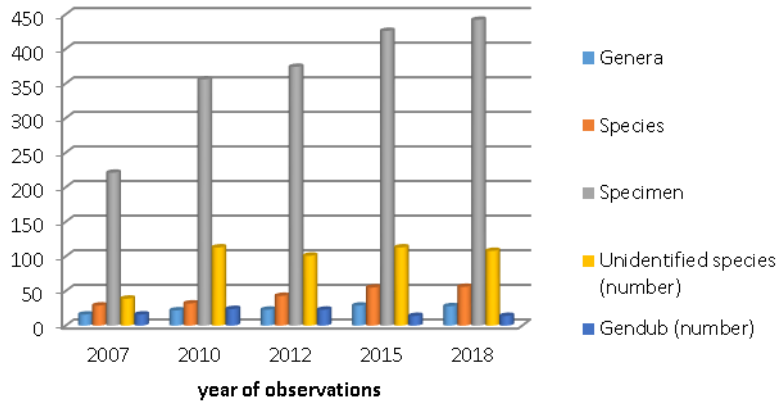

Figure 1. The dynamics of Annonaceae plants collection over the past of 12 years

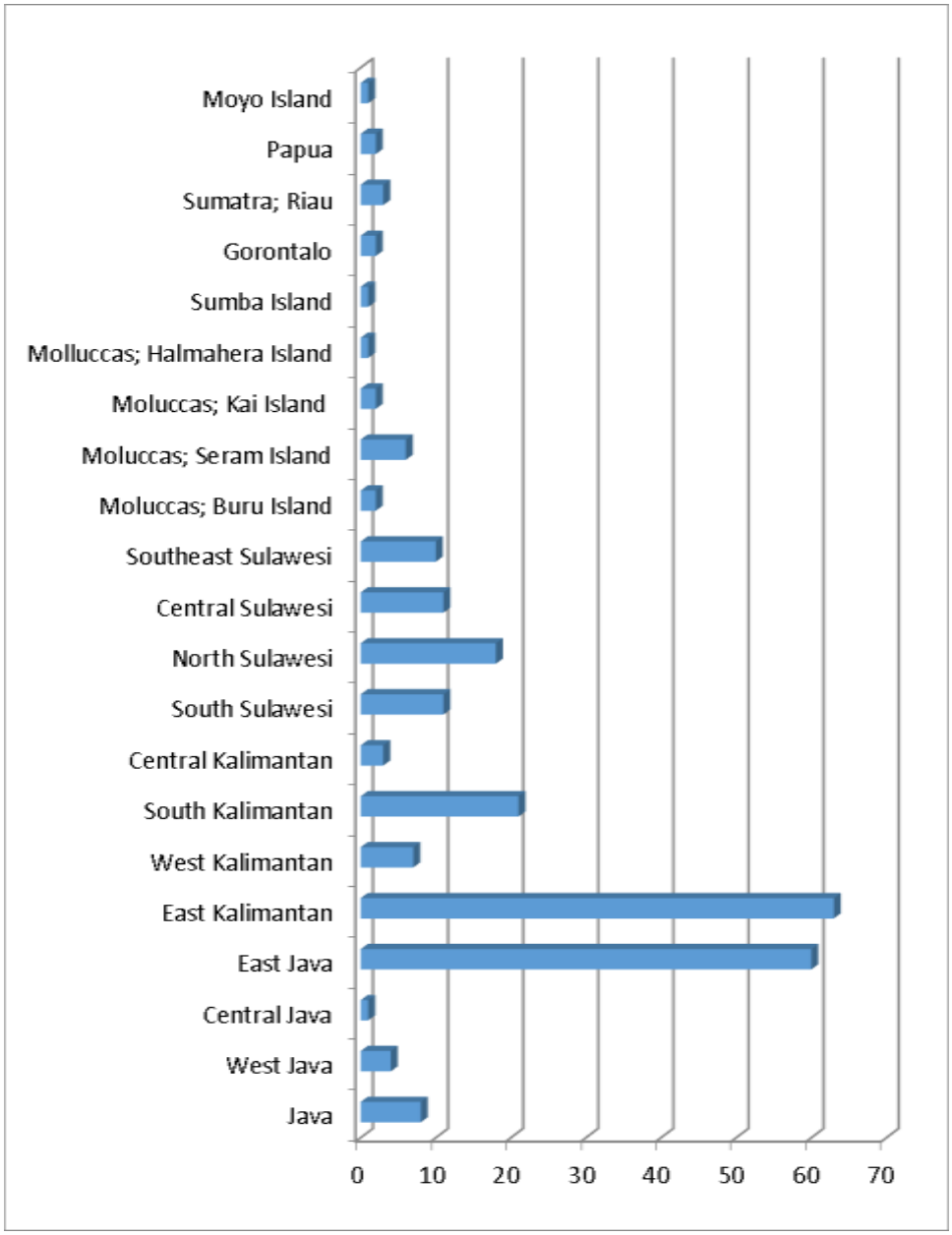

Figure 2. The origin of Annonaceae plant collections in PBG

The addition of plant collections from exploration activities will also add to unidentified species. Over the past 12 years, the changes of species identity were carried out by plant identifiers from PBG, researchers and through Herbarium Bogoriense (Table 1). The change in species identity was done based on morphological characters (especially on generative characters) or assisted with molecular characters (Dosmann & Groover, 2012; Hapsari, 2011; Lestari & Sofiah, 2015; Lestari, 2019). There are some species whose identities have been changed more than once, such as *Cyathostemma micranthum* (XVIII.C.34; XVIII.E.5), *Miliusa lineata* (XVIII.C.62), *Uvaria* sp. (XVIII.D.15), *Orophea polycarpa* (XVIII.E.43; 44; 63) and *Sageraea lanceolata* (XIX.B.I.73).

Sustainability and adaptation of Annonaceae plant collections

Annonaceae plant collections in PBG were able to well adapt and develop based on the average of branch-free stem height (BFS) and stem diameter (Figure 3). The plants planted in 1980s have larger stem diameter than the 1990s and 2000s, as well as the BFS parameter. Sustainability and adaptability of Annonaceae plant collections were also influenced by the microclimatic factors (Table 2). Because environmental cues have a major impact on plant growth, humidity and light intensity are the most influential environmental factors for plant growth, especially for branch development (stem diameter and BFS) to plant collections that were planted in 1980s (Figure 4) have larger stem diameter and BFS.

Table 1. History of identity species changes on Annonaceae plant collections over the past 12 years

Old identity species	New identity species	Number of collection	Plant identifier	Year of change
Saccopetalum horsfieldii	*Miliusa horsfieldii*	XVIII.C.2	DN	20-05-2015
Anomianthus dulcis	*Desmos chinensis*	XVIII.C.6	DAL	11-09-2017
Anomianthus dulcis	*Desmos chinensis*	XVIII.C.13	DAL	23-10-2018
Saccopetalum horsfieldii	*Miliusa horsfieldii*	XVIII.C.14	DN	20-05-2015
Mitrephora reticulata	*Pseuduvaria reticulata*	XVIII.C.20	DAL	23-10-2018
Popowia sp.	*Polyalthia littoralis*	XVIII.C.24	DN	04-03-2015
Anomianthus dulcis	*Desmos chinensis*	XVIII.C.33	DAL	23-10-2018
Artabotrys uncinatus	*Mitrella kenthii*	XVIII.C.34	DN	20-05-2015
Mitrella kenthii	*Cyathostemma micranthum*	XVIII.C.34	DAL	11-09-2017
Mitrella kenthii	*Cyathostemma micranthum*	XVIII.C.35	DAL	11-09-2017
Uvaria sp.	*Uvaria littoralis*	XVIII.C.36	HB	18-03-2010
Oxymitra sp.	*Desmos dumosus*	XVIII.C.40	DAL	11-09-2017
Polyalthia lateriflora	*Polyalthia sclerophylla*	XVIII.C.41	DAL	23-10-2018
Anaxagorea sp.	*Alphonsea javanica*	XVIII.C.42	DN	10-06-2015
Annonaceae	*Miliusa* sp.	XVIII.C.45	DN	24-3-2015
Polyalthia sp.	*Xylopia* sp.	XVIII.C.57	DAL	23-10-2018
Desmos chinensis	*Xylopia* sp.	XVIII.C.60	DN	20-05-2015
Polyalthia sp.	*Miliusa* sp.	XVIII.C.62	DN	20-05-2015
Miliusa sp.	*Miliusa lineata*	XVIII.C.62	DAL	11-09-2017
Saccopetalum horsfieldii	*Miliusa horsfieldii*	XVIII.D.6	DN	20-05-2015
Polyalthia sp.	*Meiogyne* sp.	XVIII.D.10	DN	28-05-2015
Polyalthia sp.	*Fissistigma* sp.	XVIII.D.15	DN	20-05-2015
Fissistigma sp.	*Uvaria* sp.	XVIII.D.15	DN	28-05-2015
Mitrephora sp.	*Mitrephora polypyrena*	XVIII.E.2	DN	28-05-2015
Uvaria sp.	*Uvaria concava*	XVIII.E.4	DN	28-05-2015
Polyalthia sp.	*Mitrella kenthii*	XVIII.E.5	DN	28-05-2015
Mitrella kenthii	*Cyathostemma micranthum*	XVIII.E.5	DAL	23-10-2018
Xylopia sp.	*Alphonsea javanica*	XVIII.E.6	DN	10-06-2015
Saccopetalum sp.	*Miliusa* sp.	XVIII.E.10	DN	28-05-2015
Polyalthia sp.	*Miliusa* sp.	XVIII.E.14	DN	21-12-2015
Polyalthia sp.	*Sageraea lanceolata*	XVIII.E.18	DAL	23-10-2018
Meiogyne wangii	*Meiogyne virgata*	XVIII.E.21	DN	12-04-2012
Polyalthia sp.	*Xylopia* sp.	XVIII.E.29	DN	28-05-2015

Polyalthia sp.	*Peuduvaria reticulata*	XVIII.E.30	DN	28-05-2015
Annonaceae	*Polyalthia* sp.	XVIII.E.32	DN	28-05-2015
Polyalthia sp.	*Miliusa* sp.	XVIII.E.34	DN	21-10-2015
Miliusa macropoda	*Meiogyne cylindrocarpa*	XVIII.E.36	DAL	11-09-2017
Polyalthia sp.	*Xylopia malayana*	XVIII.E.38	HB	30-12-2016
Xylopia sp.	*Alphonsea javanica*	XVIII.E.42	DN	10-6-2015
Polyaulax cylindrocarpa	*Meiogyne cylindrocarpa*	XVIII.E.43	Plantlist	
Meiogyne cylindrocarpa	*Orophea polycarpa*	XVIII.E.43	DAL	11-09-2017
Polyaulax cylindrocarpa	*Meiogyne cylindrocarpa*	XVIII.E.44	Plantlist	
Meiogyne cylindrocarpa	*Orophea polycarpa*	XVIII.E.44	DAL	11-09-2017
Polyalthia sp.	*Sageraea lanceolata*	XVIII.E.46	HB	30-12-2016
Artabotrys sp.	*Desmos chinensis*	XVIII.E.48	DN	10-06-2015
Annonaceae	*Desmos* sp.	XVIII.E.50	DN	10-06-2015
Annonaceae	*Uvaria* sp.	XVIII.E.51	DN	21-10-2015
Annonaceae	*Enicosanthum* sp.	XVIII.E.54	DN	10-06-2015
Annonaceae	*Desmos* sp.	XVIII.E.59	DN	21-12-2015
Polyalthia sp.	*Alphonsea* sp.	XVIII.E.60	DN	21-12-2015
Friesodielsia sp.	*Fissistigma* sp.	XVIII.E.62	DN	28-05-2015
Mitrephora sp.	*Mitrephora heyneana*	XVIII.E.63	DN	30-12-2016
Mitrephora heyneana	*Orophea polycarpa*	XVIII.E.63	DAL	23-10-2018
Polyalthia sp.	*Xylopia* sp.	XIX.B.I.1	DN	20-05-2015
Annonaceae	*Desmos* sp.	XIX.B.I.3	DN	21-12-2015
Polyalthia sp.	*Mitrephora* sp.	XIX.B.I.5	DAL	23-10-2017
Polyalthia sp.	*Polyalthia rumphii*	XIX.B.I.13	DN	21-12-2015
Polyalthia sp.	*Mitrephora* sp.	XIX.B.I.14	DN	20-05-2015
Polyalthia sp.	*Xylopia* sp.	XIX.B.I.15	DN	20-05-2015
Uvaria sp.	*Uvaria rufa*	XIX.B.I.23	HB	30-12-2016
Annonaceae	*Dasymaschalon borneense*	XIX.B.I.24	DN	21-12-2015
Oxymitra philippinensis	*Dasymaschalon* sp.	XIX.B.I.25	DN	21-12-2015
Polyalthia sp.	*Polyalthia rumphii*	XIX.B.I.33	DN	21-12- 2015
Uvaria sp.	*Fissistigma borneensis*	XIX.B.I.38	DN	21-12-2015
Polyalthia sp.	*Mitrephora* sp.	XIX.B.I.42	DN	21-12-2015
Polyalthia sp.	*Alphonsea* sp.	XIX.B.I.43	DN	21-12-2015
Polyalthia sp.	*Mitrephora* sp.	XIX.B.I.44	DN	21-12-2015
Annonaceae	*Uvaria* sp.	XIX.B.I.55	DN	01-11-2013
Polyalthia sp.	*Polyalthia obliqua*	XIX.B.I.58	HB	30-12-2016
Polyalthia glauca	*Desmos* sp.	XIX.B.I.61	DN	21-12-2015
Meiogyne cylindrocarpa	*Orophea polycarpa*	XIX.B.I.62	DAL	11-09-2017
Polyalthia sp.	*Polyalthia bullata*	XIX.B.I.64	DAL	23-10-2018
Polyalthia sp.	*Miliusa* sp.	XIX.B.I.68	DN	21-12-2015
Annonaceae	*Stelechocarpus* sp.	XIX.B.I.73	DN	21-12-2015
Stelechocarpus sp.	*Sageraea lanceolata*	XIX.B.I.73	DAL	23-10-2018
Anaxagorea	*Anaxagorea luzonensis*	XIX.B.I.77	DN	20-05-2015
Polyalthia sp.	*Alphonsea* sp.	XIX.B.I.82	DN	21-12-2015
Polyalthia sp.	*Stelechocarpus* sp.	XIX.B.I.86	DN	21-12-2015
Goniothalamus sp.	*Goniothalamus macrophyllus*	XIX.B.I.90	DN	21-12-2015
Lophonsea sp.	*Anaxagorea javanica*	XIX.B.I.91	DN	21-12-2015
Annona sp.	*Annona montana*	IV.A.I.5	DAL	11-09-2017

Notes: DN = Dwi Narko, DAL = Dewi Ayu Lestari, HB = Herbarium Bogoriense

Table 2. Microclimatic factors of Annonaceae plant collections in PBG

Year of planting	Humidity (%)	Temperature (°C)	Light intensity (lux)	Soil pH
1980s	58.4	25.6	2162.6	6.94
1990s	54.8	26.22	711.94	7
2000s	55	25.9	1938.4	6.9

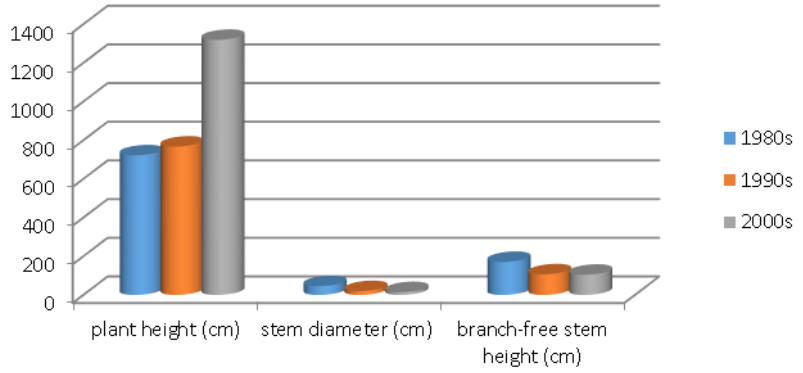

Figure 3. Sustainability and adaptation of Annonaceae plant collections in PBG

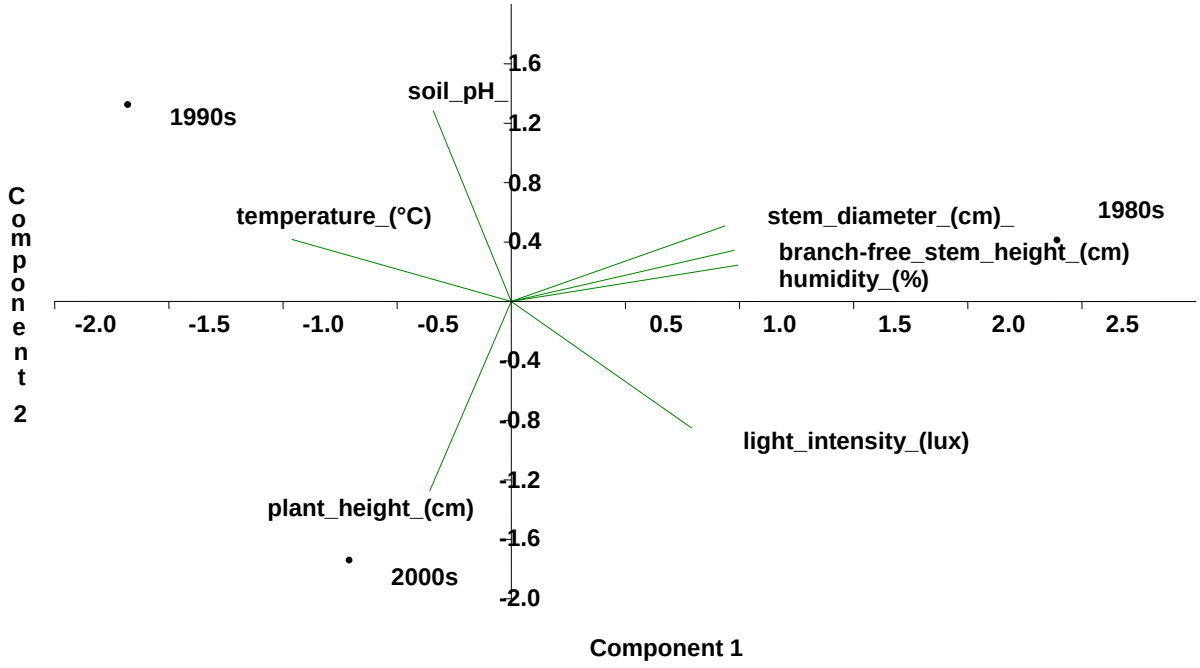

Figure 4. Influence of microclimatic factors to sustainability and adaptability of Annonaceae plant collections in PBG

Conservation efforts of Annonaceae plant collections in PBG

Annonaceae plant collections conserved in PBG consist of 28 genera (25.68% of the total Annonaceae genera in the world) and 56 species (2.3% of the Annonaceae species in the world). Annonaceae in the world consists of about 109 genera and 2440 species (Couvreur et al., 2012; Handayani, 2018; Rainer & Chatrou, 2019). Annonaceae plant collections in PBG were able to well adapt and develop based on their increasing of BFS and stem diameter. The growth performance (survival and adaptation) of plants can be known by their increasing of diameter as age increasing after planting (Budiana et al., 2017; Lestari et al., 2019). The increasing in stem diameter of plant collection was influenced by light intensity in their location. Plants grown in varying intensities of light show well-known characteristic and differences in growth and development (Thut & Loomis, 2019). Plants with full sun intensity have a good growth performance than low light intensity. Humidity and light intensity are the most influential environmental factors on the growth of Annonaceae plant collections in PBG. Humidity as an atmospheric moisture be-

came an important factor of the microclimatic environment for plant growth and development (Tibbits, 2014). Microclimatic data were effect to plant collections growth in botanic garden. This data can be used as additional information for conservation to keep the plant sustainability, as well as plant survival and cultivation development activities (Hidayat et al., 2017; Sulaeman et al., 2019).

PBG as one of the botanic gardens in Indonesia plays a role in *ex-situ* plant conservation and exploration of plant biodiversity globally to preserve certain species (Waylen, 2006; Golding et al., 2010). Conservation activities on Annonaceae plant collections are in the form of plant maintenance, so that the plant collections remain survive (pruning, watering, fertilizing, etc.). Other plant maintenance are collecting of data, arraging of plant collections, monitoring the flowering and fruiting phases of selected plant collections and increasing the number of plant collections through exploration activities. Data of plant collections is dynamic and changing every year. The changes occurred because of the death of plant collections, planting new plants (Arfianti, 2011) as well as changes in the species identity. By knowing the identity of species, the conservation value of the species concerned can be known. The conservation value that can be identifying by ethnobotany study aims to determine knowledge of economic value, breeding technique and their existence (Rahayu et al., 2017).

Living collections play a quite diverse role in plant biology research. This is because in general, the process from identification, exploration, propagation to growing plant material is a fundamental thing needed in plant biology (include living collections) (Dosmann & Groover, 2012). Therefore, *ex-situ* plant conservation requires effective and efficient collection management. Management will not be effective if the threatened species and a high conservation value species are not easy to recognize, document, test and monitor regularly. This is requiring long-term commitment (Hapsari, 2011). Because this relates to the conservation value of plant collections, which will ultimately be useful and easily accessible for conservation, education, horticultural and research purposes (Cibrian-Jaramillo et al., 2013).

Several studies on endemicity patterns, species rarity, genetics, kinship or phylogenetic relationships, as well as the presence of pathogens in plant collections are needed to support the management of plant collections in a botanic garden (Golding et al., 2010). Several studies and research that have been conducted on Annonaceae plants in PBG are shown in Table 3. So far, the studies conducted on Annonaceae plants are still limited so that it requires more intensive efforts to improve the performance and quality of plant collections. Revealing the species identity of Annonaceae plant collections is the first step that must be taken so that the conservation value of the plant collection specimen can be known. In addition, the management of collection plant management is still routinely carried out. By knowing the value of conservation, the aspects of its usefulness will be more easily explored.

Table 3. Studies on Annonaceae plant collections in PBG

Theme of studies	Research
Taxonomy	- Gland variations of *Orophea* spp. (Lestari, 2011)
	- Morphometric of *Annona* spp. (Lestari & Hikmah, 2012)
	- A new collection plant in PBG: *Anaxagorea luzonensis* (Lestari, 2014)
	- Taxonomical position of selected species from Annonaceae (Lestari et al., 2017)
	- Morphometric of *Orophea* spp. (Purnamasari & Lestari, 2018; *unpublished*)
	- Key morphological character of woody climber collection plants from Annonaceae (Isnayanti & Lestari, 2018; *unpublished*)
Physiology	- Flowering and fruiting periods of *Annona* spp. (Lestari & Sofiah, 2015)
	- Evaluation of flowering and fruiting periods of Annonaceae (Lestari, 2019)
Ecology	- Canopy structure and hydrology cycle of *Cananga odorata* (Sofiah & Lestari, 2019)
Molecular	- Species diversity of selected *Artabotrys* based on RAPD (Lestari & Rachma, 2016; *unpublished*)
	- Phylogenetic of selected Annonaceae species based on cpDNA (Lestari et al., 2018)
	- Species identity and taxonomical position of selected Annonaceae species based on *trn*L marker (Lestari & Azrianingsih, 2019)

Knowledge of the dynamics of Annonaceae plant collections in PBG associated with collection survival rate that can be known through their sustainability and adaptation. This knowledge can be basis information for management conservation efforts, especially in PBG. If the plant collections in PBG (especially for

Annonaceae) are well maintained, healthy, have accurately identity of species, information and scientific data with ethnobotany knowledge are available, it will be more beneficial for community, academics, and other consumers. Their purposes are beneficial to education tourism or environmental education for conservation.

CONCLUSION

Plant collections of Annonaceae were able to adapt and develop based on stem diameter and BFS parameters. Humidity and light intensity become the most influental factor for sustainibility and adaptability of Annonaceae plant collections. This study of Annonaceae plant collections in PBG has been carried out to support the management of plant collections so that their conservation values can be identified and aspects of their usefulness can be explored.

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