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Ex situ conservation of *Amorphophallus titanum* in Bogor Botanic Gardens, Indonesia

Konservasi ex situ *Amorphophallus titanum* di Kebun Raya Bogor, Indonesia

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Abstract. *Puspitaningtyas DM, Ariati SR. 2016. Ex situ conservation of* Amorphophallus titanum *in Bogor Botanic Gardens, Indonesia. Pros Sem Nas Masy Biodiv Indon 2: 219-225.* Titan Arum (*Amorphophallus titanum* (Becc.) Becc.) merupakan tanaman asli dan endemik Sumatera. Tumbuhan ini pertama kali ditemukan pada tahun 1878 oleh ahli botani Florentine (Italia) yang bernama Odoardo Beccari. Perbungaannya yang berukuran raksasa dianggap menarik, sehingga Kebun Raya Bogor menjadikan tumbuhan ini sebagai jenis unggulan. Titan Arum secara alami tumbuh di hutan hujan atau perkebunan/pekarangan penduduk lokal. Di alam liar, habitat alami Titan Arum telah rusak akibat tekanan jumlah penduduk yang terus meningkat, atau banyak dibabat oleh penduduk karena dianggap sebagai gulma. Selain itu, degradasi hutan akibat pembalakan liar oleh penduduk juga menjadi ancaman lain bagi habitat tumbuhan tersebut. Kebun Raya Bogor telah memainkan peranan yang penting dalam konservasi *A. titanum* secara ex situ. Tumbuhan ini telah dikembangkan sejak tahun 1954 sebagai upaya konservasi ex situ. Kajian ini menampilkan data sekunder *A. titanum* yang berasal dari *database* koleksi tumbuhan Kebun Raya Bogor. Budi daya *A. titanum* tidak mudah sehingga menjadi tantangan bagi para praktisi hortikultura. Selain teknik budi daya, teknik penyerbukan juga merupakan tantangan dalam konservasi ex situ jenis ini. Penyerbukan sendiri dalam satu bunga mempunyai peluang keberhasilan yang sangat kecil, karena serbuk sari mulai masak ketika masa reseptif putik telah berakhir. Penyerbukan buatan dengan tangan menjadi alternatif untuk memproduksi biji.

Kata kunci: *Amorphophallus titanum*, endemik, jenis unggulan, Kebun Raya Bogor, Sumatera

Abstract. *Puspitaningtyas DM, Ariati SR. 2016. Ex situ conservation of* Amorphophallus titanum *in Bogor Botanic Gardens, Indonesia. Pros Sem Nas Masy Biodiv Indon 2: 219-225.* The Titan Arum (*Amorphophallus titanum* (Becc.) Becc.) is a native and an endemic plant in Sumatra. It was first discovered in 1878 by a Florentine (Italy) botanist, Odoardo Beccari. The gigantic inflorescence of this plant is regarded as a flagship species for Bogor Botanic Gardens. The Titan Arum naturally grows in the rainforest or local inhabitant plantation/yard. In the wild, the natural habitat of Titan Arum has been damaged as a result of population pressure continues to increase, or cut off by people because it is considered as weed. In addition, the forest degradation due to an illegal logging by people may also to be another threat to the habitat of the species. Bogor Botanic Gardens has been playing an important role in the ex situ conservation of *A. titanum*. This plant has been developed as ex situ conservation since 1954. This paper presented a secondary data of *A. titanum* from the plant collections database of Bogor Botanic Gardens. The cultivation of *A. titanum* is not easy, but it offers a challenge for the practitioners of a horticulturist. Besides their cultivation techniques, the pollination techniques are also to be a challenge in ex situ conservation of this species. A self-pollination is almost not possible because of the pollens only ripe when a receptive phase of pistil has finished. A hand-pollination is the other alternative to produce seeds.

Keywords: *Amorphophallus titanum*, Bogor Botanic Gardens, endemic, flagship species, Sumatra

INTRODUCTION

Bogor Botanic Gardens was established on May 18th, 1817 by Dr. C.G.C. Reinwardt as ‘s Lands Plantentuin te Buitenzorg (Levelink et al. 1996). Bogor Botanic Gardens has an important role as a center for plant conservation with three other annexes botanic gardens. Nowadays, the Bogor Botanic Gardens’s collection reaches approximately 20.000 plants which consist of approximately 3.750 species, including orchid collections (Sari et al. 2010).

Currently, Indonesia, as a megadiversity country which has 10% of flowering plants in the world, has turned into a "hot spot country". In the effort to fulfill its mission of ex situ conservation, the botanical gardens has carried out flora exploration activities and plants inventory in Indonesia to study the plant diversity. One of the interest points in Bogor Botanic Gardens is the research on a rare plant of *Amorphophallus titanum* (Becc.) Becc. This iconic plant has been chosen as a flagship species of Bogor Botanic Gardens. It is an important symbol of the incredible diversity of the world’s plants, which needs efforts to be conserved by cultivation or in their natural habitats. By growing this species in botanic gardens, it can raise the awareness of the loss of its tropical forest in the island of Sumatra, a part of Indonesia.

The Titan Arum was first discovered in Sumatra's rainforests and scientifically described in 1878 by Odoardo Beccari, an Florentine (Italy) botanist (Hetterscheid 1998a). The aims of this study were to dessiminate the ex situ conservation of *A. titanum* in Bogor Botanic Gardens, such as exploration activities for collecting *A. titanum*, flower induction and hand-pollination to produce fruit set.

MATERIALS AND METHODS

Exploration activities were routine conducted into forest to enrich the living plant collection in Bogor Botanic Gardens, West Java, Indonesia. The material of *A. titanum* which usually brought from the forest were seeds, tubers or flowers. The plants were collected from the wild through exploration activities, then recorded in collection database of Bogor Botanic Gardens.

Although the Titan Arum was introduced in Bogor Botanic Gardens in the 1820's, this paper presented the collection data of *A. titanum* obtained from the Bogor Botanic Gardens collection's database since 1954. The data were compiled consist of the year of collection, the accession number of collection, the place of origin, the altitude of habitat, the material of living plant collections or Vak (block of plant collections where the collections planted) and the collectors. Blooming time was also recorded for each accession number of collection.

RESULTS AND DISCUSSION

Titan Arum (*A. titanum*) is a native and an endemic plant to Sumatra Island in Indonesia, from north to south (Tabel 1). It grows in opening rainforest or shady forest on limestone hills or steep hillsides at an altitude of 28-720 meters above sea level (Tabel 1).

The corpse flower requires warm temperature, high humidity and bright light with some shades in summer. Plants appreciate a fairly heavy fertilization. The soil should be kept moist at all times, even during dormancy. *Amorphophallus titanum* is difficult to be cultivated because it is prone to rotting. Propagation is apparently possible with leaf and tuber cuttings (Lobin 2007) .

Plant description

The unique plant of *A. titanum* is commonly known as Titan Arum or the giant corpse flower, which is known as the biggest flowers in the world and can produce flowers as high as 3 m (Figure 1). Its name comes from the flower which emit smells like a rotting carcass, which is intended actually to invite beetles (*Diamesus osculans* and *Creophilus villipennis*) and flesh flies to pollinate the flowers (Hetterscheid 1998b; Davis et al. 2008). This plant is a member of the Aroid family (Araceae).

Tabel 1. List collection of *Amorphophallus titanum* (Becc.) Becc. in Bogor Botanic Gardens in 1954-2014

Year	Accession number	Place of origin	Altitude (m asl.)	Material/ Vak	Collector
1954	B1954081	Pematang Siantar, North Sumatra		Seed	Dr. Schrage, Pematang Siantar, Sumatra (Afkomstig V/D Hortus Botanicus Van Singapore)
1954	B1954011	North Sumatra		Tuber	
1955	B1955120060	South Sumatra		Tuber (20)	Kepala Daerah Hutan Palembang, Sumatra, Perantaraan Balai Penyelidikan Kehutanan Bagian Botani Hutan, Bogor
1955	1955065	North Sumatra		Seed	Tn. A. H. Schrage, Hotel "Siantar", Siantar, Sumatra
1956	B1956030001	Padang-Mengatas, West Sumatra		Tuber (1)	Dr. W. Meijer, Botani, Fakultas Pertanian, Payakumbuh - Sumatra
1956	B1560800005 B1560800006 B1560800007 B1560800008	Sumatra		Plant	Botanic Gardens Durban - South Africa
1975	B1975030091	Bengkulu, Sumatra		Plant	Rusdi E. Nasution, Made Sri Prana
1975	B1975030354	Lembah Anai, West Sumatra		Plant	Rusdi E. Nasution, Made Sri Prana M.Sc.
1978	B1978010360	Sijunjung, West Sumatra		Plant	
1979	B1979010091	Riau, Sumatra		Tuber	
1981	B1981040566	Lematang, South Sumatra		Tuber	A. Tri Sunarto, Djamroni
1988	988.XII.30	Sibolangit District, North Sumatra	60 m asl.	Tuber	Soekendar
1990	B19900779	Sumatra			Rusdi Nasution
1990	B199008198 B199008225 B199008226 B199008259	Jarai District, Lahat, South Sumatra	680 m asl.	XI.C.96	Roemantyo, Enday Sudarso, Harun, Didi Supardi
1990	B199008227	Jarai District, Lahat, South Sumatra	720 m asl.		Rehd.061

1990	B199008259 B199008260	Kepahiyang Bengkulu		Seed	Roemantyo, Enday Sudarso, Harun, Didi Supardi
1990	B199008301	Kepahiyang District, Rejang Lebong, Bengkulu, Sumatra	530 m asl.	Tuber	Roemantyo, Enday Sudarso, Harun, Didi Supardi
1991	B199109108 B199109109 B199109244 B19910953 B19910955	Ipuh District, Bengkulu	220-300 m asl.	Tuber	Roemantyo, Samsu Sujahman, Dumyati, Enday Sudarso
1992	B1992110172 B1992110173 B1992110182 B1992110183 B1992110184 B1992110185 B1992110186	Muara Imat, Mt. Raya District, Kerinci, Jambi		Tuber	Roemantyo, Gregori Hambali, Sujati, Sjamsu Sujahman, Didi Supardi, Syarifudin
1992	B1992110575	Muara Kelumbu, Sumatra		Tuber	Holif Imamudin, Toto, Sutrisno
1992	B199211172 B199211173 B199211191 B199211192	Muara Imat, Mt. Raya District, Kerinci, Jambi	400-450 m asl.	VI.C.326 VI.C.327 VI.C.328 VI.C.329	Roemantyo, Gregori Hambali, Sujati, Sjamsu Sujahman, Didi Supardi, Syarifudin
1992	B1992120443	Muara Imat, Mt. Raya District, Kerinci, Jambi		Tuber	Sudjati, Roemantyo, Gregori Hambali, Sjamsu Sujahman, Didi Supardi, Syarifudin
1993	B1993090191	TKA, West Sumatra		Tuber	Roemantyo, Sutrisno, Edi Djunaedi, Harun, Sumarno, Sri Wahyuadi, Suparta
1995	B1995040012 B1995040013 B1995040014 B1995040015	Sangkir District, Solok, West Sumatra		Tuber	Didik Widyatmoko, Sujati, Didi Supardi, Sjamsu Sujahman, Enday Sudarso
1995	B19950414 B19950415	Sangkir District, Solok, West Sumatra	500 m asl.	VI.C.339 VI.C.340	Didik Widyatmoko, Sujati, Didi Supardi, Sjamsu Sujahman, Enday Sudarso.
2004	B200409157	Barumun Nature Reserve, North Sumatra		Tuber	D.M. Puspitaningtyas, Didi Supardi, Syamsuddin
2005	B200510458	Batang Pangean I, West Sumatra		Tuber	D.M. Puspitaningtyas, Tatang Darajat, Sudarsono
2005	B200510628	Malampah Protected Area, Pasaman Barat, West Sumatra		Tuber	Rismita Sari, Ruspandi, Suprih Wijayanti, Ngatari
2006	B20060521 B20060522 B20060526 B20060529	Kepahiang District, Bengkulu, Sumatra	560 m asl.	XI.C.97	Yuzammi, Tri Handayani, Syamsul Hidayat, Maman Suratman
2006	B20060534 B20060535	Kepahiang District, Bengkulu, Sumatra	210 m asl.	XI.C.98	Yuzammi,Tri Handayani, Syamsul Hidayat, Maman Suratman
2007	B200712249	Bukit Bungkuk Nature Reserve, Riau, Sumatra		Tuber	Sri Hartini, Entim Fatimah, Slamet
2009	B20091010 B20091011 B20091012 B20091013 B20091015 B20091015 B20091015 B20091017 B20091018 B20091018 B20091020 B20091021 B20091021 B2009109 B2009109 B2009109 B2009109	Pajar Bulan District, Lahat, South Sumatra	18 m asl.	VI.C.482 VI.C.483 VI.C.484 XXIV.B.83 XI.L.82 XI.C.93 XI.L.77 XI.C.94 XI.L.83 XI.L.78 VI.C.485 XI.L.84 XI.L.79 VI.C.481 XI.L.80 XI.L.81 XI.L.76	Sujati, Wihermanto,Tatang Daradjat, Enday Sudarso
2013	B2013030001 B2013030002	Kepahyang, Bengkulu, Sumatra		Flower, tuber	Sofi Mursidawati

Note: Vak = Terminology for block of plant collections in the Bogor Botanic Gardens

Figure 1. Flesh flies attracted on *spadix* of *A. titanum*

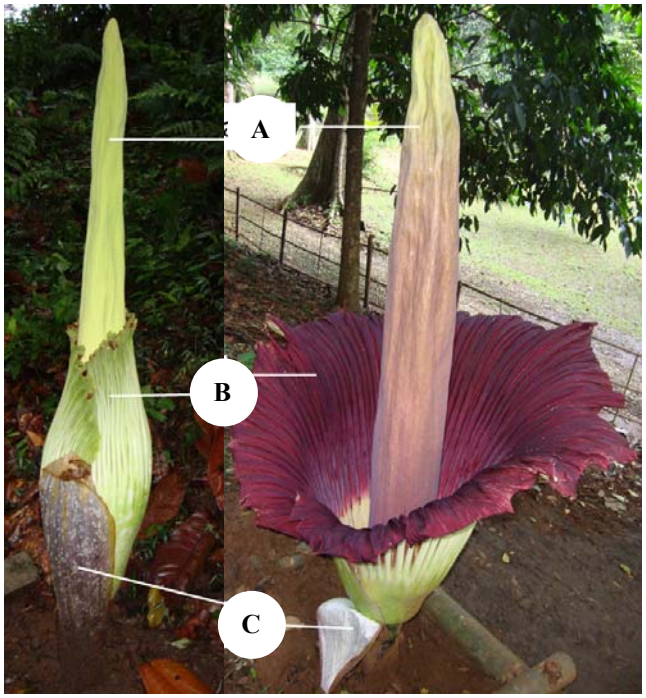

Figure 2. Flower parts of *A. titanum* (A. Spadix; B. Spathe; C. Bract)

Amorphophallus titanum is a perennial herb with the largest collection of flowers (inflorescence) in the world. It has a big underground tuber. The weight of mature tuber of *A. titanum* is between 25 kg up to 100 kg, has a diameter up to 60 cm, the tuber is depreseed globose (Gandawijaja et al. 1983; Roemantyo 1991; Hetterscheid 1998c). This plant has two phases in its life that appeared alternately, the vegetative and generative phases. In the vegetative phase appears a solitary leaf (umbrella-like canopy) on vertical petiole (green with white spots), with the height can reach 4-5 m and the lamina may reach 4-5 m across. Leaves persist for approximately 1-2 years. The plant enters a dormant phase for several months after a leaf senescence before sending up a leaf replacement and growing a new root system. If the food reserves are sufficient in the tuber with a good environmental support, the flower will appear. If the food reserves are less, the leaves will appear again. The smallest inflorescence ever recorded developing on a tuber of only 9 kg weight (Hetterscheid 1998c).

The flowers (Figure 2) are not technically single flowers, but they are actually very large and high inflorescences, consist of a peduncle (flower stalk) up to 70 cm height and pale-yellow spadix (shaped like a phallus) which can reach 3 m in length, surrounded by a purplish-red spathe (a sheath of flowers) which are also in a large size. The spadix emerges above the spathe. The male and female flowers are situated on the lower portion of the spadix where they are covered by a large spathe. The male flowers are found in a band above the female flowers. The central column is bearing many male and female flowers. The inflorescences of Titan Arum bloom at night. The female flowers are the first to become receptive and release a carrion-like odor. The male flowers mature on the following day, as a mechanism for preventing self-pollination. The carrion odor released by the volatilization-mechanism in their heating spadix can attract insects (pollinators) from kilometers away. After fertilization, the female flowers develop into bright red fruits, they are approximately 4 cm long and usually contain 1-2 seeds (Hetterscheid 1998c; Barthlott and Lobin 1998).

The flowers are monoecious and protogini, the female flowers is receptive first and release a carrion-like odor, waves of the carrion-like odour are synchronised with the heat pulses (Barthlott et al. 2009). The spadix produces metabolic heat, which sometimes results in the release of vapor and disperse its carrion odor to attract insect. Barthlott et al. (2009) found that scent molecules of thermogenic Araceae are transported by turbulent updrafts resulted from a thermal convection induced by spadix heating. The putrid smell of the corpse flower is the strongest just after the spathe opens widely, and it gradually increases from late evening until midnight and then tapers off when the morning arrives. The major components detected in the carrion and gaseous odours of *A. titanum* are the sulphur-containing compounds, dimethyldisulphide and dimethyltrisulphide (Kite et al. 1998; Shirasu et al. 2010). However, Fujioka et al. (2012) mentioned that the flower smell of *A. titanum* to be closed to a mixture of methyl mercaptan and propionic acid, the smell resembles “decayed cabbage, garlic and pungent sour”. Kite and Hetterscheid (1997) found that the main chemical components of the smell of *A. titanum* are dimethyl oligosulphides.

Ex situ conservation

Amorphophallus titanum is a rare flowering plant in the wild and more rarely when cultivated. After it was first

flowering on cultivation at Royal Botanic Gardens in Kew, London in 1889, spadix grew up to a height of 2.06 m and spathe was 1.22 m in diameter (Gandawijaja et al. 1983). Then followed by 's Lands Plantentuin te Buitenzorg (now Bogor Botanic Gardens-Indonesia), it was flowering in 1894. The first documented flowerings in Botanic Gardens of Wageningen, Netherlands in 1932, spadix grew up to a height of 2.67 m and spathe was 1.5 m in diameter.

In 2003, the highest rate of captivity record was held by Bonn Botanical Garden-Germany in which *A. titanum* produced flowers as high as 2.74 m (Lobin 2007). Furthermore, on June 21st, 2013 the flowers of *A. titanum* could reach a height of 2.90 m. In Wilhelma Zoologisch-Botanischer Gartens Stuttgart, Germany the flowers bloomed with a height of 2.91 m on October 20th, 2005. In addition, on June 18th, 2010, when it was on a display at Winnipesaukee Orchids in Gilford, New Hampshire, USA, the flowers bloomed with a height of 3.1 m. The flowers bloomed for few days or less then a week. However, Cibodas Botanic Gardens-Indonesia claimed that in the gardens, the flowers of *A. titanum* could bloom reach a height of 3.17 m on March 11th, 2004. Just recently, it bloomed again on March 7th, 2016 and it was taller than before with a height of 3.735 m. This was the forth flower of the same plant.

Ex situ conservation in Bogor Botanic Gardens

Based on data of 1997 List of Threathened Plants (WCMC 1998), the conservation status of Titan Arum is classified as Vulnerable (V). It means that this species must be conserved both in situ and ex situ conservation.

Bogor Botanic Gardens has been growing this plant for ex situ conservation since 1915. In Bogor Botanic Gardens, this flower bloomed many times. On March 14th, 1994, it bloomed spectacularly and gave the attention to a million local visitors that came to the garden to see the flower. After that, the flower bloomed many times from different specimens.

Based on the data explained above, one of specimens from Jambi, Sumatra bloomed in three consecutive years, in 1994, 1997 and 2001. This is unusual since the most of Titan Arums do not survive by the stress of flowering in cultivation and will die soon after their first flowering. This also happened in The University of Bonn Botanic Gardens (Lobin 2007).

A self-pollination is normally considered impossible, because the pollens only ripe when the phase of flowering on female flower has finished. However, in 1999, Huntington Botanical Garden (California) botanists conducted a hand-pollination with own pollens from mature male flowers. The procedure was successful, resulting in fruit and ten fertile seeds from several seedlings eventually produced. Additionally, Titan Arum at Gustavus Adolphus College (Minnesota, USA) was unexpectedly produce viable seeds through a self-pollination in 2011.

In Bogor Botanic Gardens, the cultivation techniques have also been studied for a long time and intensively since 2011. A hand-pollination (Figure 3) was successful and the fruit (*infructescence*) had been produced by using stored pollens, but it was not as good as one from the wild due to fungi attack (Latifah et al. 2014). A hand-pollination was conducted on *A. titanum* collections. The pollens collected from Titan Arum in Vak VI.C.485 of Bogor Botanic Gardens, which bloomed previously on the November 29th, 2011 were stored in temperature of 0°C. Then, the collection of VI.C.484 which bloomed on February 2nd, 2012 was hand-pollinated with the stored pollens. Those two plants were collected from the same place, Lahat-South Sumatra. The flower was successful pollinated and indicated that by the infructescence development since March 7th, then 4-5 months later on July 27th, 2012 the fruits were harvested (Latifah et al. 2014). A self-pollination had also ever tried in Bogor Botanic Gardens, but it has not been successful yet.

Micropropagation of lateral shoot from tuber has successfully been done to regenerate plants in Bogor Botanic Gardens (Irawati 2011). On the other hand, the propagation by leaf cutting and seed germination on *A. titanum* was also conducted in Bogor Botanic Gardens (Latifah et al. 2001; Purwantoro and Latifah 2013; Prana 2001; Roemantyo 1991), and also the vegetative growth of *A. titanum* in Cibodas Botanic Gardens as an action of ex situ conservation (Sholihin and Purwantoro 2005). Tuber size gave an effect on the plant growth, in which the smallest tuber will produce the longest growth. Fruits will be ripe on 7-8 months after pollination. The seeds must be sown as soon as possible after harvesting. They must not be stored because they dry out very quickly (Lobin et al. 2007). Within 3 months, the tuber tissues develop at the proximal end of the cuttings part (Lobin et al. 2007).

Problems and challenges

The number of cultivated plants has increased recently, and it is not uncommon for them to be five or more flowering events in the gardens around the world in a single year. Titan Arum is more commonly available for the advanced gardener due to the pollination techniques.

The cultivation techniques of *A. titanum* are essential to be studied further due to the potentials of tubers as functional foods. The tubers of this plant contain glucomannan about 20.19% (Ananto 2000). The nutrient content of this tuber is still also on going research. The challenge in the future is how to omit the ichy effect of crystal oxalate. This study is still on going, so the potentials of tuber can be consumed safely as functional foods.

Besides their cultivation techniques, the pollination techniques are also to be a challenge in ex situ conservation of this species. A self-pollination is almost not possible, but sometimes it was successful. The pollen of another plant is usually used for an artificial pollination. Pollens must be stored because they will have two flowering plants at the same time (Lobin et al. 2007).

From this study, it can be concluded that *A. titanum* (Titan Arum) can be regarded as a flagship species for botanic gardens. The wild populations suffer from an increasing pressure on their natural habitat, but botanic gardens can play an important role in ex situ conservation of this species. The cultivation of *A. titanum* is not easy, but it offers a challenge for any keen horticulturist.

Tabel 2. Blooming records of *Amorphophallus titanum* in Bogor Botanic Gardens cultivation

Blooming time	Location	Notes
1894	's Lands Plantentuin te Buitenzorg, Kebun Raya Bogor, Java, Indonesia	Titan Arum became the symbol of the Bogor Botanic Gardens
1924	's Lands Plantentuin te Buitenzorg, Kebun Raya Bogor, Java, Indonesia	
1934	's Lands Plantentuin te Buitenzorg, Kebun Raya Bogor, Java, Indonesia	
March 14th, 1994	Vak XI.L.51 of Bogor Botanic Gardens	It was planted on November 9th, 1992 from Jambi, Sumatra. Same corm also bloomed in 1994, 1997 and 2001.
February 15th, 1995	VakK VI. C 326 of Bogor Botanic Gardens	It was planted on November 9th, 1992 from Jambi, Sumatra. The corm weight was 26 kg. The generative phase started on December 26th, 1994 and the full bloom of the flower occurred on February 15th, 1995. Spadix grew to a height of 1.45 m and the spathe was 63 cm in diameter.
1997	Vak XI.L.51 of Bogor Botanic Gardens	It was planted on November 9th, 1992 from Jambi, Sumatra. Same corm also bloomed in 1994, 1997 and 2001.
2001	Vak XI.L.51 of Bogor Botanic Gardens	It was planted on November 9th, 1992 from Jambi, Sumatra. Same corm also bloomed in 1994, 1997 and 2001.
2005	Bogor Botanic Gardens	It was planted on November 9th, 1992 from Jambi, Sumatra.
2008	Bogor Botanic Gardens	It was planted on November 9th, 1992 from Jambi, Sumatra.
Januari 8th, 2010	Vak VI.C.483 of Bogor Botanic Gardens	It was planted on November 2th, 2009 from Lahat, South Sumatra.
December 1th, 2011	Vak VI.C.485 of Bogor Botanic Gardens	It was planted on November 2th, 2009 from Lahat, South Sumatra.
Februari 2th, 2012	Vak VI.C.484 of Bogor Botanic Gardens	It was planted in 2009 from Lahat, South Sumatra.
July 6th, 2012	Vak VI.C.328 of Bogor Botanic Gardens	It was planted on November 9th, 1992 from Jambi, Sumatra

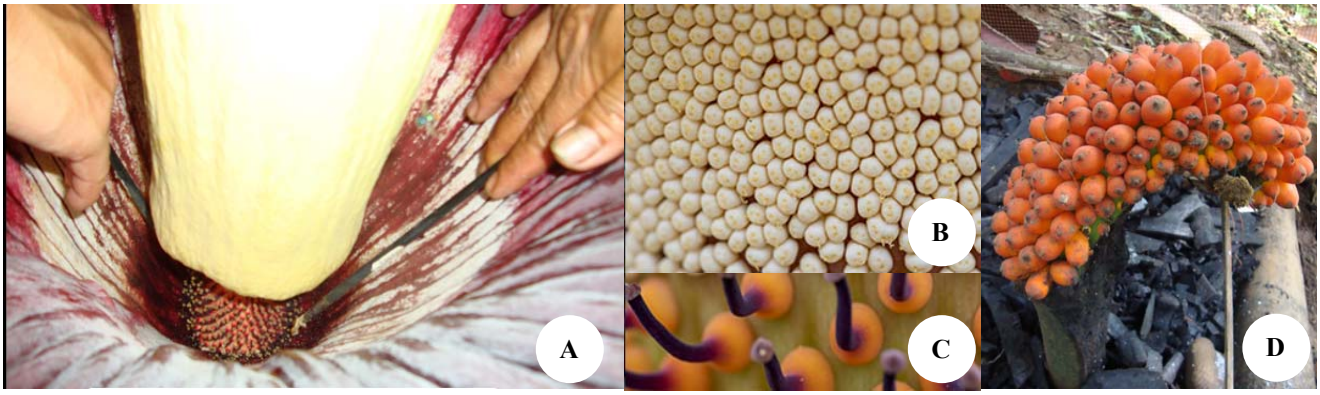

Figure 3. A. Hand-pollination, B. Male flowers, C. Female flowers, and D. Fruit set of *Amorphophallus titanum*

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