

HOW TO PREDICT THE BLOOMING OF THE GIANT CORPSE INFLORESCENCE *Amorphophallus titanum* (Becc.) Becc. ex Arcang [Prediksi Mekarnya Bunga Bangkai Raksasa *Amorphophallus titanum* (Becc.) Becc. ex Arcang]

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ABSTRAK

Bunga bangkai raksasa *Amorphophallus titanum*(Becc.) Becc. ex Arcang merupakan tanaman asli Indonesia. Jenis ini merupakan salah satu *flagship* di Pusat Konservasi Tumbuhan Kebun Raya – LIPI dalam rangka membangkitkan kesadaran masyarakat untuk menyelamatkan tumbuhan dari kepunahan serta menyayangi lingkungan hidup. Mekarnya bunga bangkai selalu menarik banyak pengunjung untuk datang ke Kebun Raya Bogor. Oleh karena itu, salah satu fokus dari penelitian ini adalah prediksisaat mekarnya agar dapat memberikan informasi kepada public lebih awal sebelum bunga mekar. Hasil dari studi ini dapat digunakan sebagai dasar untuk memprediksi waktu mekar semurnya bunga ini. Para peneliti bunga bangkai di dunia telah mencoba memprediksi waktu mekarnya berdasarkan: pertama, pembeda diagnostik baik pada tunas bunga maupun tunas daun; dan kedua, pola pertumbuhan tunas bunga yang hanya menggunakan satu sampel tanaman saja; sedangkan hasil kami menunjukkan informasi pendukung bagi temuan-temuan sebelumnya. Pada penelitian ini, prediksi didasarkan pada pengamatan 5 sampel tanaman pada tahun 2011-2012 di Kebun Raya Bogor. Hasil yang diperoleh yaitu: pembeda diagnostik di antara tunas bunga dan tunas daun tidak hanya berdasarkan bentuk tunas awal saja tetapi juga berdasarkan kecepatan pertumbuhannya, dan hasil penelitian ini menunjukkan kesesuaian dengan penemuan Lobin dengan menyertakan model regresi pertumbuhan tunas bunga.

Katakunci: *Amorphophallus titanum*, Bunga Bangkai, Prediksi, Titan Arum.

ABSTRACT

The giant corpse inflorescence (*Amorphophallus titanum*) is native to Indonesia. It is one of the *flagships* of The Center for Plant Conservation Bogor Botanic Gardens, Indonesian Institute of Sciences (LIPI) to raise *public awareness* for saving plants from extinction and caring the living environment. The blooming of the giant inflorescence attracts many visitors. Therefore, one of the research focuses of *Amorphophallus titanum* is how to predict the blooming-time in order to inform visitors earlier. The results of this study can be used as the basic information to predict the blooming of the inflorescences. Previous researchers had tried to predict the blooming based on firstly, the differential diagnostics of an inflorescence bud and leaf bud, and secondly, the growth pattern of the flowering bud from one individual sample only; whereas, our results suggested new findings. In this research, the prediction was examined from 2011-2012 on five individual samples planted in Bogor Botanic Gardens. We suggested that (1) the differential diagnostics of an inflorescence bud and leaf bud were not only based on the early bud shapes but also the growth rate, and (2) our results supported Lobin's findings by providing a statistical formula for growth pattern of the flowering bud.

Key words: *Amorphophallustitanum*, Blooming, CorpseFlower, Prediction, TitanArum.

INTRODUCTION

The giant corpse inflorescence (*Amorphophallu stitanum* (Becc.) Becc. ex Arcang) is endemic to Sumatera Island, Indonesia. Although in the wild this species only occurred in Indonesia, it has been cultivated worldwide in the glasshouses. Therefore, *A. titanum* has become icons or flagships in several botanic gardens in the world such as United States Botanic Garden, The Huntington Botanical Gardens and Missouri Botanical Garden in USA; Koishikawa Botanical Garden in Japan; Royal Botanic Gardens and Domain Trust Sydney in Australia; Edinburgh Botanic Gardens and The Royal Botanic Gardens Kew in UK; and University of Bonn Botanic Gardens in UE. The blooming of this species has always attracted a large amount of visitors. However, there is lack of information in the method

of how to predict the blooming of this giant inflorescence so the visitors will miss out the magnificent blooming event. In the prediction, Lobin *et al.* (2007) suggested three practical considerations. Firstly, a flower bud and leaf bud should be differentiated. The leaf bud is arrow shaped; round in diameter and the cataphyll tip is perfectly in the center of the bud. The inflorescence bud is bell-shaped/'pregnant'-like, irregularly rounded and the cataphyll tip is lateral. Secondly, the growth pattern of the flowering bud was used to predict the blooming. The daily growth pattern was slowly in the beginning, and then it turns to a rapid growing stage and in the final days before opening the growth rate slowed down. Thirdly, the prediction was based on the number of days in the flowering period from bud tho the full bloom stage. Licht (2013) as well as Henry and Huntington (2013)

have also tried to predict the blooming time by tracking daily growth and published the data online for public to attract more visitors when it blooms. This study aimed to investigate more thoroughly how to predict the blooming of the giant corpse inflorescence *A. titanum*.

MATERIALS AND METHODS

Plant Materials

The plant samples examined in this research were five living collections of Bogor Botanic Gardens cultivated in the garden; three individuals were used for a complete life cycle and three individuals were used for a leaf stage (Table 1). The period of inflorescence was determined from bud to the full blooming of the spathe; meanwhile that of leaf was recorded from bud to the first full opening of the umbrella-like compound leaf.

METHODS

Examination on the Differential Diagnostics of an Inflorescence Bud and Leaf Bud

The differential diagnostics of a flower bud and leaf bud were examined through analysing a series of photographs of three samples of leaf buds from three individuals: 992.XI.191/270, B2009109/TD1122 and B20091020/TD1133; and three individuals at the inflorescence stage: 992.XI.191/270, B20091011/TD1124, and B20091012/TD1125 (Table 1). The early stage of prediction is the determination

of the differences in appearance of several organs below as the parameters used to compare the differences between leaf and inflorescence buds:

- (1) the bud appearance (shape, colour and growth rate);
- (2) the cataphylls appearance (the length and the width of the opening of the cataphylls before the appearance of the petiole and leaflets at the leaf stage as well as the evidence of the spathe and spadix at the inflorescence stage; any breakage the cataphylls were also recorded);
- (3) the early rooting of the bud.

Examination on the Growth Pattern as the Main Predictors of the Inflorescence Opening Time

The growth of the leaf buds was also measured daily from bud to the opening of the leaf by examining one variable: the height of the leaf bud/leaf (measured from above ground to the highest tip of the cataphyll/leaf from a bud stage to opening-leaf stage). The leaf individuals measured were: 992.XI.191/270, B2009109/TD1122 and B20091020/TD1133. The growth pattern as the main predictors of the inflorescence opening time was examined from the inflorescence stages of three individual plants: 992.XI.191/270, B20091011/TD1124 and B20091012/TD1125. The daily growth of the flower buds was measured from bud to the full opening of the inflorescence by examining one variable: the height of the inflorescence bud at early stage

Table 1. List of *A. titanum* collections studied which are grown in Bogor Botanic Gardens

No.	Registration/ Accession No.	Location ¹	Life Stage Observed	Period
1.	992.XI.191/270	VI.C.328	Inflorescence Leaf	May 6 th - July 8 th 2012 (64 days) September 21 th - December 20 th 2012 (91 days)
2.	B2009109/TD1122	VI.C.481	Leaf	February 12 th - May 14 th 2012 (93 days)
3.	B20091011/TD1124	VI.C.483	Inflorescence	October 1 st - November 26 th 2012 (56 days)
4.	B20091012/TD1125	VI.C.484	Inflorescence	December 13 th 2011 - February 2 nd 2012 (53 days)
5.	B20091020/TD1133	VI.C.485	Leaf Inflorescence	March 20 th - June 7 th 2012 (80 days) November 15 th (start measuring from 65 cm tall bud) - 29 th 2011 (15 days)

¹The samples were simply named after the location in the garden

(measured from above ground to the highest tip of the cataphylls) to full blooming stage. Regression analyses were used to estimate the growth pattern of the flower at the 95% confidence level or $p < 0.05$ (Miles and Shelvin, 2001; Steel and Torrie, 1980). Regression analyses were applied to 53 day-leaf and 76 day-inflorescence data based on the measurements at the same stages.

Investigation on the Other Variables as the Additional Predictors

Several other variables were also observed (Figure 1):

(1) spathe:

- a. the longest circumference of the spathe (the fattest part); measured on the mid part of the spathe between limb and lower spathe;
- b. changes in coloration and formation of spathe as well as along the curly edge of limb and seam,

(2) cataphylls:

- a. the length and the width of the opening of the cataphylls at the inflorescence stage were measured;

- b. any falling of the cataphylls were recorded;

(3) spadix:

- a. length was measured from spadix base to the spadix tip;
- b. circumference of the biggest part;
- c. coloration;
- d. development of spadix form;
- e. any secretion of spadix was observed;

- (4) carcass smell: the carcass smell was measured qualitatively;

- (5) heating up of the inflorescence: any signs of heating up of the inflorescence;

- (6) limb and seam: any signs of movement of opening along the curly edge of limb and seam;

- (8) insects: the presence of insects were recorded.

Determination of canopy openness

Canopy openness at the planting site/ location was measured during the flowering period using hemispherical photographs/hemiphots with wide-angled/fish-eye lens (Turton, 1992 and ter Steege, 1996). In the current research, the fish-eye-lens

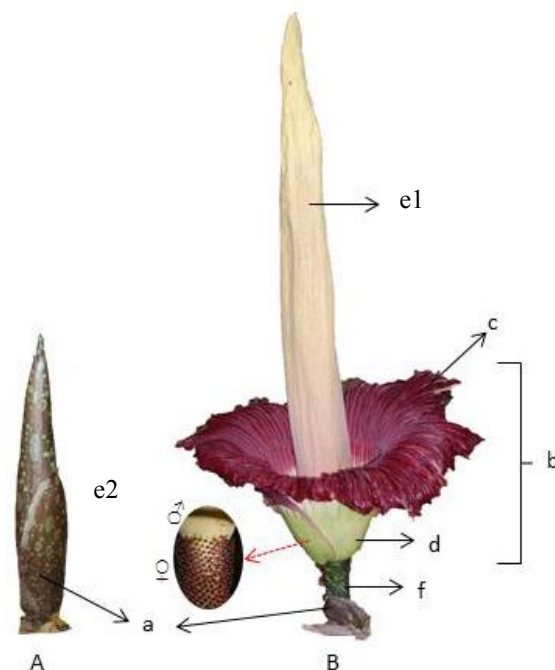


Figure 1. Inflorescence bud (A) and blooming flower (B) parts: cataphylls (a), spathe (b), limb (c), lower spathe (d), sterile spadix appendage (e1); inset: male and female flowers are located at lower part of spadix (e2), and peduncle (f) (Gandawijaja *et al.*, 1983; Graham and Hadiah, 2004; Lobin *et al.*, 2007; Li, 2013)

specifications are 180 degree-wide angled, brand: Bower, 0.42x AF, 52-46 mm, without a lense converter, fitted to a Nikon D40 Digital Camera. In the field, the camera was mounted on a bubble-levelled tripod to stabilize the camera horizontally. The height of the tripod was maintained between 75-100 cm (ter Steege, 1996) depending on the varying topographical conditions of the plots. The camera (top of image) was directed to the north for analysis with Winphot 5.0.

RESULT

The Differential Diagnostics of an Inflorescence Bud and Leaf Bud

The differential diagnostics of an inflorescence bud and leaf bud were presented in Table 2 and Figure 2. At early stage (0.5-10 cm height), the bud can be easily differentiated whether the bud will be developing as a leaf (an arrow-like) or an inflorescence (irregularly or regularly rounded).

The growth patterns of the inflorescence and leaf to predict the opening time of the full bloom and to differentiate the leaf/inflorescence bud

The time of full bloom was predicted when the growth pattern of the inflorescence demonstrated exponential pattern (Figure 3) followed by 2-3 days of without any significant growth about 0-3 cm (Figure 4).

The results (Figure 3 and 4) are to be used for blooming prediction as well as for differential diagnostics of a flower bud or leaf bud which were not only based on the early bud shapes and cataphyll

stiffness (previously explained in Table 2). Theregression formulas of leaf and inflorescence growth rates (shown in Figure 3) suggest that the growth level of flowering buds was higher (beta 1=0.074) than that of leaf buds (beta 1=0.058).

The other variables as the additional predictors

The accuracy of the prediction on ±3 day-deviation was also based on the additional variables encountered when the growth rate of the enclosed inflorescence (Fig. 4) as well as the circumference of the enclosed spathe (Table 3: No. 4) which was slowed down before opening. Closer to the blooming time the smell of carrion becomes stronger (Table 3: No. 1). When it bloomed on 18th June 2001 in Bogor Botanic Gardens] or a secretion with ‘sweating-like’ outer epidermis of appendix (Table 3: No. 7). At this stage, the spadix appendage was frequently wilted (Table 3: No. 8). The increasing visit of the number of insects which were attracted by the carrion smell was also the sign of nearly blooming (Table 3: 2). One by one of the cataphylls (5±1 cataphylls in total) senesced; however, the fall of the last cataphyll can not be only one indicating the full blooming (requiring other indicators; Table 3: No.3).

The intensity of red to purple blotches observed on the inner upper surface of enclosed spathe was increased a few days before opening (Table 3: No. 5). While the spathe enclosed, the change of appendix colours can be attractive starting from yellow green to lighter yellow green, greyed red or purple as the primary colours of the appendix near full bloom time (Table 3: No. 6). The appearance of

Table 2. The differential diagnostics to differentiate between inflorescence or leaf of tuber bud appearances

No.	Differential Diagnostics	Inflorescence Bud	Leaf Bud
1.	Bud appearance at early stage: 0.5-10 cm height	Fat-belly shaped; regular or irregularly rounded. Rooting later with less roots at the base of the bud	Pyramid-like shaped; rounded at the base but depressed in the mid part. Rooting rapidly with massive roots at the base of the bud
2.	Cataphyll stiffness at more than 10 cm- height bud (with more than 3 cataphylls)	Cataphylls thicker and more stiff.	Cataphylls thinner, less stiff and easily broken.

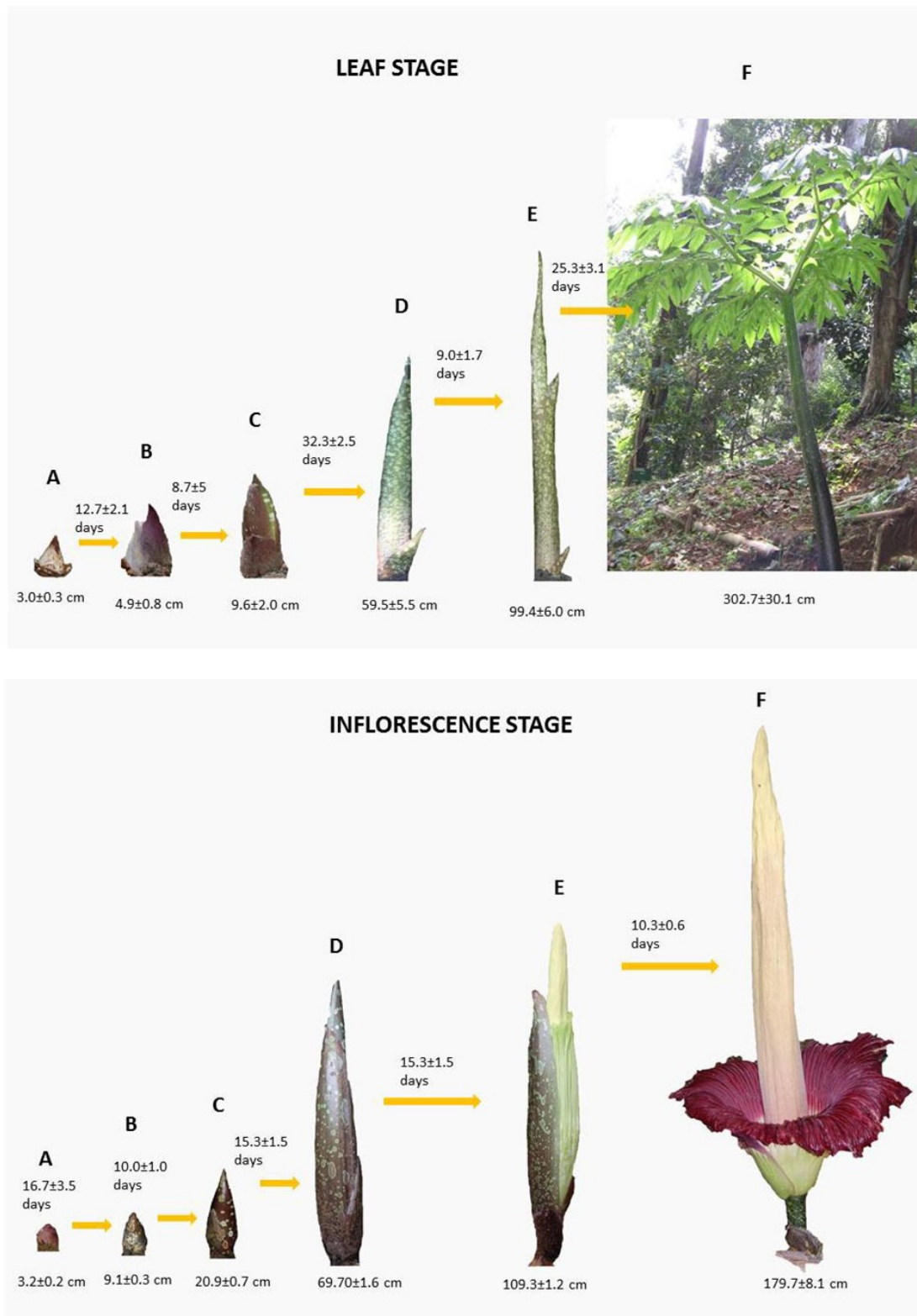


Figure 2. The differential diagnostics of leaf (vegetative) and inflorescence (generative) phases

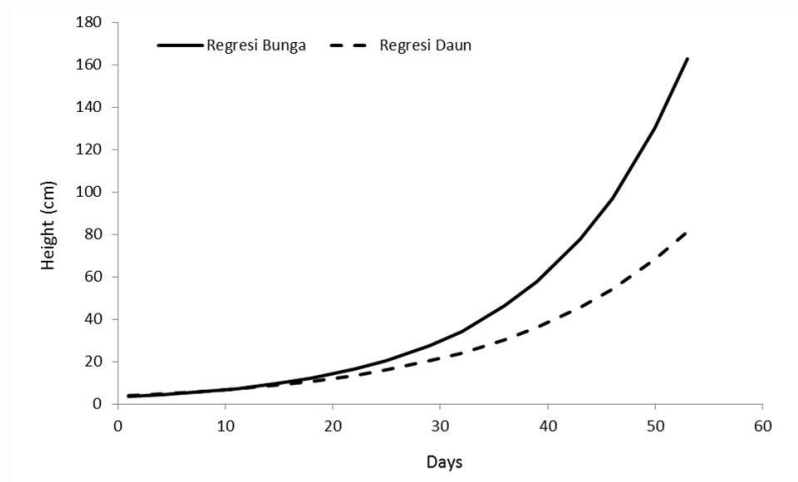


Figure 3. Exponential growth patterns of leaf and inflorescence phases before the growth rate is slowed down indicating the full blooming time of the inflorescence.

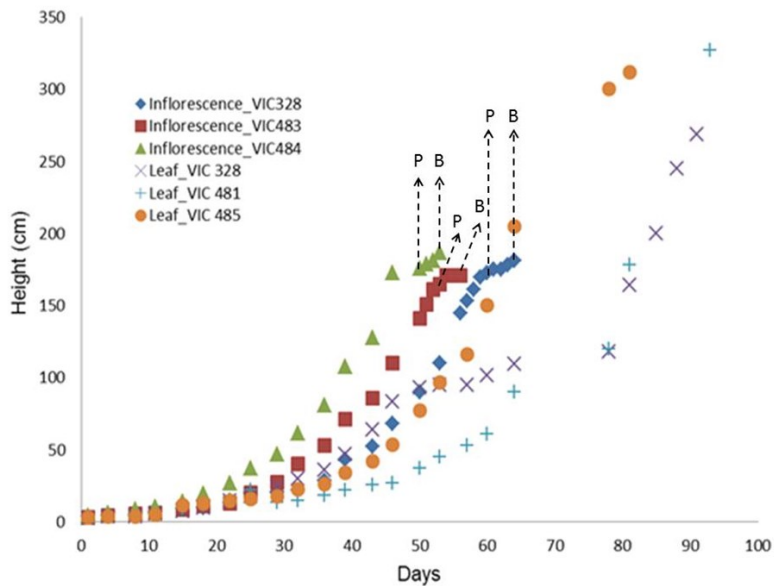


Figure 4. Comparative growth patterns of leaf and inflorescence phases; scatter plots were used due to different period of measurements; P = start to predict the blooming time;(B) after the exponential growth pattern of the inflorescence (referred to fig. 3) ended and the growth rate is slowed down; based on these inflorescence samples the blooming time was 3-4 days after P.

‘purple’ colour as a primary or gradual colour appeared to be an indicator of the closer bloom time rather than the effect of light expose (Table 4). Sometimes a sign of movement of opening along the curly edge of limb and seam was observed (Table 3:No. 8). In addition, the blooming time can be in the morning (Table 4) suggesting that the blooming time did not always occur at night as suggested by previous researchers. As a tropical rainforest species, this

plant prefers rainy season to bloom; it blooms rarely in dry season (Fig. 5).

DISCUSSION

The Differential Diagnostics of an Inflorescence Bud and Leaf Bud

The bud can be easily differentiated at early stage (0.5-10 cm height). Lobinet *al.* (2007) suggested the use of the shape of bud at the early stage as

Table 3. The predictive diagnostics of the inflorescence-full opening about 3 days prior to bloom

No.	Predictive Diagnostics	Observation results from the three samples of inflorescences
1.	Carrion/Carcass smell	The smell begun to come and stronger approaching the full blooming (2.7±0.6 days).
2.	Insects, i.e. bees, flies.	The insects started coming in small numbers firstly (5.0±1.7 days) then increase in number when the inflorescence is close to open (2±1 days).
3.	The senescence of the last cataphylls	The fall of the last cataphylls (the fourth, fifth or sixth of total 5±1 cataphylls) can not be a single indicator, often the last cataphyll still attached until the inflorescence opened, as any breakage or falling of the cataphylls was recorded. Clearly, the senescence and the changing shape or movement may be an indication which were observed by the measurement of the length, the width or the opening of the last cataphylls: the last cataphyll reached 83.0±13.9 cm long, 30.8±2.5 cm wide and the opening (the distance of opening between the tip of the cataphyll and the lower spathe) 4.8±0.4 cm at 8.7±days before the time of full blooming. At 6 days before the bloom or approaching the bloom as predicted, the last cataphyll was 70.0±2.8 cm long, 23.3±2.5 wide and open (as being senesced) down to 2.3±1.1 cm; the last cataphylls did not fall off and turned greyed black 199A with greyed black NN155B blotches, greyed purple N187A to N187B with yellow green 149C blotches, or brown 200B with brown 141C blotches.
4.	The circumference of the spathe by the time the spathe developed; measured on the mid part of the spathe between limb and lower spathe.	Within 5.3±1.2 days before full opening, the growth rate 3.3±1.2 cm/day was recorded; the circumference of the largest closed spathe on the day of blooming was up to 97.0±7.9 cm.
5.	Changes in coloration of inner spathe.	The coloration of the inner part of spathe can be noticed. From sparse, few small blotches (red purple 59C, purple N77 or greyed purple 183C, from less than 5% to 27.8±11.0% since 6.0±0.8 days before full bloom) on the lid of the curly limb to be a dense blotches (red purple 59C, purple N77A or purple N77A, 79.6±18.3% since 3.3±0.6 to 1.5±0.4 days before full opening) spreading at a whole area of inner spathe.
6.	Colour alteration of appendix	Three types of colour pattern of appendix (Table 4) can be identified: (1) combination between yellow green and purple, (2) yellow green as primary colour, and (3) dominant purple. The first sample (VI.C.328) showed yellow green initially then turned purple in the mid period but back to the first colour near blooming; VI.C.483 revealed initially yellow green then turns to lighter green; VI.C.484 expressed dominantly purple.
7.	Any signs of heating up of the appendix	Appendixes of two samples (VI.C.328 and 484) secreted which were indicated by ‘sweating-like’ appendix surfaces on 1 day before full bloom.
8.	A sign of movement of opening along the curly edge of limb and seam and wilting appendices.	One sample (VI.C.328) revealed a slight movement/alteration of opening along the curly edge of limb and seam with opening width 3 cm; and VI.C.483 showed slightly-wrinkled appendix (in some parts) on 1 day before opening. The wilting appendices near blooming time were evident in all samples.







practical considerations to determine whether it is a leaf or inflorescence bud. We observed that the shape is irregularly or regularly rounded in the inflorescence bud and the position of the cataphyll tip is not the main differential diagnostic. We added more differential diagnostics at the early bud from the rooting. The leaf bud rooted earlier and the roots were more abundant than that of inflorescence bud. Moreover, the cataphylls of leaf bud were thinner and easily broken compared to that of the inflo-

rescence bud.

The growth patterns of the inflorescence and leaf to predict the opening time of the full bloom and to differentiate the leaf/inflorescence bud

The growth pattern of the inflorescence may also be useful to predict the time of full bloom. Lobin *et al.* (2007) also found that the daily growth pattern was slowly in the beginning and then it turns to a rapid growing stage and in the final days before opening the growth rate slowed down.

Table 4. Colour alteration in appendix as one of the predictive diagnostics of the inflorescence-full opening from 9 to 1 day prior to bloom, blooming time and the canopy openness of their location in the Garden

Samples	Appendix tip	Primary colour of the whole appendix	Appendix tip	Primary colour of the whole appendix	Appendix tip	Primary colour of the whole appendix	Appendix tip	Primary colour of the whole appendix
	9.7±0.6 days		6.3±0.6 days		4.0±0 days		1.7±0.6 days prior to bloom	
VI.C.32 8	yellow green 149B	yellow green 149B	greyed purple N187C	purple N77C	greyed green 193B tinged with greyed purple N187C	greyed purple N187C	yellow green 149B tinged with purple N77C at the lower appendix	yellow green 149B tinged with purple N77C at the lower appendix 
	Blooming time							16.50-20.57 pm
	Canopy openness (% relative to full sunlight): more open/medium light							19.10
VI.C.48 3	yellow green 149B	yellow green 149B	yellow green 149B	yellow green 149B	yellow green 149B	yellow green 149B tinged with yellow green 149D (lower appendix near the curly limb tip)	yellow green 145D	yellow green 145D 
	Blooming time							09.00 am – 13.00 pm
	Canopy openness (% relative to full sunlight): less open/medium light							10.19
VI.C.48 4	yellow green 149B tinged with purple N77C	yellow green 149B	yellow green 144B tinged with purple N77C	yellow green 144B tinged with purple N77C	purple N77C tinged with yellow green 144B	 purple N77C	purple N77C tinged with yellow green 144B	purple N77C tinged with yellow green 144B 
	Blooming time							14.30-19.56 pm
	Canopy openness (% relative to full sunlight): less open/medium light							10.34
VI.C.48 5	yellow green 149B	yellow green 149B	yellow green 145C	greyed purple 187 B tinged with yellow green 145C 	yellow white 158C	yellow white 158C tinged with greyed orange 166A	green white 157D	greyed red 182C tinged with purple N187C 
	Blooming time							16.00-20.55 pm
	Canopy openness (% relative to full sunlight): more open/medium light							19.10

¹ the colours were determined based on the colour charts of RHS (2007)

² the prediction can not be relied on the the changes in the coloration of the appendix of *Amorphophallus titanum* as many Araceae reveal many variation in their appendix colour.

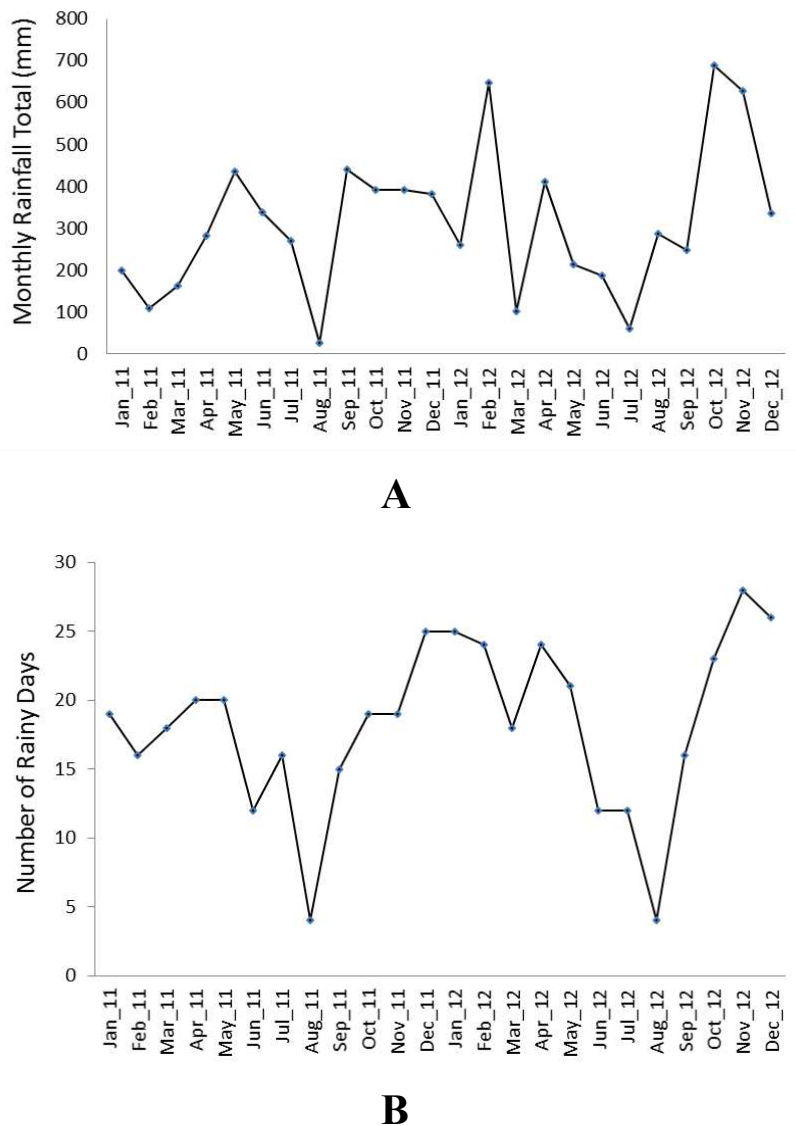


Figure 5. A. Monthly rainfall, B. Number of rainy days from January to December 2011 at Bogor Botanic Gardens (Source: Bogor Botanic Gardens Weather Station); underneath the graphs are overlaying with eblooming period of the four study species referred to Table 1.

The other variables as the additional predictors

The additional variables can be encountered when predicting the inflorescence opening. The unpleasant odor closer to blooming time was detected as Aminoaldehydes (β -indolepropionic) with “carrier” aliphatic aldehydes: acrolein, crotonaldehyde, etc. which was produced by the male flowers at the base of the spadix or the sterile spadix appendage, on which it remained unclear which of these two is the source of the odor (Vogel, 1990; Rahaju *et al.*, 2009).

This heat and odor production occurred during female stage (first day of anthesis) and was following the heat production over 36-40 °C (Vogel, 1990; Barthlott *et al.*, 2008). The generation of heat by the appendage was evident as fume/vapour production (Barthlott *et al.* 2008), as well as in one of Bogor Botanic Gardens’ collection number 992.XII.443/325 located in X.II.51. When it bloomed, the spadix appendage was frequently wilted (Vogel, 1990). At this stage, the pollinator insects

attracted were flies and dung or carrion insects such as *Diamesus osculans* Vigors (Coleoptera: Silphidae) and *Creophilus villipennis* Kraatz (Coleoptera: Staphylinidae) (Kite *et al.* 1998; Mogeia *et al.*, 2001).

Changes in reflective colours of the inner spathe were also the additional signs of blooming soon. Although the inflorescence had not bloomed yet, the reflective colours were evident and quite visible through the outer parts as the spathe is thin and enough transparent. This colour changes reflected the metabolism activity of the sterile appendage of the spadix as an osmophore (Vogel, 1990).

CONCLUSION

The differential diagnostics of a flower bud and leaf bud were not only based on the early bud shapes but also the growth rate. Our results supported Lobin's findings on the growth rate of the flowering buds with a statistical formula for the growth pattern following exponential growth model. The full blooming time can be predicted by applying the regression model in which the prediction started from the end of the exponential growth pattern of the inflorescence and considering the additional predictors such as the increase of carrion smell indicating the metabolic activity of spadix (detected by the heat production, colour alteration and wilting spadix appendage) and intensifying of inner enclosed spathe colour. However these results were required the comparative studies on the blooming time elapse and the predictive diagnostics of the inflorescence-full opening of *A. titanum* in their natural habitat.

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