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Vegetative and Reproductive Growth Behaviour of *Xanthostemon chrysanthus* (F. Muell.) Benth. – An Ornamental Tree in Malaysia

(Kelakuan Pertumbuhan Vegetatif dan Reproduktif *Xanthostemon chrysanthus* (F. Muell.) Benth. – Pokok Hiasan di Malaysia)

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ABSTRACT

A study was conducted to investigate the duration of growth stages and flowering behaviour of a landscape tree, Xanthostemon chrysanthus *(F. Muell.) Benth. This species is known as golden penda and locally known as jambu kuning. It is widely planted for urban beautification due to its distinctive coloured flowers. Under local climate condition, this species flowers throughout the year. However, the flowering of this species has not been studied extensively. In the present study, the growth of selected trees aged approximately six years after planting was monitored for a year. The growth duration was determined using the extended Biologishe Bundesanstalt, Bundessortenamt and Chemical Industry (BBCH) scale. Percentages of flower and fruit and new leaf abundances were expressed as estimated percentage of each stage as compared to total surface area of the tree crown. The vegetative and reproductive stages of the species required 198 and 176 days, respectively. The flowering period took about 40 days from inflorescence bud swelling to drying and senescence of stamens and petals. Unsynchronized flowering was observed among the trees. The occurrence of flowers was also influenced by the development of new leaves or fruits. The information on the duration of each growth stage and the flowering behaviour of the species may enhance a more detailed study related to flowering of urban trees in Malaysia.*

Keywords: Flowering behaviour; growth stages; ornamental tree; urban landscape; Xanthostemon chrysanthus

ABSTRAK

Satu kajian telah dijalankan untuk mengenal pasti jangka masa peringkat pertumbuhan dan kelakuan pembungaan pokok landskap, Xanthostemon chrysanthus *(F. Muell.) Benth. Pokok ini juga dipanggil sebagai 'golden penda' dan dikenali masyarakat tempatan sebagai jambu kuning. Ia banyak ditanam untuk mengindahkan kawasan bandar kerana warna bunganya yang cantik. Di bawah keadaan iklim tempatan, pokok ini berbunga sepanjang tahun. Walau bagaimanapun, pembungaannya tidak pernah dikaji secara terperinci. Dalam kajian ini, pertumbuhan pokok terpilih yang berusia lebih kurang enam tahun selepas ditanam telah dipantau selama setahun. Jangka masa pertumbuhannya ditentukan dengan menggunakan skala 'Biologishe Bundesanstalt, Bundessortenamt and Chemical Industry' (BBCH). Peratus kelimpahan bunga, buah dan daun baharu dianggarkan dengan membandingkan jumlah setiap peringkat pertumbuhan tersebut dengan keseluruhan permukaan silara pokok. Peringkat vegetatif dan reproduktif spesies ini masing-masing mengambil masa sehingga 198 dan 176 hari. Jangka masa pembungaan pula ialah 40 hari dari putik bunga berkembang hingga kepada stamen dan kelopak bunga kering dan seterusnya mengalami penuaan. Pembungaan berlaku secara tidak serentak di antara pokok-pokok yang dipantau. Kewujudan bunga turut dipengaruhi oleh pertumbuhan dedaun baharu atau buah. Jangka masa setiap peringkat pertumbuhan yang direkodkan dan kelakuan pembungaan spesies ini boleh menggalakkan kajian yang lebih mendalam terhadap pembungaan pokok-pokok bandaran di Malaysia.*

Kata kunci: Kelakuan pembungaan; landskap bandar; peringkat pertumbuhan; pokok hiasan; Xanthostemon chrysanthus

INTRODUCTION

Trees enhance the value and quality of a space which contribute to ecological, social and economic benefits to the environment. Texture, form, size and colour are the physical attributes of trees that offer attention, variety and aesthetic appeal to the surrounding areas (Hansen & Alvarez 2010). Ornamental factors of a tree include flowers, foliage colour and texture, bark characteristics and attractive crown shapes (Kuhns & Rupp 2000). Among these characteristics, colour usually attracts most attention. Some trees produce colourful young leaves, while others have distinctive unique and striking coloured flowers.

Under tropical condition, environmental cues play an important role to initiate flowers, while flowering of temperate deciduous trees is often autonomous (Borchert et al. 2004; Wilkie et al. 2008). In temperate region, annual changes in temperature are great and accompanied by corresponding cycles in the growth and reproduction of the flora, while in tropical, seasons are often marked by differences in rainfall, with life-history events occurring in response to water availability (Ausín et al. 2005; Bernier et al. 1993; Fenner 1998). In Malaysia, with a rather uniform rainfall distribution and temperature throughout the year, the environmental signals that promote flower bud emergence are subtle. Close observation and monitoring to understand the flowering behaviour of landscape trees are important to ensure proper management and continuation of the flowering of these species for cost effective beautification.

Periodic biological events in plants, such as bud break, flushing, flowering and fruit development, are closely regulated by climatic and seasonal changes (Beuker et al. 2010; Cautín & Agustí 2005). The knowledge of biological events and their variability provides priceless information towards proper planning and management of certain standardised practices related to plant growth and development. To date, BBCH (Biologishe Bundesanstalt, Bundessortenamt and Chemical Industry) scale is widely used for monitoring the growth changes in plants. It indicates that the BBCH scale is well accepted for communication among scientists in the management of plant growth and development in relation to the changes in environment, meteorology and climatology. BBCH scale is important in the exchange of new findings as it has a common understanding of the terms used (Meier et al. 2009).

The extended BBCH-scale is divided into 10 clearly identifiable developmental phases which illustrate the entire growth of plants. These phases are considered as 10 principal growth stages numbered from 0 to 9 and each stage considers 10 secondary growth stages numbered from 0 to 9 (Hack et al. 1992). The combination of these growth stage descriptions gives a two-digit numeric code. The scale has been used to describe numerous crops, for example, *Annona cherimola* (Cautín & Agustí 2005), *Psidium guajava* (Salazar et al. 2006), *Actinidia deliciosa* (Salinero et al. 2009), *Theobroma* sp. (Niemenak et al. 2009), *Cynara cardunculus* (Archontoulis et al. 2010), *Elaeis guineensis* (Forero et al. 2011), *Camelina sativa* (Martinelli & Galasso 2011), *Annona squamosa* (Liu et al. 2015) and *Ziziphus jujube* (Hernández et al. 2015). Phenological growth stages of an ornamental tree, *Xanthostemon chrysanthus*, using BBCH-scale was also recently described by Ahmad Nazarudin et al. (2012).

Xanthostemon chrysanthus (golden penda), also locally known as jambu kuning, belongs to the family Myrtaceace. This species is native to tropical northern Australia, New Guinea, Indonesia and the Philippines (Sosef et al. 1998). *Xanthostemon* has about 45 species and *X. chrysanthus* is among the 13 species found in its origin, Australia (Wilson 1990). Owing to its bright yellow and unique flowers, this species was introduced for ornamental purposes and has then become one of the popular landscape trees for roadsides, urban parks and residential areas in Malaysia. This species is preferred for urban planting because it is able to tolerate the harsh urban environment and it flowers throughout the year (Ahmad Nazarudin et al. 2014). However, the vegetative and reproductive growth periods of the species have not been documented precisely.

This study aimed to determine the duration of vegetative and reproductive growth stages and the flowering behaviour of *X. chrysanthus* as valuable information for future research related to flowering of urban trees in Malaysia. Precise descriptions of the various growth stages are also useful for fertilizer application regimes and probably also pest and disease control that will affect plant health and subsequently the flowering potential as the key attraction of this species.

Materials and Methods

STUDY SITE

A study site was established at Metropolitan Batu Recreational Park, MBP (3°12’49”N/101°40’43”E), an urban park located in Kuala Lumpur, Malaysia. Trees aged approximately six years after planting at MBP were established on a rather flat terrain, at a distance of about 1-1.5 m from the road shoulder of the park. Trees were planted at approximately 10 m apart from one another. The average tree height and diameter at breast height of these trees were 6 m and 11 cm, respectively. Ten *X. chrysanthus* trees were randomly selected from 21 trees available at the site for observation. All trees were free from pest and disease symptoms. During the observation period, the total annual rainfall was 3,181.7 mm and the mean minimum and maximum temperature were 22.9°C and 33.3°C, respectively, with 76.4% average relative humidity. The trees were grown on loamy sand soil containing 67% sand, 15% clay and 18% silt and the soil pH was 6.1.

DATA COLLECTION

Vegetative and reproductive organs such as leaf bud and flower bud of the trees were randomly selected and tagged. The frequency of observation of the tagged organs varied from daily to weekly depending on its rate of change. For instance, daily observation was made in the case of inflorescence bud swelling and flowering due to the rapid visible changes. Previous BBCH scale documented for *X. chrysanthus* by Ahmad Nazarudin et al. (2012) was used as a guide to identify the growth stages and the duration (number of days) of each growth stage.

Principal growth stages recognised in vegetative stage of this species included bud development (stage 0), leaf development on tree branches (stage 1) and shoot elongation (stage 3) (Ahmad Nazarudin et al. 2012). Stage 2 on formation of side shoots was ignored because it is limited to the description of side shoot emergence at the main stem. As this woody tree branching is very extensive and it goes beyond the scope of stage 2 of BBCH scale, it is better to describe using tree architectural models (Finn et al. 2007). Development of harvestable vegetative plant parts (stage 4) was also not relevant in *X. chrysanthus*. Meanwhile, five principal growth stages were recognised in reproductive phase, i.e. inflorescence emergence (stage 5), flowering (stage 6), fruit development (stage 7), fruit and seed maturity or ripening (stage 8) and senescence/ beginning of dormancy (stage 9) (Ahmad Nazarudin et al.

2012). The progress of stage 9 was not recorded in detail because at this phase the dry fruit capsules which usually remain on the twigs until the capsules drop were invaluable for landscape aesthetic. Numbering for the secondary growth stage is related to ordinal or percentage values of growth (Hack et al. 1992). For example, at principal growth stage 1 (leaf development), the first pair of leaves unfolded was given a value of 1 and its identification in the scale is 11. For flowering (stage 6), a value of 9 was assigned if more than 90% of the flowers opened and the scale is 69.

For flowering behaviour, data on flower, fruit and new leaf abundances were scored. The tree crown was divided into two portions, Face A (facing the east) and Face B (facing the west). The flower, fruit and new leaf abundances were recorded twice a week as estimated percentage of flower, fruit and new leaf coverage in relation to the crown surface (Table 1). The abundances of flower, fruit and new leaf of a tree was the average of Face A and B. Field observations were carried out for one year from November 2010 to October 2011.

Climatological data were obtained from the nearest weather station of Malaysian Meteorological Department (MMD) located at the Parliament House of Malaysia, about 5 km in radius from the study site. This was based on Larocque and Hall (2003) who used climatological data from a few meteorological stations located within 2-15 km from the study site to evaluate the potential of the use of chironomid assemblages in estimating past temperature changes in their study.

TABLE 1. Indication of abundance of new leaves, flowers and fruits

Abundance of new leaves, flowers and fruits (%)*	Abundance indicator
≤ 20	Low
> 20 – < 50	Moderate
≥ 50	Profuse

*Estimated percentage in relation to total surface area of tree crown

Results And Discussion

GROWTH STAGES

It was evident that both vegetative and reproductive growth stages could occur simultaneously within the same branch of the tree. The first evident was when only the leaf buds appeared on the tree branches, and frequently side shoots were also observed under such circumstance. For instance, at bud development (stage 0), when 10% of the leaf bud reaching final stage, its identification scale is 01 (Figure 1(a)). For leaf development (stage 1), if one pair of leaves unfolded, a value of 1 was assigned and the scale is 11 (Figure 1(b)). The leaves and internodes continued to develop until total shoot elongation was completed. It was indicated by greatly reduced of the final internode length. During the shoot elongation, the auxiliary shoots were also produced. This was actually similar to stage 2 with BBCH scale, considering side shoot growth from each branch was similar to side shoot emergence from main stem. Therefore, stage 2 was not recorded for *X. chrysanthus* tree due to the extensive branching of the tree. In some cases, parallel growth between two different stages were observed and thus a diagonal stroke is used (Hack et al. 1992). In this study, leaf development (stage 1) and inflorescence emergence (stage 5) occurred simultaneously. For example, at stage 1, two pairs of leaves unfolded and its identification was indicated as 12. At stage 5, 20% of the inflorescence emerged and its identification was indicated as 52. Hence, the scale 12/52 was assigned to show the un-sequenced developmental stages (Figure 1(c)). The existence of these two growth conditions on the same branch implied that the flowering of this tree species is most likely not seasonal. In non-seasonal flowering trees, the newly emergence buds may develop into flowers whenever appropriate flowering requirements are imposed. Earlier observation in some perennial tropical species indicated that flowering can potentially occur at any time throughout the year. However, the timing of flowering varies among species (Bawa 1983). The differences in flowering characteristic, particularly the duration of flowering, were also reported in the tropical tree species within the same community (Opler et al. 1980). Hence, the flowering trends in non-seasonal tropical trees are very diverse (Bawa et al. 2003).

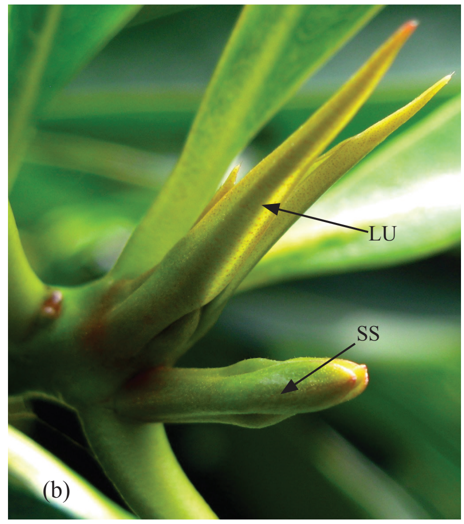
Vegetative and reproductive stages of *X. chrysanthus* required 198 and 176 days, respectively (Table 2). In reproductive stage, the flowering period lasted about 40 days, starting from inflorescence bud swelling (stage 51) and was completed at the stage of end of flowering or beginning of ovary maturity (stage 69). In this study, scale 69 defines more than 90% of flower opened or end of flowering stage, indicating the beginning of maturity of the ovary (Figure 1(d)). The flowers were conspicuously observed for 29 days (stage 51-69), representing 16.5% of the whole timeline of the reproductive phase. The aesthetic value of the flowers declined when the main feature of the flower, i.e. stamens, dried out and dropped, indicating the initial stage of fruit development. Fruit development and fruit maturity or ripening required about 136 days or 77.3% of the whole timeline of the reproductive phase. Upon completion of fruit ripening, the tiny seeds were explosively discharged.

FLOWERING BEHAVIOUR

Only nine trees flowered while the other one remained in the vegetative stage throughout the study period of 12 months. Unsynchronized flowering occurred amongst the trees (Figure 2). There were four trees that showed profuse flowering covering 50-80% of the crown surface at their flowering peaks, portraying beautiful landscaping facade (Figure 2). The other five flowering trees only had maximal 40% flower coverage in relation to the total crown surface. Hanke et al. (2007) stated that flowering was influenced by endogenous and environmental factors which triggered the change of shoot meristem from generating leaves to the development of reproductive organs.

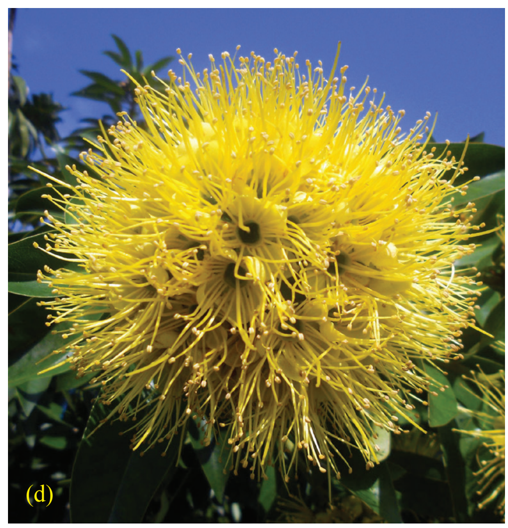
These results showed that rainfall was probably not the sole factor but other environmental factors,

Scale 01: Beginning of leaf bud (LB) swelling



Scale 11: Visible leaves unfolded (LU); side shoots (SS) developed

Scale 12/52: Two pairs of leaves unfolded (LU); inflorescence emergence (IE)



Scale 69: More than 90% of flower opened; end of flowering; beginning of ovary maturity

FIGURE 1. Macrophotographs of two growth possibilities of *X. chrysanthus* according to BBCH scale (transition of shoot meristem into vegetative or/and reproductive stages)

TABLE 2. Vegetative and reproductive stages of *X. chrysanthus*

Growth stage	BBCH scale	*Duration (days)	Duration (Accumulated days)
Vegetative			
Bud development	01-10	14 ± 0.5	14
Leaf development on tree branches	10-11	18 ± 1.7	32
Shoot elongation	31-39	166 ± 12	198
Timeline (days)			198
Reproductive	51-54	14 ± 1.3	14
Inflorescence emergence	54-61	4 ± 0.7	18
	61-65	6 ± 0.7	24
Flowering	65-69	5 ± 0.5	29
	69-70	11 ± 0.7	40
	70-75	11 ± 0.8	51
Fruit development	75-79	22 ± 1.4	73
	79-81	32 ± 1.9	105
Fruit/seed maturity or ripening	81-89	71 ± 1.3	176
Timeline (days)			176

*Mean value ± standard deviation

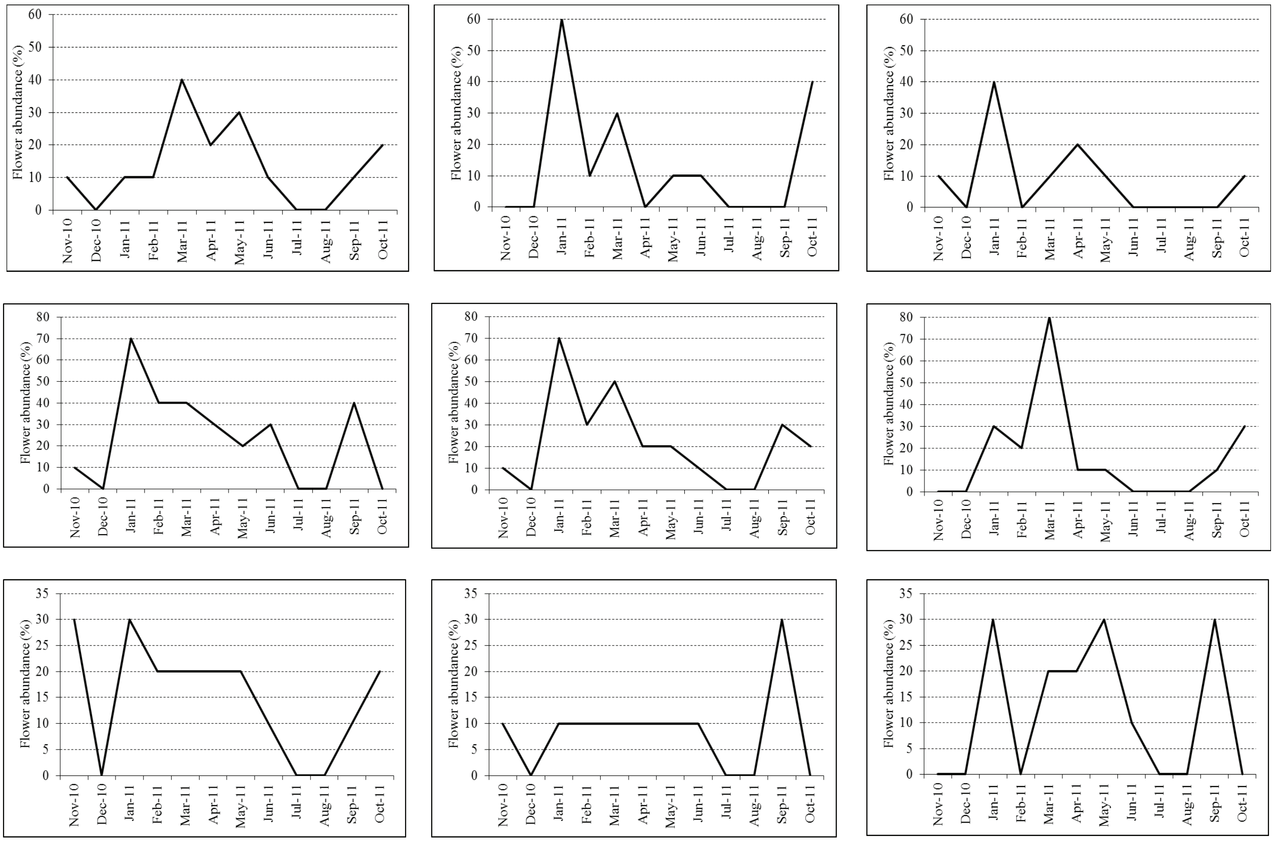


FIGURE 2. Flower abundance with individual flowering trees (*n*=9)

individual tree conditions and flowering cycle could be equally important in the flowering of *X. chrysanthus*. Higher amount of precipitation received in the end of the year, as frequently recorded in Malaysia (Malaysian Meteorological Department 2014), provided more water for promoting flowering of those trees in the subsequent months (Figure 3). However, new leaf and fruit development occurred in February and July 2011 resulted in low abundance of flowers. A similar flowering pattern was also recorded even after high rainfall months of March to April 2011 for the following flowering cycle (Figure 3). In addition, none of the trees flowered between July and August 2011 due to higher abundance of new leaf and fruit. These results showed that the vegetative or other reproductive stages of the trees played an important role in influencing the flowering of the species. Species that flower a few times a year usually flower for a shorter period as compared to annually flowering species due

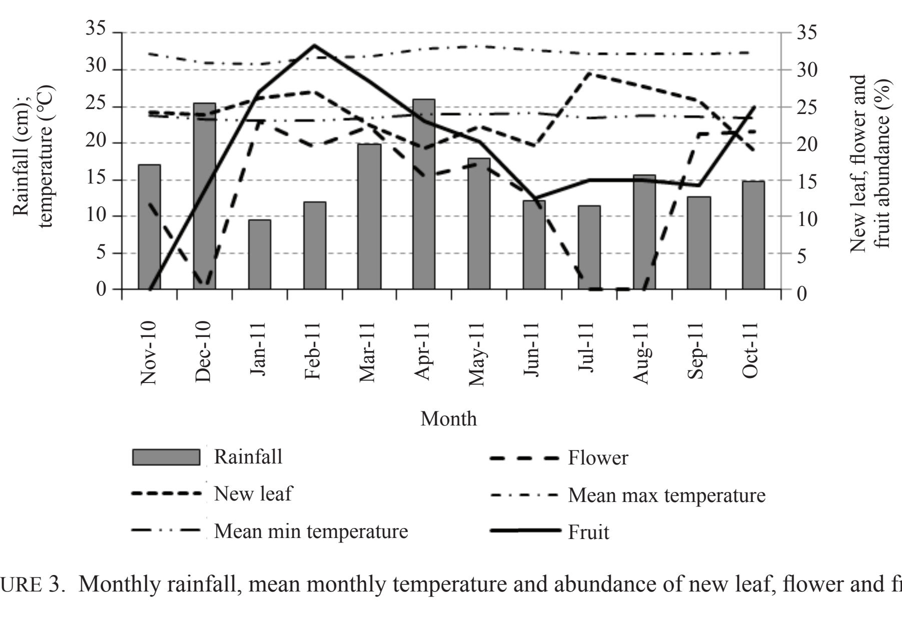


FIGURE 3. Monthly rainfall, mean monthly temperature and abundance of new leaf, flower and fruit

to interference of fruit formation with flowering (Bawa 1983; Rathcke & Lacey 1985). Internal flower-promoting factors also seemed to influence the flower development in *X. chrysanthus*. Among individual trees, the internal flower-promoting factors such as carbohydrates and flower-inhibiting factor, most likely gibberellin levels, have been found evident to influence the flowering of trees in previous studies (Achard et al. 2004; Blazquez & Weigel 2000). Previous studies showed that there was a strong positive relationship between flower development and carbohydrate content in the plant tissues (Iglesias et al. 2003; Jean & Lapointe 2001; Rodrigo et al. 2000; Ruiz et al. 2001; You-Min et al. 2008). Moreover, plant growth regulator interactions (Wilkie et al. 2008) and the difference in terms of genetics superiority of the individual trees (Iannucci et al. 2008; Meier et al. 2009; Nicotra et al. 2010; Omolaja et al. 2009) also manipulated flowering.

Conclusion

Vegetative and reproductive stages of *X. chrysanthus* were completed in 198 and 176 days, respectively. The flowering period required about 40 days from inflorescence bud swelling to drying and senescence of stamens and petals. Flowering of this species was unsynchronized and non-seasonal. The documented duration of each growth stage and flowering behaviour of *X. chrysanthus* may benefits future studies on flowering of urban trees in Malaysia. For instance, some approaches can be further explored to promote tree conditions that favour flowering or flowering induction treatments may be applied under certain tropical climatic settings.

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