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Growth Stages of Torch Ginger (*Etlingera elatior*) Plant

(Tahap Tumbesaran Tumbuhan Kantan (*Etlingera elatior*)

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ABSTRACT

*Torch ginger (*Etlingera elatior*) is a herbaceous clumping plant. It is a multifunctional crop that has been used for culinary, medicinal, antibacterial agent, ornamental and floral arrangement purpose. However, from the literature, no work has been carried out to study its growth and development morphological characteristics. It is important to understand the developmental morphology of the torch ginger plant for research purpose, commercial usage and apply proper production practices by growers for higher yields and profits. Therefore, the aim of this study was to determine the time course of morphological changes during the growth and development of torch ginger. Results showed that it took 155 days from leafy shoot emerging from rhizome until senescence of inflorescence. The growth and development of torch ginger plant were divided into vegetative and reproductive phases. The vegetative phase mainly involved the growth activities of leafy shoot. The transition of vegetative to reproductive phase happened when the inflorescence shoot emerged from the rhizome. In the reproductive phase, the growth and development of the inflorescence were categorized into four phenological stages which were peduncle elongation, inflorescence emergence, flowering and senescence. The growth pattern of the leafy shoot and inflorescence demonstrated a monocarpic plant growth habit with the remobilization of photoassimilates from senescing plant parts to developing true flowers that caused whole-plant senescence. Further research is needed to study the mechanisms that regulate flowering and senescence in torch ginger plant.*

Keywords: Monocarpic; morphology; phenology; photoassimilates remobilization; whole-plant senescence

ABSTRAK

*Kantan (*Etlingera elatior*) adalah merupakan tanaman herba. Kantan merupakan tumbuhan yang mempunyai pelbagai fungsi yang boleh digunakan dalam masakan, perubatan, sebagai agen anti-bakteria dan gubahan bunga. Walaupun demikian, tiada kajian dijalankan ke atas ciri morfologi tumbesaran dan perkembangannya. Memahami perkembangan ciri morfologi kantan adalah penting untuk penyelidikan dan kegunaan komersial dan penanam juga boleh mengaplikasi amalan pengeluaran yang sesuai untuk memperoleh hasil dan keuntungan yang lebih tinggi dan lumayan. Oleh itu, tujuan kajian ini adalah untuk menentukan perubahan ciri morfologi dalam tumbesaran dan perkembangan kantan. Keputusan menunjukkan kantan mengambil masa selama 155 hari berkembang daripada kemunculan pucuk daun sehingga penuaan bunga. Tumbesaran dan perkembangan kantan terbahagi kepada fasa vegetatif dan reproduktif. Fasa vegetatif melibatkan aktiviti pertumbuhan daun pada pucuk. Peralihan fasa vegetatif ke reproduktif berlaku apabila pucuk bunga tumbuh keluar daripada rizom. Dalam fasa reproduktif, tumbesaran dan perkembangan bunga dikategorikan kepada empat peringkat fenologi iaitu pemanjangan tangkai bunga, kemunculan perbungaan, berbunga dan senesen. Corak tumbesaran pucuk daun dan perbungaan kantan menunjukkan tabiat tumbuhan monokarpa yang melibatkan mobilisasi fotoasimilat daripada bahagian tumbuhan yang mulai tua ke bunga sebenar dalam perkembangannya. Akhirnya proses ini menyebabkan kematian pada tumbuhan tersebut. Penyelidikan lanjutan diperlukan untuk mengkaji mekanisme yang mengawal pembungaan dan penuaan kantan.*

Kata kunci: Fenologi; mobilisasi fotoasimilat ; monokarpa; morfologi; penuaan seluruh tumbuhan

INTRODUCTION

Torch ginger (*Etlingera elatior*), also known as torch lily, wild ginger or Philippine wax flower belongs to the family of Zingiberaceae. It is native to Malaysia and Indonesia. Torch ginger is a herbaceous clumping plant that can be propagated sexually (seeds) and asexually (rhizomes). Torch ginger inflorescence consists of three colours which are red, pink and white. The pink torch ginger is usually found in rural areas and jungle fringes while the white and red variants are rare. In Southeast Asia, torch ginger especially the inflorescence bud is famous for culinary purpose. It is an important ingredient as flavouring in many Malay, Nyonya, Indonesia and Thai dishes. Other plant parts such as rhizome, leaf and inflorescence of torch ginger have been traditionally used as condiment and medicine (Chan et al. 2011).

Torch ginger is an aromatic plant, thus works on extracting its essential oil from different parts of plant (rhizome, leaf and inflorescence) and its phytochemistry and pharmacological properties have been extensively

studied (Abdelmageed et al. 2011; Abdelwahab et al. 2010; Jackie et al. 2011; Lachumy et al. 2010; Mohamad et al. 2005). The essential oils are used as a therapeutic agent for treating sore throats, sea and travel sickness, and relieve cramps and rheumatic pains. The extracts from torch ginger leaf and inflorescence exhibited antibacterial activity against Gram-positive bacteria (Chan et al. 2007; Wijekoon et al. 2013). Inflorescence bud extract has been reported to inhibit *Colletotrichum gloeosporioides* mycelial growth, and it has the potential use as an antifungal agent to control anthracnose diseases (Punnawich et al. 2009). In commercial, the rhizome and inflorescence are used as a natural ingredient in cosmetics such as soap, shampoo and perfume (Voon et al. 2012).

In recent year, besides the culinary and medicinal usage, torch ginger is getting popular to be planted as ornamental and landscape plant in garden and urban areas. The extravagant and showy inflorescence with bright colour is suitable to be used as cut flower. In Australia, Brazil, Hong Kong, Thailand and United States of America, torch ginger has been used in floral arrangements. Depending on the market demand, the torch ginger inflorescences from the tight bud to the blooming stage could be used as cut flower. This has increased the marketability of the inflorescence.

Being a multi usage crop in different industries, however, from the literature, no work has been carried out to study the growth and development of the torch ginger plant. The changes on morphological landmarks during the growth and development of the torch ginger plant for both leafy and inflorescence shoots have not been identified. To date, there is no grading standard for developmental stage of touch ginger. Therefore, the aim of this work was to determine the time course of morphological changes during the growth and development of torch ginger from the leafy shoot emerged from rhizome until the senescence of inflorescence shoot. The finding from this study will expand our knowledge for a new insight into the torch ginger plant growth and development cycle. Besides, physical, physiological and biochemical characteristics of a plant are influenced by its developmental stage. By defining the growth stages of torch ginger plant, it could provide detail information for research purpose and commercial usage. It also beneficial to growers as they can apply proper production practices for higher yields and profits.

Materials and Methods

Pink torch ginger plants grown at Field 2, Faculty of Agriculture, Universiti Putra Malaysia, Malaysia (3°00′21.34″N, 101°42′15.06″E, 37 m elevation) since November 2011 were used in this study. The mean daily temperature during the observation period was 23-35°C with a monthly precipitation of 100-200 mm. Fertilization was done monthly with NPK Blue (12:12:17:2) with the rate of 500 g/clump. Watering and weeding were carried out when necessary.

The growth and development of 20 torch ginger plants were observed daily. Number of days taken since the emergence of a leafy shoot from rhizome until the senescence of inflorescence was recorded. The growth parameters of inflorescence including peduncle length, peduncle diameter at the upper (3 cm beneath inflorescence head) and basal part (3 cm from soil surface), inflorescence bud diameter (middle part of the bud) and bract opening diameter (widest opening of two bract edge crossed the centre of the inflorescence) were recorded daily. Measuring tape and caliper (Mitutoyo, Japan) were used for the measurements. The data were analysed using SAS Version 9.2 (2010) and expressed as mean ± standard deviation (SD).

In cellular structure studies, the upper and basal parts of peduncle during elongation and flowering stages were used. Transverse sections of the upper and basal parts were cut (1 mm) using the freehand section technique with a razor blade and stained with iodine solution (I_2KI) for 5 min. Sections were viewed using a compound microscope (Meiji Techno, Japan) equipped with a digital camera (Olympus, USA).

Results and Discussion

The growth and development cycle of torch ginger plants was divided into vegetative and reproductive phases. The vegetative phase began with the emergence of a leafy shoot (pseudostem) from the rhizome beneath the ground (Figure 1). Once the inflorescence shoot emerged from the rhizome, it was considered as reproductive phase. From the observation, one leafy shoot produced only one inflorescence. The inflorescence was borne on a long and leafless peduncle.

Vegetative Phase

The leafy shoot of torch ginger plant was formed by layers of leaf sheath (Figure 1). It took about 18-22 days for the leafy shoot that emerged from the rhizome to form its first leaf (Figure 2). During the growth of leafy shoot, cigar leaf emerged and unfolded one after the other (Figure 3). The leaves were lined alternatively on the leafy shoot and leaves number increased as the leafy shoot elongated. The leafy shoot may reach a height of 3-4 m (Figure 4). It took about 70 days for the plant to stay as vegetative phase before entering the reproductive phase with the emergence of inflorescence shoot from the same rhizome as the leafy shoot (Figure 5).

Reproductive Phase

Inflorescence

The reproductive phase of torch ginger started once the inflorescence shoot emerged from the rhizome (Figure 5). The growth and development of inflorescence were classified into four phenological stages which

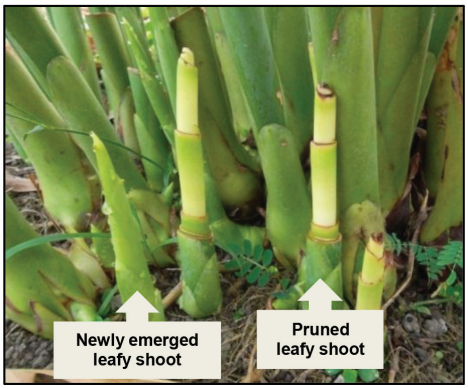


FIGURE 1. Emergence of leafy shoot from rhizome. Leafy shoot (pseudostem) was formed by layers of leaf sheath which could be seen clearly from pruned shoot

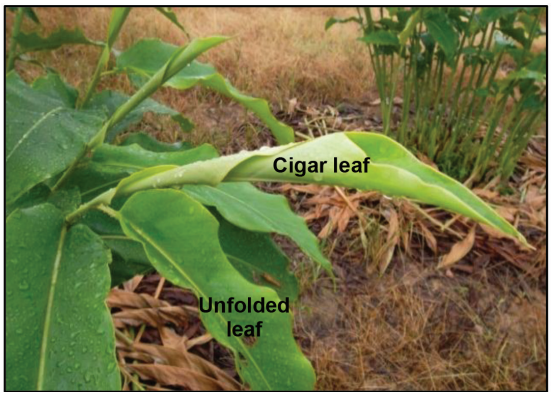


FIGURE 3. Cigar leaf emerged from the growing point of leafy shoot and unfolded one after the other

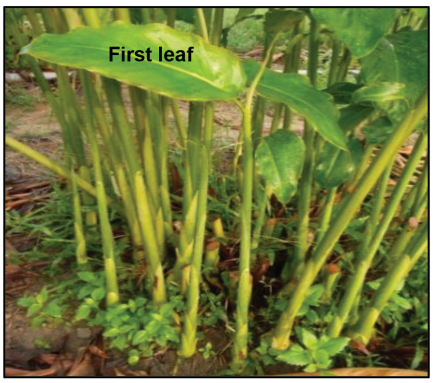


FIGURE 2. First leaf formed from leafy shoot after 18-22 days of emergence from rhizome

FIGURE 4. The mature leafy shoot in vegetative phase may reach a height of 3-4 m

were peduncle elongation, inflorescence emergence, flowering and senescence according to its phenological characteristics. The growth parameters such as length and diameter of peduncle, bud diameter and bract opening diameter were subdivided in 10-day intervals as regards to the morphological changes (Table 1). At the initial growth stage of inflorescence shoot, peduncle elongation was actively taking place with 59% increase in the first 20 days of growth (Table 1). The peduncle elongated with basal diameter larger than the upper part by an average of 21% (Table 1). Once the inflorescence bud formed, the elongation of peduncle slowed down and almost no elongation was noticed during the flowering stage.

The inflorescence bud started to form after 30 days of emergence from shoot. Thereafter, the inflorescence bud swelled gradually with deposition of pink pigments on bracts, and it was known as inflorescence emergence stage. The torch ginger inflorescence is composed by two types of bracts which are floral and involucral bracts. A mature inflorescence at full bloom may contain 20-25 layers of floral bracts and 3-4 layers of involucral bracts. The sequential development of a mature inflorescence bracts was further characterized into seven distinct stages based on its size, i.e. length and diameter (Table 2). The

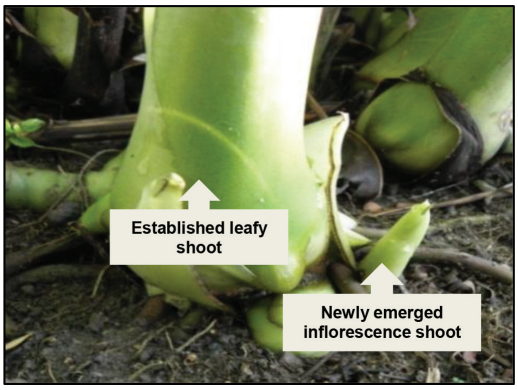


FIGURE 5. Emergence of inflorescence shoot from rhizome which connected to leafy shoot represented the start of reproductive phase

seven developmental stages of bracts were identified from the innermost layer (stage 1) to outermost layer (stage 7). Bracts with developmental stages 1-4 were floral bracts while stages 5-7 were involucral bracts (Figure 6). The floral bracts that formed the inflorescence head increased 2-fold in size from stages 1 to 4 as the inflorescence matured. The floral bracts were tender and smaller than

TABLE 1. Phenological stages of torch ginger inflorescence during reproductive phase

Phenological Stage	Days after flower shoot emerges	Peduncle characteristics			Bud diameter (cm)	Bracts opening diameter (cm)	Morphological characteristics
		Length (cm)[a]	Diameter (cm)				
			Upper	Basal			
Peduncle elongation	10	27.41 ± 8.38	0.97 ± 0.09	1.17 ± 0.11	-	-	Peduncle elongates
	20	43.51 ± 8.79	0.97 ± 0.07	1.21 ± 0.11	-	-	Peduncle elongates
	30	60.02 ± 9.32	0.99 ± 0.08	1.22 ± 0.12	1.39 ± 0.33	-	Peduncle elongation ends; inflorescence bud forms
Inflorescence emergence	40	69.37 ± 10.69	0.99 ± 0.09	1.25 ± 0.11	2.35 ± 0.67	-	Inflorescence bud swelling, inflorescence head increases in size; pink pigments deposit in the bracts
Flowering	50	70.01 ± 11.80	1.01 ± 0.10	1.27 ± 0.12	4.28 ± 1.45	6.41 ± 1.90	Outermost layer of involucral bracts unfold
	60	70.39 ± 11.35	1.02 ± 0.10	1.29 ± 0.13	-	10.20 ± 1.36	All involucral bracts unfold and true flowers open at the end of flowering stage
Senescence	61	-	-	-	-	-	True flowers open ring by ring from outer to inner layers; involucral bracts dry
	85	-	-	-	-	-	All true flowers opened; inflorescence head turns brown and dry

[a] Each value is the mean of 20 inflorescences ± SD

TABLE 2. Torch ginger inflorescence bract and true flower at different developmental stages

Bract	Developmental stage[a]	Bract		True flower	
		Length (mm)[b]	Diameter (mm)	Length (mm)	Diameter (mm)
Floral	1	14.74 ± 2.43	3.69 ± 0.51	13.06 ± 0.64	2.93 ± 0.27
	2	28.21 ± 4.56	5.43 ± 0.66	15.40 ± 0.84	3.40 ± 0.15
	3	36.47 ± 3.66	6.78 ± 0.61	18.64 ± 0.84	4.01 ± 0.25
	4	45.07 ± 6.68	8.65 ± 1.12	22.55 ± 1.81	4.81 ± 0.23
Involucral	5	58.41± 7.86	15.52 ± 2.10	27.50 ± 1.10	5.38 ± 0.10
	6	73.80 ± 8.80	19.66 ± 3.87	42.14 ± 1.17	6.29 ± 0.22
	7	100.17 ± 15.20	32.39 ± 5.11	39.38 ± 1.53	5.78 ± 0.10

[a] Developmental stages were based on a mature inflorescence at full bloom stage when first ring of true flowers opened
[b] Each value is the mean of 20 inflorescences ± SD

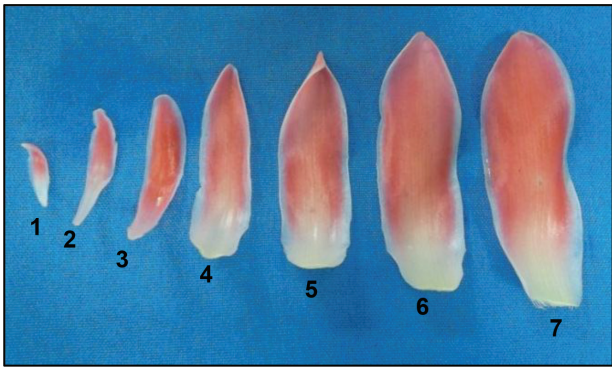


FIGURE 6. Two types of bracts in an inflorescence head of torch ginger. Stages 1-4: floral bracts and stages 5-7: involucral bracts

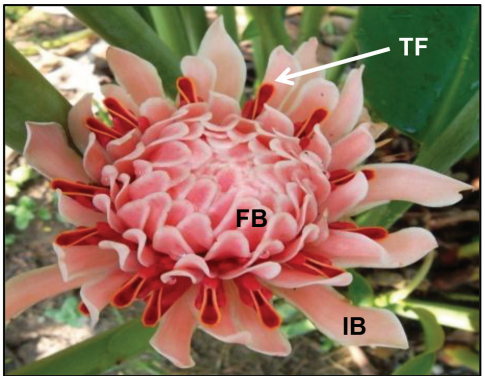


FIGURE 7. Torch ginger inflorescence at the end of flowering stage with first ring of true flower opened. IB: involucral bract, FB: floral bract, and TF: true flower

involucral bracts. The involucral bracts, on the other hand, were bigger in size with rough texture and waxy surface. The involucral bract edges curled inward and a tip formed on top of the bract but no tip was found in floral bracts. The function of involucral bracts was mainly for protection purpose.

By day 50, the inflorescence had entered the flowering stage. At the early of the flowering stage, the outermost involucral bracts of inflorescence started to unfold. By day 60, all involucral bracts unfolded and the bract opening diameter achieved an average of 10.20 cm (Table 1). During this period of time, first ring of the true flowers opened sequentially (Figure 7). The true flower of torch ginger inflorescence could be found among the floral bracts. One layer of floral bracts was followed by one ring of true flowers and so on. A mature inflorescence may contain 90-120 true flowers. The developmental stages of true flowers were categorized based on its size and morphology. From stages 1-5, true flowers were in the developing process. By stage 6, the true flowers had opened with yellow margin of labellum. By stage 7, the labellum of true flower had closed and true flowers entering senesced stage. As the inflorescence matured, true flowers developed and increased in length and diameter, and finally opened as in stage 6 (Table 2). Each true flower lasted only 24 h before the labellum with yellow margin closed and dried as shown in stage 7 (Figure 8). The bract opening diameter decreased thereafter with involucral bracts drying as the opening of true flowers continued. Bud diameter could not be measured anymore at this stage as all the involucral bracts had unfolded.

When the first ring of true flowers opened, browning/drying on the outermost of involucral bracts was found. The browning/drying started from the margin of the bracts (Figure 9) and progressed from outer layer towards inner layers of inflorescence head. This followed by the opening of true flowers until the end of the inflorescence senescence stage, which took 24 days (Table 1). The true flowers opened ring by ring from the fringe of the head towards the torch of inflorescence (Figure 10(a)). Once all the true flowers had opened, the inflorescence head turned brown and dried (Figure 10(b)). In this study, the

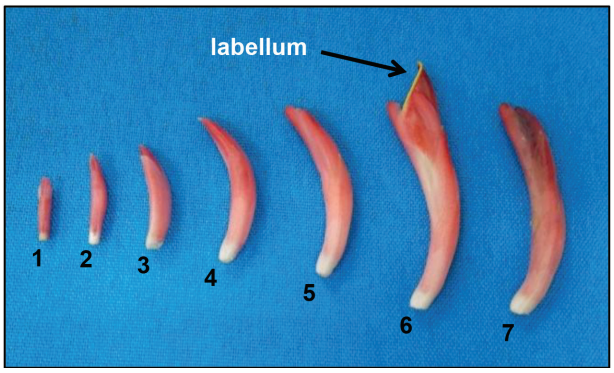


FIGURE 8. True flowers of torch ginger inflorescence at different developmental stages. Stages 1-5: true flowers are developing with increase in length and diameter, stage 6: true flower opens by showing yellow-margin of labellum, and stage 7: senescence of true flower with closed labellum

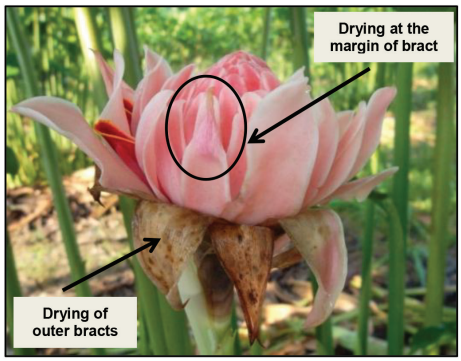


FIGURE 9. Browning/drying of the bracts starting from the margin and browning/drying process progressed from outer layer towards inner layers of inflorescence head

true flowers failed to develop into fruits and seeds resulted from the absence of spider-hunter bird. It is believed that spider-hunter bird is an important pollinator for torch ginger (Sakai et al. 1999).

In the cellular structure studies, transverse section of the peduncle at elongation stage stained with iodine

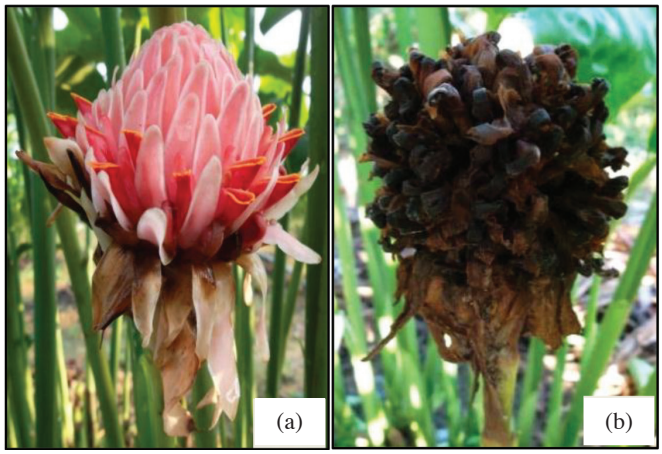
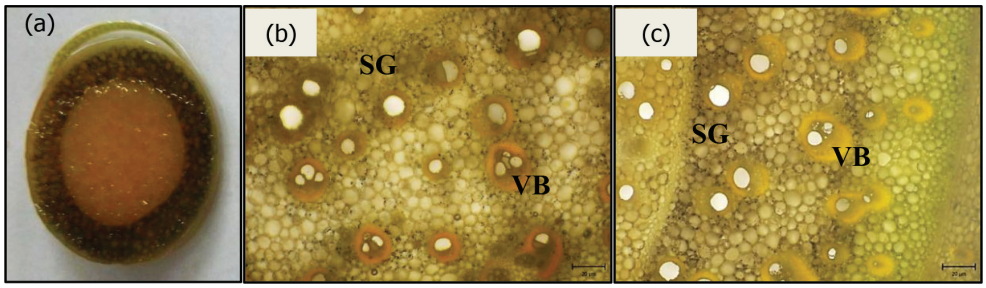


FIGURE 10. (a) Opening of true flowers ring by ring from the fringe of head towards the torch of inflorescence with browning/dying of involucral and outer layer floral bracts and (b) Senescence of inflorescence head without seed forming

solution showed accumulation of starch at the basal part of peduncle (Figure 11(a)). The starch density at the upper part of the peduncle was lesser than the basal part (Figures 11(b) and 11(c)). However, at flowering stage, the starch density at basal part of peduncle reduced compared to elongation stage (Figure 12(b)). The brown colour showed at the upper part of peduncle at flowering stage indicated that no starch was found (Figure 12(a)).

LEAFY SHOOT

During inflorescence emergence stage with swelling of inflorescence bud, the growth of new leaves on the leafy shoot had slowed down or almost none. Yellowing of leaves was noticed and the yellowing started from the basal part of the leafy shoot which near to ground. When the inflorescence entered flowering stage with true flowers opened, yellowing of leaves became chronic and advanced



VB: vascular bundles, and SG: starch granules. Scale bar = 20 µm

FIGURE 11. (a) Transverse sections with free-hand sectioning of the peduncle stained with iodine solution at elongation stage. The blue-black colour shown on the peduncle section indicates the presence of starch. (b) Upper and (c) basal parts of peduncle observed under compound microscope

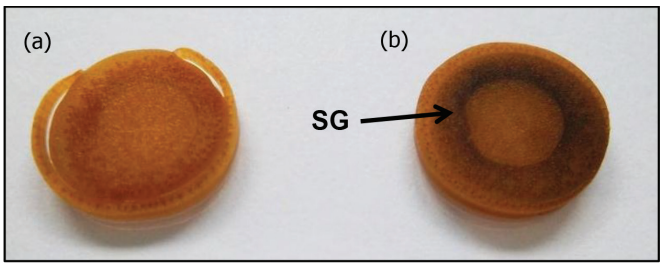


FIGURE 12. Transverse sections with free-hand sectioning of the peduncle stained with iodine solution at flowering stage (a) Upper and (b) basal parts of peduncle. Brown colour shown on the upper part of peduncle indicates no starch being found SG: starch granules

to the upper part of the leafy shoot. Eventually, the leaves at the basal part of leafy shoot withered one after another (Figure 13). From the observation, when the inflorescence was harvested before the inflorescence emergence stage, the growth of new leaves was found in the leafy shoot. Contrary, when the senescence of leafy shoot occurred before the flowering stage, the inflorescence failed to develop or premature death of developed inflorescence (Figures 14(a) and 14(b)).

During vegetative phase, leafy shoot of torch ginger plant grows vigorously. The transition from vegetative to reproductive growth phase was noticeable by the emergence of inflorescence shoot. At the initial growth stage of inflorescence, only elongation of peduncle was taking place. The torch ginger inflorescence is borne on a leafless peduncle and is unable to carry out photosynthesis. The leafy shoot, therefore is expected to act as a source to translocate photoassimilates for the growth and development of the inflorescence. This was proven by the failure of inflorescence development resulted from the death of leafy shoot (Figures 14a and b). Furthermore, transverse section of peduncle during elongation and flowering stages showed that starches were mainly accumulated at the basal rather than the upper part (Figures 11 and 12). This may indicate photoassimilates has been translocated from leafy shoot to basal part of peduncle. Gradually, the photoassimilates at basal part is distributed to the upper part for peduncle elongation and inflorescence formation.

From the observation, the growth pattern of torch ginger leafy shoot and inflorescence demonstrated a monocarpic plant growth habit. Monocarpic plants are those that flower and set seeds only once in their life (Guiboileau et al. 2010). In the life cycle of monocarpic plants, they undergo a programmed cycle of organ degradation followed by senescence (Sklensky & Davies 2011). This senescence process, also known as whole-plant senescence (Guiboileau et al. 2010), eventually causes the death of the whole plant with remobilization of the nutrients to the reproductive organs or seeds as happens in *Glycine max*, *Oryza sativa*, *Triticum aestivum* and *Zea mays* (Munné-Bosch 2008). In torch ginger plant, one leafy shoot produces only one inflorescence. During the growth and development of the torch ginger inflorescence, the onset of senescence on a leafy shoot coincided with inflorescence flowering stage (Figure 13). The leafy shoot senesced after the inflorescence flowering stage ended.

Senescence is the last stage of plant development. A genetically controlled senescence programme in plant allows the recycle and reallocation of nutrients from dying to developing tissues, thus contributes to the plant survival and developmental program (Guiboileau et al. 2010; Jones 2013). In monocarpic plants, senescence occurs at the whole plant level during the development of reproductive sink and senescence symptom is first shown on the leaves (Schippers et al. 2007). A delay in reproductive development has an effect on the longevity of leaves (Hensel et al. 1993). In *Triticum aestivum*, the removal of spikelets which acts as reproductive sink after anthesis delays flag leaf and whole-plant senescence (Srivalli & Khanna-Chopra 2004). In torch ginger plant, it is noticed that harvesting the inflorescence before inflorescence emergence stage enables the growth of new leaves in leafy shoot and delayed senescence of mature leaves.

In monocarpic plants, nutrients are mobilized from senescing leaves to reproductive tissues before plant death occurs (Munné-Bosch 2008). Yellowing of leaves is a visible paradigm of leaf senescence (Del Duca et al. 2014). Leaf yellowing during senescence was resulted by the breakdown of chloroplast and other macromolecules such as proteins, membrane lipids and RNA (Lim et al. 2007). These macromolecules are converted into exportable nutrients and to be translocated to other growing organs. In torch ginger, the progressive senescence of the leaves is associated with the development of inflorescence. The yellowing of leaves on leafy shoot was found during inflorescence emergence stage and was obvious at inflorescence flowering stage. At flowering stage, development of inflorescence involves increases in floral bract size and developing of true flowers. Developing

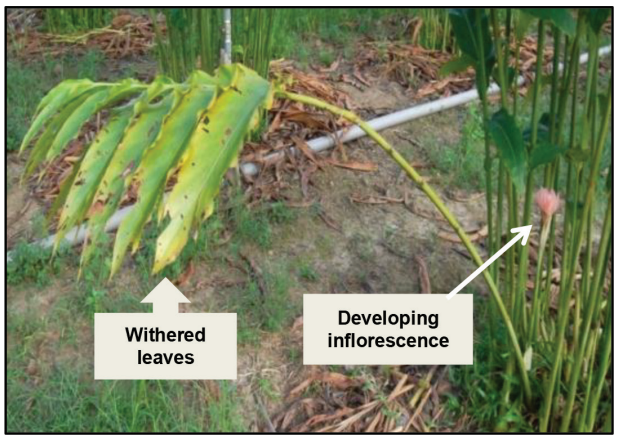


FIGURE 13. Transportation of photoassimilates from leafy shoot to developing inflorescence causing yellowing and withered of leaves

flowers are active sink organs that require a continuous supply of carbohydrates as an energy source (Ranwala & Miller 2009). The leaf yellowing was getting chronic when inflorescence bloomed with true flowers developed. Eventually, the leaves withered gradually from the basal until the upper part of the leafy shoot. Consequently, no new leaf was formed. The senescence of leaves showed on leafy shoot may indicate the remobilization of nutrients from leaves to the developing inflorescence occurred as the development of inflorescence progressed.

Opening of true flowers is important for pollination in the torch ginger plant. From the observation, the longevity of a true flower was 24 h. Therefore, a constant supply of nutrients to enable the continuous opening of these ephemeral true flowers is essential. However, the decreased number of viable leaves on the leafy shoot (Figure 13) might not be able to generate enough of photosynthates for the opening of true flowers. The translocation of photosynthates from senescent leafy shoot is expected to be limited at this stage. In order for the continuous opening of true flowers under the photoassimilate limited condition, remobilization of stored carbohydrates from other plant parts besides leafy shoot seems crucial. In *Triticum aestivum*, remobilization of stored assimilates in vegetative tissues such as stem and leaf sheaths to complete grain filling during the later developmental stages has been reported (Scofield et al. 2009). In *Lilium asiaticum*, the longevity of flowers after harvest is correlated with the redistribution of tepal carbohydrate (van der Meulen-Muisers et al. 2001). In the leafless torch ginger inflorescence, carbohydrates stored in peduncle and bracts might be the only source at this stage. This was proven by the reduced density of starch at the basal part and none was found at the upper part of peduncle during flowering stage (Figure 12).

In flowering stem, bract browning or petal senescence resulted from lack of carbohydrates has been reported in *Curcuma alismatifolia* (Bunya-atichart et al. 2004) and *Hemerocallis* cv. 'Cradle Song' (Bieleski 1995). van Doorn and Woltering (2008) reported that during petal senescence, marcomolecules are degraded to mobile compounds then transported through the phloem out of the petal. In *Gladiolus* sp., the development of the inflorescence involved a transfer of carbohydrate from the senescing lower florets to the developing florets (Waithaka et al. 2001). The removal of older *Gladiolus* florets before they senesced resulted in a decrease in the opening and dry weight of younger florets. In torch ginger inflorescence, drying of bracts therefore might due to the breakdown of the macromolecules or soluble carbohydrates. These soluble carbohydrates are expected to be transported from bracts to actively growing true flowers. The remobilization of soluble carbohydrates seems to happen as the bract browning occurs layer by layer from outer to inner followed by the opening of true flowers ring by ring (Figure 10(a)). At this stage, the older bracts and true flowers in the outer layers might act as a source for the development and opening of new true flowers in inner layers which acts as a sink. The remobilization of stored carbohydrates from bracts for the continuous developing and opening of true flowers is important in increasing pollination success in torch ginger.

Conclusion

It took 155 days from torch ginger leafy shoot emerged from rhizome until the senescence of inflorescence. The growth and development cycle of torch ginger were divided into vegetative and reproductive phases. The vegetative phase mainly involved the growth of leafy shoot with leaf development. The reproductive phase started once the inflorescence shoot emerged from the rhizome. The growth pattern of the torch ginger demonstrated a monocarpic plant growth habit that consequently caused whole-plant senescence. Torch ginger inflorescence, which composes of multi layers of bracts and true flowers that developed at different time frame, can be used as a model to study the remobilization of nutrients from senescing plant parts to developing true flowers. Further research is needed to study the mechanisms that regulate flowering and senescence in torch ginger plant.

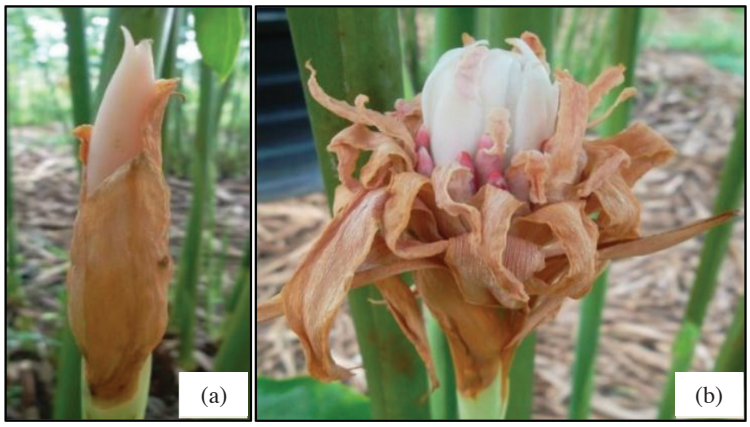


FIGURE 14. The senescence of leafy shoot occurred before the flowering stage causing (a) the inflorescence bud failed to develop or (b) the premature death of developed inflorescenc

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