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PHYSIOLOGICAL CHANGES IN INFLORESCENCE DURING FLOWERING STAGES OF TORCH GINGER (*Etlingera elatior* 'RED TORCH')

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ABSTRACT

The rhizomatous herb known as "torch ginger" (*Etlingera elatior*), which belongs to the Zingiberaceae family, is prized for its torch shaped inflorescences with vividly coloured bracts and tall stalks. The species is native to the humid tropical regions of South-East Asia. Torch ginger is an economically significant tropical cut flower and foliage crop. In addition to the aesthetic value, these inflorescences are used for culinary and medicinal purposes throughout the region. However, little information exists on physiological changes occurring in its flowering stages. To find the best harvest stage for cut flowers, physiological and biochemical changes were assessed at three flowering phases of torch ginger: six reflexing tip (SRT), involucral unfolded bract (IUB), and full bloom (FB). The experiment comprised three replications and was conducted following a Completely Randomized Design (CRD). Observations were recorded for fresh weight, dry weight, moisture content, total carbohydrate, total sugar, cell membrane stability, relative water content and bract colour. Flower development greatly enhanced fresh and dry weights, increasing from 51.32 g and 4.10 g at the SRT stage to a maximum of 116.41 g and 11.64 g at full bloom, respectively. Relative water content, cell membrane stability, and moisture content all gradually dropped from 84.82, 74.74, and 92.01% at SRT to 72.31, 65.53, and 89.99% at full bloom. Total sugar and carbohydrate contents were found to be increasing from 1695.23 and 1903.14 mg 100 g^{-1} at the SRT stage to a maximum of 1790.47 and 2129.81 mg 100 g^{-1} at the IUB stage and then sharply decreased to 1480.15 and 1563.14 mg 100 g^{-1} at full bloom, indicating the remobilization of reserves before anthesis and their utilization during floral maturation. Progressive changes in bract colour were also observed during the flowering phase. The optimal harvest stage of torch ginger cut flowers based on the combination of high carbohydrate and sugar reserves, good membrane stability and favourable water status was identified as the involucral unfolded bract stage for better postharvest handling and storage life.

***Key words*:** *Etlingera elatior*, torch ginger, cut flower, physiological characteristics

Introduction

Torch ginger (*Etlingera elatior* (Jack) R.M. Smith) is a perennial herb from the Zingiberaceae family. It is a specialty cut flower and tropical foliage crop, valued for its large ornamental inflorescences, long flowering stalks and brightly coloured bracts. It is used for ornamental, culinary, medicinal and antimicrobial purposes (Chan *et al*., 2011; Ismail and Ridzuan, 2023). The flower has additionally shown wider commercial and pharmacological value, including its use as a natural colourant in lipstick formulation (Adliani *et al*., 2012), oviposition deterrent activity of its essential oil against the dengue vector *Aedes aegypti* (Bezerra-Silva *et al*., 2016), and strong antibacterial activity of subcritical CO_2 extracted flower oil against *Salmonella typhimurium*, *Staphylococcus aureus* and *Escherichia coli* (Anzian *et al*., 2020).

The stage of harvest has a marked effect on the quality, marketability and postharvest behaviour of cut flowers. Torch ginger goes through a variety of developmental stages, from shoot emergence to inflorescence senescence, during which the morphology of bracts is altered and carbohydrate reserves are

remobilized to support flower development, thus influencing flower quality (Choon and Ding, 2016). Physiological and biochemical attributes such as moisture content, relative water content, membrane stability and carbohydrate/sugar reserves change during flower development and can influence postharvest performance (van Doorn and Woltering, 2008; Cunha Neto *et al.*, 2024). However, information on these characteristics in the flowering stages of torch ginger is limited. Hence, present investigation was therefore undertaken to evaluate physiological changes occurring at three different stages of flowering of torch ginger 'Red Torch' i.e. six reflexing tip (SRT), involucral unfolded bract (IUB), and full bloom (FB) for determining the best stage of harvest.

Materials and Methods

The experiment was conducted out at the Department of Floriculture and Landscaping, College of Agriculture, Vellanikkara, Kerala Agricultural University, Thrissur, Kerala, India, from 2025–2026. For the study, uniform, healthy torch ginger cv. 'Red Torch' plants raised in accordance with suggested agronomic procedures were utilized. Inflorescences harvested fresh at three flowering stages six reflexing tips (SRT), involucral unfolded bract (IUB), and full bloom (FB) were selected and assessed following a Completely Randomized Design (CRD), replicated three times (Fig. 1). Biochemical and physiological assay were performed in triplicates. Choon and Ding's (2016) developmental categorization was used to categorize the flowering stages.

Fresh weight of individual inflorescences was determined immediately after harvest with a digital electronic balance. Samples were subjected to drying in a hot air oven maintained at 65 ± 2°C until their weight become constant, after which the dry weight was recorded. The difference between fresh weight and dry weight was used to calculate the percentage moisture content. The total carbohydrate content was calculated using the Anthrone technique (Hedge and Hofreiter, 1962). The total sugar content was evaluated using the Phenol-Sulphuric acid method (Dubois *et al.*, 1956). Cell membrane stability was determined following the procedure outlined by Sairam (1994), while relative water content was estimated as per the method described by Barrs and Weatherley (1962). Bract colour at each flowering stage was examined using the Royal Horticultural Society (RHS) Colour Chart. Data obtained were subjected to analysis of variance (ANOVA) under a Completely Randomized Design, and mean comparisons among treatments were performed using the LSD test at 5% significance.



Fig. 1: Developmental stages of torch ginger (*Etlingera elatior*) inflorescence: six reflexing tip (SRT), involucral unfolded bract (IUB) and full bloom (FB).

Results and Discussion

Physiological and biochemical characteristics of torch ginger inflorescences were significantly different among three flowering stages (Table 1). Fresh weight increased significantly as flower development progressed, with the highest value recorded at full bloom (116.41 g), followed by involucral unfolded bract (86.91 g), while the lowest was noted at the six reflexing tip stage (51.32 g. The dry weight also showed a similar trend, increasing significantly from 4.10 g at the six reflexing tip stage to 11.64 g at full bloom. These findings indicate that the inflorescence continues to grow and develop as reflected by the significant increase in fresh and dry weights with the advancement of flowering stages. The increase in fresh weight from the six reflexing tip (SRT) stage to full bloom (FB) is due to progressive expansion of bracts, elongation of floral tissues and accumulation of water and dry matter during flower development. Similarly, an increase in dry weight indicates continuous deposition of structural carbohydrates and other assimilates in developing inflorescences. Choon and Ding (2016) noted that torch ginger inflorescences undergo progressive enlargement and biomass accumulation during reproductive development, with active translocation of assimilates from vegetative organs to floral structures.

A significant decline in moisture content was observed as flowering progressed, with the highest value recorded at the six reflexing tip stage (92.01%), followed by involucral unfolded bract (90.80%), and the lowest at full bloom (89.99%). Likewise, relative water content decreased significantly with flower development, ranging from a maximum of 84.82% at six reflexing tip to a minimum of 72.31% at full bloom. The higher moisture content observed at the SRT stage indicates better hydration and tissue turgidity in young developing inflorescences. As the flowers progressed towards full bloom, water loss through transpiration and increased metabolic activity probably contributed to the reduction in tissue moisture. A similar decline in water status during flower maturation has been reported in cut flowers and is associated with reduced cellular hydration and commencement of senescence (van Doorn and Woltering, 2008).

Table 1: Physiological and biochemical changes during inflorescence development in torch ginger (*Etlingera elatior* 'Red Torch') inflorescence.

Flowering stages	FW	DW	MC	TC	TS	CMS	RWC
Six reflexing tip (SRT)	51.32^{c}	4.10^{c}	92.01^{a}	1903.14^{b}	1695.23^{b}	74.74^{a}	84.82^{a}
Involucral unfolded bract (IUB)	86.91^{b}	7.99^{b}	90.80^{b}	2129.81^{a}	1790.47^{a}	70.89^{a}	79.92^{a}
Full bloom(FB)	116.41^{a}	11.64^{a}	89.99^{c}	1563.14^{c}	1480.15^{c}	65.53^{b}	72.31^{b}
CD (0.05)	4.98	0.74	0.50	5.03	5.01	4.52	7.29
CV	2.93	4.74	0.27	0.13	0.15	3.21	4.62

FW: Fresh weight (g); DW: Dry weight (g); MC: Moisture content (%); TC: Total carbohydrate (mg /100g); TS: Total sugars(mg/100g); CMS: Cell membrane stability (%); RWC: Relative water content (%)

No significant difference in cell membrane stability was observed between the six reflexing tip (74.74%) and involucral unfolded bract (70.89%) stages, whereas full bloom (65.53%) showed a significantly lower value. This indicates that cell membrane stability remained comparable during the SRT and IUB stages but declined significantly by full bloom. The decline of membrane stability at the late flowering stage could be associated with the progressive deterioration of membrane integrity as a result of increased membrane permeability and oxidative changes associated with flower maturation. Maintenance of membrane stability is considered to be an important indicator of physiological quality and delayed senescence in cut flowers (van Doorn and Woltering, 2008).

Significant differences were observed in total carbohydrate and total sugar contents across the flowering stages. The involucral unfolded bract stage recorded the highest total carbohydrate (2129.81 mg 100 g^{-1}) and total sugar (1790.47 mg 100 g^{-1}) contents, followed by the six reflexing tip stage, whereas full bloom showed the lowest values for both carbohydrate (1563.14 mg 100 g^{-1}) and total sugar (1480.15 mg 100 g^{-1}). The highest values of total carbohydrates and total sugars were found at the involucral unfolded bract (IUB) stage and decreased significantly at full bloom. Accumulation of carbohydrates and soluble sugars at IUB stage suggests active translocation of photoassimilates from source tissues to the developing inflorescence before anthesis. Rapid cell expansion and flower opening are supported by the energy and carbon skeletons obtained from these reserves. The reduction observed at full bloom may result from the consumption of carbohydrates and soluble sugars during respiration, maintenance metabolic processes, and true flower opening. In torch ginger, stored assimilates move from vegetative tissues into the reproductive organs during flower development, as noted by Choon and Ding (2016). Similar reductions of carbohydrate reserves during flower opening have been reported in several cut flower species, where carbohydrates are consumed to support increased respiratory activity and floral maturation (van Doorn and Woltering, 2008).

Distinct changes in bract colour were observed among the flowering stages as assessed using the Royal Horticultural Society (RHS) Colour Chart (Table 2). Progressive changes in bract colour across the flowering stages, from moderate yellowish pink at the SRT stage to deep pink at the IUB and FB stages (Table 2), further confirmed the progression of floral development. The pink to red bract colouration of torch ginger is primarily caused by the accumulation of anthocyanins derived from flavonoids along with carotenoids. The intensity and hue of the bract colour are determined by the relative proportions of these pigment groups (Sinsuebpol *et al.*, 2023). Chlorophyll degradation, along with ongoing anthocyanin biosynthesis and accumulation, intensifies bract pigmentation as the bracts mature. A similar trend was reported during bract development in other ornamental bract bearing species, such as poinsettia (*Euphorbia pulcherrima*), where anthocyanin content gradually increased while chlorophyll decreased as the bracts matured (Slatnar *et al.*, 2013). Therefore, the deepening bract colour observed in the current study from the SRT to the IUB stage probably represents a similar transition from chlorophyll dominance toward greater pigment deposition, offering a useful visual indicator for determining the optimal harvest time. Therefore, the deepening bract colour shown in the current study from the SRT to the IUB stage probably represents a similar transition from chlorophyll dominance to increased

Table 2: Bract colour across different flowering stages in torch ginger (*Etlingera elatior* 'Red Torch') inflorescence using the Royal Horticultural Society (RHS) Colour Chart.

Flowering stage	RHS Colour Group	RHS Code	Colour name
Six reflexing tip (SRT)	Red Group	39C	Moderate yellowish pink
Involucral unfolded bract (IUB)	Red Group	52C	Deep pink
Full bloom (FB)	Red Group	50B	Deep pink

pigment deposition and can serve as a visual cue to identify the ideal harvest time. The involucral unfolded bract (IUB) stage appears to be the stage of development with the highest physiological activity, exhibiting high carbohydrate and sugar reserves and good membrane stability. Therefore, it can be considered as the optimal harvest stage for further postharvest studies. Similar physiological and morphological screening approaches have been used to select superior torch ginger genotypes for the cut flower trade, wherein agro-morphological traits such as inflorescence size, fresh mass and postharvest durability were evaluated to grade genotype suitability (Araújo *et al.*, 2018), further supporting the use of physiological parameters, as adopted in the present study, for identifying commercially optimum flowering stages.

Conclusions

Findings from the present study indicate that the torch ginger inflorescence undergoes considerable physiological and biochemical changes as it develops. Fresh and dry weights increased with flower development, however moisture content, cell membrane stability and relative water content decreased towards full bloom. The involucral unfolded bract (IUB) stage had the highest total carbohydrate and total sugar contents, indicating higher physiological activity at this stage. The results indicate that IUB stage is the best harvest stage of torch ginger cut flowers and can be used as a suitable stage for further postharvest handling and storage studies.

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