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Commercial Potentials and Agronomic Status of *Etlingera elatior*, a Promising Horticulture Plant from Zingiberaceae Family

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ABSTRACT

Etlingera elatior or torch ginger is a species under the Zingiberaceae family, primarily distributed in tropical forests and humid, shady places. It is a coarse herb often growing in large colonies, characterized by elongated leafy stems up to 5 m height arising from underground rhizomes. It is known as *kantan* in Malaysia and *kecombrang* in Indonesia. The inflorescence is famous as an ingredient in Malay, Indonesian and Thai dishes. The extract from its stem is used to reduce swelling, and post-partum women use the leaves while the fruits are used to treat earache, diarrhea, coughs, and mouth sores. Because it has a beautiful appearance, it is also widely marketed as a promising floriculture and horticulture plant. Recently, the rising demand from customers for the versatility and durability of cut flowers has made farmers and the horticulture industry search for new cultivars. Thus, researchers are keen to generate cultivars with various colors, shapes, yields, and longer vase life. This could be done through different techniques such as intensive germplasm collection, hybridization programs, and plant biotechnology techniques. Towards achieving these aims, this review provides current insight on *E. elatior* from botanical, physiological growth, breeding, taxonomy, ecology, commercial potential, postharvest, medicinal, and food nutritional aspects.

INTRODUCTION

Genus *Etlingera* is found in Southeast Asia, South Asia, and the Pacific Islands, with Borneo and Papua New Guinea serving as epicenters of species richness. This genus has many plant species in various colors, sizes, and shapes (Poulsen, 2006). *Etlingera* plants have a lot of potential as cut flowers and ornamental plants. The plants themselves are beautiful, and their blossoms have a lot of decorative value. As of 2020, 129 *Etlingera* species were reported by Plants of the World (2020). Out of the 1587 species known globally, at least 25 genera and 650 species of *Etlingera* are found in Malaysia (Sirirugsa, 1999).

Malaysia is located in one of the floristic regions globally and recognized as one of the mega biodiversity countries diverse in exotic plant species. The export value of Malaysia's floriculture industry stands at US$ 119 million (RM 500 million) in 2017, which created 50,000 jobs opportunities. Moreover, Malaysia is ranked 8th in the world as an exporter of floriculture products. Thus, the expansion of the industry will increase the national income and strengthen the nation's economy (Nik Mohd Masdek, Ahmad, Mazwan Muhammad, Ahmad, & Abu Dardak, 2020). Interestingly, the government of Malaysia has targeted *E. elatior* as one of the potential herbs to be commercialized. In Malaysia, *E. elatior* has increased steeply from 905.07 metric

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tons in 2014 to 1,787.13 metric tons in 2018, where Pahang remains the primary producer of this plant (Department of Agriculture, 2018). In addition, the floriculture industry remains economically viable even during the economic downturn (Nik Mohd Masdek & Ab Halim, 2016). The varying shades of white, pink, and red colors of the bracts and flowers make this species an attractive ornamental plant. Due to the commercial value of the plant, in-depth biological studies have been performed by the researchers on ecology, habitat, growth habit, life cycle, postharvest, and development of new cultivars. Hence, this review highlights the insight of *E. elatior* from the botanist, ecologist, physiologist, and breeder perspectives that will help the industry in the future.

The Taxonomy of *Etlingera elatior*

Zingiberae, Hedychieae, Alpineae, and Globbeae are the four tribes that make up the monocotyledonous Zingiberaceae family (Larsen, Ibrahim, Khaw, & Saw, 1999). Plants of the Worlds Online, an online database developed by Royal Botanic Gardens at Kew, England, stated that this family consists of 58 accepted genera with 1587 accepted species. The systematics of this family, however, is far from complete. Zingiberaceae family is resilient to climate change with high adaptability towards different growing conditions. The Zingiberaceae plants are rhizomatous, perennial and they grow on the ground of tropical forests and humid, shady places (Hintze, 2013). Perennial herbaceous plants from the family of Zingiberaceae, are well-known for their ornamental, unique flavors, and medicinal values (Zahara, Hasanah, & Zaliand, 2018). Zahara, Hasanah, & Zaliand (2018) also specified that all or some parts of the plant from Zingiberaceae family are usually aromatic. That is why this ginger family is commonly found as primary ingredients in food, spices, medicines, dyes, and perfume (Kumar, Saxena, Singh, & Saxena, 2013). The majority of the Zingiberaceae family is widely used in traditional medicine in Malaysia (Ibrahim & Khamis, 2004; Sivasothy, Sulaiman, Ooi, Ibrahim, & Awang, 2013) and one of the well-known genera from Zingiberaceae family is Genus *Etlingera*.

The *Etlingera* species varies in size, ranging from less than a meter, and can reach 5-6 m. Even though traditionally used by a large segment of the community, the majority of the *Etlingera* species lack ornamental value due to their short vase-life span. The inflorescences of the *Etlingera* species, either with short stems or the inflorescence, appear above the surface, except for *E. elatior*, *E. venusta*, *E. corneri*, *E. hemispherica* and *E. pyramidosphera* which have long peduncles (Yeats, 2013).

E. elatior is one of the most commonly known species of *Etlingera*. Based on Yeats (2013), the genus *Etlingera* was first described by Paul Dietrich Giseke in 1792. This genus is also known as torch ginger or wax flower due to the striking resemblance of the inflorescence to a flaming torch. Cultivated throughout the tropics, *E. elatior* is native to Peninsular Malaysia and Indonesia (Larsen, Ibrahim, Khaw, & Saw, 1999).

Previously, *E. elatior* has been classified under few different scientific names: *Alpinia elatior* Jack; *Nicolaia elatior* (Jack) Horan.; *Phaeomeria magnifica* (Roscoe) K. Schum.; *Phaeomeria speciosa* (Blume) Koord. However, in later years, the genus is named after a German botanist Andreas Ernst Etlinger. Meanwhile, the species name is *elatior*, derived from the Latin word "taller" (Yeats, 2013) . On the other hand, many other *Etlingera* species have vast potential for development, such as Philippine endemic ginger, *E. dalican*, *E. pandanicarpa*, *E. fimbriobracteata* and *E. burtii* (Acma & Mendez, 2018). Below is the taxonomical classification of *E. elatior*:

Domain: Eukaryota
- Kingdom: Plantae
  - Phylum: Spermatophyta
    - Subphylum: Angiospermae
      - Class: Monocotyledonae
        - Order: Zingiberales
          - Family: Zingiberaceae
            - Genus: *Etlingera*
              - Species: *E. elatior*

Ecology, Habitat, and Botanical Description

E. elatior grows in open areas within its native range, at primary and secondary forest margins, and low elevation. It thrives in partial shade, humus-rich fertile, well-drained, moist soil and grows on acidic soils (Lim, 2012). The plant is known for its beautiful appearance of deep red-colored inflorescence and is surrounded by red bracts. Due to its high ability of colonization, its seeds can spread widely across forest grounds and unaltered forests, covering new habitats quickly. Moreover, this plant can grow in disturbed areas, forest edges, and roadsides (Mertz, 1999).

E. elatior is a fast-growing medicinal plant, and several researchers have described its morphology. It is a large plant with elongated leafy stems arising from underground rhizomes, which may reach up to 4 m in height (Chin, 1999; Choon & Ding, 2016). The leaves are lanceolate in shape, 38-85 cm in length, and 8-18 cm wide, with a short leaf stalk. The lower young leaf surface is often purplish and is glossy green above the surface. Moreover, the leaf tip is short with a narrow point, and the leaf base is broad with wavy edges (Saidin, 2000).

The inflorescence stalk is around 90 cm tall, with green sheaths and a flower head about 20-25 cm in diameter and about 10 cm long (Fig. 1). The head of inflorescences is pine-cone shaped, consisting of spirally overlapping flowers and leafless peduncles (Chin, 1999; Choon & Ding, 2016; Larsen, Ibrahim, Khaw, & Saw, 1999). Its inflorescence is considered a terminal flower that emerged from the same rhizome as the mother plant (Choon, Ding, Mahmud, & Shaari, 2016). The inflorescence has red, pink, or white bracts surrounding its base. The individual flowers of *E. elatior* with ornamental arrangements consist of fertile inner bracts surrounded by sterile outer bracts (Fig. 2) (Hintze, 2013). Commonly, the outer bracts are showy, prominent, broad, and spreading.

Fig. 1. *E. elatior* is a large plant elongated leafy stems arising from underground rhizomes which may reach up to 4 m height. It flowers all year round with average of 18-24 flowers bloom from single inflorescence

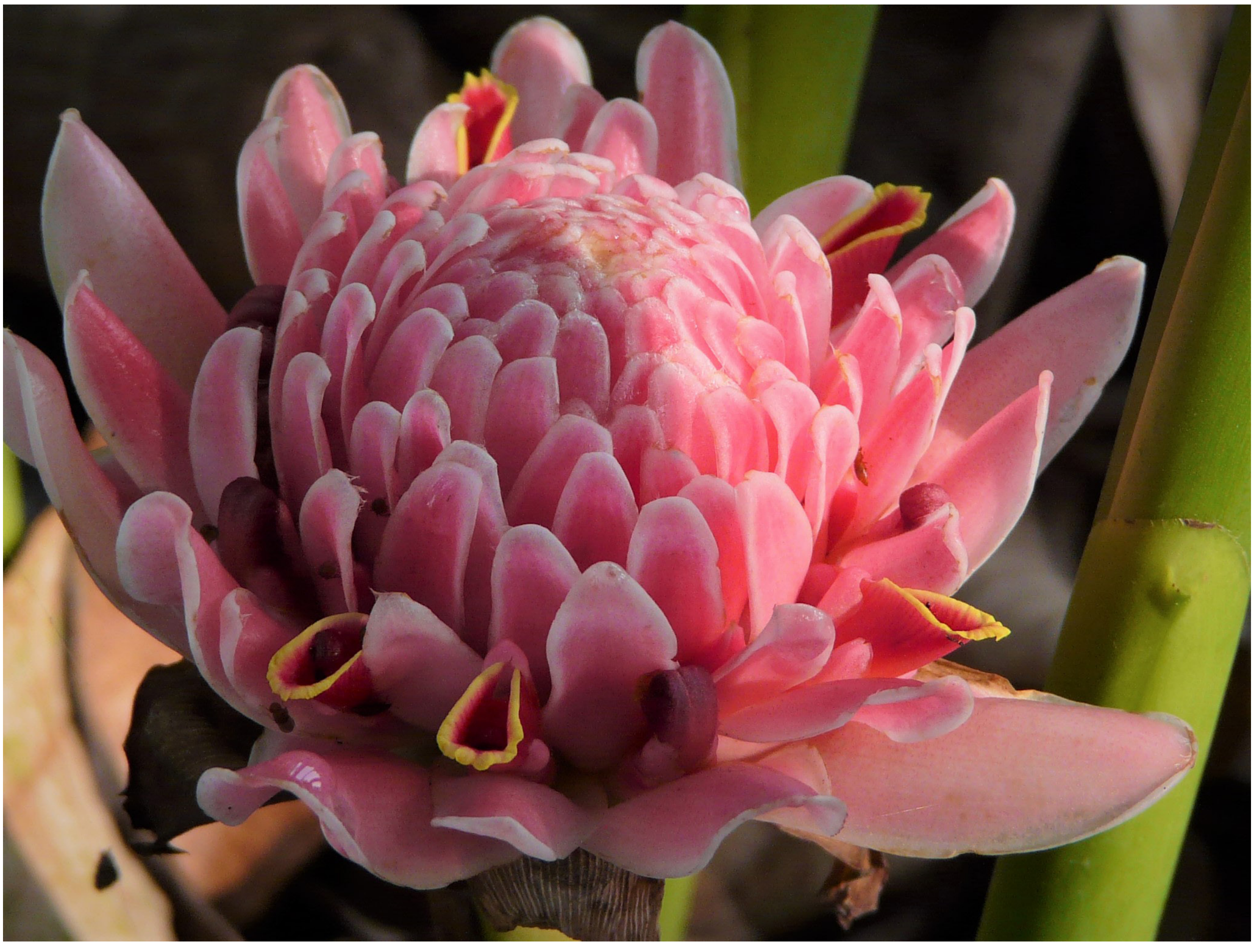

Fig. 2. The numerous flowers are close together and opening in a series of concentric circles. The individual true flowers of *E. elatior* with ornamental arrangements consist of fertile inner bracts and surrounded with sterile outer bracts

Meanwhile, the inner bracts are narrow, pinkish petals, labellum deep red with a narrow white or yellow margin (Henderson, 1954; Poulsen, 2006). The labellum or lip petal functions as a platform for small insects, which assist the pollination process (Aswani, Sabu, & Smisha, 2013). The flowers are densely packed and open in a sequence of concentric circles. Three small teeth are generally found on the tubular calyx. The corolla, tubular at the base with three petals, is frequently longer than the calyx.

Furthermore, the labellum is longer than the petals with infolded sides. Meanwhile, the staminodes are insignificant or non-existent, and the stamen stalk is short (Chin, 1999; Saidin, 2000).

Fruits are found in the inflorescence head, with around 2.5 cm length, smooth or hairy, round or capsule-shaped, containing black seeds (Aswani, Sabu, & Smisha, 2013). The fruits of this plant can be either green or red, with an abundance of seeds produced from a single inflorescence (Aswani, Sabu, & Smisha, 2013; Henderson, 1954). The fruit's head develops atop the robust scape as the fruits develop. Meanwhile, the large and fleshy syncarps are eaten and dispersed by squirrels (Larsen, Ibrahim, Khaw, & Saw, 1999).

Butterflies, Amegilla bees, stingless bees (*Tetragonula iridipennis*), and sunbirds (*Nectarinia asiatica* and *N. zeylonica)* have all been spotted pollinating this species (Aswani, Sabu, & Smisha, 2013; Specht, Yockteng, Almeida, Kirchoff, & Kress, 2012). Research from Aswani, Sabu, & Smisha (2013) showed that *N. asiatica*, *N. zeylonica* and *T. irridipennis* carried more pollen load on their body parts with frequent visits and a high transferring rate of pollen to the stigma.

Growth Habit and Life Cycle

There are four phases in the development and growth of the inflorescence, as described in detail by Choon, Ding, Mahmud, & Shaari (2016). They are peduncle elongation, inflorescence emergence, flowering, and finally, senescence. The inflorescence comprises floral and involucral bract in which a mature inflorescence has 20-25 layers of floral bracts and 3-4 layers of involucral bracts. A mature inflorescence consists of around 120 actual flowers. *E.elatior* begins flowering after 50 days of inflorescence development. The involucral bracts start to unfold layer by layer until the first ring of actual flower opens, found between the floral bracts. It roughly takes 155 days for the *E.elatior* to develop from rhizome until the inflorescence senescence (Choon & Ding, 2016).

E. elatior has two different growth stages, the vegetative and the reproductive stage. Choon & Ding (2016) reported that the vegetative stage of *E. elatior* takes about 22 days for the first leaf shoot to emerge from rhizome. In addition, during the leafy shoot growth, cigar leaf emerges one after another, unfold and lines alternatively on the leafy shoot. This plant remains in a vegetative stage for 70 days until inflorescence shoot emerges, where it switches into the reproductive stage once the floral stem emerges from the clump. It flowers all year round, with an average of 18-24 flowers blooms from a single inflorescence (Aswani, Sabu, & Smisha, 2013).

Floral development of *E. elatior* has been divided into four different stages by Choon & Ding (2017). The four developmental stages include (1) First stage: Tight or closed buds, occurring 35 days after stem emerged from the ground (Fig. 3); (2) Second stage: Six reflexing tips and unfolding of six pieces of involucralbracts, 45 days upon stem emergence from the ground (Fig. 4); (3) Third Stage: Complete unfolding of involucral bracts, 58 days after stem emergence from the ground and (4) Fourth stage: Full bloom, 60 days after stem emergence from the ground (Fig. 5).

According to Choon & Ding (2016), there are two *E. elatior* propagation methods, i.e., sexual method through seeds or by asexual method through rhizomes. For flowering, the period will start almost 12 months after planting the rhizome, and a year longer may be needed if seeds were used (Choon & Ding, 2016).

Commercial Potentials of *E. elatior*

Production of herbal plants in Malaysia for 2018 has reached a good value of RM 69 million (Department of Agriculture, 2018). According to Department of Agriculture (2018), the planting area for *E. elatior* alone has increased from 178.31 ha in 2014 to 356.18 ha in 2018. This statistic shows that the demand for *E. elatior* is gradually increasing year by year. The 2018 production in Malaysia has reached 1,787.13 metric tons, a steep increase from 905.07 metric tons in 2014. The average yield of this plant was reported at 6.06 mt/ha, with an overall production value of RM 9.83 million. Across Malaysia, the average retail price per stalk is RM 1.45. In Malaysia, the state of Pahang is the largest producer of *E. elatior* with 1,132.35 mt or 64% of national production. Moreover, *E. elatior* plantation in Pahang has increased from 178.31 ha in 2014 to 356.18 ha in 2017 (Department of Agriculture, 2018). Thus, this species needs to be propagated in large numbers and continuous improvement on certain plant characters.

Meanwhile, in recent years, demand for small pot plants has led to research for producing dwarf *E. elatior* for ornamental purposes (Muangkaewngam & Te-chato, 2018). Paclobutrazol was chosen as the best treatment for dwarfing the plant through inhibition of gibberellin synthesis. Paclobutrazol application was successful and has been used on chrysanthemum, orchid, and lily previously to get small plants by controlling the canopy character, which revealed no difference for stomatal opening and ability to photosynthesize (Muangkaewngam & Te-chato, 2018).

Traditional Uses

Traditional medicine has long been regarded as a cultural heritage in some countries. Most people in the countryside still depend on medicinal plants as the primary source for treatment and health care (Lianah, Krisantini, & Wegener, 2020). This plant has a long history of traditional commercial uses in Southeast Asia, where every part is valuable and can be used as material in preparing traditional medicines. In Malaysia and Southern Thailand, the young inflorescences are used as herbs and food ingredients. The extract from the stem is used to reduce swelling, while decoctions of the leaves are used to clean wounds. Post-partum women also use the leaves for bathing to remove body odor and wound cleaning. In Malaysia and Indonesia, the fruits are also used to treat earaches, diarrhea, coughs, mouth sores, and increase human appetite (Habsah et al., 2005; Ismail, Rafii, Mahmud, Hanafi, & Miah, 2019; Sabilu et al., 2017).

Other than that, *E. elatior* has also been effective in treating typhoid fever symptoms within one to two weeks. The pseudostems were blended and filtered to get the liquid and served to treat the typhoid fever patient. In Indonesia, it also serves as a traditional supplement drink (Sabilu et al., 2017).

In Southeast Asia, the inflorescence is famous as an ingredient in Malay, Nyonya, Indonesian and Thai dishes. It was reported by Lim (2012) that its flower petals and half-ripe fruiting shoots are widely used as an ingredient in traditional Malay cuisines such as Penang *laksa, nasi ulam, nasi kerabu* and mixed vegetables. The mature fruits of *E. elatior* are edible with a sour taste and preferably processed into candies. In North Sumatra, the flower buds and the ripe seed pods containing tiny black seeds are used for cooking fish dishes.

Fig. 3. Floral development of *E. elatior* has been divided into four different stages by Choon & Ding (2017). The picture shown above is a first stage or tight or closed buds, occurring 35 days after stem emerged from the ground

Fig. 4. Second stage of floral development consists of six reflexing tips and unfolding of six pieces of involcural bracts. Occur 45 days upon stem emergence from the ground. *E.elatior* begins flowering after 50 days of inflorescence development

Fig. 5. The head of inflorescence is pine-cone shaped, consisting of spirally overlapping flowers and leafless peduncle. Fourth stage of floral development or full bloom, 60 days after stem emergence from the ground

Development of New Cultivars through Breeding Programme

An attempt for genetic improvement from wild cultivars has emerged in early human civilization. One of the oldest reports of successful generation of the new cultivar was reported during the 355-417 AD in China, as mentioned in the poem of Tao Qian for Jiahua Chrysanthemum. Report of the first time using wild species as the ornamental plant goes back to the Chinese Xia Dynasty during 2100 BC-1600 BC (Heywood, 2003).

In response to the floriculturist demand, extensive research is being conducted, leading to more variation in the range of colours, shapes, yield, and extending vase-life. Screening for suitable breeding materials can improve the classification and utilization of the plant. For *Etlingera* species, *E. elatior* has been most commonly promoted as profitable horticultural and floricultural products. Numerous cultivars with high ornamental values have been registered worldwide, including cultivars of Thai White, Tropical (Hoult & Marcsik, 2000), Almost White, Bloody Mary, Frilly Pink, and Red Torch (Hintze, 2013). Other *Etlingera* species with great ornamental value which have been registered were *Etlingera helani* 'Black Tulip', *E. hemispherica* 'Alba-Red Tulip', *E. hemispherica* 'Flower Forest', *E. hemispherica* 'Olympic Torch', *E. venusta* "White Venusta" (Hintze, 2013; Marcsik, Hoult, Connelly, Lasker, & Ford, 2003).

Attempt to create a hybrid was performed to broaden its genetic variation, and it remains a challenging process. The selection of different agro-morphological characters like colors and yield was conducted by Marcsik, Hoult, Connelly, Lasker, & Ford (2003). Only 9 from 89 crossing attempts were able to produce seed pods. However, only 7 out of 9 putative crossings were generated, with only half reaching the seedling stage. Only 40% of seedlings survived up to field trial, and three new cultivars with improved vase life ranging from 12 to 16 days were generated and commercialized by the Australian floriculturist (Marcsik, Hoult, Connelly, Lasker, & Ford, 2003).

However, as a cut-flower, *Etlingera* lacks a good vase-life. *E. elatior* 'Thai White' cultivar has a vase life of 6-10 days, while 'Tropicas' cultivar has a short vase-life with 3-5 days, limiting its market potential (Hoult & Marcsik, 2000). Researchers have started an intense hybridization program to extend the vase-life of *Etlingera* varieties to solve this shortcoming. However, only one cross-hybridization attempt from ten different combinations involving four parents resulted in a successful cross (Marcsik, Hoult, Connelly, Lasker, & Ford, 2003).

de Araújo et al. (2018) proposed that cultivar IAC 41 and IAC Camburi were chosen as the suitable cultivars for the breeding program based on their flower appearance and vase life where 8 and 5 days were observed, respectively. On a positive note, application of 1-Methylcyclopropene (1-MCP) and Florissant® were reported to be successful in prolonging the durability of the blooming inflorescence up to five days (Bayogan & Gratuito, 2015; Unemoto, de Faria, Takahashi, de Assis, & Lone, 2011).

Due to the inflorescence structure, the crossing process of the *Etlingera* and its analysis is challenging to perform. Thus, a more effective means of identifying individual flowers which have been pollinated is needed. Furthermore, a more thorough understanding of stigma receptivity and pollen viability would be beneficial (Marcsik, Hoult, Connelly, Lasker, & Ford, 2003). The difficulty of crossing is proven with low fruit set due to the position of the individual flowers in inflorescence, identifying crossed and pollinated flowers (Aswani, Sabu, & Smisha, 2013). Interestingly, artificial cross-pollination showed a better fruit set than open pollination, with adequate pollination observed if some external agents are used. Stigmas under natural pollination were screened, and only 30% of the stigmas observed have attached pollen grains (Aswani, Sabu, & Smisha, 2013).

Continuous improvement is needed for long-term viability, especially for the cut flower market. Floriculturists have different demands, different harvesting times based on the demand of floral design and vase life. Harvesting stages are divided into three stages: closed (base bracts closed), semi-open (base bracts beginning to open and central part of the inflorescence visible), or open (base bracts completely open and flower opening) (de Araújo et al., 2018). Closed buds, known as "candlesticks," were harvested early for export (Marcsik, Hoult, Connelly, Lasker, & Ford, 2003). Additionally, inflorescences mass that can weigh up to a kilogram makes the postharvest process tedious and laborious, leads to the high price for the consumers (Gonçalves, Colombo, & Castro, 2014).

For cut flower plant, *E. elatior* has the shortcoming of several agro-morphological characters where the durability of the flower cut is just an average of six days of vase-life, heavy flower stems, and low yield of flowers (Choon & Ding, 2016). Some of the cultivars show good yields, for example cultivar of Tropicas can produce 150-200 stems per plant, Thai White can yield 100-120 stems/plant, and Ironstone produced 50 stems/plant (Hoult & Marcsik, 2000). In addition, IAC 41 and the cultivar IAC Camburi produced 33.25 and 41.20 flower stems/plant, respectively (de Araújo et al., 2018).

Post-Harvest

To determine *E. elatior* suitability as cut flower with great acceptability for export industry, the researchers developed a grading system based on floriculturist standard. The vase life grading system by Marcsik, Hoult, Connelly, Lasker, & Ford (2003) suggested that *E. elatior* inflorescences at four developmental stages can be used as a standard to help farmers with the export market. The stages are (1) tight bud (TB: closed and pigmented bud, 35 days after emergence above ground), (2) six reflexing tips (SRT: six pieces of involucral bracts unfolded, 45 days after emergence), (3) all involucral bracts unfolded (IBU: 58 days after emergence above ground), and (4) full bloom (FB: the first ring of actual flowers opened, 60 days after emergence above ground) (Choon & Ding, 2017). Postharvest durability (PHD) or period acceptable floricultural plants for consumers to use varies between varieties in different countries. On average, Australia's cultivars varied between 3-10 days, Malaysia is 6 days, Latin Americas IAC 41 is 8 days, while both IAC Prumirim and IAC Camburi are 5 days (Choon, Ding, Mahmud, & Shaari, 2016; de Araújo et al., 2018; Marcsik, Hoult, Connelly, Lasker, & Ford, 2003).

Comprehensive studies were performed to get an insight into the nature of the flower blooming and the mechanical aspect of the inflorescence growth. The previous report has shown that the transfer of photo-assimilates from the vegetative stem for flower stem development occurs once it switches to the reproductive system (Choon & Ding, 2017). For a cut flower, the ability of the stem to stand without any support is related to its mechanical strength, which involves rigidity and strength of the stem. Choon & Ding (2017) stated bract's cell wall metabolism relationship between inflorescence opening and peduncle strength where degradation of cellulose in involucral and floral bracts occurred during inflorescence opening.

A strong peduncle is necessary to support heavy and oversized flowers at the flower blooming stage. Anatomy studies performed by Choon & Ding (2017) revealed that the upper and lower part of the peduncle shared identical characters throughout the growing period. Higher mechanical support is characterized with two essential events, lignification of vascular bundle and cellulase activity. The anatomical studies revealed that vascular bundles were abundant in the peduncle. Vascular bundles involved in the translocation process were found in the upper and lower part of the peduncle throughout the growing period. The cellulase activity varies during the closed buds, and involucral bracts unfolded stage; the cellulase activities were high and lower cellulase activity was observed during flower booming, which leads to the shortage of cellulose content in involucral bract. Before the complete bloom stage, substantial turgor pressure with the cell wall thickening occurred in the peduncle. In addition, a surge of cellulose content and mobilization of lignin to the vascular bundle happened. Those lignified vascular functions support the increment of water and carbohydrates from the mother plant to maintain the pressure turgor for the flower blooming.

During the flower blooming stage, two enzymes were involved: cellulase and pectin methylesterase. Both cellulose and pectin involve loosening the cell walls, cause the influx of water and cell expansion before the flower blooming stage. It is a stage where water uptake occurs at the highest rate (Bayogan & Gratuito, 2015). Accumulation of soluble sugars and starch grains occurred before flower blooming. The concentration of both compounds decreased once the flower starts to open sequentially. This led to the changes of color to dark and drying of external bracts and the upper part of the peduncle (de Araújo et al., 2018).

Medicinal and Food Nutritional Values of *E. elatior*

Many researchers have reported on the medicinal values of *E. elatior*. Flavonoids, terpenoids, saponins, and tannins are essential compounds successfully isolated from *E. elatior* inflorescences. Anthocyanin is the highly detected flavonoid compound in inflorescence (Anzian, Rashidah, Nazamid, Che Wan Sapawi, & Meor Hussin, 2017; Chan, Lim, & Wong, 2011). Study from Juwita, Puspitasari, & Levita (2018) showed that anthocyanin in the inflorescence is able to inhibit the ovarian cancer lines through cytotoxic activity. In addition, the ethanolic extract of *E. elatior* inflorescence has a vigorous antioxidant activity and could be used as a treatment for lead poisoning (Chan et al., 2008; Habsah et al., 2005; Haleagrahara, Jackie, Chakravarthi, Rao, & Pasupathi, 2010; Jackie, Haleagrahara, & Chakravarthi, 2011). Moreover, the *E. elatior* flower extracts were also proved to repress Human breast carcinoma tumor cell lines of MCF-7 and MDA-MB-231 (Ghasemzadeh, Jaafar, Rahmat, & Ashkani, 2015). Plus, Wong, Sivasothy, Boey, Osman, & Sulaiman (2010) has successfully extracted essential oil from leaves, roots and rhizomes of *E. elatior*.

There is always a demand for marketable and high nutritional products in the food and health supplement sectors (Kumari, Ujala, & Bhargava, 2021). The nutritional properties of the inflorescence are highly valued. The inflorescence contains a high level of protein, crude lipid, and fiber, with the contents on dry weight basis is 12.6%, 18.2%, and 17.6%, respectively. Furthermore, the inflorescence contains essential minerals like potassium, calcium, magnesium, phosphorus, iron, zinc, sodium, and boron. These elements are necessary for human functioning, both intracellular and extracellular (Wijekoon, Karim, & Bhat, 2011). The presence of anthocyanin in a flower makes it more resistant to heat during food processing or pasteurization, reducing the flower's susceptibility to degradation as the temperature rises. It maintains the quality of the food products and makes them more marketable for export purposes.

CONCLUSION

This section highlights different perspectives to increase the value of this ornamental plant. In Malaysia, the economic potential of this plant remains promising with *E. elatior's* planting area alone increased from 178.31 ha in 2014 to 356.18 ha in 2018. This proves that the demand for *E. elatior* is gradually increasing year by year. The data by the Malaysian government agencies also showed the increasing trend of the bud's price, that are used as a spice in culinary. From a floriculturist perspective, customers' rising demand for versatility, durability, and low cost has cut flower markets constantly search for new options in diversifying the product. Incentives by the government for the floriculture industry are suggested options in strengthening the competitiveness of the industry. In the meantime, further research is necessary to understand the market's dynamic by taking into account the response by the farmers and industry for diversification of the export market.

Thus, to meet the demand of the cut flower market, floriculturists need to create new *E. elatior* variants in range of colours, shapes, yield and extended vase-life. To date, researchers are implementing intensive hybridization programs to improve the quality of *E. elatior*. However, low success rates have been reported, with only one successful attempt of cross-hybridization from ten different combinations. Additionally, the national germplasm and national database portal for collections need to be constructed to select traits that can be used in the future to generate more new cultivars.

In recent years, research on the vase life of the flowers gains attention among scientists. Longer vase-life and understanding the postharvest process to maintain the quality of the cut flowers are necessary. The dynamic response of the cut flower to various postharvest treatments is something that can be further explored. Even though the attempt to prolong the flower blooming using one of the most used postharvest chemicals, 1-MCP has failed, there are plenty of other options to be investigated. Therefore, it is suggested to use physical chemicals and gaseous treatments in reducing senescence.

Another prospect is for landscape development using *E. elatior* as the main attraction. Naturally, it attracts its pollinators with no serious problems with pests and low-cost maintenance. On the other side, the garden in the house is a new trend in Malaysia where researchers can grab an advantage from it. One of those is to get plants suitable for indoor conditions as Malaysians move towards modern interior decorations. The successful inducing dwarfism of *E. elatior* was the starting point to produce cultivar suitable for indoor plants. Moreover, the flower is used for floral arrangement during festive and wedding occasions.

Another prospect is new cultivars development and genetic improvement through biotechnology. Biotechnological techniques that can be manipulated are somaclonal variation through plant tissue culture, genetic engineering, and *in vitro* mutation. Moreover, *E. elatior* is a valuable plant species where every part, including young inflorescences, stem, leaves, and fruit, has its nutritional value. It would be worth exploring the possibility of improvising and producing new food products based on the nutritional value of the plant. In conclusion, continuous genetic improvement is suggested to generate premium cultivars for planting materials with higher quality flower appearance, vase-life, and medicinal value.

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