



## Growth and development of inflorescences and fruit of *Areca catechu* L. (Dwarf) in Thailand

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### ABSTRACT

*Areca catechu* L. (dwarf-type palm) was studied to determine the morphology of the inflorescences, the growth and development of the flower and fruit, and the appropriate flower stage for pollination. Results indicated that the growth and development of male and female flowers were divided into three phases. During the first phase, the male flowers (green mixed with white) fell daily after the inflorescence emerged, while the female flowers had white sepals mixed with green and a prominent fragrance. In the second phase, the male flowers fell continuously, and the female flowers enlarged. In the third phase, the male flowers fell off the flower stalk, and the female flowers bloomed as the ideal period for pollination. At 14 days after pollination, small green fruit appeared in the inflorescence. The fruit kernel was fully formed at 98 days, with full fruit development at 182 days. The husk of the *A. catechu* fruit started to turn yellow at 196 days, with the fruit becoming fully ripe at 280 days.

**Keywords:** *Areca catechu* L.(Dwarf), development, inflorescence, morphology, pollination

### Introduction

*Areca catechu* L., commonly known as the betel nut palm, is a member of the family Arecaceae (Heatubun *et al.*, 2012), and is widely distributed throughout South and Southeast Asia (Peng *et al.*, 2015). The genus *Areca* exhibits high species diversity in the Sunda Region, the Philippines, and East Malaysia (Heatubun *et al.*, 2012), with the first species recognized in the genus described from East Malaysia. The genus *Areca* and the first species, *A. catechu*, were listed by Linnaeus in his Species Plantarum in 1753 based on plate IV of the study by Rumphius (1741). The fruit of the betel nut has been chewed as a traditional herbal medicine for more than 2000 years in South Asian countries (Senthil *et al.*, 2012; Peng *et al.*, 2015), with 400 to 600 million people now chewing betel nuts in tropical and subtropical countries (Zhang *et al.*, 2022).

The seeds of *Areca catechu* are widely used in clinical practice in China, India, and other countries across South and Southeast Asia. Phytochemical investigations demonstrated that *A. catechu* contains several major classes of bioactive compounds, including alkaloids, tannins, flavonoids, triterpenes,

steroids, and fatty acids. These compounds exhibit a broad spectrum of pharmacological activities, including antiparasitic, antidepressant, antifatigue, antioxidant, antibacterial, antifungal, antihypertensive, anti-inflammatory, analgesic, and antiallergic effects. They have also been reported to enhance digestive function, inhibit platelet aggregation, and exert regulatory effects on blood glucose and lipid levels (Peng *et al.*, 2015). In Thailand, the use of *A. catechu* is deeply embedded in local culture, traditions, and daily life. Chewing betel nut has long been a customary practice among Thai people, with the crop cultivated commercially on an industrial scale (Taengplub *et al.*, 2019). *A. catechu* can be classified into three types according to leaf morphology, height characteristics, and reproductive traits, as tall-type palms (trees higher than 12-30 m), semi-tall type palms (trees 5-11 m high), and dwarf-type palms (trees 4-5 m high) (Naidu, 1963). Growing tall areca palms commercially is popular with a high yield; however, harvesting fruit from tall-type palms is labor-intensive and poses considerable practical and safety challenges due to the height of the trees. This study conducted a preliminary investigation of dwarf-type *A. catechu*

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cultivars, laying the groundwork for future breeding programs to develop high-yielding varieties with enhanced accessibility and greater efficiency in fruit harvesting.

## **Materials and Methods**

### **Plant materials**

Ten *A. catechu* (Dwarf) trees were selected from the Trang Horticultural Research Center, Mai Fat Subdistrict, Sikao District, Trang Province, Thailand. The trees were 25 years old, had straight and strong trunks, were free from diseases and insects, had a cylindrical shape with plant height 4-5 m, girth 34-58 cm, frequent nodes, internode length of 1-4 cm, short leaves, short spikes, large stalks, and continuous yield.

### **Morphological characteristics of inflorescences**

Flowering in *A. catechu* (Dwarf) started in December 2023. The composition and characteristics of the inflorescences (male and female flowers) were counted and described, with images recorded.

### **Flower growth and development**

Daily observations were made between December 2023 and April 2024 when *A. catechu* (Dwarf) flowering started. Seven inflorescences (complete male and female flowers) were tagged with codes (1, 2, 3, 4, 5, 6, and 7). The first day of inflorescence was noted, and the growth characteristics of the male and female flowers were documented every 7 days until the female flowers bloomed. The average number of male flowers/rachilla, length of rachilla (cm), days taken for opening of the first male flower, number of male flowers bloom/day/rachilla, days taken for falling of male flowers from the inflorescence (day), number of female flowers/inflorescence, length of the female flowers at day one and 25 days (cm), and days taken for opening of the first female flower were recorded. Thirty rachilla/inflorescence of males and thirty flowers/inflorescence of females were used for each treatment.

### **Pollination**

Pollen was manually transferred to the stigmas of female flowers using a fine paintbrush between 08:30 am and 10:00 am from December 2023 to April 2024. Immediately after pollination, each inflorescence or fruit cluster was enclosed with an insect-proof net (mesh size 32) to prevent cross-pollination and external contamination, and the netting was removed seven days after pollination. The development of the flower into fruit was systematically monitored and recorded in terms of days after pollination (DAP). Data collection included the percentage of successful pollinations per inflorescence, as well as mean fruit width and mean fruit length measured at 7, 14, and 21 DAP.

$$\% \text{ pollination} = \frac{\text{number of female flowers after pollination}}{\text{total of number female flowers before pollination}} \times 100$$

### **Fruit growth and development**

After pollination, ten inflorescences were used to observe the fruit (shape, size, and color), with growth characteristics observed up to ripe fruit yield. Fruit growth was recorded as average fruit width, length, girth, total fruit weight, fresh fruit weight, and fresh husk weight every 14 days after the first day of pollination using a ruler and calipers, with three fruit/inflorescences used for each treatment.

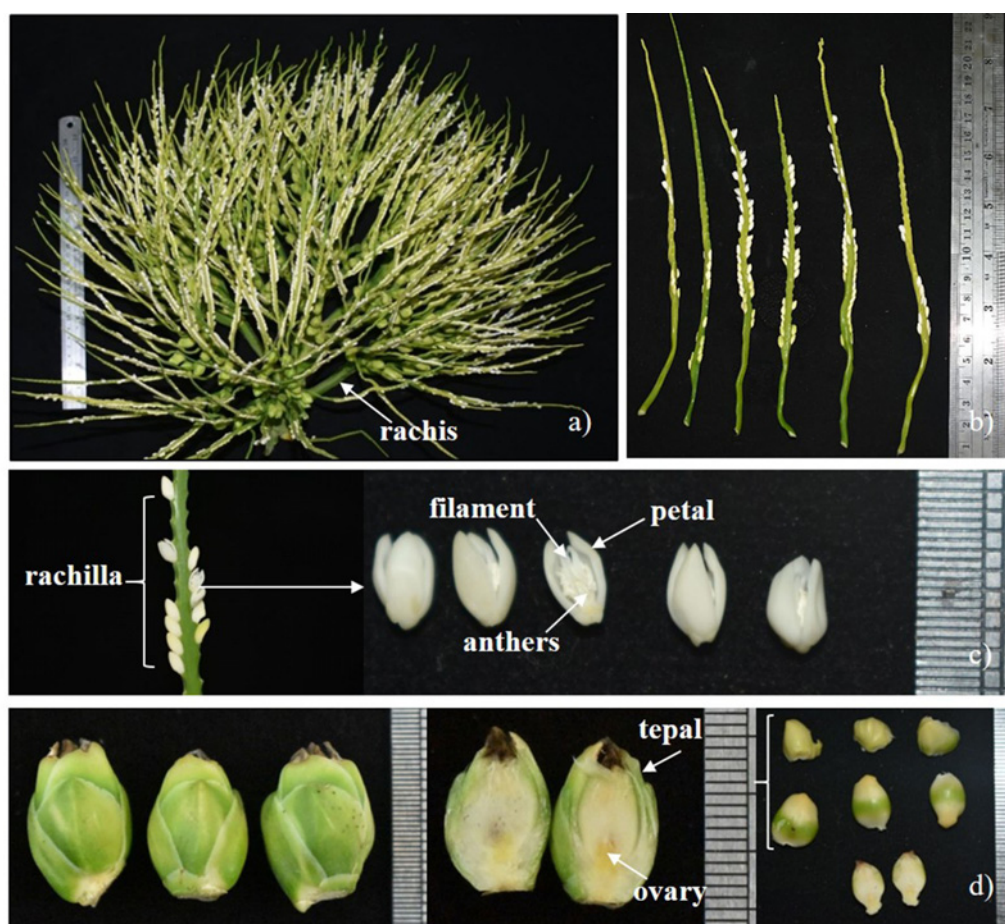
### **Statistical analysis**

The growth and development of the fruit were analyzed by a completely randomized design (CRD) experiment, with statistical significance assessed using ANOVA and differences between the mean values identified using Duncan's multiple range test (DMRT).

## **Results and Discussion**

### **Morphological characteristics of the inflorescences**

*A. catechu* (Dwarf) is a unisexual flower containing either male (staminate) or female (pistillate) flowers (Fig. 1a). A large inflorescence occurs at the base of the leaf sheath. The base of the inflorescence peduncle is large and the tip is small. Each inflorescence is composed of several rachis and rachilla. The rachis is the main axis of the inflorescence. Each rachis has male and female flowers while the rachilla is the axis within each spikelet (15.5-19.5 cm) that bears the florets (Fig. 1b). Similar results were reported by Yudaputra *et al.*, (2016), who studied the rachilla of *A. catechu* in Bogor Botanic Gardens, Indonesia. Each rachilla has many sessile, creamy-white male flowers, with three small sepals and three large stiff lanceolate petals. The fragrant flowers are 0.4-0.5 cm long and arranged in two rows on the rachilla. The sepals are 0.1 cm long and the petals are 0.3-0.4 cm in length with acute valvate tips, situated next to the six stamens (Fig. 1c), concurring with Bavappa (1966). The female flowers (1.2-1.5 cm long) are sessile, without bracts, with three sepals (cordate), three petals (like the sepals), six staminodes (connate), few styles, and three stigmas (short) (Fig. 1d). Similar results were reported by Blatter (1926) and Murthy and Bavappa (1960). The general characteristics of the inflorescence of *A. catechu* (Dwarf) are consistent with *A. catechu* (tall and semi-tall type). However, the size of the inflorescence, including the rachis and the rachilla of *A. catechu*, is larger than *A. catechu* (Dwarf) (Peng *et al.*, 2015) due to differences in type and genetic composition.



**Fig. 1. Morphology of the inflorescence of *A. catechu* (Dwarf): a) inflorescence, b) rachilla, c) male flowers and d) female flowers.**

#### **Growth and development of male and female flowers**

When the spathe cracks, the male flowers emit a fragrant smell. The male and female flowers of *A. catechu* (Dwarf) can be divided into three phases according to their growth and development characteristics (Table 1). The male flower is the first to open in the inflorescence from the tip of the rachilla and then down to the base (Fig. 2a). Similar results were recorded by Bavappa and Ramachander (1967). After the male flowers blossom, pollen is released and falls to the ground within one day. The number of male or staminate flowers averaged 41.63 flowers/rachilla, and the average length of the rachilla was 14.22 cm. The number of male flower blossoms was 6-10 flowers/rachilla/day. All the male flowers fell off the flower stalk between 15 and 18 days (average 16.57 days) (Table 2). Characteristics of the male flowers are shown in Table 1 and Fig. 2c. This period differed from *A. catechu* in Bogor Botanic Gardens, which was 10-13 days (Yudaputra *et al.*, 2016). Murthy and Bavappa (1960) determined the male Areca nut phase as the time between the opening of the first male flower and the last male flower in a spadix at 25-46 days, with a mean time of 31 days. The blooming characteristics of the first male flowers

can be divided into three phases, as shown in Fig. 2f. These results differed from Waghmare *et al.* (2022), who recorded the number of male flowers per rachis of Areca nut (*Areca catechu* L.) cv. Shrivardhan and Mangala at 75.99 and 70.90, respectively. The differences were due to Areca nut type, the genetic makeup of varieties, and the climatic conditions of the region (Rajesh and Ananda, 2019). The female flowers numbered 163-280 flowers/inflorescences, with lengths 0.83 and 1.13 cm at 1 and 25 days, respectively. The female flowers for all the inflorescences opened between 24 and 30 days (average 25.29 days) or 8.72 days after the completion of the male phase (Table 3). Characteristics of the female flowers are shown in Table 1 and Fig. 2e. The period for proper fertilization was consistent with Waghmare *et al.*, (2022). This result differed from Murthy and Bavappa (1960), who found female flowers of *A. catechu* at 3 days (84%) after the end of the male phase. The female phase normally presented at 3-10 days, with maximum receptivity of the stigma on the day of flower opening under Coimbatore condition (Thangarajan, 1985). The number and characteristics of the male and female flowers of betel nuts differ depending on type, growing areas, climatic conditions, and maintenance.

**Table 1. Male and female phases of *A. catechu* (Dwarf).**

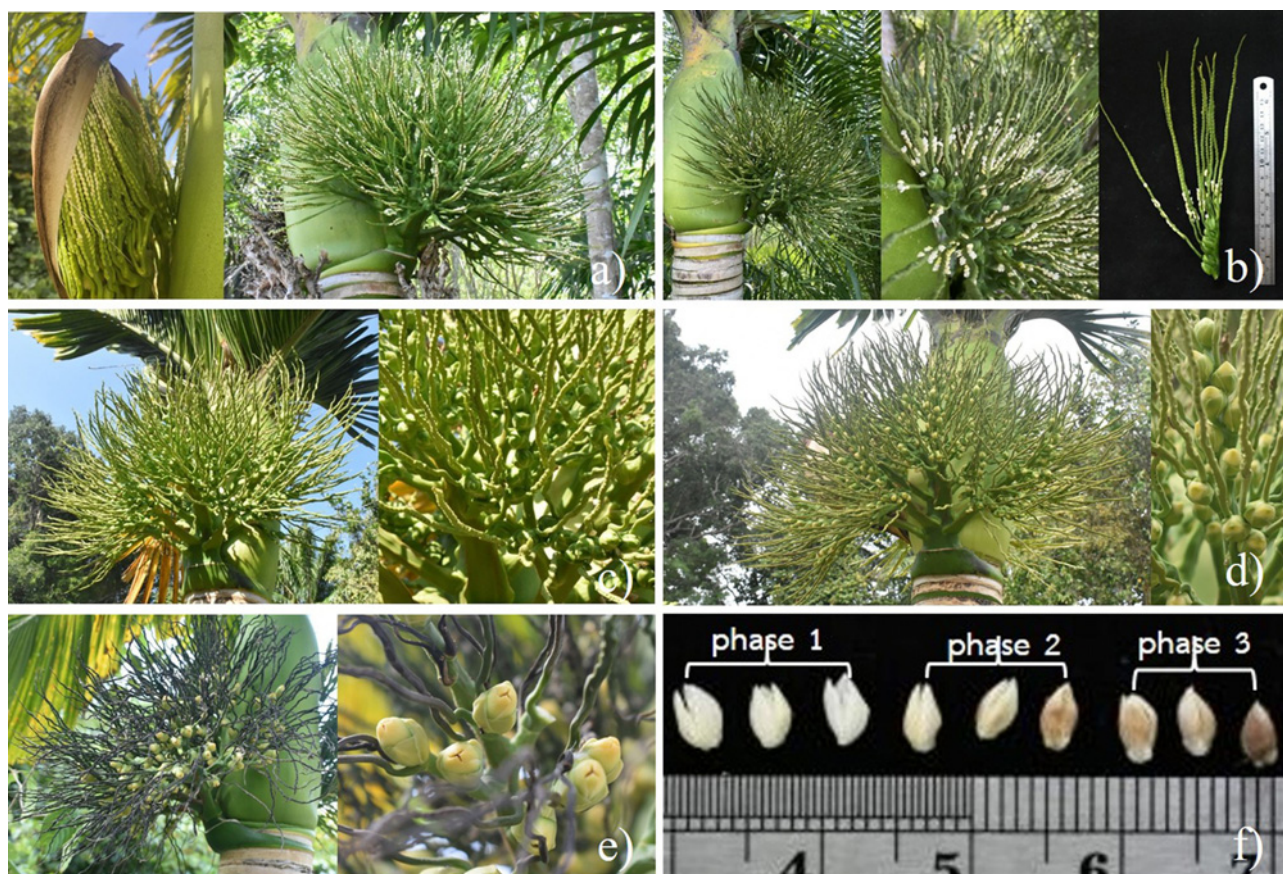
| Flowering phase           | Characteristicsof the male and female flowers                                                                                                                                                                                                                                                                                                                                                                                                                       |
|---------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| First phase (1-14 days)   | The inflorescence spathe start to fall off the inflorescence. Male flowers number 24-63 flowers/rachilla. The flowers are green mixed with white. The male flowers start to fall off one day after the inflorescence emerges and then fall off daily at 5-6 flowers/day/flower stalk. The flowers that fall off have opened and are yellowish brown. Female flowers are flower buds with white sepals mixed with green and have a slight fragrance (Fig. 2a and b). |
| Second phase (15-24 days) | Male flowers fall off every day until the rachilla is bare. Female flowers are enlarged, the flower buds begin flowering, with white sepals mixed with green, and have a slight fragrance. In the flower buds, the calyx enlarges, and the color changes to yellowish green with a faint fragrance (Fig. 2c and d).                                                                                                                                                 |
| Third phase (25-37 days)  | Male flowers fall off the flower stalk. Female flowers bloom and the light-yellow calyx enlarges. The yellow flowers bloom at 2-3 mm (Fig. 2e).                                                                                                                                                                                                                                                                                                                     |

**Table 2. The number, length of rachilla, days taken for opening of first male flower, number of male flowers opened, and age of falling flower inflorescences of male flowers of *A. catechu* (Dwarf).**

| Inflorescences | Number of male flowers/rachilla | Length of rachilla (cm) | Days to first male flower opening (day) | Number of male flowers opened Day <sup>-1</sup> Rachilla <sup>-1</sup> | Time of male flower abscission (days) |
|----------------|---------------------------------|-------------------------|-----------------------------------------|------------------------------------------------------------------------|---------------------------------------|
| 1              | 63.60                           | 17.03                   | 1.00                                    | 7.90                                                                   | 18.00                                 |
| 2              | 47.20                           | 12.75                   | 1.00                                    | 4.90                                                                   | 17.00                                 |
| 3              | 39.30                           | 16.95                   | 1.00                                    | 3.80                                                                   | 15.00                                 |
| 4              | 34.70                           | 12.4                    | 1.00                                    | 6.50                                                                   | 18.00                                 |
| 5              | 35.80                           | 12.55                   | 1.00                                    | 7.50                                                                   | 16.00                                 |
| 6              | 46.20                           | 11.9                    | 1.00                                    | 6.00                                                                   | 17.00                                 |
| 7              | 24.63                           | 16.00                   | 1.00                                    | 10.57                                                                  | 15.00                                 |
| Mean ± SE      | 41.63 ± 4.66                    | 14.22 ± 0.88            | 1.00 ± 0.00                             | 6.74 ± 0.83                                                            | 16.57 ± 1.27                          |

**Table 3. The number, length and age of the first flowering of female flowers of *A. catechu* (Dwarf).**

| Inflorescences | Number of female flowers/inflorescences | Length of female flowers at day one (cm) | Length of female flowers at 25 days (cm) | Days to first female flower opening (days) |
|----------------|-----------------------------------------|------------------------------------------|------------------------------------------|--------------------------------------------|
| 1              | 280                                     | 0.86                                     | 0.94                                     | 30.00                                      |
| 2              | 255                                     | 0.94                                     | 1.22                                     | 25.00                                      |
| 3              | 178                                     | 0.79                                     | 1.19                                     | 24.00                                      |
| 4              | 257                                     | 0.51                                     | 0.92                                     | 24.00                                      |
| 5              | 229                                     | 0.80                                     | 1.35                                     | 26.00                                      |
| 6              | 163                                     | 1.00                                     | 1.23                                     | 25.00                                      |
| 7              | 158                                     | 0.94                                     | 1.03                                     | 24.00                                      |
| Mean ± SE      | 217.14 ± 18.95                          | 0.83 ± 0.06                              | 1.13 ± 0.06                              | 25.29 ± 0.87                               |



**Fig 2.** Growth period of *A. catechu* (Dwarf) flowers: a) first phase (1-7 days), b) first phase (8-14 days), c) second phase (15-21 days), d) second phase (22-28 days), e) third phase (29-35 days) and f) the staminate flower (phases 1-3).

### Pollination

Pollination of *A. catechu* (Dwarf) flowers occurred after the female flowers opened at 25-30 days, with pollen from the anthers transferred to the stigma. Seven days after pollination, the female flower tips closed and turned brown (Fig. 3a and b). The number of female flowers falling from the inflorescences was low. The width of the female flowers was 1.12 cm, with length 1.58 cm. The female flowers began to fall in large numbers at 14 days. The flowers developed into fruit at 14 days (1.23 cm wide, 1.75 cm long), with increasing size at 21 days (1.32 cm wide, 1.86 cm long) (Table 4 and Fig. 3). Betel fruit are small and green with a smooth fruit husk. The

percentage of fruiting 7 days after pollination was 88.60%, and this decreased with increasing fruit age at 14 days (47.05%) and 21 days (42.31%) (Table 4). The number of fruits remained constant after 21 days. Areca nut cv. Shrivardhan and Mangala had fruiting percentages at 61.99 and 67.00, respectively (Waghmare *et al.*, 2022). Similar results were recorded by Rajesh and Ananda (2019) and Archana (2017) in Areca nut. The percentage of fruit set after pollination depends on microclimatic factors such as light intensity, temperature, humidity, wind speed, soil pH, soil moisture, and rainfall (mm) (Yudaputra *et al.*, 2016).

**Table 4.** Growth and development of *A. catechu* (Dwarf) fruit after pollination.

| Inflorescences | Age 7 days            |                        | % Fruiting | Age 14 days           |                        | % Fruiting | Age 21days            |                        | % Fruiting |
|----------------|-----------------------|------------------------|------------|-----------------------|------------------------|------------|-----------------------|------------------------|------------|
|                | Width of flowers (cm) | Length of flowers (cm) |            | Width of flowers (cm) | Length of flowers (cm) |            | Width of flowers (cm) | Length of flowers (cm) |            |
| 1              | 1.05                  | 1.86                   | 88.46      | 1.14                  | 2.00                   | 55.56      | 1.15                  | 2.01                   | 44.44      |
| 2              | 0.99                  | 1.34                   | 96.67      | 1.08                  | 1.44                   | 75.00      | 1.18                  | 1.53                   | 62.5       |
| 3              | 1.17                  | 1.57                   | 94.74      | 1.27                  | 1.80                   | 31.58      | 1.36                  | 1.88                   | 26.32      |
| 4              | 1.21                  | 1.83                   | 98.29      | 1.25                  | 1.91                   | 63.94      | 1.45                  | 2.11                   | 45.45      |
| 5              | 1.15                  | 1.46                   | 96.25      | 1.35                  | 1.83                   | 66.67      | 1.44                  | 1.96                   | 66.67      |
| 6              | 1.15                  | 1.53                   | 81.6       | 1.18                  | 1.58                   | 35.56      | 0.89                  | 1.16                   | 35.56      |
| 7              | 1.08                  | 1.29                   | 66.66      | 1.29                  | 1.55                   | 25.00      | 1.38                  | 1.66                   | 25.00      |
| 8              | 1.08                  | 1.74                   | 100        | 1.13                  | 1.79                   | 41.18      | 1.12                  | 1.78                   | 41.18      |
| 9              | 1.11                  | 1.30                   | 83.33      | 1.42                  | 2.02                   | 43.00      | 1.55                  | 2.18                   | 43.00      |
| 10             | 1.25                  | 1.70                   | 80.00      | 1.28                  | 1.73                   | 33.00      | 1.37                  | 1.83                   | 33.00      |
| Mean±SE        | 1.12±0.02             | 1.58±0.06              | 88.60      | 1.23±0.03             | 1.76±0.05              | 47.05      | 1.32±0.04             | 1.86±0.06              | 42.31E     |



**Fig. 3.** *A. catechu* (Dwarf) flower development into fruit after pollination: a-b) 7 days, c-d) 14 days and e-f) 21 days.

### Fruit growth and development

The growth and development of *A. catechu* (Dwarf) fruit was reported after pollination at 14 to 252 days. At 14 days, the small fruit was green and contained within the calyx. The average width and length of the fruit were 1.10 cm and 1.49 cm, respectively (Table 5 and Fig.4). *A. catechu* fruit growth and development continued with age. *A. catechu* fruit began to develop fresh fruit kernels at 98 days, had an average fresh fruit weight of 1.55 g, an average fresh fruit kernel weight of 0.22 g, and an average fresh husk weight of 1.31 g (Table 5 and Figs. 4 and 5). At 140 to 168 days, the average fresh fruit weight

was 24.25, 25.92, and 32.50 g, respectively, and the average fresh fruit pulp weight was 7.68, 7.73, and 10.26 g, respectively. The fresh fruit kernel attained full fruit development with a dry and slightly hard fruit texture at 182 days, with the exocarp outer layer becoming dark green and tough. The mesocarp middle layer comprised brown and tough fibers, and the innermost endocarp layer contained the endosperm. The fruit of *A. catechu* started to ripen and the skin turned yellow at 196 days (Fig. 5n and Fig. 6n). *A. catechu* (Dwarf) fruit ripened at 256 to 280 days, the fruit husk turned deep yellow, and the endocarp (flesh) was dark brown and hard like a stone (Figs.

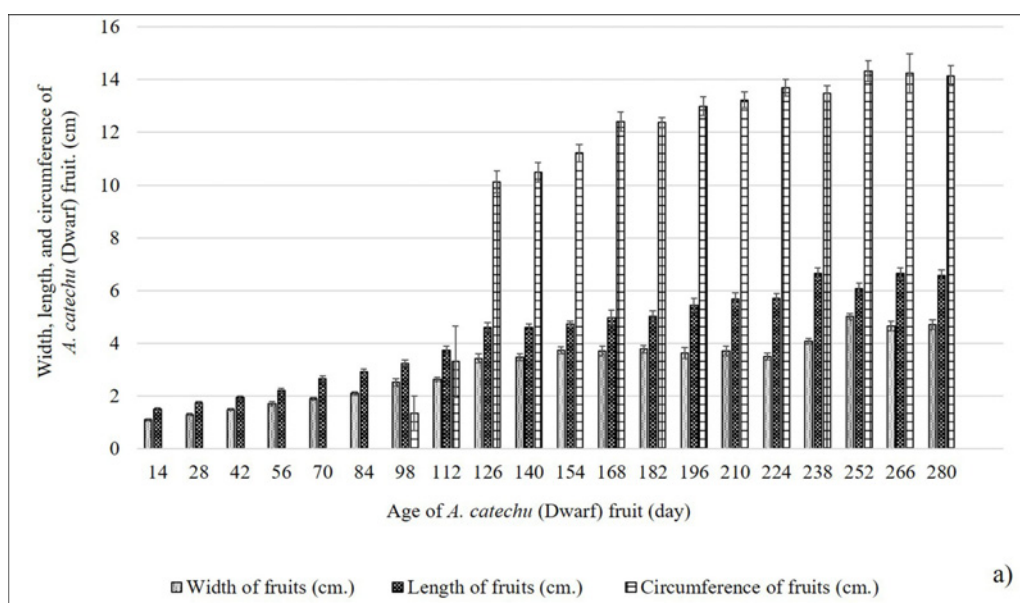
4, 5, and 6). A fibrous, ovoid drupe, yellow to orange or red formed when ripe with a fibrous pericarp. The seed, usually one, was ovoid, globose, or ellipsoidal with the base sometimes flattened, the endosperm was ruminated, with reddish-brown dark wavy lines

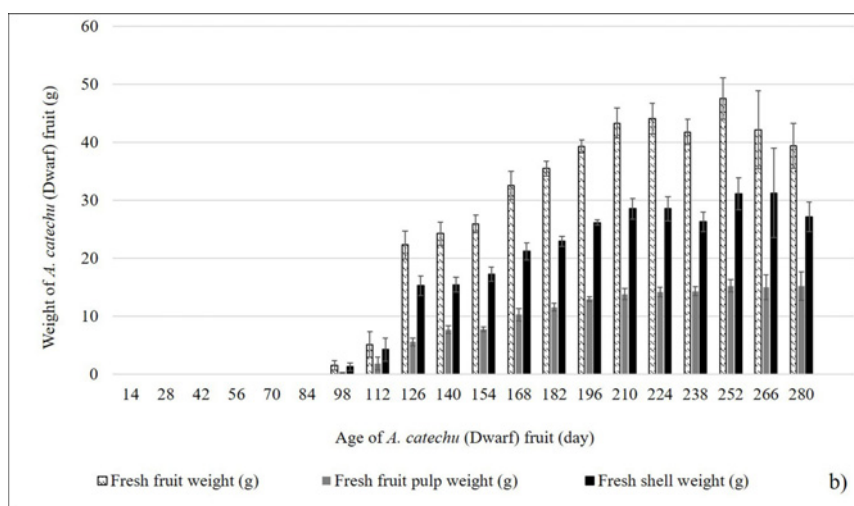
giving it a marbled appearance (Bavappa, 1966; Nagaraja *et al.*, 2025). The embryo was conical and located at the seed base (Staples and Bevacqua, 2006).

**Table 5. Growth of *A. catechu* (Dwarf) fruit after pollination at 14-280 days.**

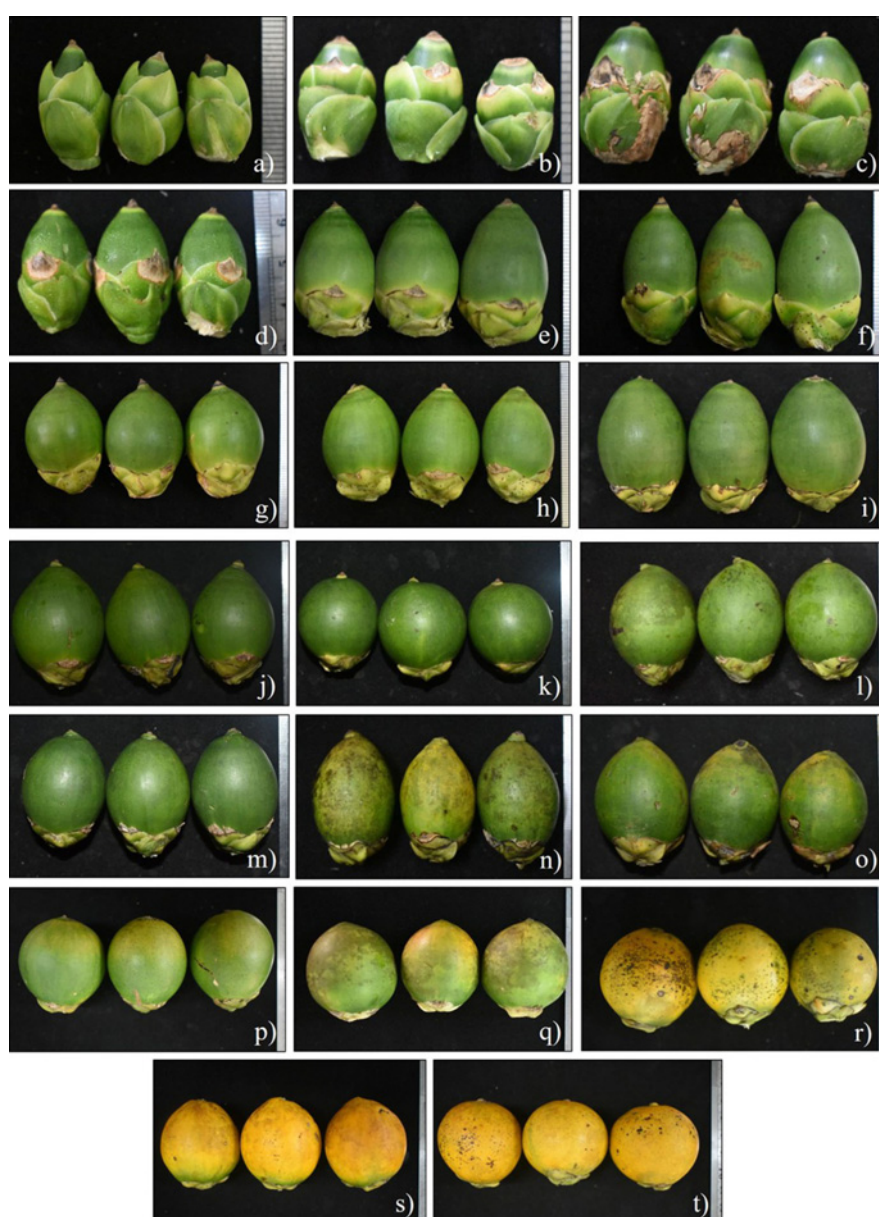
| Age (day) | Width of fruit (cm)<br>Mean±SE | Length of fruit (cm)<br>Mean±SE | Girth of fruit (cm)<br>Mean±SE | Fresh fruit weight (g)<br>Mean±SE | Fresh fruit kernel weight (g)<br>Mean±SE | Fresh husk weight (g)<br>Mean±SE |
|-----------|--------------------------------|---------------------------------|--------------------------------|-----------------------------------|------------------------------------------|----------------------------------|
| 14        | 1.10±0.04 <sup>f</sup>         | 1.49±0.06 <sup>k</sup>          | 0.00±0.00 <sup>f</sup>         | 0.00±0.00 <sup>f</sup>            | 0.00±0.00 <sup>f</sup>                   | 0.00±0.00 <sup>f</sup>           |
| 28        | 1.29±0.04 <sup>f</sup>         | 1.74±0.05 <sup>jk</sup>         | 0.00±0.00 <sup>f</sup>         | 0.00±0.00 <sup>f</sup>            | 0.00±0.00 <sup>f</sup>                   | 0.00±0.00 <sup>f</sup>           |
| 42        | 1.47±0.04 <sup>fg</sup>        | 1.93±0.07 <sup>jk</sup>         | 0.00±0.00 <sup>f</sup>         | 0.00±0.00 <sup>f</sup>            | 0.00±0.00 <sup>f</sup>                   | 0.00±0.00 <sup>f</sup>           |
| 56        | 1.71±0.07 <sup>ef</sup>        | 2.21±0.08 <sup>ij</sup>         | 0.00±0.00 <sup>f</sup>         | 0.00±0.00 <sup>f</sup>            | 0.00±0.00 <sup>f</sup>                   | 0.00±0.00 <sup>f</sup>           |
| 70        | 1.89±0.06 <sup>e</sup>         | 2.65±0.10 <sup>hi</sup>         | 0.00±0.00 <sup>f</sup>         | 0.00±0.00 <sup>f</sup>            | 0.00±0.00 <sup>f</sup>                   | 0.00±0.00 <sup>f</sup>           |
| 84        | 2.09±0.07 <sup>e</sup>         | 2.91±0.10 <sup>gh</sup>         | 0.00±0.00 <sup>f</sup>         | 0.00±0.00 <sup>f</sup>            | 0.00±0.00 <sup>f</sup>                   | 0.00±0.00 <sup>f</sup>           |
| 98        | 2.51±0.15 <sup>d</sup>         | 3.24±0.11 <sup>g</sup>          | 1.34±0.66 <sup>f</sup>         | 1.55±0.79 <sup>f</sup>            | 0.22±0.11 <sup>f</sup>                   | 1.31±0.67 <sup>f</sup>           |
| 112       | 2.63±0.08 <sup>d</sup>         | 3.74±0.15 <sup>f</sup>          | 3.30±1.36 <sup>e</sup>         | 5.12±2.21 <sup>f</sup>            | 1.84±1.15 <sup>f</sup>                   | 4.27±1.99 <sup>f</sup>           |
| 126       | 3.42±0.17 <sup>c</sup>         | 4.61±0.18 <sup>e</sup>          | 10.11±0.42 <sup>d</sup>        | 22.30±2.37 <sup>e</sup>           | 5.56±0.65 <sup>e</sup>                   | 15.26±1.68 <sup>e</sup>          |
| 140       | 3.47±0.14 <sup>c</sup>         | 4.60±0.14 <sup>e</sup>          | 10.49±0.36 <sup>d</sup>        | 24.25±1.99 <sup>e</sup>           | 7.68±0.68 <sup>d</sup>                   | 15.44±1.30 <sup>e</sup>          |
| 154       | 3.73±0.13 <sup>bc</sup>        | 4.73±0.10 <sup>e</sup>          | 11.21±0.32 <sup>cd</sup>       | 25.92±1.51 <sup>e</sup>           | 7.73±0.38 <sup>d</sup>                   | 17.22±1.23 <sup>de</sup>         |
| 168       | 3.71±0.18 <sup>bc</sup>        | 4.96±0.29 <sup>de</sup>         | 12.41±0.36 <sup>bc</sup>       | 32.50±2.47 <sup>d</sup>           | 10.26±1.10 <sup>c</sup>                  | 21.17±1.49 <sup>cd</sup>         |
| 182       | 3.77±0.14 <sup>bc</sup>        | 5.03±0.20 <sup>de</sup>         | 12.37±0.20 <sup>bc</sup>       | 35.44±1.31 <sup>cd</sup>          | 11.57±0.64 <sup>bc</sup>                 | 22.89±0.83 <sup>bc</sup>         |
| 196       | 3.63±0.21 <sup>c</sup>         | 5.44±0.26 <sup>cd</sup>         | 12.99±0.35 <sup>ab</sup>       | 39.27±1.09 <sup>bc</sup>          | 12.93±0.44 <sup>ab</sup>                 | 26.14±0.48 <sup>ab</sup>         |
| 210       | 3.70±0.19 <sup>bc</sup>        | 5.68±0.23 <sup>bc</sup>         | 13.23±0.30 <sup>ab</sup>       | 43.28±2.57 <sup>ab</sup>          | 13.80±0.96 <sup>a</sup>                  | 28.51±1.82 <sup>a</sup>          |
| 224       | 3.50±0.13 <sup>d</sup>         | 5.71±0.17 <sup>bc</sup>         | 13.69±0.32 <sup>ab</sup>       | 44.06±2.68 <sup>ab</sup>          | 14.19±0.83 <sup>a</sup>                  | 28.50±2.08 <sup>a</sup>          |
| 238       | 4.08±0.11 <sup>b</sup>         | 6.66±0.21 <sup>a</sup>          | 13.48±0.28 <sup>ab</sup>       | 41.75±2.18 <sup>ab</sup>          | 14.32±0.80 <sup>a</sup>                  | 26.26±1.69 <sup>ab</sup>         |
| 252       | 5.01±0.12 <sup>a</sup>         | 6.08±0.19 <sup>b</sup>          | 14.33±0.39 <sup>a</sup>        | 47.53±3.54 <sup>a</sup>           | 15.24±1.06 <sup>a</sup>                  | 31.14±2.76 <sup>a</sup>          |
| 266       | 4.65±0.19 <sup>a</sup>         | 6.64±0.23 <sup>a</sup>          | 14.24±0.75 <sup>a</sup>        | 42.11±6.73 <sup>ab</sup>          | 14.99±2.16 <sup>a</sup>                  | 31.24±7.70 <sup>a</sup>          |
| 280       | 4.70±0.19 <sup>a</sup>         | 6.57±0.20 <sup>a</sup>          | 14.15±0.38 <sup>a</sup>        | 39.38±3.90 <sup>bc</sup>          | 15.21±2.46 <sup>a</sup>                  | 27.13±2.55 <sup>ab</sup>         |

Mean values ± standard errors within a column followed by the same letter are not significantly different according to Duncan's multiple range test at p d" 0.05.





**Fig. 4. Growth of *A. catechu* (Dwarf) fruit after pollination at 14-280 days: a) width, length and girth of fruit, and b) weight of fruit.**



**Fig. 5. Age of the fruit of *A. catechu* (Dwarf): a) 14 days, b) 28 days, c) 42 days, d) 56 days, e) 70 days, f) 84 days, g) 98 days, h) 112 days, i) 126 days, j) 140 days, k) 154 days, l) 168 days, m) 182 days, n) 196 days, o) 210 days, p) 224 days, q) 238 days, r) 252 days, s) 266 days and t) 280 days.**



**Fig. 6.** Cross-sections of *A. catechu* fruit (Dwarf): a) 14 days, b) 28 days, c) 42 days, d) 56 days, e) 70 days, f) 84 days, g) 98 days, h) 112 days, i) 126 days, j) 140 days, k) 154 days, l) 168 days, m) 182 days, n) 196 days, o) 210 days, p) 224 days, q) 238 days, r) 252 days, s) 266 days and t) 280 days.

## Conclusions

The growth and development of *A. catechu* (Dwarf) male and female flowers were divided into three phases, with each presenting important event. During the first phase (1-14 days), the spathe started to fall off the inflorescence. During the second phase (15-24 days), the male flowers fell off daily until the rachilla were bare. In the third phase (25-37 days), the female flowers bloomed and the calyx enlarged. These three phases covered the pollination period. However, the percentage of fruiting after pollination was low (42.31%). At 14 days after pollination, the *A. catechu* (Dwarf) fruit was green, when becoming yellow-orange when ripe. The fruit pulp started to develop at 98 days and continued to grow until

attaining full fruit pulp at 182 days. As the fruit ripened, the peel color changed from green to yellow at 252 days. The outer layer of the ripe fruit was deep yellow to orange and the endocarp was dark brown, becoming hard like a stone at 266-280 days.

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