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# Unveiling the Secrets of Dragon Fruit Flowering

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**ARTICLE ID: 48**

## Introduction

Dragon fruit (*Hylocereus* spp.) also known as Pitaya, Strawberry pear, or Scaly fruit is a highly nutritious fruit that originated in tropical regions of central south America. Due to its increase in demand in international markets it a high-potential crop for tropical and subtropical regions. Dragon fruit belongs to the family Cactaceae which includes genus *Selenicereus* and *Hylocereus* (Raveh et al.,1993). Four commercially cultivated varieties of dragon fruit include *Hylocereus undatus* (Red peel and white pulp), *Hylocereus monacanthus* (Red peel and red pulp), *Hylocereus costaricensis* (Red peel and violet red pulp) and *Hylocereus megalanthus* (Yellow peel and white pulp) (Perween et al., 2018). The former 3 species of dragon fruit are diploid (2n=2x=22) and the latter is tetraploid (2n=4x=44) (Lichtenzveig et al., 2000). Dragon fruit plants start bearing fruits 2-3 years after planting. Therefore, to understand the fruiting process it is important to know the flowering of the plant.

## Flowering process (Flower initiation to Flower development)

Once the plants attain maturity, they begin to flower when the photoperiod exceeds 12 hours a day and the temperature ranges from 20-30 °C (Kakade et al., 2022). This is true for species such as *Hylocereus undatus*, *H. monacanthus* and *H. costaricensis*. However, when the temperature rises above 40 °C, it is harmful to these plants, causing flower abortion and sunburn damage. However, in *Hylocereus megalanthus* the flowering begins with the onset of winter, during fall (Jiang et al., 2011).

The flower bud formation on dragon fruit plants occurs on areoles, terminally or laterally on the cladode. It takes around 2-3 weeks from flower bud formation to anthesis (Osuna-Enciso, 2016) The period varies depending upon the species, variety and region, which influence factors such as temperature, humidity and photoperiod (Jiang et al., 2012).

The process of anther dehiscence, where pollen is released from the anthers, starts 3-4 hours before the flower opens (at around 10 p.m.) and continues till 2 a.m. early morning. The

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stigma becomes receptive with the opening of the flower and remains receptive for 11-12 hours, until the flowers close (Weiss et al., 1994). This timing is crucial for successful pollination and fruit development. In dragon fruit, flowering occurs in 4-7 cycles during summer. Typically, the fruit from the previous cycle matures around the same time as the flowers of the next cycle are blooming (Dhokane et al., 2023). The flower is nocturnal which means that the key process-anthesis (flower opening), anther dehiscence (pollen release) and pollination in flower occur at night. The flowers begin to open around 8 p.m and are fully opened by around 10 p.m (Yah et al., 2008). The pollination is carried out by nocturnal pollinators like fruit bats, hawk moths and flies.

**Parts of flower**

The flowers of dragon fruit are large, 25-30 cm in length having green to greenish-yellow sepals and white to whitish-yellow petals. However, there are some species of the genus *Selenicereus* such as *Selenicereus anthonyanus, S. atropilosus* which have small flowers, around 12 cm long and have purplish sepals and cream petals.

The dragon fruit flower is hermaphrodite and mainly consists of four parts: Sepaloid, Petaloid, Androecium and Gynoecium.

- **Sepaloid**: These form the outermost part of the flower. Sepals are arranged in whorls and the length of sepals increases as the come close to the petals. Also, the colour of the sepals changes from green to pale yellow (outside to inside). Dragon fruit flowers have an average of 76-78 sepals (Muniz et al., 2019).
- **Petaloid**: The petals are greenish- white to white, which reflects at night to attract pollinators. Their number varies from 9-15 in different species (Weiss et al., 1994).
- **Androecium**: Stamen are cream coloured and their number ranges from 1100-1150 (Pushpakarma et al., 2005).
- **Gynoecium**: Carpel is also cream coloured and stigma is divided into several of stigma lobes. A creamy-white ovary is present at the base and the ovules are arranged in parietal placentation (Pushpakarma et al., 2005).

**The trend of dragon fruit flowering in India**:

In India, the flowering pattern of dragon fruit mirrors the arrival of the monsoon across different states. Flowering in dragon fruit plants starts in the southern regions and gradually moves to northeastern states, followed by eastern, central, and western states and finally the northern parts of the country.

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- **Kerala**: Flowering starts from March and continues till October (Sethunath and Bhaskar, 2024).
- **Karnataka**: Flowering occurs from April to August (Karunakaran et al., 2019).
- **Mizoram**: Flowering begins in early April.
- **Bihar**: Flowering begins in late April.
- **West Bengal:** Flowering begins in the first half of May and continues until end of October (Devi et al., 2023).
- **Madhya Pradesh:** Flowering occurs from May to August (Tandon et al., 2020).
- **Gujarat:** Flowering occurs from May to November (Jinger et al., 2024).
- **Punjab:** Flowering begins in June and continues until the end of October.
- **Chhatisgarh**: April- Nov or Dec (Patel et al., 2023)

This sequential flowering pattern across different regions of India aligns closely with the progression of the monsoon season, ensuring that dragon fruit plants receive optimal conditions for blooming and fruit development.

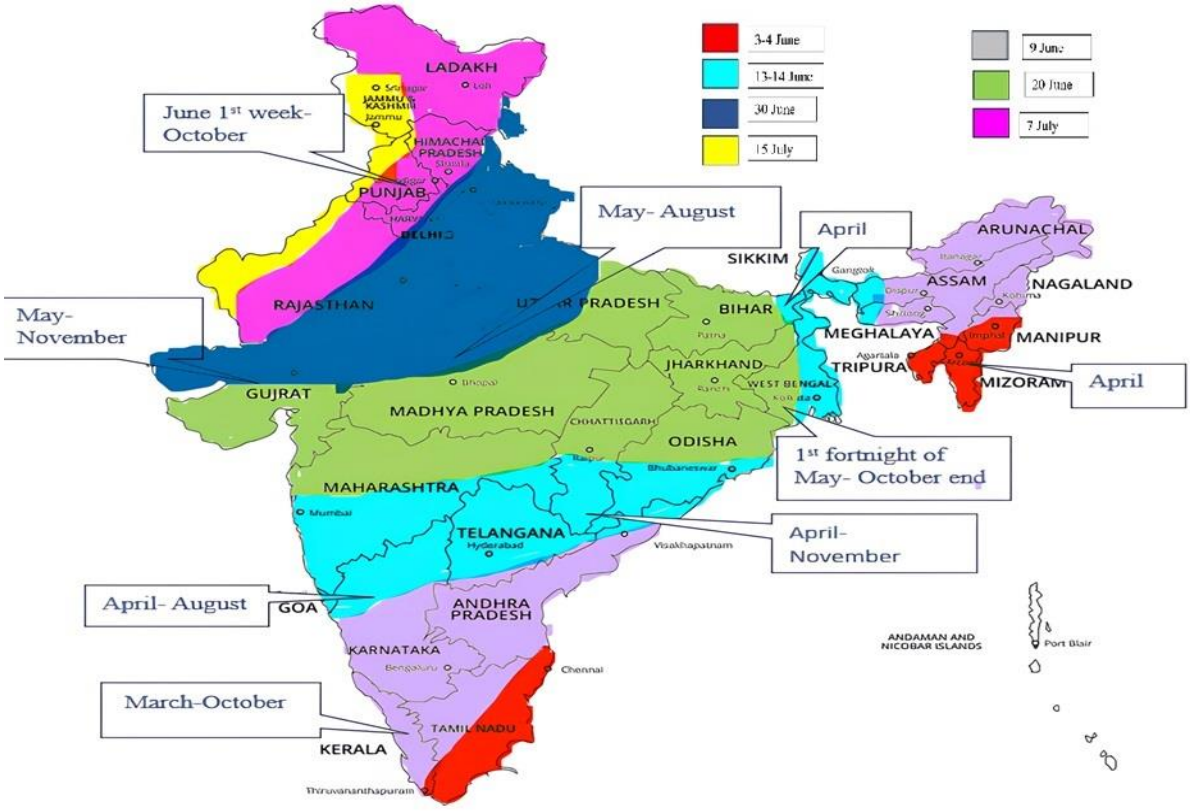


**Figure 1: Time of flowering of dragon fruit and date of monsoon arrival in different states of India.**

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**Pollination**:

The pollination is mainly carried out by nocturnal pollinators around at night. Since a large number of stamens are present in dragon fruit flowers, it leads to the production of a large number of pollen grains. These pollens are released by the anthers from around 4 p.m. and continue to till 2 a.m. early morning. The stigma remains receptive for 11-13 hours (8 p.m. to 7 a.m.). The flowers are cross-pollinated due to the problem of self-incompatibility and self-sterility. Hand pollination is preferred for dragon fruit flowers which results in a 100 % fruit set (Weiss et al.,1994; Kakade et al., 2022).

**Pollinators**:

The main pollinators involved in the pollination of dragon fruit flowers are fruit bats and hawk moths. Honey bees are also involved but are not very efficient pollinators due to the large size of flowers and difficult flower arrangement. Bees visit flowers late evening or early morning for nectar and pollen and assist a little in pollinating dragon fruit flowers. The pollinators are attracted to the large white petals of the flower which are reflected at night or to the odour of the flower. The flowers release a musky scent at night during anthesis to attract the nocturnal pollinators, and is released until the flower closes in the early morning (Weiss et al., 1994; Kakade et al., 2022).

**Problems in flowering:**

- **Self-incompatibility:** Self-incompatibility is defined as the failure of male and female gamete to fertilize. The problem of total or partial self-incompatibility has been observed in the case of dragon fruit flowers. Self-incompatibility in the case of *H. polyrhizus* and *H. costaricensis* is very strong and weak self-incompatibility is observed in the case of *H. undatus.* The flowers of dragon fruit are self-incompatible due to herkogamy (carpel is longer than stamen) (Valverde et al., 2015).
- **Self-sterility:** Self-sterility is a condition in plants where flowers are unable to produce viable seeds or fruit when self-pollinated. This occurs because the pollen from the same plant is ineffective in fertilizing its ovules. A problem of self-sterility has been observed in double-haploid *H. monacanthus* and reduced fertility is observed in double di-haploid *H. megalanthus.* The reason for this problem is connected to their reduced heterozygosity and it significantly impacts how normally developing male and female organs are developed (Li et al., 2018).

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- **Lack of pollinators:** Since the dragon fruit flowers open at night, they need to be cross-pollinated by nocturnal pollinators which are present in fewer numbers as compared to daytime pollinators. Also, daytime pollinators like bees visit the dragon fruit flowers during the evening or early morning for nectar, but they are not able to effectively pollinate the flowers due to complex arrangement of the flower and hence, the bee-pollinated flowers remain small in size (Nerd and Mizrahi., 2010).
- **Pollen viability-** A large number of viable pollens are required to fertilize the ovules of the dragon fruit flower. Reduced pollen viability of some species of *Hylocereus* reduces the fruit set due to inadequate fertilization. Though the pollen viability of *Hylocereus* group is upto 90 % but that of *H. megalanthus* is around 40 % only (Lichtenzveig et al., 2000)

**Off-season flower production:**

For the year-round production of dragon fruits, off-season flower production can be induced in dragon fruit plants. As dragon fruit is a long-day plant and its critical daylength requirement is 12 hours so night-breaking treatment is required from September to March for off-season fruit production. The period of the night-breaking treatment depends on the temperature of the region (Jiang et al., 2012).

**Stages of flowering of dragon fruit**

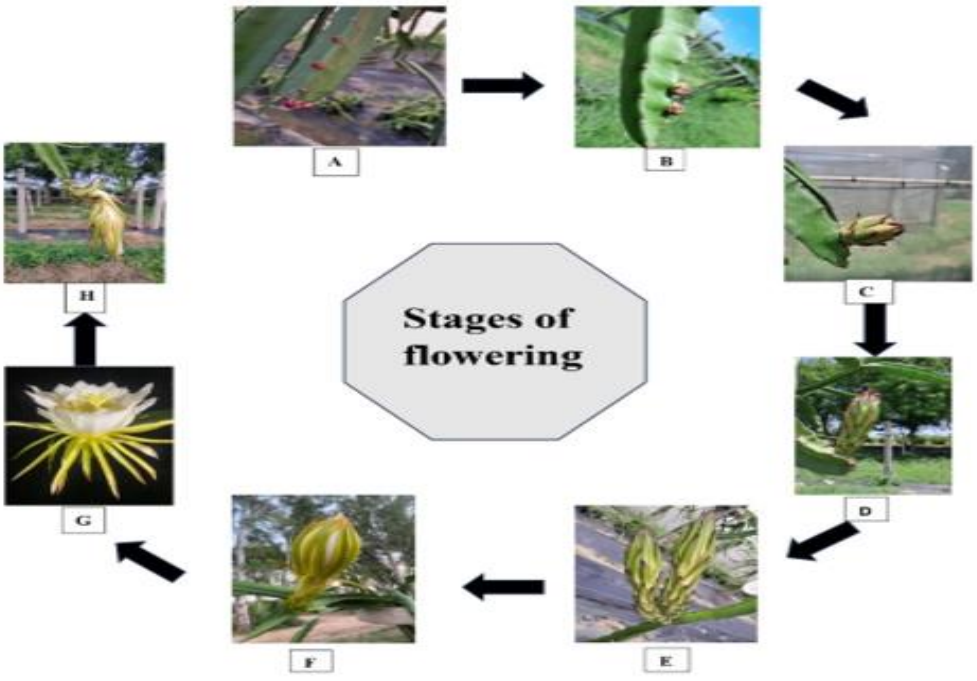

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**Figure 2**: **Stages of flowering in dragon fruit. A. Reproductive bud emergence. B. Swelling of bud. C. Beginning of bud elongation. D. Continuation of bud elongation. E. Elongation of floral tube. F. Formation of hollow ball before anthesis. G. Flower opening at night. H. Wilting of flower after pollination.**

**Conclusion**:

The study of dragon fruit flowering is an important aspect of the effective production of the crop and production of new varieties. The flower life commences with the production of reproductive buds on the cladode margins and ends with the wilting of flowers after pollination after which fertilization takes place and the fruit is produced. It takes 2-3 weeks from flower bud formation to pollination and the production of fruit is dependent on this period. Fruit bats and Hawk moths are the pollinators that aid in the cross-pollination of the flower. Summer season is the main dragon fruit flowering season but flowering can even be induced in winters by inducing night-breaking treatment. There are several problems in dragon fruit flowering such as self- incompatibility, self-sterility etc. which are needed to be taken care in future new varieties need to be developed which overcome these problems.

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