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**Cherreddy Raghavendra Reddy**  
M.Sc. Department of  
Horticulture, Lovely  
Professional University,  
Phagwara Punjab, India

**Jatinder Singh**  
Associate Professor, Lovely  
Professional University,  
Phagwara Punjab, India

## A study on phenological growth stages of BER

**Cherreddy Raghavendra Reddy and Jatinder Singh**

### Abstract

Understanding plant behavior at various development phases is critical for improving fruit quality, regulating production times, and lowering production costs. Observations on phenological phases would aid in determining the dates of certain stages of crop growth, allowing the operations to plan, and carry out agronomic practices such as irrigation, fertilization, and crop protection on time. The Indian National Genetic Resources Programme and the International Centre for Underutilized Crops in the United Kingdom have identified the Indian jujube (*Ziziphus mauritiana* Lamk.) as an underutilized plant deserving of further study and improvement. The Indian jujube was described using 6 major development phases. vegetative bud formation; leaf formation; inflorescence formation; flower formation; fruit set and fruit maturity. Based on these stages growers may better decide when to do orchard management practices like canopy training and pruning, water application, pest and disease control, post-harvest processing, etc., The purpose of this review is to gain a better understanding of the relevance of phenological research in ber.

**Keywords:** Ber, environmental factors, phenological study, growth stage, and phenophase

### Introduction

Indian jujube (*Ziziphus mauritiana* Lamk.) belongs to the family Rhamnaceae and is an indigenous fruit crop of India (Krishna *et al.* 2014)<sup>[30]</sup>. It is also known as desert apple, jujube, ber (Hindi), or Indian plum, and is a tropical fruit tree species in the Rhamnaceae family (Karuppaiah *et al.* 2015)<sup>[34]</sup> and (Sapkota *et al.* 2020)<sup>[58]</sup>. It is a common fruit crop in India's arid and semi-arid regions, with the majority of plantations concentrated in Rajasthan, Haryana, Punjab, Gujarat, Maharashtra, and Uttar Pradesh. Indian jujube is widely distributed in warm regions of the world but India is its main site of cultivation. Currently, it is grown over approximately 49,000 ha with 481,000 t production per year in India (Anon *et al.* 2017)<sup>[6]</sup>. Ber is a hardy fruit that likes hot and dry weather (Babuta *et al.* 2015)<sup>[18]</sup>.

Jujube is a viable alternative and dependable crop due to its late start-up, and nutritional value (Huang *et al.* 2017)<sup>[22]</sup>, Growers are becoming more interested in the crop since it thrives in severe weather conditions and provides significant returns (Chaurasiya *et al.* 2016)<sup>[59]</sup>. Wild jujube (*Ziziphus acidopujuba* Mill.) is highly tolerant to alkaline, saline, and drought stress (Guo *et al.* 2017)<sup>[20]</sup>. The plant can tolerate temperatures as high as 49-500C and as low as -20C (Awasthi *et al.* 2009)<sup>[3]</sup>. It can produce fruits even in areas that receive an average annual rainfall of only 150–200 mm and thus is a suitable crop for the arid and semi-arid regions of the world (Tel- Zur *et al.* 2009). Ber trees can withstand very short periods of freezing temperatures, however, frost will damage the young twigs and developing fruits, and may kill the tree (Navjot *et al.* 2015)<sup>[42]</sup>.

Growth, flowering, and fruiting development phases may vary depending on the temperature conditions. Jujube blossoms range in size from 3.5 to 10 mm (Liu *et al.* 2006)<sup>[35]</sup> and (Yao *et al.* 2013)<sup>[63]</sup>. The leaf surface is glabrous above and dark-green in color with three conspicuous, depressed, longitudinal veins originating from the base, which later converges at the tip (Krishna *et al.* 2014)<sup>[30]</sup>. Flowers are short-stemmed, greenish-white to yellow, and formed at the leaf axil The inflorescence is a cyme with 2-13 florets. Fruit diameter varies between varieties, ranging from 1.4 to 4.0 cm (Sapkota *et al.* 2020)<sup>[58]</sup>.

The Jujube tree has several advantages, including its adaptability, food (fruits, wine, tea), fodder, and nectar (Liu *et al.* 2006)<sup>[35]</sup>. The fruit is rich in vitamins (A, B, and C), phenols, and antioxidants (Outlaw *et al.* 2002)<sup>[44]</sup> and (Pareek *et al.* 2017)<sup>[46]</sup>.

**Corresponding Author**  
**Jatinder Singh**  
M.Sc. Department of  
Horticulture, Lovely  
Professional University,  
Phagwara Punjab, India

The mature fruits are also high in protein, phosphorus, calcium, and carotene, making them more nutritious than other fruits, in addition, it has been widely used in traditional Chinese medicine for the purpose of analeptic, palliative, tonic medicine, and health supplement for blood nourishment and sedation (Guo *et al.* 2013; Lam *et al.* 2016) [20]. jujube fruit color is associated with changes in antioxidant activity (Shi *et al.* 2018). Flavonoids and polysaccharides could contribute to the antioxidative act of jujube (Choi *et al.* 2011). jujube polysaccharides, composed of glucose (23%), xylose (31.3%), mannose (12.9%), and fructose (21.6%), possess antioxidant acts that may have contributed to observed positively (Wang *et al.* 2011) [55].

Phenology has the potential to improve several scientific fields, including climate change, biodiversity, agriculture, forestry, and human health. Phenological observations would assist growers in understanding the dates of specific stages of crop development, allowing them to plan, organize, and carry out timely schedules of agronomic practices such as irrigation, fertilization, and crop protection, as well as serve as a tool for monitoring the effects of climate change (Ruml *et al.* 2005) [53].

### Phenology study

Studies of periodic biological events (such as bud breaks, flushing, flowering, and fruit development) are known as phenology, which is primarily affected by climatic conditions (Hernández *et al.* 2015) [23]. According to Cui *et al.* (2008), the phenological periods of the jujube tree can be divided into bud burst to leafing (stage I, early April-early May), flowering to fruit set (stage II, mid-May-late June), fruit growth (stage III, late June-late July), fruit maturation (stage IV, early August-early September) and dormancy (stage V, this October-next March) stages. Meanwhile, phenological stages for Chinese jujube are three for the vegetative stage, four for the reproductive phase, and one for winter dormancy. The major stages were bud growth, leaf formation, and growth, shoot growth, formation of inflorescence, flowering, fruit formation, growth and development, and fruit maturation (Sundar *et al.* 2020) [56].

In available literature six of the ten major development phases are based on the existing Biologische Bundesanstalt, Bundessortenamt, and Chemische Industrie (BBCH) scales commonly utilized to describe Indian jujube, as well as numerous related studies. The BBCH scale has a two-digit designation that defines different events of plant life. The first number, which ranges from 0 to 9, denotes the key development stage. Similarly, the second number signifies the subsequent stages of life (Melgarejo *et al.* 2016) [40]. Different stages of development as per traits are as follows: vegetative bud characters, leaf characters, inflorescence development, flower characters, fruit set, and fruit maturation.

However, cv. Gola required 1,652.5, 300.8, 1,343.9, 807.8, 576.6, 1,651.8, 325.9, 1,532.9-degree days (mean of high and low temperature) for the principal growth stages 0, 1, 3, 5, 6, 7, 8 and 9, respectively. Gupta, Gill, and (Babuta *et al.* 2015) [18] reported that cv. Gola required 1976, 2,889-, 3,027-, 3,252-, and 3,769-degree days (mean of high and low temperature) for the phenological stages of flowering initiation, full bloom, fruit set initiation, fruit set, and fruit ripening, respectively, under semi-arid conditions. These values are different from those reported here and this could be due in part to differences in determining the growth stage between the two studies. (Gupta *et al.* 2015) [18] did not define

growth stages based on the BBCH scale. Temperature sums for the same phenological stages are higher for seedlings than for cultivars (Mishra *et al.* 2009) [38].

### Bud characters

The whole period of bud development from its appearance up to the bloom stage was divided into eight stages. In the initial stage, the bud has properties like tiny size, roundish shape, coverage with pubescence, etc. During the early four stages, the bud development was slow in all the six ber cultivars but accelerated during the last four stages. The cv. Umran took the longest time from initial bud stage to flower i.e., 22 days, whereas cv. Sanaur-2 entailed the least (20.8 days) it was noted that different cultivars of ber took 21- 22 days for completing the bud development (J.S. Dhaliwal *et al.* 1998) [15].

### Leaf characters

Morphological characteristics in ber cultivars and reported the leaf color from light green to dark green; leaf shape as oblong, oval-elliptic, round; leaf base as obtuse, broad, round, oblique, narrow, acute; leaf apex as round-obtuse, flat obtuse, cupped-acute and curved-acute (Pareek *et al.* 2001) [49]. Leaf shape, leaf base, leaf color, and petiole length were used as tertiary characters (Bal *et al.* 2006). Leaf apex was the most dependable character for the classification of different cultivars through vegetative characters and obtuse in cultivars like Desi, Karela, and cv. Gola, Khati Mithi and cv. Kernal Local, whereas, leaf apex shapes were noted as cuspidate, acute, or sub-acute in all of the other cultivars. Most of the cultivars were classified with sub-acute to the acute apex and some are classified with obtuse apex. Similarly, the leaf base was found to be obtuse in most of the cultivars except cv Selection 11, and cv Badam in which the leaf base turned to be cuneate, and cv Ghor, which was the only one to exhibit a cordate shaped leaf base (Muhammad *et al.* 2013) [37]. The leaf surface is glabrous above and dark-green in color with three conspicuous, depressed, longitudinal veins originating from the base, which later converges at the tip (Krishna *et al.* 2014) [30].

### Flowering habit

The flowers of all the cultivars are borne in clusters in the axil of leaves. Ber possesses mixed buds, giving rise to both flowering and vegetative buds simultaneously. The flowers on the lower portion of the branch were first to open and progressed onwards to the apex. The central flower within the cluster opened earlier than those on the edges. Flowers are borne both current season growth and mature wood. Except for Banarasi Karaka, Gola, Jokia, and Mundia, the flowers of most of the cultivars are borne in current season growth. Awasthi *et al.* (2009) [3] also reported that the flowers are borne on the current season's growth in the leaf axil, and the inflorescence is cymose. According to Parul Mehra *et al.* (2020) [27], the flowering habit in ber is Pleoanthic.

### Flower characters

Flowers are greenish-white to yellow, short-stalked, and produced at the axil of leaves. Jujube flowers vary from 3.5-10 mm in diameter Sundar *et al.* (2020) [56]. Flowering begins in July and continues until September; However, the time of pruning may influence the onset of flowering (Tel-Zur *et al.* 2009). Different cultivars of *Z. mauritiana* like Banarasi Karaka, Ponda, Ilaychi, Gola, and Tikdi, and observations

were made on 4 uniform branches facing N, S, E, and W. The study revealed that the peak period of flowering was Sep.-Oct. in all cultivars. The earliest flowering (11 Sep.) was observed in Tikdi, which had the shortest duration of flowering (47 days). The longest duration of flowering (61 days) was observed in Ilaychi (Sharma *et al.* 1990) [61]. Bearing characters of 35 cultivars of ber and the genotypes were classified into three categories as early, medium, and late harvesting. Umran, Katha Bombay, Chhuhara, Illaichi, ZG-3, Kathaphal, Jogia, Fonda, BS-2, and Desi Alwar are late bearing varieties while Gola, Gola Gurgaon No.3, Gola Gurgaon No.2, Safeda Rohtak, Seo, Katha Rajasthan, Laddu and Akhrota comes under early bearing varieties. Kaithali, Dandan, and Mirchia varieties are categorized as mid-season varieties (Sharon *et al.* 2006).

Sayeh *et al.* (2012) [60] reported that the tree has small green-yellow flowers with short peduncles (1 to 5 mm) and cymes, which are located beside the leaves. These flowers contain 5 sepals which are triangular and flat, 5 tiny, separated petals, and 5 stamens. Aulakh *et al.* (2005) [4] flowering time in ber cvs. Chhuhara, Ellaichi, Sanaur No. 2, and ZG-2 commenced during the last week of August while flowering in ber cvs. Umran, Kaithli, Gola, and Nazuk it is the first week of September. The flowering in ber takes place mostly during the current season's growth while flowering starts in the first week of September and continues till the middle of November (Jain *et al.* 2020) [27]. According to Pareek *et al.* (2001) [49], the peak flowering and fruit set in Banarashi Karaka, Illaichi, and Gola were September-October which coincided with the highest hermaphrodite percentage in our study.

### Inflorescence development

The inflorescence was axillary cyme. The flowering time is the most commonly recognized plant phenological phase since it is one of the easiest to record. Scientists have found that the temperature of the surrounding air has a major influence on flowering time along with other phenological phases in plants. Ruml *et al.* (2005) [53] concluded that the following steps are included in the blooming process: sepal splitting, sepal flattening, petal standing, petal and anther separation, petal flattening, anther standing, and stigma browning. The duration and length of each phase varied based on the cultivar and the type of flowering (Yao *et al.* 2015) [63]. The inflorescence is a cyme and consists of 2-13 flowers (Sundar *et al.* 2020) [56].

### Fruit set

Flowering in ber, in general, was very profuse but the life span of the hermaphrodite flower was very short and many flowers were not pollinated during their receptive period resulting in such a low fruit set. Kulkarni *et al.* (2016) observed that there was a marked variation in fruit set in different cultivars depending upon the percentage of the hermaphrodite flower which ranged from 3.9% Chhuhara to 31.4% in Sanur-2. The higher fruit set was also recorded in BAU Kul-1 (26.5%), Umran (26.1%), Banarasi Karaka (24.8%), Dandan (23.3%), Topa (23.1%), Illaichi (21.4%), Madhavpur (20.8%) and Jogia (20.4%). According to (Jain *et al.* 2020) [27] temperature required for a proper fruit, the set is 25 to 320C.

Aulakh *et al.* (2005) [4] fruit set of all cvs. was observed during the second week of October. Sharif *et al.* (2013) studied the categorization of ber varieties viz. Karela, Umran, Khobani, Fauladi, Suffon, Anokhi, Mehmood Wali, Ajooba,

Yazman local, Saddqia, Pakwhite, Gorh, Dilbhar, Dehli Sufaid, and Bahwalpur among all these cultivars fruit set is observed at the end of November. Babuta *et al.* (2015) [18] under semi-arid conditions, the phenological stages of cv. Gola such as fruit set initiation, and fruit ripening required 2,889-, 3,027-, 3,252- and 3,769-degree days respectively. Markovski *et al.* (2015) studied fruit growth on dynamics of jujube (*Ziziphus Jujube* Mill.) cvs. Zu tao czao, Da baj czao, Ja czao, Vahshski 45/2, Kitajski 2A, and Wild Midleasiatic jujube and observed fruit set in the middle of June. The fruit set in ber is very low under open pollination but the majority of the fruit set occurs in October (Jain *et al.* 2020) [27].

### Fruit maturity

Sapkota *et al.* (2020) [58] fruit maturity can be done by the pericarp of the fruit color changing from a green color to a dark reddish-brown color around four to six weeks. According to Bhargava *et al.* (2001) [43], a low temperature of 6.2–180C and a high temperature of 23.3–30.10C are favorable for fruit Gola. According to Krishna *et al.* (2019) [29] the lowest and highest temperatures recorded throughout fruit ripening range between 8.9 and 27.90C with an average of 18.40C The weather and climatic conditions have a considerable impact on fruit maturation. The range of heat units was between 3868° and 4529°C Day for fruit maturity in all the varieties. The minimum number of days was taken by Gola while Seb took the maximum in both the years. It may be that the early maturing varieties usually took a smaller period from bud burst to fruit set, thus resulting in early ripening (Navjot *et al.* 2015) [42].

### Conclusion

Ber (*Ziziphus Mauritania*) is a minor fruit crop that is important in India's agriculture. After many years of domestication, the crop has now become widely available across the world. Several issues in crop development have developed as a consequence of the growing commercialization of agricultural commodities. It is vital to be aware of the phenological stages of trees to reduce the likelihood of these complications occurring. Additional information like phenological data and pollen germination information would be very beneficial in establishing cultivar recommendations for particular growing conditions if such data were made accessible.

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