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Phenology, floral biology and pollination in bael varieties under rainfed semi-arid conditions of western India

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Abstract

The present paper deals with phenological events, flower biology, foraging behaviour of flower visitors, pollen germination (*in-vitro*) and stigma receptivity of different bael (*Aegle marmelos* Correa) varieties under rainfed hot semi-arid conditions of western India. Phenology of all the plants in terms of leaf initiation started from 1st week of May to 4th week of June, leaf fall initiation from 2nd week of April to 4th week of June. The inflorescence pattern was observed specific in each variety *i.e.*, axillary uniparous cyme, axillary biparous cyme, terminally axillary multiparous cyme. The peak period of flowering among all the varieties was early1st fortnight of June. Inkling of flower opening in different varieties started from 4.00 A.M. to 9.00 A. M. but peak period of anthesis was noticed between 5.00 to 7.45 A. M.. As soon as flowers open, different kinds of insects like honey bees, bugs, butterflies, ants, houseflies start visiting flowers during 6-9 P.M. in a large number to collect forage materials and help in pollination. Visually, the floral morphology of different variety appeared to be more or less similar, but the quantitative as well as qualitative characters of different floral organs were differed in terms of arrangement and number of petals and sepals. The number of flowers per inflorescence was recorded the maximum in Pant Shivani (24.67) followed by NB-16 (23.93) and Pant Sujata (21.24) and it was recorded the minimum in Pant Urvashi and CISHB-1 (6.97). A single flower of variety produced an average of 45.98 anthers being maximum in Pant Urvashi (61.23) and least was observed in Pant Aparna (36.67). Stigma receptivity was observed maximum at the day of anthesis in Pant Urvashi (68.53%) and one day after anthesis in NB-7 (14.37%) among all the varieties. All the varieties had pollen viability more than 95 % being highest in NB-7.

Key words : Beal, floral biology, pollilation.

Introduction

Bael (*Aegle marmelos* Correa) occupies an important place among the indigenous fruit of India not only because of its religious significance but also due to its high medicinal and nutritive values and ability to grow under aberrant agro-climatic conditions. It is considered to be one of the richest sources of riboflavin (Mukharjee and Ahmed, 1957) and known to provide lots of minerals and vitamins to diet (Barthakur and Arnolds, 1989). Owing to its hardy nature, bael can be grown successfully in wider range of habitats of arid, semi-arid to mesophytic conditions (Arya, 1986). Its cultivation can be done successfully in even alkaline and stony soils having pH range 5-10 (Jauhari and Singh, 1971, Ram and Singh, 2003, Srivastava and Singh, 2000). In western India, a wide range of genotypes of naturally grown trees is available contributing to wide genetic diversity in their morphological characters. In order to initiate any crop improvement programme, it would be imperative to generate information regarding growth and flowering behavior. Distinct changes in plants like flushing pattern, leaf defoliation, flowering and fruiting mainly determine phenological behaviour in trees.Van Schaik *et al.*, (1993) opined that the phenological events are not mutually independent; flowering may be partly or wholly dependent on leafing activity. Nevertheless, tree species with similar leaf phenology often differ in the timing of their flowering and fruiting (Seghieri *et al.*, 1995).The knowledge of floral biology, including pollination is prerequisite for any rational breeding programme and determination of extent of seed and fruit setting. Seeds and fruits are the economic products of more than 90% of flowering plants. Good fruit set and high crop yield generally depend on viable pollen grains. It is evident that fruit retention till maturity in bael is very low when compared to the number of flowers actually produced. However, the causes of low fruit production are uncertain, in part because many aspects of the reproductive biology of bael are not thoroughly studied. The purpose of the present study is to generate information by reporting on different bael varieties related to phenology, floral biology and pollination behavior, ?ower structure and development

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during the pre fertilization period, stigma receptivity, foraging behavior of insect visitations and the pollination mechanism.

Materials and Methods

The present investigation was carried out at Experimental Farm of the Central Horticultural Experiment Station (CIAH), Vejalpur, Panchmahals, Gujarat during the year 2013-14. A total of twelve varieties *viz.*, CISH-B-1, CISH-B-2, NB-5, NB-7, NB-9, NB-16, NB-17, Pant Aparna, Pant Shivani, Pant Sujata, Pant Urvashi and Goma Yashi were established through *in-situ* patch budding during 2003. The experiment was laid out in randomized block design and each variety was considered as treatment, hence sample from twelve varieties were taken for study. Uniform cultural practices were followed during the course of study. Twenty shoots spread over four directions on each selected trees, ten flowers were earmarked randomly and ten floral buds were scored for different desired attributes. The structure of the flower, their position and number in the inflorescence, the morphology of separate floral parts were assessed. Observations on phenological events were recorded during the deciduous, vegetative, ?owering and fruiting phases of the plant. Average number of ?owers in an in?orescence was counted from the tagged ?owering branches. Observation on different phonological events were derived in all the varieties trees from leaf flush initiation; leaf fall initiation; leaf fall completion; initiation of bud, initiation of flowering; duration and mode to consummate anthesis, chronology of flower opening within inflorescence, anther dehiscence, mode and duration of pollination, stigma receptivity on the day of anthesis,one day before and a day after anthesis were estimated by the method as described by Dafni (1992)and pollen viability were recorded in May during the experiment. Stigma receptivity was measured by Perex Test. Pollen viability per cent was carried out using 1% acetocarmine stain test (Johnsen, 1940). The data were analyzed as suggested by Gomez and Gomez (1984).

Result and Discussion

Different phenological events

Results of study on various pheonological events divulged that the varieties (12) exhibited dissimilar pattern. The inflorescence among all the varieties differed with regards to morphology and phenological characteristics *viz*., type of inflorescence, number of floral parts, inflorescence etc.

Leaf defoliation and initiation

Phenologically, all the varieties had long leaf fall period of 21-25 days, starting from 2nd week of April in variety Pant Aparna, Pant Sujata and Goma Yashi which completes in 3rd, 4th and 2nd week of May, respectively. Variety Pant Shivani had 2nd week of April to 3rd week of April, Pant Urvashi had 3rd week of April to 2 nd week of May, whereas NB-5, NB-7, NB-9 had leaf fall from 3rd, 2 nd, 1st week of May, respectively which completes in the 4th week of May. Variety CISHB-1 had 4 th week of March to 2 nd week of April; CISHB-2 had 1stweek of June to 3rd week of June. NB-16 had 1st week of June to 2 nd week of May. Leaf initiation started from 4 th week of April in CISHB-1, Pant Shivani; 2 nd week of May in NB-9; 3 rd week of May in Goma Yashi, 4th week of May in NB-16, NB-17 and Pant Urvashi; 1st week of June in NB-5, NB-7, Pant Aparna, Pant Sujata, which proceeded from the top of the tree towards the lower branches. (Singhal *et al*., 2010).

Flowering, anthesis and dehiscence

Inkling of bud emergence in all the varieties started from different time, but it lasted from April to late June. The peak period of it was observed during 2nd fortnight of May in all the varieties. All the buds are globose, spheroid in shape in each variety and green in colour which commenced to full bloom from 13th May to 26th June among all the varieties (Table1). It was observed early blooming in (mid May) in the varieties CISHB-1, NB-16, Pant Urvashi and in Goma Yashi, the peak period started from 6th June to 11th June whereas rest of the varieties had blooming in between 20th May to 26th June while peak period started from 7th June to 12th June. The varieties which has long flowering period may serve as a long-term resource (Bertin, 1982 and Dobkin, 1984) whereas flowering phenology of different cultivar affects reproductive success (Ollerton and Diaz, 1999) which allows the presence of a constant population of pollinators (Stiles, 1977; Waser and Real, 1979). There were deviation in the time of initiation and termination of the anthesis was observed between 5 to 8 A.M. among all the varieties of bael. It was observed early initiation (5.00A.M.) in the variety NB-7, NB-9, Pant Shivani and Pant Sujata. No flowers of any variety opened completely before 5 .00 A.M and followed specific time under semi-arid condition of western India (Table 1). During anthesis flowers starts loosening their floral part which later on blooms completely. Some flowers opened all petals at the time while other petals start opening one by one which takes 45 to 60 minutes in complete opening which may vary flower to flower. In the inflorescence, lower side bud opened earlier as compare to rest of buds localized centrally in all varieties whereas varieties had anthesis vice versa where centrally located buds which were opened first compare to lateral buds. After anthesis within half an hour, the hint of the anthers dehiscence

started which continued between 5.45- 8.30 A.M. The pollens were coming outside by bursting the anther centrally by pore. The anthers and floral organs shrunk and turn into brick red after dehiscence as time passed on. The findings regarding anthesis clarified that anthesis and anther dehiscence in bael varieties took place early in the morning (5.30 -8.30 A.M.) where low temperature and high humidity prevailed. More or less similar results were obtained by Singh (1989), Misra and Bajpai (1975), Srivastava and Singh (2000) and Kumar *et.al.* (1977) in bael cultivars. Among the varieties where reproductive success is limited by the pollen, any floral trait that contributes to pollination success should be selected (Uma Shanker and Ganeshaiah, 1990). Higher flower to fruit production ratio is a universal phenomenon in plants and the low frequency of fruit production might reflect resource constraints and pollen limitation (Cao *et al.,* 2005).

Pollen viability and stigma receptivity

In newly opened flowers of all the varieties, pollen viability is about 95 % or more than in the different varieties. Stigma receptivity after anthesis was recorded highest on same day within hour in all the varieties being the maximum in Pant Urvashi (68.53%) followed by Goma Yashi (65.19%) and it was least in NB-7 (45.27%) whereas similar trait was recorded between 7.95 - 15.52 % and 3.62-14.37% one day before and after the anthesis respectively, which showed considerable difference in their values which had lesser percentage of stigma receptivity (Table 3). Pollen viability among all the varieties had more than 95% which more or less similar findings with respect to pollen viability have been reported in the various underexploited fruits by Singh and Singh (2005) in mahua, Suranyi (1991)in apricot, Thimmaraju *et. al.* (1997), Singh *et al.* (2014) in *Morinda*, Singh *et al. (*2014) in bael, Singh and Singh (2005) in Mahua, Singh *et al.* (2007) in jamun, and Singh and Singh (2005) and Singh *et. al.* (2006 and 2010) in tamarind.

Pollination

As soon as flower started opening, large number of honey bees (*Apis dorsata*), and beetles, houseflies and butterflies less in number arrived and started the visiting the flowers for the foraging purpose and they directly enter on the central portion of the flower whether it completely opened or just started to open due to which large number of pollens stick to their abdomen and legs. Effective pollination occurred through the honeybees which visited the flower 5-23 times in 1 hour and carried highest number of pollen grains (29.65) than the rest of pollinators (Table 4).

Honeybees have been recognized as e?ective pollinators in many tropical trees (Cruden *et al.,* 1990; Sedgley *et al.,* 1992; Carthew, 1993; Ish-Am and Eisikowitch, 1993; Visuthitepkul and Moncur, 1993). They forage on bael flower only in the forenoon and recognized as ultimate pollinators than others, because their presence was noticed in plenty and carried large number of pollen grains, but the presence of other pollinators were less in number and carried less pollen grains owing to their foraging behavior and had less contact to the pollen grains.

Inflorescence morphology

Data presented in table 2 and 3 divulged considerable variations in their morphological characters of inflorescence among the varieties. Generally, all the varieties have axillary cymose with long peduncle type of inflorescence which was biparous, multiparous and uniparous. It was axillary biparous in CISHB-1, CISHB-2, NB-7, Pant Aparna, and Pant Urvashi; terminally multiparous cyme in NB-5 and NB-16; terminally biparous cyme in Pant Shivani and rest of the varieties had axillary multiparous cyme. and differed in their length and number of flowers. Pant Sujata had the highest inflorescence length (10.85 cm) followed by Pant Aparna (10.82 cm), CISHB-2 (10.54 cm), NB-7 (9.37 cm) and NB-5 (8.73 cm) and the same was the lowest in Pant Shivani (5.67 cm) followed by Pant Urvashi (6.52cm) and NB-9 (6.74 cm). The maximum number of flowers per inflorescence was observed in the variety Pant Shivani (24.27) followed by NB-16 (23.22), Pant Sujata (21.18) and it was least in the variety CISHB-1(6.03) followed by NB-7(11.13). Larger number of flowers are important for effective pollination (Hedegrat, 1976) Varieties of the bael have a virtually similar ?oral morphology *viz.,* stalked, bracteolate, erect, sweet-scented, complete, actinomorphic, bisexual, slender pediillate, calyx shallow, united at the base short, broad teeth and pubescent outside, petals oblong-oval, dotted with glands, blunt and thick, hypogynous, anthers were long linear cream in colour having white short filaments. Ovary oblong-ovoid, slightly tapering into the thick short style which is again somewhat thicker at upward and capitates stigma. Corolla was also differed in their colour *i.e.* light green (NB-5and NB-17), whitish green (CISHB-1, NB-9, Pant Shivani and Goma Yashi) and greenish white (CISHB-2, NB-6, NB-16, Pant Aparna, Pant Sujata and Pant Urvashi) among the varieties. The aestivation of sepals and petals also varied among different variety *i.e.* imbricate to quincuncial. It was observed imbricate aestivation in CISHB-1, NB-5, NB-7, Pant Aparna, Pant Sujata and Pant Urvashi whereas rest of the varieties had quincuncial aestivation observed.

The quantitative characters of the floral parts varied significantly among all the bael varieties. The

flowers were mostly tetramerous, but number of sepals and petals varied from 4 to 6 among the varieties. Varieties namely CISHB-1, NB-5, NB-7, NB-17 and Pant Urvashi had two kinds of flower which having 4 sepals-4 or 5 petals and 5 sepals and 4 or 5 petals (tetramerous and pentamerous). NB-9, Pant Shivani had tetramerous flowers, Pant Aparna, Goma Yashi and Pant Sujata had 5 - 6 sepals from it one was unequal in size compare to rest of the sepals. Similarity was also observed in the case of petals where it was 5-6 in number in Pant Sujata. There were variability in the number of anthers which ranged between 36.67- 61.23 among all the variety where it was maximum in Pant Urvashi (61.23) and least number of anthers were observed in Pant Aparna (36.67) followed by CISHB-2 (38.43), NB-5 (38.95)and NB-9 (39.57). Singh and Singh (2005) and Singh *et. al.* (2006 and 2010) have reported similar kind of inflorescence morphology in tamarind.

Table 1. Phenological changes in different bael varieties under rainfed conditions of western India.

Variety	Leaf fall initiation	Leaf fall completion	Leaf initiation	Flower bud emergence	Flowering duration	Time of athesis	Time of dehiscence
CISHB-1	4th week of March	2nd week of April	4th week of April	25 Apr-21 June	14 May - 24 June	5.30-7.00 A.M	6.30-8.15 A.M
CISHB-2	1st week of June	3 rd week of June	4th week of June	26Apr-18 June	21 May-26 June	5.15-6.45 A.M	6.00-7.45 A.M
NB-5	3 rd week of May	4th week of May	1st week of June	5 May -24 June	26 May-22 June	5.30-7.30 A.M	6.15-8.00 A.M
NB 7	2nd week of May	4th week of May	1st week of June	30 April-13 June	24 May-20June	5.00-7.00 A.M	6.30-8.30 A.M
NB-9	1st week of May	4th week of May	2nd week of May	7 May-29 June	16 May - 26 June	5.00-8.00 A.M	5.30-8.15 A.M
NB-16	1st week of May	2nd week of May	4th week of May	11 May -29 June	13 May-27 June	6.00-7.45 A.M	6.30-8.35 A.M
NB-17	4th week of April	3 rd week of May	4th week of May	1 May-22 June	26 May-21 June	5.30-7.30 A.M	6.30-8.20 A.M
Pant Aparna	2nd week of April	3 rd week of May	1st week of June	7 May-20 June	16 May-20 June	5.15-7.45 A.M	6.30-8.30 A.M
Pant Shivani	2nd week of April	3 rd week of April	4th week of April	3 May - 20June	20 May-19 June	5.00-6.30 A.M	5.45-8.15 A.M
Pant Sujata	2nd week of April	4th week of May	1st week of June	16 May -8 June	24 May-18 June	5.00-7.00 A.M	6.30-8.00 A.M
Pant Urvashi	3 rd week of April	2nd week of May	4th week of May	10 May -26 June	18 May-23 June	5.15-6.45 A.M	6.30-8.15 A.M
Goma Yashi	2nd week of April	2nd week of May	3 rd week of May	23 April-21 June	13 May-14 June	5.30-7.30 A.M	6.25-8.30 A.M

Table 2. Floral Morphology of different bael Varieties under rainfed conditions of western India.

Varieties	Type of Inflorescences	Flower colour	Flower character	No.of sepal		Number of Petal	
				C	R	C	R
CISHB-1	Axillary biparous cyme ,	Whitish gren	Bracteolate , ,actinomorphic,imbricate	4	5	4	5
CISHB-2	Axillary biparous cyme ,	Greenish white	Bracteate, bracteolate , actinomorphic, quincuncial aestivation	4	5	4	5
NB-5	Terminally,multiparous cyme ,	Light green	Ebracteate, bracteolate , ctinomorphic, Imbricate aestivation	4	5	4	5

NB-7	Axillary biparous cyme ,	Greenish white	Bracteate, bracteolate , actinomorphic, Imbricate aestivation	4	5	4	5
NB-9	Axillary uniparous cyme,	Whitish gren	Bracteate, bracteolate , ctinomorphic, quincuncial aestivation	4	5	4	5
NB-16	Terminally mutiparous cyme ,	Greenish white	Ebracteate, Bracteolate , actinomorphic, quincuncial aestivation	4	5	4	6
NB-17	Axillary multiparous cyme ,	Light green	Bracteate, bracteolate, actinomorphic, quincuncial aestivation	4	5	4	5
Pant Aparna	Axillary biparous cyme,	Greenish white	Bracteolate , actinomorphic,imbricate aestivation	4	5, 6, hafly cleved	4	5
Pant Shivani	Terminally biparous cyme	Whitish green	Ebracteate, bracteolate, actinomorphic, quincuncial aestivation	4	5	4	5
Pant Sujata	Axillary multiparous cyme ,	Greenish white	Bracteolate , actinomorphic, Imbricate aestivation	4	5,6	4	5
Pant Urvashi	Axillary biparous cyme ,	Greenish white	Bracteolate , actinomorphic, imbricate aestivation	4	5	4	5
Goma Yashi	Axillary cyme, multiparous	Whitish green	Bracteolate, actinomorphic, quincuncial aestivation	4	5, 6	4	5

R-Rare, C- Common

Table 3. Stigma receptivity and pollen viability of different bael varieties under rainfed conditions.

Varieties	Infloros cence length (cm)	Number of flower / inflorosce nce (cm)	Average number of anthers per flower	Stigma receptivity at the day before anthesis (%)	Stigma receptivity at the day of anthesis (%)	Stigma receptivity 1 day after anthesis (%)	Pollen Viability (%)
CISHB-1	08.58	06.03	46.35	15.52	54.31	08.43	96.17
CISHB-2	10.54	18.12	38.43	11.93	58.54	12.13	95.35
NB-5	08.73	20.85	38.95	12.53	57.35	14.32	95.42
NB-7	09.37	11.13	39.57	09.64	45.27	14.37	98.62
NB-9	06.74	20.24	55.00	12.53	52.28	04.23	95.25
NB-16	08.65	23.22	48.23	10.70	55.83	09.48	97.34
NB-17	07.63	18.00	43.68	15.45	52.48	11.37	95.23
Pant Aparna	10.82	12.31	36.67	10.72	57.34	06.33	96.15
Pant Shivani	05.67	24.27	49.43	11.13	56.31	03.62	96.83
Pant Sujata	10.85	21.18	46.34	14.82	59.15	04.15	95.30
PantUrvashi	06.52	13.24	61.23	15.13	68.53	07.82	97.48
Goma Yashi	06.83	10.15	40.95	07.95	65.19	10.57	97.13
C.D at 5 %	0.77	1.35	4.36	1.71	3.54	0.80	08.71

Table 4. Pollinators visit, and pollen load carried and duration to bael

Insects	Visitation Time	Number of visits/flower	Duration of stay on flower (min)	Pollen load/insect
Honey bees	6-9 pm	5-23	1-5	29.65
Houseflies	6-9 pm	1-5	1-5	16.75
Beetles	6-9 pm	1-2	1-15	15.53
Butterflies	6-9 pm	2-7	1-5	09.00
Ants	6-9 pm	1-5	2-7	05.34

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