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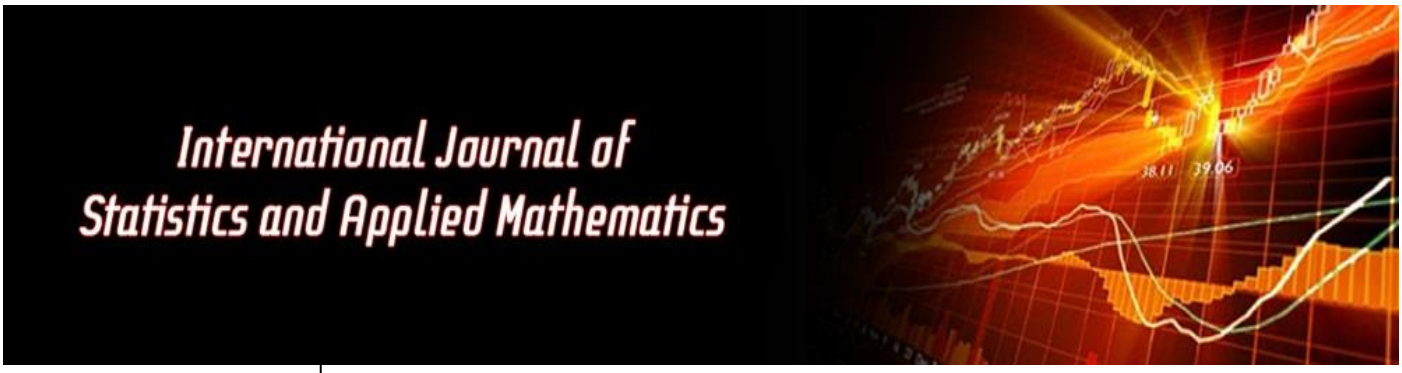

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Studies on floral biology of different varieties of guava (*Psidium guajava* L.)

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Abstract
Guava (*Psidium guajava* L.), a resilient tropical fruit tree belonging to the Myrtaceae family, plays a significant role in the agriculture of tropical and subtropical regions. Originating from Tropical America, guava was introduced to India in the 17th century, earning it the monikers "Poor man's Apple" and "Apple of the Tropics." India leads global guava production, with Gujarat being a prominent contributor. Despite its hardiness, guava faces challenges, such as Fusarium wilt and fruit fly infestations. This paper explores the flowering characteristics of guava, focusing on various aspects from flower bud initiation to fruit maturity. The study encompasses multiple flowering seasons, emphasizing regional variations. Guava's potential for improvement is highlighted, emphasizing the need for disease-resistant varieties and reduced seed presence. The significance of genetic variability in enhancing guava quality for export is underscored. Detailed investigations into flower bud development, time and duration of flowering, anthesis, dehiscence, stigma receptivity, pollen grain studies, and flower morphology are presented. The intricate relationships between these factors are explored, providing valuable insights for guava breeders aiming to develop superior cultivars. The paper concludes with an examination of fruit set and drop, shedding light on factors influencing successful guava cultivation. Overall, this comprehensive study contributes to the ongoing efforts to enhance guava cultivation through informed breeding programs and improved agricultural practices.

Keywords: Anthesis, dehiscence, stigma, pollen grain, morphology

Introduction
Guava (*Psidium guajava* L.), a member of Myrtaceae family, is an important fruit crop of tropical and subtropical region. It is native to Tropical America, an area comprising from Mexico to Peru. It was introduced in India by the Portuguese travellers during the early 17th century (Hayes, 1975) [8]. Guava is the hardiest among tropical fruit trees and excels most other fruit crops in productivity and adaptability. It occupies a premier position by virtue of its high food value, rich in vitamin-C content, a pleasant aroma, rich flavour and adaptability to varying soils conditions with low cost of production. Therefore, it is aptly referred to as "Poor man's Apple" and "Apple of the Tropics". India is the leading producer of guava in the world (Kahlon *et al.*, 1987) [9]. The total area and production of guava in India is about 260 thousand million hectare and 3826 thousand million tones, respectively. The total area and production of guava in Gujarat are 12,087 hectare and 160808.11 million tones, respectively. Guava is fifth most important fruit crop in production after banana, mango, citrus and papaya. Major guava producing districts in Gujarat are Bhavnagar, Vadodara, Mehsana, Gandhinagar, Kutch, Kheda, ChhotaUdepur and a part of Junagadh (Anon., 2017) [1].
Flowering characters right from flower bud initiation to maturity of fruit have been studied by different workers (Balasubramanyam, 1959; Sharma *et.al.*, 1988, Singh, 1996, Singh and Rao, 1996, Dubey *et al*., 2000, Malam *et al.*, 2022) [2, 18,21, 20, 6, 12]. Three flowering seasons for guava have been observed ambe bahar, mrig bahar and hastha bahar. The peak anthesis is found to occur between 5.00 and 6:30 AM in most of the varieties under South Indian conditions. In Northern India, guava flowers twice in a year (April–May and August-September). However, under North Indian conditions, anthesis occurs between 6.00 and 7:30 AM (Dhaliwal and Singla, 2002) [5]. Guava's importance can be further enhanced through the evolution of varieties possessing a combination of medium fruit size, attractive red pulp, excellent flavour and seedlessness. In most of the commercial cultivars, presence of hard seeds in large number,

however, seems to be the major single factor responsible for restricting its cultivation. Although, guava may survive to a great extent in the adverse climatic and soil conditions, wilt caused by *Fusarium oxysporium*, *Fusarium solani* or *Macrophamina phaseoli* is the most serious disease of this crop (Ray, 2002) [15]. Furthermore, many of the commercial cultivars are prone to the attack of fruit fly, which is a major menace in certain parts of India. The need for improvement of this fruit crop is therefore, imperative and requires active consideration.

The floral biology study has been carried out in various parts of the world but there is still scope to study. An existence of variability in variety provides an opportunity and opened a new vista for the export of good quality guava to abroad and more reliably in favour of the growers. Variability gives an opportunity and imparts for research to guava breeders. In the various guava growing regions, crop improvement through breeding attempts are always in process for creating better cultivars. Precise information on the genetic relationship is needed for carrying out different breeding programmes.

Flower bud development

Dasrathy (1951) [4] reported that Lucknow-49 took 30 days for its flower bud to come into flowering under Dharwad conditions. This variation may be due to the locality difference. Balasubrahmanyam (1959) [2] observed that the flower buds took 30 days to develop into flower and 29 days required for complete development of the flower from visible initiation in variety Lucknow-49 and in other varieties like Allahabad Round and Chittidar, it took 37 and 31 days, respectively. Sehgal and Singh (1967) [23] observed 38-42 days from visible differentiation of flower bud to full bloom in Allahabad Safeda and Lucknow-49 under Delhi conditions. Teaotia *et al.* (1970) [25] studied that *Psidium coriaceum* required 61 days to complete its full development from bud stage to flowering stage. The *Psidium guinenses*, however took the shortest period (38 days). The growth of bud remained slower in the beginning but accelerated in the later stage. However, a marked difference was visible in the total number of days required by each variety for the bud development. Nalawadi *et al.* (1973) [13] reported that the variety Lucknow-49 took 30 days for complete development of flower bud from the visible initiation and described the different stages of flower bud development which was arbitrarily fixed on size.

Time and Duration of flowering

Dwivedi *et al*. (1991) [7] reported that there were mainly three flowering season in guava i.e., summer, rainy and autumn. However, flowering was heavy in summer, medium in rainy and light in autumn. The peak period of flowering was observed in last week of April in summer, last fortnight of July in rainy season and October-November in autumn crop without observing the peak of flowering. The seasonal influence was very much pronounced on the number of flowers born. Maximum numbers of flowers per plant were born in summer flowering, medium in rainy, light in autumn flowering and it showed significant differences. Chatterjee *et al*. (1992) [3] observed the duration of flowering in three main guava cultivars i.e. Allahabad Safeda, Red Fleshed and Lucknow-49. It was recorded minimum in Lucknow-49 (34 days) and maximum in Allahabad Safeda (38 days).

Kundu and Mitra (1994) [11] opined that in the laterite tracts of West Bengal, guava flower twice a year, once between May and June and againbetween September and October. However, more number of flowers were observed in summer compared with autumn. Two season of flowering were observed in other guava growing region like Bihar, U.P., Punjab and Delhi. The cultivar Apple Colour was first to flower (12thMay) in summer as well as in autumn (8th September) followed by Chittidar (15th August) in summer and (13th September) in autumn while cultivar Seedless and Baruipur were last to commence flowering in summer (31st May) and Seedless and Banarsi in autumn (27th September). The cultivar Apple Colour and Chittidar showed the longest flowering period (35-43 days) whereas in cultivar Seedless and Banarasi it continued for 27 to 34 days. In general the flowering season was longer in autumn (31 to 43 days) than in summer (27 to 38 days). Singh (1996) [21] reported that flowering in all the guava cultivars i.e. Baraf-Khana, Seedless, Behat Coconut, Chittidar, Allahabad Safeda, L-49 and Red Fleshed started in the last week of March and fruits set in April. First flowering and fruit set were noticed in Red Fleshed followed by Chittidar. Flowering in seedless variety took place at last relative to other varieties. Fruit ripening started in the first week of August; Red Fleshed was observed to be the precocious followed by L- 49 and Allahabad Safeda.

Anthesis

Shrivastava (1974) [22] studied that the anthesis took 45-50 minutes to complete in guava. The petals open in the order of their aestivation. At first the outer most petals were started straightening up and was followed by the next in succession. Gradually they get pushed backwards exposing the stamens and pistil. During April flowering, the maximum number of flower opened between 6.30 AM to 7.30 AM, 5.00 AM to 5.30 AM and 6.00 AM to 7.00 AM in Apple Colour, Chittidar and Red Fleshed, respectively. Ojha *et al*. (1986) studied the floral biology of guava (*Psidium guajava* L.) and reported that flower opening in rainy season was late in the morning as compared to spring season in cultivar Allahabad Safeda and Sardar. Kahlon *et al*. (1987) [10] reported that the anthesis and dehiscence showed almost the same pattern and trend in guava. Dehiscence took place half an hour before the opening of flower. Pollen dehiscence took place about 15 to 30 minutes before the opening of flower. Anthesis and dehiscence took place respectively at 5.00 AM and 5.30 AM and increased with the rise of temperature up to 7.00 AM and 7.30 AM followed by sharp decline and continued at diminishing rate up to 11.00 AM and 10.30 AM, respectively. Both the process were at their peak from 6.00 AM to 7.00 AM and 6.30 to 7.30 AM. Sandhu *et al*. (1987) [16] reported that peak period of flower opening was 5.30 AM to 6.30 AM in autumn and spring flowering season in Pink Flesh, Lucknow-49 and Allahabad Safeda. During the autumn flowering in Pink Flesh, Lucknow-49 and Allahabad Safeda an average number of flowers opened between 5.30 to 6.30 AM was 78, 90 and 80 while in spring flowering it was 96, 100 and 80, respectively. After 8.30 AM percentage of opened flowers declined sharply. It took 2-3 hours for the flower buds to open completely.

Dehiscence

Balasubrahmanyam (1959) [2] noticed that the anthers, after dehiscence, turned yellowish brown and faded away. The dehiscence in all the three varieties (Allahabad Round, Chittidar and Lucknow) took place from outside towards the centre. The time taken for the full bursting of anthers was also studied and it was 7 minutes in Allahabad Round and 6 minutes in both Chittidar and Lucknow. The anther were deep

yellow in Chittidar and Lucknow. Soon after the anthers burst, the colour became dull white in all the three varieties. Nalawadi *et al*. (1973) [13] observed that the anther dehiscence in guava, cultivar Lucknow-49 commenced after one hour of anthesis i.e., at 6.30 AM and continued up to 8.00 AM with maximum pollen bursting at 7.00 AM. After 8.00 AM there was no dehiscence under Dharwar conditions. Kundu and Mitra (1994) [11] reported that the peak period of anther dehiscence in guava was observed between 5.30 and 7.30 AM except in seedless variety where peak period was between 7.30 and 8.30 AM. Dhaliwal and Singla (2002) [5] observed that anther dehiscence commenced just before/after opening of flower, i.e. at 5.30 AM and continued up to 11.30 AM. The optimum time for anther dehiscence was from 5.30-9.30 AM, with the peak period of dehiscence being 6.30-8.30 AM in all the genotypes.

Receptivity of stigma

Balasubramanyam (1959) [2] follow that pollen germination on stigma was poor in all the three varieties viz., Allahabad Round, Chittidar and Lucknow. After two days of pollination the stigma and style turned deep brown and the petals dropped off. Seth (1962) [17] reported that the stigma became fully receptive on the day of anthesis and remained so, at least up to the end of the 3rd day. No fruit set was noticed from the 4th day onwards. *Psidium guajava and Psidium molle* buds artificially pollinated twenty four hours before their opening showed normal germination of pollen on their stigmas. Pollen grains in all the species, except *P. Cattleianum* var. Lucidum, also germinate in the flowers pollinated 32 hours after their opening. In *Psidium guajava* and *Psidium molle*, during rainy season, pollen grains germinated even up to 48 hours. Nalawadi *et al*. (1973) [13] found that the percentage of fruit set was 18, 32, 20, 15 and 16 on a day prior to the opening of flowers, on the day of opening of flowers, one, two and three days after opening of flowers, respectively. The stigma was receptive a day prior to the opening of flowers. The stigma was non-receptive from the 3rd day after the opening of flower.

Pollen grain studies

Balasubrahmanyam (1959) [2] experimented that glucose solutions varying from 2 to 10 per cent for the artificial germination of pollen grains. For Allahabad Round 15, 20 and 25 per cent glucose and sugar solutions were also tried. The pollen grains of varieties Chittidar and Lucknow germinated well in six per cent glucose solutions, whereas the pollen grains of Allahabad Round did not germinate well under any concentration of glucose and sugar solutions. The maximum length of pollen tube recorded after 24 hours was 225µ and 220µ in Chittidar and Lucknow-49 and 22.5µ in the case of Allahabad Round. Seth (1962) [17] observed that pollen grains of *Psidium* species varied in shape and size. Pollen grains of *P. guajava, P. Guineense* and *P. chinense* had either three or four apertures, but in *P. molle* and *P. Cattleianum* var. Lucidum even five aperture pollen grains were also common. The normal pollen grains in all the species were of medium size showing only slight variation in their longest axis. The germination of pollen grains in varying concentrations of sucrose, lactose and dextrose showed no remarkable differences. The germination of pollen grains as well as their tube length was poorest in dextrose. The optimum concentration of dextrose for pollen germination and tube growth was 5 per cent for *P. guajava, P. Guineense* and *P. molle* and 10 per cent for *P. Chinense* and *P. cattleianum* var. Lucidum.

Nalawadi *et al.* (1973) [13] noticed that there was no marked difference in pollen size in different solutions viz. water, glycerin, acetocarmine and dry, except a slight increase of size in water. The average pollen size was 21.5µ, 26.5µ, 22.5µ and 25.5µ in dry, water, glycerin and acetocarmine, respectively. The maximum artificial pollen germination was 90.4% in Kwack's medium. The pollen germination was rapid as compared with that in agar and sucrose media, whereas, the longest pollen tube (200µ) was observed in Kwack's medium. Srivastava (1974) [22] reported that the size of the pollen grains in different guava varieties under different media varied to some extent. The maximum size of pollen grains was found in variety Red Fleshed (22.273µ). Fertility of pollen grains was tested in acetocarmine and sucrose of different concentrations. Deeply stained and normal looking grains were recorded as viable while weakly stained and others were counted as non-viable. The viability of pollen grains varied with variety.

Kahlon *et al*. (1987) [9] opined that average length of pollen grain was in order of 21.2µ and 22.0µ in Allahabad Safeda and 22.2µ and 21.2µ in Sardar Guava as compared to corresponding equatorial length of 23.1µ and 25.5µ in Allahabad Safeda and 26.6 and 26.1µ in Sardar guava during autumn and spring season, respectively. The sucrose solution proved the most effective in enhancing pollen germination. Maximum pollen germination of 68.5 and 74.4 per cent in Sardar guava and 64.5 and 67.5 per cent in Allahabad Safeda was recorded in 10 per cent sucrose solution during autumn and spring season respectively. Dhaliwal and Singla (2002) [5] studied that in guava selection of Sardar seedlings in general exhibited higher pollen viability than the selection of Bangalore seedlings and others. The highest percentage of pollen germination was found 4/10, with the lowest in Dharwar during rainy and winter season, respectively. Further, the pollen viability was found higher during the rainy season over the winter season and the reverse of it held true for pollen germination.

Flower morphology

Balasubrahmanyam (1959) [2] marked that the flowers of guava were epigynous, cyclic, actinomormphic and hermaphrodite. The petals were alternate of the calyx and varied in numbers 6 to 10 in one or two whorls. The flower of Allahabad Round consisted of only one whorl of petals which are comparatively thick. In Chittidar and Lucknow-49 the petals were arranged in two whorls. The stamens were superior, indefinite vary in number from 160 to 400. Kahlon *et al*. (1987) [10] studied the flower morphology of Allahabad Safeda and Lucknow-49 reported that there was no appreciable difference in the number and size of sepals and petals with regard to cultivar and season of flowering. However, Lucknow-49 slightly larger sized flower than Allahabad Safeda in both the flowering season. Greater variations were also recorded in the number of stamens in these cultivars. Higher number of stamens (406) was found in the Lucknow-49 as compared to Allahabad Safeda (382). The difference in size of flower and number of stamens in each cultivar may be attributed to genetic variation. The flower in these cultivars was found to be cyclic actinomorphic, hermaphrodite and white in colour.

Sandhu *et al.* (1987) [16] concluded that the flower size of Pink Flesh, Lucknow-49 and Allahabad Safeda were found to be non-significant. The maximum size of flower was observed in Lucknow-49 (2.0 to 1.7 cm) and followed by Pink Flesh (1.9

to 1.7 cm) and Allahabad Safeda (1.8 to 1.6 cm). The mean number of sepals/flower was found to be four in all the cultivars. The mean number of petals/flower in Allahabad Safeda and Lucknow- 49 was nine whereas in Pink Flesh it was eight. There was significant difference between the numbers of stamens/flower in different cultivars. The maximum number of stamens/flower was found in Pink Flesh (447) followed by Lucknow-49 (435.2) and Allahabad Safeda (408.6).

Fruit set and fruit drop

Singh *et al*. (1968) [19] reported that fruit set in the beginning was 80 to 96 per cent in guava but due to serious fruit drop within two months only 34-56 per cent fruit matured. In the case of Seedless cultivar six per cent fruits matured while the initial fruit set was 54 per cent. They also reported that 14 per cent fruits were retained till maturity in Local Seedless. Syamal *et al*. (1980) [24] reported that some of the flower bud dropped before anthesis on different dates. Bud drop started earlier in Allahabad Safeda as compared to that of Habshi, which took 12.00 to 12.5 days on average. It was observed that 14.19 per cent total flower buds produced by the shoot of Allahabad Safeda during February flush, dropped before anthesis. Habshi showed lesser per cent of bud drop (9.36%). During June flush, the drop in Allahabad Safeda was similar to that of February flush, but Habshi showed quit low flower drop of 3.7 per cent only. In general, Habshi showed lesser bud drop in both season.

Ray (2002) [15] observed that in general open pollination gave the highest fruit set (62-82%) than self-pollination by bagging (48-64%). The fruit set in cultivar Habshi and Local seedless was significantly high under hand cross pollination than those under self-pollination. In nature, initial fruit set was found to be 62-82 per cent. This shows that the initial fruit set was quit high in all the cultivars, although the cultural differences were conspicuous. The fruit set obtained after a month was 30 to 64 per cent and varied from 18 to 58 per cent after 60 days of anthesis. The percentage of the fruits reached to maturity varied from 14 to 54 per cent. Thus, shedding of immature fruits took place more or less faster in all the cultivars within a month or two from anthesis. Kahlon *et al*. (1987) [9] studied that higher percentage of fruit set was in spring than in autumn in Allahabad Safeda and Lucknow-49. The days required for fruit set to maturity were more in winter (122.3 to 135.7 days) compared with that required during the rainy season (104.7 to 118.5 days) which was due to prevailing low temperature during the period of fruit growth in winter while a high temperature accompanied with high humidity in summer and rain accelerates fruit growth and maturity.

Sandhu *et al*. (1987) [16] reported that the fruit set by selfing in Allahabad Safeda, Pink Flesh and Lucknow-49 varied from 16.0% to 7.7% in autumn and spring flowering season. In autumn flowering maximum fruit set (12.1%) was obtained in Pink Flesh cultivar followed by Allahabad Safeda (11.6%) and Lucknow-49 (7.7%). However, in spring flowering it was 16.0, 13.0 and 12.0 per cent in cultivar Allahabad Safeda, Pink Flesh and Lucknow-49, respectively. The fruit set in selfing was low as compared to open pollination and cross pollination in Allahabad Safeda, Pink Flesh and Lucknow-49 during both the flowering season. Sandhu *et al*. (1987) [16] reported that the fruit set in open pollination in autumn, flowering was the highest (74.6%) in Allahabad Safeda followed by Lucknow-49 (68.1%) and Pink Flesh (63.3%). In spring, flowering the fruit set was recorded 71.4%, 68.78% and 59.2% in Allahabad Safeda, Lucknow-49 and Pink Flesh, respectively.

Conclusion

Flowering characteristics, studied extensively by different researchers, reveal distinct seasons for guava flowering. The need for improvement in guava varieties is evident, with a focus on traits such as medium fruit size, attractive red pulp, excellent flavour, and seedlessness. However, challenges like Fusarium wilt and fruit fly infestations pose significant threats to guava cultivation, necessitating active consideration for improvement. Floral biology studies have provided valuable insights, yet there is still room for further exploration. The existing variability in guava varieties presents opportunities for export and research. The understanding of genetic relationships is crucial for successful breeding programs aimed at creating improved cultivars.

Detailed investigations into flower bud development, time and duration of flowering, anthesis, dehiscence, receptivity of stigma, pollen grain studies, flower morphology, fruit set, and fruit drop have expanded our knowledge of guava biology. These studies lay the foundation for future research, aiding guava breeders in developing improved varieties with enhanced traits. In conclusion, the continued exploration of guava's biology and breeding possibilities holds promise for further advancements in this important fruit crop, ensuring its sustainability and continued contribution to the agricultural landscape.

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