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STUDIES ON FLORAL BIOLOGY OF DIFFERENT CULTIVARS OF POMEGRANATE (*PUNICA GRANATUM* L.) IN SEMI-ARID REGION OF BUNDELKHAND INDIA

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ABSTRACT

A study on the floral biology of eight pomegranate cultivars (Super Bhagwa, Mridula, Jalore Seedless, Ruby, Bhagwa, G-137, Ganesh, and Arakta) was conducted during the Ambe Bahar season (January–March) of 2021 in the semi-arid region of Bundelkhand. The research, carried out at the Instructional cum Research Orchard, Department of Horticulture, COH&F, Rani Lakshmi Bai Central Agricultural University, Jhansi, aimed to examine the bearing habit, flowering period, and floral biology of these cultivars to support crop improvement programs.

The study revealed variations in flower biology across pomegranate cultivars. Most cultivars showed dominant axillary solitary bearing. Mridula required the longest bud growth period (22.92 days), while Bhagwa had the earliest first flower (8th Feb) and 50% flowering (18th Feb), and Arakta was the latest (16th and 26th Feb, respectively). Flowering duration ranged from 26 days in G-137 to 39 days in Bhagwa, with Ruby closing first (10th March). Super Bhagwa recorded the highest bisexual flower percentage (38.50%) and sex ratio (0.63), while Arakta had the most male flowers (70%). Thrum flowers (58.59%) were more prevalent than pin (34.38%) and homostylous flowers (10%).

Conclusion: In conclusion, the study highlighted significant variations in the floral biology of pomegranate cultivars in the semi-arid region of Bundelkhand. The findings provide valuable insights that will facilitate targeted efforts in pomegranate crop improvement programs.

Keywords **:** Pomegranate (*Punica granatum L.*), Floral Biology, Sex ratio

Introduction

Pomegranate (*Punica granatum L.*), belonging to the Punicaceae family, is a popular tropical and subtropical fruit crop originally found from Iran to the Himalayas of Northern India (Holland *et al*., 2009). It has been cultivated across the Mediterranean since ancient times (Nath & Randhawa, 1950). While pomegranates can be grown throughout India, profitable cultivation is mainly in Karnataka, Rajasthan and Maharashtra, with smaller-scale cultivation in states like Himachal Pradesh, Haryana, Punjab, Uttar Pradesh, Tamil Nadu and Andhra Pradesh (Manju *et al*., 2020; Yi *et al*., 2013). Pomegranate is valued for its refreshing juice and medicinal properties. Studies suggest that consuming red fruit juices like pomegranate can reduce the risk of heart disease, stroke, cancer and aging (Wetzstein *et al.,* 2011).

Pomegranate is a monoecious species that produces both male and hermaphrodite (perfect) flowers and can be self- or cross-pollinated. Hermaphrodite flowers are more fertile than male ones, and these "vase-shaped" flowers develop into fruit, while male "bell-shaped" flowers rarely produce fruit. A higher percentage of perfect flowers is associated with better fruit yield (Rawat, 2006). There are three types of flowers in pomegranate: pin, thrum and homostylous. Understanding floral biology is essential for crop improvement, as flowering patterns vary based on the cultivar, location, weather and research timing (Manju *et al*., 2016). Pomegranates can bloom abundantly year-round, but flowering characteristics

differ by various factors. To study the floral morphology of resistant/tolerant cultivars helps in resistance breeding for breeders. To know flowering behaviour and response of pomegranate flowering in Ambe Bahar (Jan-Feb) in the semi-arid agroclimatic region of Bundelkhand the study has been conducted.

Material and Methods

The research was conducted during 2020-21 at the Instructional cum Research Orchard, Rani Lakshmi Bai Central Agricultural University, Jhansi, UP. The study used 3-4-year-old pomegranate trees that were uniform, healthy and pest-free. A Randomized Block Design (RBD) was applied with four replications and each treatment had four trees.

To study the bearing habit, 12 random flowers from all sides of each replication were tagged, noting whether they appeared solitary or in clusters on current season shoots. Flowering was observed from February to March 2020. The time from bud emergence to fruit set was recorded. Flowering duration was measured as the time between the start and end of flower bud emergence. For each cultivar, six shoots were tagged per plant to record the first flower bud emergence. The date of 50% flowering (when 50% of the tagged buds opened) and full bloom (75% flower opening) was recorded. The last flower emergence date was noted and the difference between the first and last flowering dates determined the flowering period.

To observe flower types (hermaphrodite, staminate and intermediary), 100 flower buds were tagged and percentages were calculated. Periodic changes in flower bud growth were recorded every 5 days by measuring bud length (base to tip of the last petal) and width (middle part of the bud) in cm. For anthesis and anther dehiscence, 15 flowers from each of the eight cultivars were tagged. Flowers were observed every 2 hours from 6:00 a.m. to 6:00 p.m. to record the number of opened and dehisced flowers. Pollen grains were stained using acetocarmine, observed under a microscope and the viability percentage was calculated from three microscopic fields. Pollen tube growth was assessed by placing pollen on slides with a sucrose-boric acid solution and observing germinated grains with pollen tubes at least four times longer than the pollen size.

Results and Discussions

The study's findings on the studies on floral biology of different cultivars of pomegranate have been presented here.

Bearing habit

The highest axillary cluster bearing habit (31.25%) was recorded in cultivar (Table.1) Ruby followed by Bhagwa (29.17%) and Mridula (24.20%) which were at par with each other. Whereas Super Bhagwa, G-137, Ganesh and Arakta showed similar value with highest bearing under axillary solitary (43.75%) whereas Jalore seedless showed lowest (20.83 %).

In terminal flowering, all the cultivars bore more flowers in terminal clusters than terminal solitary (Table.1). Most of the cultivars bore terminal solitary flowers less than 18.75 per cent except Jalore seedless which recorded the highest (27.08 %). On the other hand, Jalore seedless had highest flowering in terminal cluster (33.33 %) followed by Mridula (30.77%), Super Bhagwa, G-137, Ganesh and Arakta (27.08%). It was also noticed during visual observation that aid buds were formed in the leaf axils under axillary bearing in all the cultivars which generally fall off before fruit set.

The axillary bearing habit dominating in most of the cultivars than terminal bearing except Jalore Seedless might be due to the genetical characters of the variety. Nath and Randhawa (1959a) and Josan *et al.* (1979) reported similar findings of bearing habit in different pomegranate cultivars. Dilip Kumar (1983) also found similar results that flowers were either terminal or in the axils of the leaves, and the axillary flowers were more numerous in all three seasons.

Table 1 : Bearing habit of different pomegranate cultivars

Cultivars	Axillary cluster (%)	Axillary solitary (%)	Terminal cluster (%)	Terminal solitary (%)
Super Bhagwa	18.75	43.75	27.08	10.42
Mridula	24.20	28.85	30.77	16.19
Jalore Seedless	18.75	20.83	33.33	27.08
Ruby	31.25	29.17	25.00	14.58
Bhagwa	29.17	27.08	25.00	18.75
G-137	18.75	43.75	27.08	10.42
Ganesh	18.75	43.75	27.08	10.42
Arakta	18.75	43.75	27.08	10.42
SE(m)±	3.08	2.64	2.02	1.64
CD (P= 0.05)	8.89	7.62	5.84	4.73

Flowering parameters

Data pertaining to various flowering parameters in different pomegranate cultivars are presented below.

The emergence of first flower bud in different cultivars was observed between 19th January to 27th January 2021, represented in Table. 2. The earliest emergence of flower bud was noticed in Bhagwa on 19th January and latest in Arakta on 27th January 2021. Days to anthesis among different cultivars did not vary much and took 20-23 days to anthesis. Cultivar G-137 took the shortest time (20.33 days), whereas Mridula took the longest time (22.92 days).

Date of opening of the first flower varied among different cultivars and was recorded between 8th February to 16th February (Table. 2). The earliest cultivar to open its first flower was Bhagwa (8th February) followed by cultivar Jalore Seedless (9th February) and Ruby (11th February). The date of 50 per cent flowering in different cultivars was observed between 18th February to 26th February 2021 (Table. 2). Most of the cultivars attained 50 per cent flowering in between 3rd and 4th week of February. Bhagwa recorded the earliest to reach 50 per cent flowering on 18th February 2021 while Arakta exhibited late flowering on 26th February 2021.

Table 2 : Flowering parameters in different pomegranate cultivars

Cultivars	Date of emergence of first flower bud	Days to anthesis	Date of first flower opening	Date of 50% flowering
Super Bhagwa	26-01-2021	21.17	15-02-2021	25-02-2021
Mridula	23-01-2021	22.92	12-02-2021	21-02-2021
Jalore Seedless	20-01-2021	21.17	09-02-2021	19-02-2021
Ruby	22-01-2021	22.83	11-02-2021	21-02-2021
Bhagwa	19-01-2021	22.50	08-02-2021	18-02-2021
G-137	25-01-2021	20.33	14-02-2021	24-02-2021
Ganesh	23-01-2021	21.42	12-02-2021	22-02-2021
Arakta	27-01-2021	21.92	16-02-2021	26-02-2021

Duration to full bloom recorded the variation among the different cultivars and ranged between 6 to 15 days. Full bloom period varied among the different cultivars and occurred between 2nd week of February to 2nd week of March (Table. 3). The Earliest cultivar to reach full bloom was Ganesh, in 6 days followed by Mridula, Ruby and G-137 in 7 days. Date of opening of last flower also showed variation in different cultivars ranging from 2nd fortnight of February to 2nd week of March (Table 3). The earliest cultivar to open its last flower was Ruby on 10th March followed by G-137 on 12th March and Jalore Seedless on 13th March (Table 3).

Significant variation in the duration of flowering was recorded among different cultivars. It ranged from 26 days to 39 days in G-137 and Bhagwa cultivar, respectively. However, no significant difference on flowering duration was found among cvs. Arakta, Mridula, Ganesh, and between G-137 and Ruby (Table 3).

Variation in blooming period among pomegranate cultivars was also recorded by Chadha (1983) and he observed the onset of flowering in the last week of March to first week of April and full bloom during the latter week of April and the first week of May under the Bilaspur condition of Himachal Pradesh. Similarly, Nirmal Sharma (2001) observed flowering in deciduous cultivars lasted 39 days (PS-75-K-5) to 55 days (Jodhpur Red), while flowering in evergreen cultivars remained longer (very few flowers).

The result exhibited variation on flower bud emergence and flowering time among the cultivars, which might be due to the genetic makeup and agro-ecological condition of the area play significant role to bring variation in flowering behaviour. Similar findings were obtained in North Indian conditions by Nath and Randhawa (1959b) and Singh *et al.* (1967) in pomegranate. Griggs (1959) discovered that the agroclimatic conditions of a certain site altered the time when specific fruit trees bloomed.

Table 3 : Time and duration of flowering in different pomegranate cultivars

Cultivars	Full bloom period	Full bloom period (days)	Date of opening of the last flower	Duration of flowering (days)
Super Bhagwa	Last week of February to 2nd week of March	11	16-03-2021	29
Mridula	3rd week of February to 1st week of march	7	14-03-2021	32
Jalore Seedless	3rd week of February to 1st week of March	8	13-03-2021	32
Ruby	3rd week of February to first week of March	7	10.03.2021	27
Bhagwa	2nd week of February to 1st week of March	15	19-03-2021	39
G-137	Last week of February to First week of March	7	12.03-2021	26
Ganesh	Last week of February to First week of March	6	14.03-2021	30
Arakta	Last week of February to 2nd week of March	11	19-03-2021	31
SEm±	-	-	-	0.57
CD (P= 0.05)	-	-	-	1.65

Stages of flower bud development

The flower buds went through a series of morphological changes after initiation to reach the anthesis stage. The data in (Table 4) shows the temporal order of various developmental stages. Changes in chronology of bud development stages (Ist to Vth) studied in different pomegranate cultivars. Data on number of days required for quantitative change in bud development from appearance (Stage I) till anthesis (stage 5) recorded lesser variation within the cultivar. Among the different bud development stages, stage I took maximum days (11.87) and stage IV took minimum days (1.96). From bud appearance to blooming, the cultivar G-137 took the shortest time (20.33 days), whereas Mridula took the longest time (22.92 days). It takes 21.17 days for Jalore seedless and Super Bhagwa to complete all phases of bud growth. In comparison to the other cultivars, Cultivar Ruby took a longer time (13 days) to progress from Stage I to Stage II of bud development. Mridula took a longer time to complete the I and II Stages. However, when compared to the others, Stage 5 required less time (1.33) to complete. In comparison to the others, cv. Bhagwa took the longest (2.5 days) to complete the final stage.

Table 4 : Chronology of bud development stages in different pomegranate cultivars

Cultivars	Bud development stages (days)				Total no. of days
	I-II	II-III	III-IV	IV-V	
Super Bhagwa	11.33	4.58	2.83	2.42	21.17
Mridula	12.75	4.50	4.33	1.33	22.92
Jalore Seedless	11.33	4.75	3.50	1.58	21.17
Ruby	13.17	4.58	2.67	2.42	22.83
Bhagwa	11.58	5.00	3.42	2.5	22.50
G-137	11.42	4.58	2.83	1.50	20.33
Ganesh	11.42	4.92	3.08	2.00	21.42
Arakta	11.92	4.83	3.25	1.92	21.92
Mean	11.87	4.72	3.24	1.96	21.78

Flower types

Data on flower types recorded statistically significant difference between the cultivars (Table. 5). All the cultivars showed that hermaphrodite flower percentage was almost half of the male flower percentage.

Percentage of hermaphrodite flower

Hermaphrodite flower percentage varied among the cultivars. It ranged between 30 to 39 per cent. The cv. Super Bhagwa had the highest percentage of bisexual flowers (38.50%), followed by G-137 (37.25%) Ganesh (36.75%), Mridula (36.25%) and Ruby (33.25%) which were at par with each other (Table 5).

Percentage of male flower

Male flower percentage varied significantly among the cultivars (Table. 5). It ranged from 61 to 70 per cent. The cv Arakta recorded the highest percentage of male flowers (70%) followed by Jalore Seedless (69%) and Bhagwa (68.25%).

Sex ratio

Sex ratio also varied significantly among the cultivars (Table 5). It ranged between 0.43 to 0.63. The cv. Super Bhagwa had the highest sex ratio of 0.63 followed by G-137 and Ganesh with sex ratio 0.59 and 0.58 respectively.

Variation in percentage of hermaphrodite and male flower in different pomegranate cultivars recorded under semi-arid region of Bundelkhand in ambe bahar flowering could be due to the season, plant age, position within the plant, plant vigour, and environmental conditions which all might influence the sex expression in various cultivars. The findings analogous to this observation were also reported by Nalawadi *et al.* (1973), El-Sese (1988), Assaf *et al.* (1991), Martinez *et al.* (2000) and Babu *et al.* (2011) in different pomegranate cultivars.

Table 5 : Percentage of types of flowers in pomegranate cultivars

Cultivars	Hermaphrodite flower (%)	Male flower (%)	Sex ratio
Super Bhagwa	38.50	61.50	0.63
Mridula	36.25	63.75	0.57
Jalore seedless	31.00	69.0	0.45
Ruby	33.25	66.75	0.50
Bhagwa	31.75	68.25	0.47
G-137	37.25	62.75	0.59
Ganesh	36.75	63.25	0.58
Arakta	30.00	70.00	0.43
SEm±	2.73	2.74	**0.04**
CD (P= 0.05)	5.70	5.80	**1.13**

Heterostyly condition

All the pomegranate cultivars under the study were found to be heterostyly in nature. Data recorded on heterostyly condition in pomegranate cultivars showed significant differences on the percentage of pin, thrum and homostylous (intermediate) flower (Table. 6). In general, average percentage of thrum flowers (58.59%) was highest as compared to pin flowers (34.38%) in all the cultivars. While, proportion of intermediate / homostylous flowers was found to be less than 10 per cent in all cultivars.

Pin flower (%)

The percentage of pin (styles longer than stamen) flowers varied among the cultivars and ranged between 28.75 to 42.50 per cent. Super Bhagwa exhibited the highest pin flowers (42.50%) followed by Mridula (40%) (Table. 6).

Thrum flower (%)

The percentage of thrum (styles shorter than stamen) flowers among the cultivars varied from 50 to 67.50 per cent. The percentage of thrum flowers was highest in cv. Arakta (67.5%), followed by Ruby (65%), Ganesh (61.25%) and Bhagwa (60%) and lowest (50%) in cv. Super Bhagwa, followed by Mridula (52.5%) (Table 6).

Homostylous flower (%)

The percentage of homostylous flowers (intermediate) varied from 3.75 to 8.75 per cent (Table. 6). The cv. Bhagwa recorded the highest percentage of homostylous flowers (8.75%) and cultivars Super Bhagwa, Mridula, Jalore Seedless, G-137, and Ganesh recorded the same value (7.50%).

Differences in the percentage of pin, thrum and homostylous conditions among the pomegranate cultivars recorded in ambe bahar flowering might be due to the genetic makeup of the variety, growing season, bearing habit and agro-ecological conditions, all of which could influence the heterostyly condition in different pomegranate cultivars. Heterostyly nature in pomegranate cultivars was also reported by Bavale (1978) and Babu *et al*. (2008). The present findings on variation in percentage of pin and thrum flowers due to cultivars were found to be analogous of the findings reported by Bavale (1978) in pomegranate cultivar.

Table 6 : Heterostyly condition in different pomegranate cultivars

Cultivars	Pin flower (%)	Thrum flower (%)	Homostylous flower (%)
Super Bhagwa	42.50	50.00	7.50
Mridula	40.00	52.50	7.50
Jalore seedless	36.25	56.25	7.50
Ruby	28.75	65.00	6.25
Bhagwa	31.25	60.00	8.75
G-137	36.25	56.25	7.50
Ganesh	31.25	61.25	7.50
Arakta	28.75	67.50	3.75
Mean	34.38	58.59	7.03
SEm±	0.76	0.86	0.56
CD (P= 0.05)	2.19	2.49	1.61

Pollen germination test (%)

The pollen germination test was conducted under different cultivars of pomegranate and total pollen grains and germinated pollen grains recorded under microscopic field counted. There was a significant variation for total pollen grains, germinated pollen grains and pollen germination percentage. Total pollen grains ranged from 48.75 in Arakta to 73.25 in Jalore Seedless. Whereas, germinated pollen grains varied from 23.0 in Arakta to 54 in G-137. The highest pollen germination rate was obtained in Mridula (76.93%) followed by Bhagwa (75.85%) and G-137 (75.11%), which were at par with each other whereas lowest germination in Arakta (47.43%) and Ruby (47.63%).

Pollen germination in pomegranates is largely a hereditary feature, as same, as same cultivars repeatedly showed higher percentages of pollen germination under various climatic circumstances. Minor differences in pomegranate pollen germination may be due to differences in testing methodologies and pollen collection times performed by different persons. Variation in pollen germination in pomegranate cultivars was also reported by many workers like Nath and Randhawa (1959), Nalwadi *et al*. (1973), Singh (1977) and Chitale & Deshpande (1970).

Our findings align with Nath and Randhawa (1959), who reported 78% pollen germination in a 5% sucrose solution, with viability ranging from 67.70% to 91.54%. Derin *et al*. (2011) observed high pollen

viability and germination in Hicaz and 33 N 26 cultivars. Eshghi *et al*. (2010) found boron and molybdenum to significantly impact pollen germination, while Shangshang *et al*. (2015) described pomegranate pollen as prolate in morphology. Sangma and Singh (2017) confirmed the genetic basis of viability across cultivars and wild germplasm, and Melgarejo *et al*. (2000) highlighted the influence of environmental factors and media on germination. Gadže *et al*. (2011) examined in vitro viability, germination, and tube growth in cultivars from Croatia and Bosnia. Kumar and Kaur (2019) also explored factors affecting viability.

These results emphasize that pomegranate pollen viability is shaped by genetic, procedural, and environmental factors, reinforcing findings by Engin and Gökbayrak (2019) and Wetzstein *et al*. (2013) on its role in fertilization and fruit production.

Table 7 : Pollen germination in different pomegranate cultivars

Cultivars	Total pollen grains	Germinated pollen grains	Germination (%)
Super Bhagwa	68.75	42.25	61.45
Mridula	63.25	48.50	76.93
Jalore Seedless	73.25	48.25	66.13
Ruby	69.50	33.00	47.63
Bhagwa	54.25	41.00	75.85
G-137	72.00	54.00	75.11
Ganesh	68.50	44.00	64.70
Arakta	48.75	23.00	47.43
S.Em ±	2.35	0.85	2.43
CD (P=0.05)	6.77	2.46	7.00

Conclusions

Pomegranate cultivars exhibit differences in bearing habits, with some showing a preference for axillary cluster bearing while others favour solitary flowers. Flowering times and durations vary among cultivars, with some blooming earlier and others taking longer to reach full bloom. Hermaphrodite flowers are generally less common than male flowers, though their proportion varies by cultivar. Additionally, cultivars show differences in heterostyly, with certain varieties producing more thrum or pin flowers, influenced by genetic and environmental factors.

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