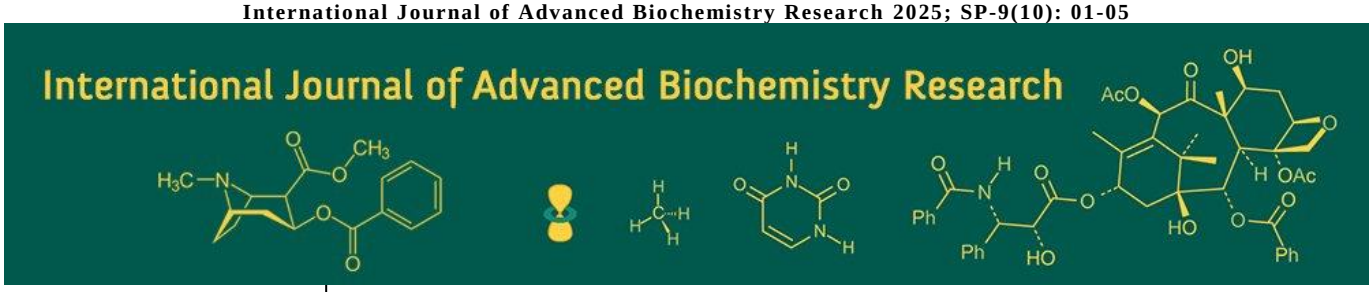

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Sakshi K Nanote
PG Scholar, Horticulture Section, College of Agriculture, Nagpur, Maharashtra, India

Dr. Ekta P Ningot
Assistant Professor, Horticulture Section, College of Agriculture, Nagpur, Maharashtra, India

Dr. VU Raut
Head of Department, Horticulture Section, College of Agriculture, Nagpur, Maharashtra, India

Avinash R Khandare
PG Scholar, Horticulture Section, College of Agriculture, Nagpur, Maharashtra, India

Aniket Bajad
PG Scholar, Horticulture Section, College of Agriculture, Nagpur, Maharashtra, India

Corresponding Author:
Sakshi K Nanote
PG Scholar, Horticulture Section, College of Agriculture, Nagpur, Maharashtra, India

Studies on floral biology in citrus

Sakshi K Nanote, Ekta P Ningot, VU Raut, Avinash R Khandare and Aniket Bajad

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Abstract
The genus citrus comprises of the most extensively cultivated group of fruits in the world. The long history of citriculture and richness in germplasm of citrus has benefited breeding work. The knowledge of floral morphology and fruit set is the pre-requisite for initiation of any breeding programme. With these objectives the present research work was carried out at Santra Improvement Project, Horticulture, section, College of Agriculture, Nagpur during the ambia bahar of 2024-25. Different eight citrus species and varieties *viz*. Nagpur mandarin, Nagpur seedless, Fairchild mandarin, Kinnow mandarin, Daisy, Katol gold, Grape fruit and Pummelo were examined for floral biology in Randomized Block Design with four replications, Duration of flowering ranged from 19.50 to 42.60 days while length of pedicel was between 0.43 cm to 1.31 cm. length of flower bud was maximum in pummelo (2.09 cm) and minimum in Nagpur mandarin and Fairchild mandarin (1.33 cm). Colour of flower bud and open flower was white for all citrus parents except in Grape fruit which was white with green spot. Position of flower was found to be axillary terminal for all evaluated parents.

Keywords: Floral biology, citrus species, anthesis, dehiscence

Introduction
Citrus, recognized as the most economically significant fruit crop globally, is cultivated in both developed and developing nations, and undoubtedly serves as a primary source of vitamin C. In accordance with the recommendations from the World Health Organization, there is a growing demand for high quality fresh citrus. This fruit boasts the highest concentration of carotenoids found in any fruit, along with a diverse range of secondary compounds, including vitamin E, provitamin A, flavonoids, limonoids, polysaccharides, lignin, fiber, phenolic compounds, and essential oils, all of which possess crucial nutritional benefits (Iglesias *et al*., 2007) [8]. The term citrus commonly refers to the genus of flowering plants within the family Rutaceae, subfamily Aurantioideae, tribe Citreae, and subtribe Citrinae, characterized by a chromosome number of 2n=18.
Citrus species typically generate a significant quantity of flowers throughout the year. The number of flowers produced is contingent upon factors. Such is cultivar, age of of the tree and environmental conditions (Monselise 1986) [11]. Flowering is a key process in citriculture and its evaluation is often difficult due to the canopy structure and field Sampling (Ribeiro *et al*. 2008) [16].
However most of the citrus forms exhibit abundant heterozygosity making breeding process significantly complicated. Hence information on floral morphology and pollen viability are the ideal tools to select a superior genotypes as a parents with better crossing efficiency for hybridization work in citrus thus with a view of study the floral biology of different citrus species and varieties, the present work was carried out at Nagpur condition.

Materials and Methods
The current experiment was carried out at the Santra Improvement Project, Horticulture Section, College of Agriculture, Nagpur, during the ambia bahar season in the year 2024-2025. The field comprised of plantaion of Nagpur mandarin, Nagpur seedless, Fairchild mandarin, kinnow mandarin, Daisy, Katol gold, Grapefruit and pummelo, all of which were planted in 2016 with a spacing of 6m x 6m. Observations were recorded on various parameters including the duration of flowering, length of pedicel, length of flower bud, Stamens flower^{-1}, petals flower^{-1}, percentage of staminate flowers, percentage of perfect

flowers, time of anthesis, time of anther dehiscence, flower position, color of flower bud, colour of open flower, and stigma receptivity. The analysis was conducted using a Randomized Block Design with eight treatments and four replications. The data was statistically analysed as given by Panse and Sukhatme (1968) [14].

Results and Discussion

Table 1: Flowering behaviour of different citrus parent

Sr. No.	Parents	Duration of flowering (days)	Length of pedicel (cm)	Length of flower bud (cm)	Colour of flower bud	colour of open flower	Position of flower
1.	Nagpur mandarin	42.60	0.46	1.33	White	White	Axillary Terminal
2.	Nagpur seedless	42.10	0.45	1.34	White	White	Axillary Terminal
3.	Fairchild mandarin	37.95	0.43	1.33	White	White	Axillary Terminal
4.	Kinnow mandarin	37.90	0.45	1.36	White	White	Axillary Terminal
5.	Daisy	32.65	0.44	1.35	White	White	Axillary Terminal
6.	Katol gold	22.20	0.77	1.69	White	White	Axillary Terminal
7.	Grape fruit	19.50	0.78	1.73	White	White with green spot	Axillary Terminal
8.	Pummelo	27.40	1.31	2.09	White	White	Axillary Terminal
	F test	Sig	Sig	Sig			
	SE (m) ±	0.21	0.06	0.04			
	C.D. at 5%	0.63	0.18	0.14			

Flowering behavior

Duration of flowering (days)

Significant variations in duration of flowering was observed amongst several mandarin varieties, sweet orange, Grape fruit and Pummelo genotypes, as shown in the Table 1 Nagpur mandarin, recorded the longest flowering duration (42.60 days) which was followed by Nagpur seedless (42.10 days). Whereas grape fruit showed the shortest flowering period (19.50 days).

The blossoming period lasted from February to March of 2025. These results are consistent with Kumatkar *et al.* (2016) V and Manju and Rawat (2010) [10], who reiterated that the flowering period lasted 16 days, from the last week of February to the second week of March. According to Singh *et al.* (2014) [20], flowering times for several citrus species are also observed throughout other seasons. This could be because the flowering season is mostly determined by climatic factors, particularly temperature. The genetic composition of the cultivars and environmental conditions determine the variation in flowering season. (Nebauer *et al.* 2006) [13].

Length of pedicel (cm.)

As evident from Table 1, significant differences were observed in the pedicel length among various cultivars of Mandarin, Sweet orange and Grapefruit. The maximum pedicel length was recorded in pummelo (1.31 cm), which was followed by grape fruit (0.78). Whereas shortest pedicel length was observed in Fairchild mandarin (0.43 cm).The variation in pedicel length may be attributed to the genetic makeup of different species and varieties (Akhter *et al.*, 2009) [2].These findings are in confirmation with the reports of Hassan *et al.* (2008) [6] in 13 citrus parents and Baswal *et al.* (2017) [4] in grapefruit.

Length of bud (cm.)

Significant differences in bud length were noted across citrus parents and are shown in Table 1. The Pummelo had the longest bud length (2.09 cm), which was followed by grape fruit (1.73 cm), whereas shortest bud length was observed in Nagpur mandarin (1.33 cm) and Fairchild mandarin (1.33 cm)

Hassan *et al.* (2008) [6] reported 0.2 to 0.9 cm range of pedicel length among 13 mandarin varieties studied. Hossain and Rabbani (2011) [7] noted similar findings in lemon genotypes. The genotypic influence may be the cause of bud length variation among cultivars (Akhter *et al.* 2009) [2].

Colour of flower bud

It is from table 1 clear that flower buds in Nagpur mandarin, Nagpur seedless, Fairchild mandarin, Kinnow, mandarin, Daisy, katol gold, Grape fruit and Pummelo were all in white in colour. Conversely, Hossain and Rabbani (2011) [7] noted that in lemon genotypes, flower buds were reddish white, white, and greenish white in colour.

Colour of open flower

All of the citrus parents in Nagpur mandarin, Nagpur seedless, Fairchild mandarin, Kinnow, mandarin, Daisy, katol gold had white open flowers, but Grape fruit had white open flowers with green spots. Bankar *et al.* (2021) [3] reported similar results, showing that all genotypes' open flowers were white with green dots.

Position of flower

The flowers were found in both axillary and terminal positions across all five parent varieties of mandarin, sweet orange, grapefruit and pummelo as illustrated in Table 1.

The flower buds give rise to determinate shoots, which may be either mixed or generative. The apical meristem of a leafy shoot transforms into a terminal flower, while axillary buds can also produce flowers. Consequently, this results in five types of shoots, including those with leafy inflorescences that bear terminal flowers alongside numerous axillary flowers.

Kumatkar *et al*. (2016) [9] reported similar observations, noting that sweet orange flowers exhibited an axillary flower position. Additionally, Shilpy Kumari *et al*. (2021) [18] documented the axillary positioning of acid lime genotypes. This aligns with the findings of Agusti *et al*. (2022) [1].

Table 2: Floral morphology of different citrus parents

Sr. No.	Parents	Stamens Flower^{-1}	Petals Flower^{-1}	Staminate flower percentage (%)	Perfect flower percentage (%)
1.	Nagpur mandarin	18.80	4.96	1.27	97.94
2.	Nagpur seedless	20.25	4.98	0.35	98.13
3.	Fairchild mandarin	21.95	4.95	1.11	97.09
4.	Kinnow mandarin	22.55	4.95	0.65	95.59
5.	Daisy	16.65	4.97	1.43	95.49
6.	Katol gold	21.30	4.98	2.47	98.06
7.	Grape fruit	29.55	4.90	1.96	99.03
8.	Pummelo	28.80	4.01	1.56	97.91
	F test	Sig	Sig	Sig	Sig
	SE (m) ±	0.38	0.01	0.008	0.56
	C.D. at 5%	1.12	0.05	0.02	1.66

Floral morphology

The data regarding different aspects of floral morphology of citrus parent species is displayed in Table 2.

Stamens Flower^{-1}

The data regarding the stamens of flower-1 across various citrus genotypes is presented in Table 2. It has been noted that the highest number of stamens was found in grape fruit (29.55), which was at par with Pummelo (28.80), whereas lowest count of stamens was observed in Daisy (16.65), which was significantly lower than that of the other genotypes.

These results align with the findings of Kumatkar *et al*. (2016) [9], who documented the highest number of stamens in sweet orange (20). Additionally, Baswal *et al*. (2017) [4] reported a count of 23.75 in the Red Blush and Rio Red grapefruit cultivars.

Petals Flower $^{-1}$

A notable variation in the petals flower-1 was detected among various citrus parent types, as illustrated in Table 2. The highest count of petals flower-1 was recorded in Nagpur seedless (4.98) and katol gold (4.98) which was at par with daisy (4.97), Nagpur mandarin (4.96) Fairchild mandarin (4.95) and kinnow mandarin (4.95) Significantly lowest petals flower-1 was observed in pummelo (4.01), which was markedly lower than that of the other parent types.

These results align with the findings of Kumatkar *et al*. (2016) [9], which noted five petals in the flowers of sweet orange.

Staminate flower percentage (%)

It is clearly demonstrated in table 2 there was a notable variation in the percentage of staminate flowers among all citrus parent varieties. The Katol gold variety recorded the highest percentage of staminate flowers at 2.47% while the lowest percentage was recorded in Nagpur seedless at 0.35%. This finding contradicts the results reported by Baswal *et al*. (2017) [4], who noted maximum and minimum percentages of 8.25% and 4.75% for staminate flowers in grapefruit cultivars, respectively. This discrepancy may be attributed to differing climatic factors, particularly temperature, which plays a crucial role in the development of flowers.

Perfect flower percentage (%)

The data illustrating the percentage of perfect flowers is displayed in Table 2. The highest percentage of perfect flowers was noted in Grapefruit (99.03%), which was at par with Nagpur seedless (98.13%), Katol gold (98.06%), Nagpur mandarin (97.94%) and pummelo (97.91%) In contrast, the lowest percentage of perfect flowers was observed in Daisy (95.49%).Similar findings were reported by Baswal *et al*. (2017) [4], who noted a maximum of 95.25% of perfect flowers in Marsh Seedless Grapefruit.

Table 3: Floral biology of different citrus parents

Sr. No.	Parents	Time of anthesis (hrs.)	Time of dehiscence of anther (hrs.)	stigma receptivity (Days)
1.	Nagpur mandarin	7-8	6	4-5
2.	Nagpur seedless	7-8	5	3-4
3.	Fairchild mandarin	6-7	7	3-4
4.	Kinnow mandarin	7-8	6	3-4
5.	Daisy	7-8	5	4-5
6.	Katol gold	8-9	6	4-5
7.	Grape fruit	6-7	5	3-4
8.	Pummelo	8-9	5	4-5

Floral biology
Different aspects of the floral biology of citrus parents is presented in table 3

Time of anthesis (hrs)
As illustrated in Table 3, the anthesis timing for all citrus parent varieties occurred between 6:00 am and 9:00 am. The anthesis for all Mandarins and sweet orange cultivars was noted to take place between 7:00 am to 8:00 am and 8:00 am to 9:00 am, Whereas the grape fruit cultivar exhibited anthesis from 6:00 am to 7:00 am and pummelo 8-9 am. This observation contradicts the findings of Kumatkar *et al*. (2016) [9], who indicated that the anthesis period for all sweet orange cultivars spans from 8:00 am to 6:00 pm, with peak anther activity occurring between 10:00 am and 12:00 noon, followed closely by the period from 12:00 noon to 2:00 pm, A similar anthesis pattern was documented in local Malta (Manju and Rawat 2010) [10]. The variation in anthesis timing may be attributed to factors such as the plantation site, the age of the cultivars, soil health, and the genetic characteristics of the cultivars.

Time of dehiscence of anther (hrs)
Anther dehiscence commenced immediately following the opening of flowers, specifically at 8:00 AM, and persisted until 6:00 PM (refer to Table 3). The optimal period for anther dehiscence across all Mandarins cultivars was identified between 8:00 AM and 4:00 PM, with the highest frequency of dehiscence occurring from 10:00 AM to 12:00 noon in all cultivars.
No cultivar exhibited anther dehiscence prior to 8:00 AM or subsequent to 6:00 PM.
These observations align closely with the research conducted by Motial (1964) [12] and Choudhari and Rane (1976) [4], who noted that anthesis occurred between 9:00 AM and 12:00 noon, while anther dehiscence was recorded between 10:00 AM and 2:00 PM, thereby suggesting species and varietal variations concerning anthesis and anther dehiscence. Similar dehiscence pattern was noted in Nagpur mandarin, where anther dehiscence initiated at 8:00 AM and continued until 4:00 PM, with the highest percentage observed between 10:00 AM and 12:00 noon under Marathwada conditions (Rohidas and Chakrawar, 1982) [17].

Stigma receptivity (days)
Data depicted in table 3 indicates that the stigma receptivity in Mandarin cultivars ranges from 3.00 to 4.00 and 4.00 to 5.0 days post-anthesis. In contrast, the stigma of the grapefruit cultivar was found to be receptive for a duration of 3.00 to 4.00 days and Pummelo 4.00 to 5.0 days. Additionally, Rajput and Hari Babu (1985) [15] noted that the highest stigma receptivity occurred on the day of anthesis, followed by the day before and the day after anthesis. The duration of stigma receptivity is affected by the existing weather conditions. Similar results were obtained by Singh and Dhuria (1960) [19] who studied floral biology of sweet lime. They found that, the stigma receptivity lasted for 6 days and was at maximum at the time of flower opening.

Conclusion
In terms of floral characteristics, Grape fruit and Nagpur seedless exhibited the highest number of flowers, each with five petals and perfect morphology. In contrast, the maximum occurrence of staminate flowers was recorded in Katol gold. Additionally, Katol gold demonstrated superior Furthermore, Nagpur mandarin, Daisy, Katol gold, and Pummelo showed the highest stigma receptivity. Each parent was examined for flower positioning, both axillary and terminal. Nagpur mandarin, Nagpur seedless, Fairchild mandarin, Kinnow mandarin, Daisy, Katol gold, and Pummelo were characterized by white open flowers, whereas Grape fruit displayed flowers that were white with green spots.

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