



RESEARCH ARTICLE

Impact of climate change on phenology of *Delonix regia* (Bojer ex Hook.) Raf. across Mumbai

Farhan Suraliwala & Bindu Gopalkrishnan*

Department of Botany, SVKM'S Mithibai College of Arts, Chauhan Institute of Science & Amruthben Jivanal College of Commerce and Economics, (Autonomous). Affiliated to University of Mumbai, Vile Parle (West), Mumbai 56, India

*Email: bindu_phd@rediffmail.com

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ABSTRACT

The average annual temperatures are gradually increasing over time since few decades. This has led to global warming and change in climate. The increase in temperature has not only affected the humans but the flora too. In many flowering plants the temperature has altered the phenology (timing) of flowering, example *Cassia fistula*, *Samanea saman*, *Delonix regia* etc. An attempt is made to investigate the tree *Delonix regia* (Bojer ex Hook.) Raf. commonly known as Gulmohar. It is monitored for its flowering time since 2016 to 2019. The area selected for study was Bhayandar, Mira road, Andheri and Vile Parle in Mumbai. The data obtained was further analyzed with the literature from different Flora's and research papers. The actual flowering time according to the old literature was April to June. Since few years it has been observed that Gulmohar flowered twice i.e. October to December and also April to June. The amount of flowers bloomed during October – December was scanty while mass bloom was witnessed during April to June. The phenology of flowering has shifted earlier in response to warming during October – December. The shift in the timing of flowering may have resulted in reproductive failure in the plant. This behaviour of plants is of great concern. More broadly it is important to mitigate climate change by controlling global warming in order to conserve the *D. regia* trees. It can be used as bio indicator stating the climate change in Mumbai.

Introduction

Our mother earth has experienced a constant climate change. It has not only affected mankind but also the flora and fauna. Plant phenology is strongly controlled by climate (1 – 4). It has consequently become one of the most reliable bio indicators of ongoing climate change (5). In the past the phenology of several plants were recorded by various Botanical gardens, individual families and networks as an indicator of oncoming climate of a place. Mr. Robert Marsham the father of British Phenological recording has carried out many work in this field (6). Recently many countries are focusing on phenology of plant with respect to climate change. For example in Nigeria phenological study of *Delonix regia* (Bojer ex Hook.) Raf. was recorded (7). Studies on phenological response of plants to climate change in an urban environment is also done with respect to ecosystem (8). In Macao, 12 species of plants for its phenological changes under the effects of extreme climate was also reported (9). There are also studies related to plant phenology and distribution in relation to recent climate change (10). Researchers have worked on the

change in phenology in ephemerals and its implications for pollination and fruit settings (11). In India, *Rhododendron* from eastern Himalaya was investigated with respect to change in flowering time (12). Thus, in India also plants have been used as an indicator for the arrival of various seasons. But due to climate change there is an increase in temperature during past several decades (13). This has affected the phenology (timing) of flowering, in many trees such as *Cassia fistula*, *Samanea saman*, *D. regia* etc. Current study is an attempt made to know the impact of climate change on the phenology of *D. regia*.

Delonix regia (Bojer ex Hook.) Raf. belongs to family Caesalpiniaceae and is commonly known as Gulmohar (14). It is a large deciduous street tree of India, native to Madagascar. The Gulmohar was discovered by Botanist Wensel Bojer in 19th Century. It is a multipurpose tree planted on eroded sites for erosion control and for soil rehabilitation. Gulmohar is planted as avenue tree due to its huge canopy to provide shade and aesthetic beauty. In Bangladesh, the aboriginals used the leaves and flowers in curing diabetes. The large pods and wood is used as fuel. The seed contains gum that is used in textile, food

industries and also as a binder in the manufacture of tablets. Recent research on Gulmohar have shown many medicinal properties like antidiabetic, anti-inflammatory, in gynaecological disorders etc. (15). Due to its economic and medicinal values the tree was investigated. According to the various literature and Flora it is evident that the tree flowered from April to May when the average temperature is 37 °C to 40 °C (16 -18). Since few years as there is increase in temperature even in the month of October and the trees bloomed although not profusely. There was lot of changes observed within those flowering period. Thus, this shift of flowering in Gulmohar is of great concern with respect to the ecosystem.

Materials and Methods

Study Locations

The area selected for the study was Andheri, Vile Parle, Mira Road and Bhayandar in Mumbai, India. The average temperature recorded since four years are April to June (max 38.82 °C to 32.43 °C; min 27.36 °C to 25.33 °C) and October to December (max 35.84 °C to 33.93 °C; min 22.68°C to 17.89 °C). The meteorological data for 4 consecutive years was obtained from Regional Meteorological Centre, Mumbai (19).

Methodology

For the current study, the trees from the above mentioned locations were observed since the first blooming of flowers till the last ones. The flowering periods were compared with the various Flora since 1903 to 2005. The trees were monitored for its flowering and fruiting during both the occasion.

Results and Discussion

Meteorological data

The data was obtained from Regional Metrological Centre, Mumbai. It is represented in Table 1.

Floristic record from Literature

Various Flora were referred to check the flowering time of *Delonix regia* in the past. The details are given in Table 2.

Phenological studies

The data obtained from the phenological studies are represented in Table 3-6.

It was observed that *D. regia* flowered twice in a year i.e. from April-June and October -December over past few years. The tree flowered in Mumbai in the months of October and lasted till December to first week of January. The maximum temperature noted during the blooming period was ranging from 32 °C-35 °C. The flowers bloomed and dwindled leading to no fruitification. Certain flower showed abnormal arrangement of petals. The size of the flowers was much smaller compared to the flowers which bloomed on the same tree during the month of April to June. The maximum temperature recorded during these years were 38.82 °C to 32.43 °C. The colour of the flower were much lighter than the normal

bloomed flowers. The Gulmohar tree when bloomed in October – December month, was fully covered with foliage whereas the tree was deciduous during the actual flowering season (Fig. 1, 2).

Table 1. Meteorological data stating average maximum and minimum temperature since 2016 -2019

Year	Max Temperature (°C)	Min Temperature (°C)
April 2016	33.69	24.18
April 2017	33.78	22.63
April 2018	33.75	23.73
April 2019	38.82	24.11
May 2016	34.35	27.36
May 2017	33.01	26.32
May 2018	34.29	26.48
May 2019	33.79	26.00
June 2016	32.91	26.77
June 2017	32.62	26.18
June 2018	32.53	25.33
June 2019	32.43	27.03
October 2016	32.20	22.68
October 2017	33.68	25.00
October 2018	35.84	23.52
October 2019	32.99	24.36
November 2016	34.79	18.74
November 2017	33.99	22.40
November 2018	35.30	21.83
November 2019	33.71	23.04
December 2016	33.93	17.89
December 2017	31.12	18.44
December 2018	32.37	18.14
December 2019	32.53	21.45

Table 2. Comparison of Flowering time of *D. regia* (Bojer ex Hook.) Raf. tree with the different Flora

Sl. No.	Flora	Years	Flowering time
1	Flora of Bombay Presidency	1903	April-June
2	Flora of Maharashtra	1998	April-June
3	BSI Flora of Maharashtra	2001	April - Sept
4	Flora of Sanjay Gandhi National Park Borivali-Mumbai (Bombay)	2005	March-June

While studying the phenology it was observed that the flowers were visited by pollinators during the month of April – June but none of the pollinators were seen during October – December. Detailed studies on the pollinators were not carried out. The literature survey revealed that the pollinators which visited *D. regia* were Lepidoptera and Hymenoptera members. The Lepidopterans include *Papilio polytes*, *Graphium agamemnon*, *Pachliopta hector* and *Pachliopta aristolochiae* (20). The flowers which bloomed in April – June produced fruit in the month of July which lasted for long time. The fruit setting was absent for the trees that bloomed in the month of October – December.

Conclusion

Delonix regia (Bojer ex Hook.) Raf. used to flower earlier in all over Mumbai from the month of April to June. This is also evident from the flowering time

Table 3. Phenological observations of *D. regia* tree during the year 2016

YEAR 2016												
Parameters/Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Vegetative phase	■											
Leaf fall			■									
Leaf emergence							■					
Bud initiation			■							■		
Flowering			■							■		
Fruiting					■							
Fruit maturation						■						

Table 4. Phenological observations of *D. regia* tree during the year 2017

YEAR 2017												
Parameters/Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Vegetative phase	■											
Leaf fall				■								
Leaf emergence							■					
Bud initiation			■							■		
Flowering			■							■		
Fruiting					■							
Fruit maturation						■						

Table 5. Phenological observations of *D. regia* tree during the year 2018

Year 2018												
Parameters/Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Vegetative phase	■											
Leaf fall				■								
Leaf emergence							■					
Bud initiation			■							■		
Flowering			■							■		
Fruiting					■							
Fruit maturation						■						

Table 6. Phenological observations of *D. regia* tree during the year 2019

Year 2019												
Parameters/Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Vegetative phase	■											
Leaf fall				■								
Leaf emergence							■					
Bud initiation			■							■		
Flowering			■							■		
Fruiting					■							
Fruit maturation						■						

**Fig. 1.** *D. regia* with profuse flowering in the month of April.



Fig. 2. *D. regia* with scanty flowering in the month of December.

mentioned in Flora of Bombay Presidency written in 1903 and Flora of Maharashtra 1998. As the year passed the flowering period also showed changes like in BSI Flora of Maharashtra published in 2000 a shift from April to September, Flora of Sanjay Gandhi National Park Borivali-Mumbai (Bombay, 2005) recorded the flowering time from March –June. It always flowered only once in a year. The current investigations at different sites in Mumbai recorded that, Gulmohar flowered twice a year i.e. in the month of April – June and also October – December. During the flowering period of October – December the tree did not produce any fruit. This reproductive failure in plant species may be due to absence of pollinators which is only present in the month of April - June. Changes in Gulmohar flowering period in Mumbai is a visible indicator of the significant increase in temperature. It also highlights the need of Mumbai to control the increase in temperature in order to maintain the ecological balance. It is a significant warning given by Gulmohar tree. Detailed studies of Gulmohar with regard to pollinators and edaphological aspects will be carried out in future.

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Authors' contributions

FS and BG both the authors have carried out the observations and collections of data in the field, wrote the full manuscript with critical analysis.

Conflict of interests

Authors do not have any conflict of interests to declare.

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Additional information

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