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Effect of Environmental Changes on Phenology and Reproductive Biology of *Sida cordifolia* with Special Reference to the Temperature and Relative Humidity

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Authors' contributions

This work was carried out in collaboration between all authors. This article is from M. Phil. Author DKS performed the Dissertation. Authors RKA and SC designed the study. Authors GS and SAG managed the literature searches, analyses of the study performed. Author RS coordinated the whole work. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Impact of environmental factors (temperature and relative humidity) on phenology and reproductive biology of a medicinal plant *Sida cordifolia* L. growing at district Agra was studied. The study revealed that phenological events (leaf fall, leaf renewal, flowering and fruiting) varied considerably with the fluctuations in temperature and relative humidity. Flowering was observed throughout the year with maximum in the months of February-April (11.8 – 38.3ºC) and August-September (24.4- 33.9ºC). Floral biology studies showed that pollen viability, pollen-ovule ratio and fruit-set percentage was greatly reduced with rise or fall in temperature and relative humidity. The maximum pollen fertility (71%), fruit-set (70- 90%) and pollen-ovule ratio (190:1) was recorded in the month of March when temperature was ranging between 15.1-32.6ºC with 22- 76% RH. With the fall in temperature in the month of January (6.8 - 17.9ºC) the pollen fertility was reduced to 52%. At the end of April 32.5- 45.3ºC with 16- 43% RH, the plants under observation exhibited

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a gradual decline in fruit-set percentage (45- 55%). The anthesis, anther dehiscence and stigma receptivity also varied during the entire flowering period. As the temperature rises, the anthesis takes place earlier and the time of anther dehiscence and stigma receptivity changed accordingly. In this investigation it was found that the changes in temperature and relative humidity during the entire flowering period was associated with the variation in different phenological and reproductive events in the *Sida cordifolia* plant.

Keywords: Anthesis; dehiscence; phenology; pollen fertility; Sida cordifolia.

1. INTRODUCTION

The environment in which an organism lives affects its reproductive success [1]. The Physiology of reproduction in most of the flowering plants is closely under the direct control of environmental factors [2]. Environment exerts considerable influence on flowering, pollen fertility, *in vitro* pollen germination and fruiting in plants [3]. Extensive studies have been made on the effect of various environmental factors on floral development, pollen fertility, female sterility, and flower and fruit abscission including diseases on the development of fruit in the plants [3]. Climate change has affected many aspects of the biology of trees and its effect on plant's first flowering dates would be of great significance [4-5]. Therefore, reproductive phenological analysis of trees provides a potential tool to unravel critical questions related to monitoring and modelling of climate change. In recent years, the focus of such studies has shifted to questions of how reproductive phenology will be affected by climatic factors and what consequences any climatic change may have for species distribution and ecosystem function. Plant communities show conspicuous seasonal pattern in vegetative and reproductive phenologies at both community and species levels particularly to tropical plant [6-7].

The effect of temperature on floral initiation of tree crops varies with species. In cool temperate species, the relatively high temperature of summer and early autumn appear to promote initiation, whereas in warm temperate, subtropical and tropical species, a relatively reduction in temperature is beneficial [8-12]. In the temperate regions, the seeds and fruits of most of tree species ripen and are shed during the autumn or early winter.

Sida cordifolia commonly known as Indian ephedra belongs to family Malvaceae. In India the genus is represented by 5 species, however *S. cordifolia* is the most common wild herb representative occurring in different tropical and subtropical part [13]. The whole plant of *Sida cordifolia* is of great medicinal value. It is used in the treatment of branchial asthma, cold, flu, chills, headache, nosal congestion, cough and sneezing [14], weight loss [15], bleeding piles and urinary diseases.

Keeping in view the above importance of plant present investigation has been undertaken to study the effect of temperature and relative humidity on different phenological and reproductive events of this important medicinal plant for its better cultivation and conservation.

2. MATERIALS AND METHODS

The effect of temperature and relative humidity on phenology and reproductive biology was studied at Botanical garden, Department of Botany, School of Life Sciences, Khandari

Campus, Dr. B. R. Ambedkar University, Agra, during August, 2010 - August, 2011. 25 marked plants and 100 inflorescences, selected at random were tagged to record the floral density, plant-pollinator interaction, fruit and seed- set percentage. The tagged inflorescence was followed every 3d until flowering closed and every 7d until the end of the fruiting period. Number of pollen grain/flower, number of anther/flower and number of ovule/ovary were studied by various methods given by [16]. For pollen and ovule counts, we randomly choose 25 flowers from different individuals. Collected flowers were of the same flowering stage and location on the inflorescence. Flowers were stored in denatured alcohol and ovules were later counted at 10× magnification. Pollen had already dehisced at the time these flowers were collected, therefore, a separate nearby random transect was used to collect all undehisced anthers from different individuals of the same flowering stage in denatured alcohol. Anthers were transferred to a vial containing deionized water and sonicated for one minute until the pollen was released from the anther sacs. One drop of diluted liquid detergent was placed in the vial and vortexed to suspend and equally distribute pollen grains in the vial. Pollen grains were counted under a microscope and total pollen per flower was estimated from aliquoted pollen solutions and anther number. Although the pollen and ovule counts are not from the same flower or individual, this method provides reliable population-level estimates of pollen to ovule ratio. Pollen viability at different temperatures during the entire flowering period was checked by 1% TTC, FCR and Alexander stain tests.

The mode of pollination was evaluated by bagging the emasculating mature buds and hand pollination. Different pollinators, their population types and visitation rates were recorded.

The fruit- set and seed-set was observed by counting the number of fruits per inflorescence to the number of flowers per inflorescence and number of seed per fruit to the number of ovules per pistil respectively. Percentage of fruit-set and seed-set was calculated by the following formula:

$$\text{Fruit - set \%} = \frac{\text{No. of fruits per inflorescence}}{\text{No. of flowers per inflorescence}} \times 100$$

$$\text{Seed - set \%} = \frac{\text{No.of seeds per fruit}}{\text{No. of ovules per pistil}} \times 100$$

Data on daily maximum and minimum temperature and relative humidity during the entire flowering period were collected from Department of Environmental Sciences, School of Life Sciences, Khandari campus, Dr. B. R. Ambedkar University, Agra.

3. RESULTS AND DISCUSSION

3.1 Effect of temperature and relative humidity on phenology

Flowering occurred throughout the year, however, maximum floral density was observed during the months of February- April and August- September, when the temperature ranges from 27.4ºC to 38.3ºC with 76-90% RH, while minimum flowering was observed during the month of October – November and May – June, when the temperature ranges from 28.8 to 35ºC with 40 - 88% RH (Table 1 and Fig. 1).

The effect of temperature on floral initiation of tree crops varies with species. In cool temperate species, the relatively high temperature of summer and early autumn appear to promote initiation, whereas in warm temperate, subtropical and tropical species, a relatively reduction in temperature is beneficial [8-12].

Table 1. Effect of temperature and relative humidity (RH) on different reproductive parameters of *S. cordifolia*

Month	Temp.		RH%	Time of anthesis	Time of anther dehiscence	Time of stigma receptivity	Floral density	No. of pollen/ flower
	Max.	Min.						
Sep.	33.9	24.4	39 – 92	1400 – 1445	1430 – 1445	1400 – 1450	+++	9500
Oct.	35.0	18.9	42 – 88	1410 – 1500	1440 –1450	1410 -1500	+	6000
Nov.	28.8	14.6	40 – 85	1435 – 1515	1450 – 1515	1435 – 1535	+	7000
Dec.	21.9	9.8	37 – 90	1445 – 1525	1510 – 1545	1445 – 1525	++	9000
Jan.	17.9	6.8	58 – 92	1455 – 1540	1500 – 1540	1455 – 1540	+++	10200
Feb.	27.4	11.8	35 – 90	1445 – 1510	1440 – 1525	1445 – 1515	+++	10800
Mar.	32.6	15.1	22 – 76	1435 – 1500	1430 – 1500	1435 – 1500	+++	11400
Apr.	38.3	22.3	12 – 45	1420 – 1450	1420 – 1450	1420 – 1450	+++	11100
May	42.3	26.0	16 – 50	1300 – 1345	1410 – 1445	1305 – 1345	+	7800
Jun.	45.8	32.2	16 – 43	1320 – 1400	1400 – 1430	1320 – 1400	+	5400
Jul.	34.7	26.5	72 – 97	1335 – 1400	1410 – 1445	1335 – 1405	++	9200
Aug.	32.7	25.0	78 – 98	1350 – 1420	1420 – 1500	1350 – 1420	+++	9800

+: minimum, ++: moderate, +++: maximum

Fig. 1. Phenological events in *S. cordifolia*

Fruiting was more or less similar to flowering. Maximum fruiting was observed in the months of November - December and March – May (24.4-42.3ºC with RH 40-85 and 16-50%) and minimum fruiting was recorded during the months of January – February and July – August (22-33.4ºC with RH 46.5-91 and 75-97.5%). It is clear from the present study that the phenological events are directly correlated with environmental factors and prevailing temperature.

3.2 Effect of Temperature and Relative Humidity on Reproductive Biology

3.2.1 Floral biology

The flowers open at 1410 – 1500 h in October followed by anther dehiscence at 1440 – 1450 h and stigma became receptive between 1410–1500h, when the temperature ranged between 18.9 to 35.0ºC with 42–88% RH, while in June, anthesis took place between 1320 – 1400 h followed by anther dehiscence 1400 – 1430 h and stigma became receptive between 1320 – 1400 h, when temperature ranged between 28.2-38.1ºC with 28 – 55% RH. It is clear from the Table 1 that anthesis varied considerably during the entire flowering period. As the temperature rises floral opening takes place earlier and the time of anther dehiscence and stigmatic receptivity changes accordingly.

The study showed that number of pollens per anther and the number of pollens per flower varied with change in the temperature and relative humidity. Maximum number of pollen per anther was 190±3.33 and pollen per flower was 11400±25.57 in the month of March, when the temperature was 15.1- 32.6ºC with 22–76% RH. On the other hand, in the month of June the number of pollens per anther and pollens per flower were reduced (90±3.33, 5400±11.78 respectively) when the maximum and minimum temperature were 45.8 and 32.2ºC respectively with 16-43% RH. The pollen-ovule ratio was found to be 190:1 and 90:1 during the month of March and June, respectively. It is clear from the study that the number of pollens per anther, number of pollens per flower and pollen-ovule ratio was reduced with the increase in temperature and decrease in relative humidity in the month of June. Similar results have also been reported by [17] in *Murraya exotica*, who observed 1245:1 pollen-ovule ratio during the months of January – March, 595:1 during April – June and 1515:1 during July – September.

3.2.2 Pollen viability

Pollen viability was greatly reduced with rise or fall in temperature and relative humidity during the entire flowering period. The pollen viability was maximum (71.0%) in the month of March, when the temperature was 15.1 to 32.6ºC with 22 – 76% RH while minimum pollen viability (17.0%) was found during the month of June when the temperature was 32.2 to 45.8ºC with 16 – 43% RH (Fig. 2).

Various investigators have recorded reduction in pollen viability and pollen production caused by decline or increase in temperature in several crop and ornamental plants [18-23]. [20] have found adverse high temperature effects on pollen viability, seed-set and yield in *Sorghum bicolor*. They have observed that growth temperatures $\geq$36/26ºC significantly decreased pollen production, pollen viability and seed-set. Thus the viability of pollen is under direct control of climatic conditions, temperature and relative humidity in particular.

3.2.3 Pollination biology

The attractants (yellow flowers, inflorescence, flower architecture, floral density) and rewards (nectar and pollen grains) of *S. cordifolia* invited a variety of insects during the entire flowering period. Although all the insect species recorded were found foraging throughout the flowering period but it was observed that their visitation period varied with the temperature. Honey bees were more common during November - April, houseflies April - July, butterflies in November, March-April and July and the large ants in the month of March and July.

Activity of pollinators is related to the ambient temperature. Their activities were limited by low temperatures in temperate climates and high temperature in tropical climates [1]. According to [24] the insect activity is reduced below 10ºC.

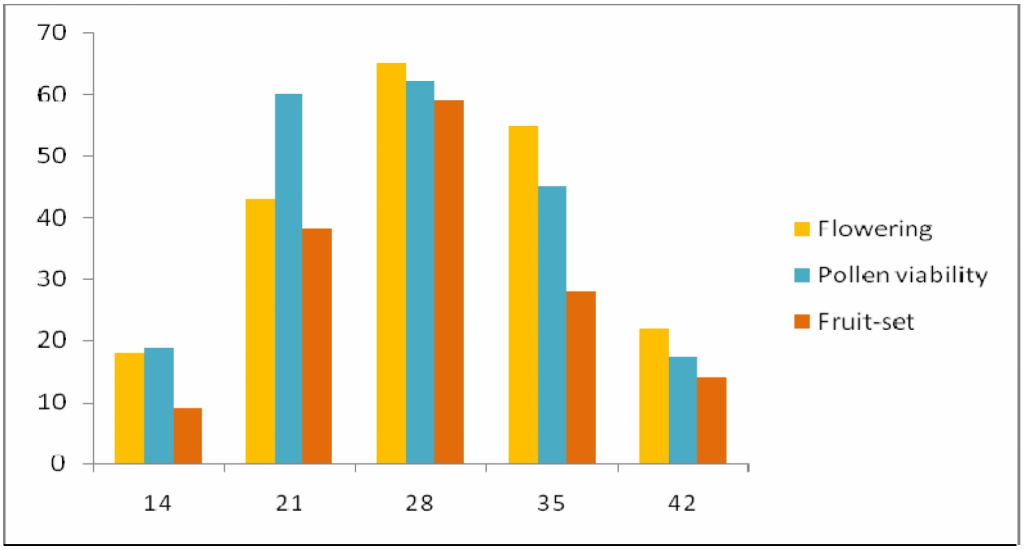

Fig. 2. Impact of temperature on different reproductive parameters of *S. cordifolia*

3.2.4 Fruit and seed-set

It is clear from Fig. 2 that the fruit-set percentage varied with the fluctuations in temperature in different flowering periods. The maximum fruit-set was 60-70% in the months of February and March when the temperature was ranging between 15.11 and 32.69ºC with 22-90% RH. At the end of April, in the month of May- June, the plants under observation exhibited a gradual decrease in fruit-set percentage (30–40%) when the temperature was 32.5- 45.3ºC with 16–43% RH. It is interesting to note that during this period, most of the effective pollinators were remarkably absent and pollen grains became more or less sterile. It seems probably that on account of the absence of the effective pollinators and the presence of sterile pollens, the plants exhibited lowest fruit-set. Similar observations have also been recorded by [25] in several other ornamental plants. According to these workers, during the months of May and June, when temperature reaches to its peak at Agra, the pollen grains become sterile to a large extent.

4. CONCLUSION

Thus, the changes in various phenological and reproductive parameters in *Sida cordifolia* growing at Agra city are brought about by the changes in environmental factors, particularly temperature and relative humidity. Temperature ranging between 28-35ºC would be the optimum for better growth and cultivation of *S. cordifolia.* Varied insects that visit this plant obtain their nourishment; as such the existence of this kind of species in a community is paramount to the functioning of the ecosystem.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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