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Morphometric and Reproductive Phenophases in *Bauhinia* Species

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***Abstract*:** The present paper deals with the morphometric and reproductive phenophases of two important tropical tree species, namely, *Bauhinia variegata* and *Bauhinia purpurea*. The study was carried out on nine trees selected from Punjab Agricultural University, Ludhiana and Dr. YS Parmar UHF Nauni, Solan. Phenophases like leaf bud swell, leafing, opening of bud, and flowering characteristics were recorded in year 2018-19. Phenophases were species-specific and dependent on the research area's environmental and meteorological circumstances. The present investigations revealed that mean days of leafing, bud opening, and leaf bud swell remains were similar in both species, but leaf area (cm^2) was higher in *B. purpurea* than in *B. variegata*. The mean days of flowering were different in both species. Petal length and breath, filament length, were all higher in *B. purpurea* species, and the maximum anther dehiscence was observed between 7.30 and 8.30 am in selected genotypes. These discoveries are important for botany, especially in the fields of forestry and ecology, where they will help with work to improve genetics.

Keywords: *Bauhinia variegata*, *Bauhinia purpurea,* Phenophases, Reproductive biology

Bauhinia L. is an extremely variable genus of shrubs, medium-sized and large trees of the family Caesalpinioideae, with a pan tropical distribution of about 600 species. It is native to South and Southeast Asia (China, India, Pakistan, Burma, Sri Lanka, and Nepal). In India, around 30 species are found and generally prevalent in the sub and outer Himalayas from the Indus River eastwards, ascending to an altitude of 1,830 m.s.l. in Assam, Burma and other parts of the Indian Peninsula. *Bauhinia variegata* is a moderately sized tree and the bark is ashy to dark brown in color, almost smooth. Dropsy, rheumatism, convulsions, insanity, and septicemia have all been treated using the complete *Bauhinia purpurea* L. plant. The plant *Bauhinia purpurea* L. may have anti-proliferative and antioxidant properties (Zakaria et al 2011). Various extracts of *Bauhinia racemosa* L. leaves have been investigated in developing a novel pharmaceutical medication to prevent enteric infection (Dahikar et al 2011). *B. purpurea* leaves are rich in nutrient content and are fed to lactating buffaloes, sheep, goats, and cattle, with crude protein content estimated at 12.6 per cent (Orva et al 2009). Taking into consideration their importance, it is important to study their morpho-metric and reproductive characteristics. Studies of phenology, in general, and blooming phenology, in particular, are important for establishing conservation strategies and creating methods for large-scale cultivation of such species (Bernardello et al 2001). The purpose of this study is to investigate the variation in leaves and flowers characters of *Bauhinia variegata* and *Bauhinia purpurea*.

MATERIAL AND METHODS

Five parent trees V_1, V_2, V_3, V_4, V_5 of *Bauhinia variegata* and two trees P_1, $P_2$of *Bauhinia purpurea* were selected at Dr. Yashwant Singh Parmar, University of Horticulture and Forestry, Nauni, Solan (Latitude: 30°51'N, Longitude: 76°11'E). The area experiences sub-tropical weather with relatively hot summers and cold winters (Fig. 1). The hottest months are May and June, while the coldest months are December and January. The site's mean annual rainfall is 1000–1300 mm/yr, with heavy rainfall during the monsoon. Two trees of *Bauhinia purpurea* $P_3$and P_4were selected by the Punjab Agricultural University, Ludhiana. The experimental site is located at an altitude of 247 m above mean sea level in the central zone of Punjab and lies between 30°-50'N latitude and 75°-52'E longitude. The climate of this area is sub-tropical to tropical and average annual rainfall of 700 mm per year.

The selection of superior trees was made on the basis of various morphological characteristics in the natural distribution region of Himachal Pradesh and Punjab. For their floral characters (floral bud swell, floral bud formation, flowering span), petal length and breath, stigma length, pollen size, leafing, *etc.* were observed. Three branches on each tree will be marked, and on each branch, five buds and

flowers were observed. Randomized block design was used to analyze data on phenotypic characteristics of *Bauhinia* genotypes. The significance of differences among the treatment means was tested by using SPSS software.

RESULTS AND DISCUSSION

Vegetative (leafing) characters: The mean number of days of vegetative bud opening, leaf bud swells and leafing was statistically on par with all the selected trees of *Bauhinia* species with a maximum in V_3(98.0 days) (Table 1). Blooming periods are significantly determined by the timing of vegetative phenology, according to a study of the proximal controls of flowering in tropical deciduous forest species, and therefore flowering is at least indirectly dependent on environmental periodicity (Rivera et al 2002). Leaf initiation in *T. bellirica, S. colorata,* and *C. arborea* started in April and in *B. variegata, S. villosa,* and *D. pentagyna* during May. Bud swell and bud burst are essential adaptation characteristics because they govern the tree's vegetative period's co-adoption to periodic variations in climatic components in the environment where it flourishes. Leafing is initiated during the dry-summer period and those species which can produce new leaves during the dry season depend on water stored in the tree stem or water remaining in the subsoil (Sayer & Newbery 2003). Moreover, deep rooting canopy trees do not experience a water deficit condition during dry season and can continue leaf-flushing activity. Seasonal duration of leafing, flowering and fruiting mainly determine phenological behavior in tropical trees. These phenological events are not mutually independent in woody species, and flowering may be partly or wholly dependent on leafing activity. The leaf area of certain genotypes showed that *Bauhinia purpurea* (96.9-99.3 cm^2) has a lot more leaf area than *B. variegata* (85.9-89.4 cm^2) (Table 1).

Floral Characters

Mean day flower character: Floral bud swell of different species was statistically significant with maximum days of reproductive bud swell in P_3 (67.8) and P_4 (68.6), which is on par with each other. Floral bud formation was significant with mean days for floral bud formation in P_1 (16.7), which are on par with species of *Bauhinia purpurea* but attain mean maximum days in comparison to *Bauhinia variegata* (Table 2). The flower bud development starts with the onset of physiological activity within the plant, and buds take a maximum of 16.7 days. There was significant difference between the flowering span of both the species. P_3(88.7) and P_4 (87.4) had the highest day flowering than remaining, which was statistically higher than the other parents. All species of

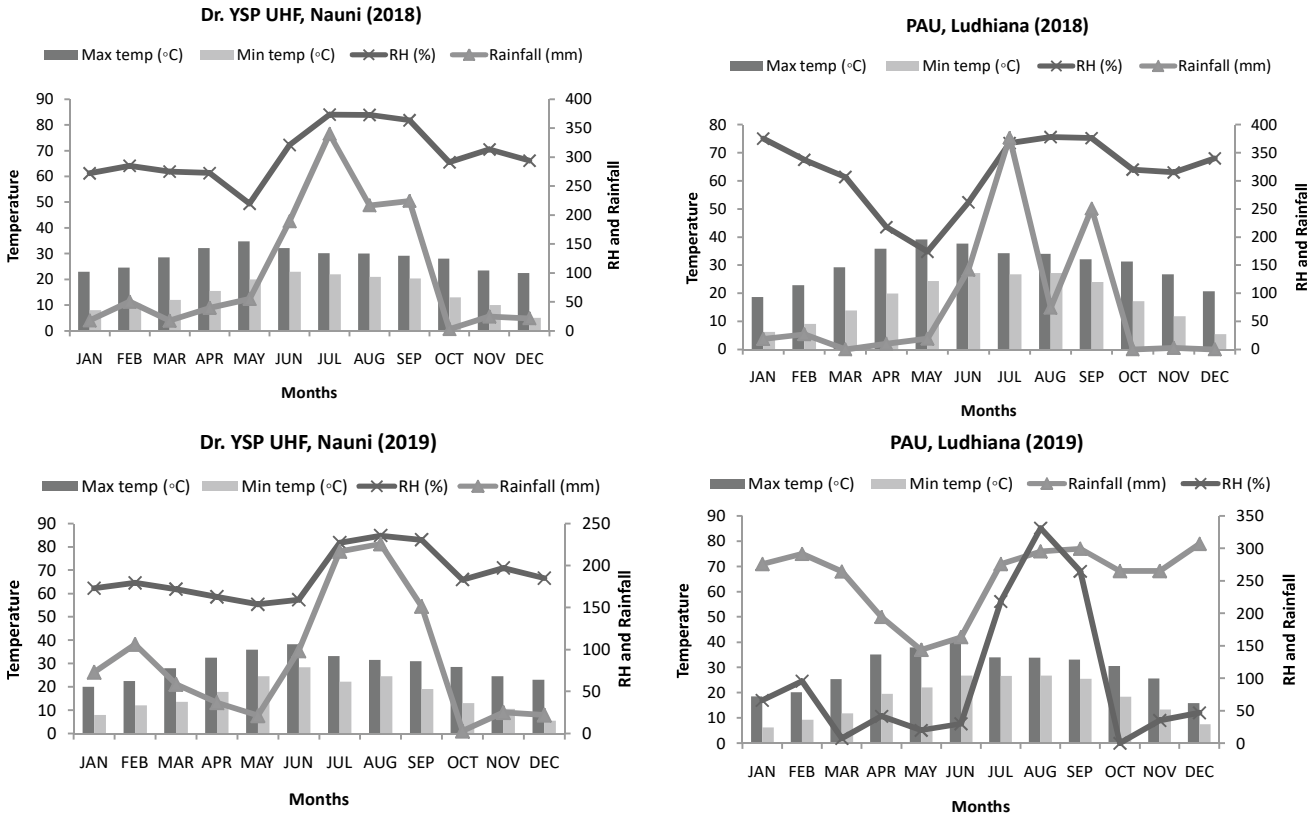

Fig. 1. Mean monthly meteorological data of Dr. YS Parmar UHF Nauni, Solan (HP) and PAU Ludhiana (Pb) for the year 2018-19

B. variegata remain at par; *B. purpurea* genotypes P_1 and P_2 also remain at par (Table 2). Flower initiation occurs during the dry season. This is in conformity with the report of Yadav and Yadav (2008) for dry deciduous forest trees. Flowering in the dry season indicates the availability of water from many sources, such as intermittent winter rainfall, soil absorption, and water retained in the stem (Singh and Kushwaha 2006). Other researchers have noted a peak blooming time prior to the rainy season (Kikim and Yadava 2001), and been suggested that moisture, temperature, and photoperiod are all factors influencing flowering (Pandey et al 2002). Pollen size varies statistically among different selected species. Maximum pollen size was obtained in V_5 (80.99 m), which is on par with V_1 (70.3 m) and V_2 (70.3 m), while minimum pollen size was in P_4 (54.6 m) (Table 2).

Flower length and breadth: Maximum flower length was in P_3 (9.53 cm), which is on par with all the rest of the species except V_2 (8.86 cm) and P_4 (7.55 cm). Higher flower breath was obtained in *Bauhinia purpurea, i.e.,* P_3 (50.5 cm), which is on par with all the other *B. purpurea* species and superior to other species of *B. varigeta* (Table 3).

Petal length (mm): Posterior petal length was significantly superior in all the genotypes of *Bauhinia purpurea* and P_3 was having maximum posterior petal length (50.5 mm) which was statistically at par with P_1, P_2 and P_3 (50.5 mm to 50.1 mm), whereas value of *Bauhinia variegata* ranges between 49.8 mm to 46.5 mm and V_5 was having minimum length. Anterior petal length 1 and 2 showed significant difference with maximum length in B. *purpurea* (53.9 mm, 51.1 mm) and *B. variegata* (44.1 mm, 42.8 mm), respectively. Lateral petal length 1 and 2 of both species was also differing significantly. Lateral petal length 1 has maximum value in V_2 (45.3 mm) which was at par with P_1, P_2, P_3 but superior than remaining genotypes. Lateral petal length 2 was higher in P_2 (44.8 mm) which were at par with P_1, P_3, but statistically more than remaining genotypes (Table 3).

Petals width (mm): Posterior petal width of all the parents were also statistical differ with each other with maximum width in P_1 (36.3 mm) which was at par with P_2, P_3 and higher than remaining selected genotypes. Anterior petal width 1 and 2 was significantly more in P_1 (30.8 mm), V_4 (26.6 mm) and lesser in V_1 (21.7 mm) and V_5 (22.9 mm), respectively.

Table 1. Duration of different vegetative phase in Bauhinia species (days)

Parents	Bud opening	Leaf bud swell	Leafing	Leaf area (cm^2)
V_1	4.07	95.2	97.8	86.8
V_2	4.17	93.2	95.5	85.8
V_3	4.07	94.8	98.0	86.9
V_4	3.80	97.5	95.8	89.4
V_5	4.10	96.1	97.1	86.7
P_1	4.03	95.9	97.8	96.7
P_2	3.93	95.9	95.5	96.9
P_3	4.03	98.4	90.7	97.5
P_4	3.97	95.1	95.7	99.3
CD (p=0.05)	NS	NS	NS	7.1

Table 2. Mean days for different floral parameter of *Bauhinia* species

Parents	Floral bud swell	Floral bud formation	Flowering span	Pollen size
V_1	36.9	15.8	41.3	70.3
V_2	37.6	14.5	41.5	70.3
V_3	38.8	15.8	40.2	64.7
V_4	44.2	15.1	40.9	62.7
V_5	38.3	15.3	40.3	81.0
P_1	37.7	16.7	55.7	57.5
P_2	39.2	16.1	54.2	60.4
P_3	67.9	15.7	88.7	57.7
P_4	68.6	16.6	87.4	56.5
CD (p=0.05)	4.92	1.22	3.43	14.0

Lateral petal width 1 and lateral petal width 2 was higher in P_1 (25.7 mm) and P_1 (24.8 mm) and lesser in V_5 (19.7 mm) and V_5 (19.5 mm) (Table 3).

Filament length (mm): Anterior filament length was more in P_2 (45.4 mm) which are at par with all the other species except V_3 (43.0 mm) and V_4 (42.9 mm). Posterior filament length 1 was statistically more in P_2 (35.5 mm) which was at par with P_1 and P_3 and inferior in V_4 (25.5 mm) and posterior filament length 2 was higher in P_3 (32.7 mm) that was at par with P_2, P_1 and least was in V_5 (24.2 mm). Lateral filament length 1 were more in V_4 (43.5 mm) which was at par with V_1, V_2, V_5 lesser in all the rest parents and lateral filament length 2 was more in V_5 (43.3 mm) that was at par with V_1 and V_2 (Table 3).

Floral Bud Diameter (mm)

Stage 1 to 3: At stage one reproductive bud diameter shows statistical significant differences with maximum in P_1 (2.69 mm) which was at par with P_4 (2.41 mm) and minimum in P_3 (2.21 mm). Stage two shows maximum bud diameter in P_1 (3.63 mm) which was at par with V_4 and P_3 and minimum bud diameter was in V_5 (2.87 mm) and stage three shows maximum bud diameter was in P_1 (4.54 mm), which was at par with P_2, P_4 and V_1 and least diameter in V_5 (3.92 mm) (Table 4).

Stage 4 to 6: Maximum value of bud diameter in stage four was in P_1 (7.58 mm) and least in P_2 (6.71 mm). In stage five, genotype V_1 (9.07 mm) was maximum bud diameter which was at par with V_2 and minimum in P_2 (7.66 mm) and at stage seven, bud diameter of V_3 (10.9 mm) and V_1 (10.9 mm) significantly superior to other parents (Table 4).

Stage 7 to 9: Bud diameter of P_3 (13.2 mm) was found to be more than other selected genotype in stage seven; minimum was in V_4 (12.0 mm). At stage eight maximum diameter of bud was in P_3 (15.3 mm) that was at par with V_3, V_2, V_1, P_2 and P_4

Table 3. Flower parameters of Bauhinia species

Parents	Flower size(cm)		Petals										Stigma (mm)		Anthers length(mm)				
			Length					Breath					Length	Breadth	A	P1	P2	L1	L2
	L	B	P	A1	A2	L1	L2	P	A1	A2	L1	L2							
V_1	9.04	10.00	46.8	44.1	45.7	41.3	41.7	23.3	21.7	23.8	20.5	20.1	40.6	2.6	44.1	26.3	25.6	43.1	42.4
V_2	8.86	10.80	48.1	44.9	45.8	45.3	41.5	21.7	22.8	23.7	23.2	20.3	39.6	2.5	44.5	26.2	25.9	42.1	42.2
V_3	9.17	9.95	47.8	45.2	44.6	44.0	43.5	28.1	27.0	26.1	24.1	23.1	40.4	2.6	43.0	25.6	25.8	41.0	41.5
V_4	9.35	10.50	49.8	45.7	45.0	43.4	42.9	27.6	26.9	26.6	25.4	23.0	39.6	2.8	42.9	25.5	24.9	43.5	41.6
V_5	9.11	10.10	46.5	42.1	42.8	40.3	38.7	25.5	24.0	22.9	19.7	19.5	40.5	2.5	43.2	26.0	24.2	43.3	43.3
P_1	9.07	9.48	50.1	53.5	50.2	44.9	44.7	36.3	30.8	25.9	25.7	24.8	43.4	1.9	45.1	35.3	32.5	32.1	32.9
P_2	9.22	9.58	50.4	53.9	50.1	44.6	44.8	35.9	29.2	25.7	25.5	24.3	43.7	2.0	45.4	35.5	32.6	32.1	33.2
P_3	9.53	9.60	50.5	53.9	49.5	44.5	44.3	35.6	28.9	25.0	25.3	24.6	44.1	2.0	45.2	35.4	32.7	32.3	33.2
P_4	7.55	9.20	50.3	51.1	46.8	42.5	42.4	27.1	26.7	23.7	23.9	21.1	38.5	2.20	44.2	30.2	29.3	37.5	37.3
CD (p=0.05)	0.64	0.65	1.37	2.33	2.59	1.12	1.38	1.65	2.62	1.87	2.28	2.98	2.86	0.32	1.44	1.37	2.15	2.84	2.60

Table 4. Floral bud diameter at different developmental stages of bauhinia species

Parents	Diameter of buds at different stages								
	Stage-1	Stage-2	Stage-3	Stage-4	Stage-5	Stage-6	Stage-7	Stage-8	Stage-9
V_1	2.48	3.52	4.29	7.08	9.07	11.0	12.2	14.9	18.0
V_2	2.40	3.33	4.07	6.77	8.90	11.0	12.2	14.9	18.0
V_3	2.34	3.42	4.22	6.85	8.21	9.60	12.1	15.1	18.2
V_4	2.27	3.57	4.24	6.91	8.00	9.59	12.0	15.1	18.1
V_5	2.23	2.87	3.92	7.01	8.16	10.2	12.1	14.0	18.0
P_1	2.69	3.63	4.54	7.58	8.45	9.72	11.9	14.0	16.3
P_2	2.23	3.42	4.48	6.71	7.66	9.90	12.9	14.9	18.1
P_3	2.21	3.29	4.52	6.87	8.03	10.2	13.2	15.3	18.1
P_4	2.41	3.50	4.32	7.11	8.63	10.1	12.2	14.8	17.6
CD (p=0.05)	0.21	0.20	0.25	0.31	0.42	0.40	0.33	0.49	0.59

were superior to other genotypes. At stage nine maximum bud diameters was obtained in P_2 (18.1 mm), it was at par with V_1, V_3, V_4, P_3 (Table 4).

Changes in the timing, length, and synchronization of phenological episodes in tropical forests may be influenced by global climate change. Because tropical trees differ greatly in terms of adaptations to seasonal dryness and signals for bud break of vegetative and floral buds, are predicted to respond differently to variations in rainfall and temperature (Singh and Kushwaha 2005). As a result of climate change, several studies considerable variation (earlier or later) in blooming beginning dates (Fitter and Fitter 2002) and fruiting responses (Chapman et al 2005) in tree species. Climate change impacts are likely to be best examined at the functional type level, depending on deciduousness length and reproductive phase beginning time (first-visible-flower).

Floral bud length (mm)

Stage 1 to 3: Bud length in first stage was found to be higher in P_1 (6.57 mm) than all other parents and minimum in V_4 (4.33 mm) which were at par with V_1, V_3 and P_2. In stage two, maximum bud length was obtained in V_1 (8.70 mm) and minimum in V_5 (7.39 mm) which was at par with each other and inferior then V_1. Higher bud length was found in stage three for genotype V_4 (12.6 mm) that was at par with all other parents except P_1, P_2 and P_3 (Table 5).

Stage 4 to 6: Stage four shows statistically more bud length in P_3 (23.0 mm) which was at par with V_2 and minimum was found in P_1 (19.5 mm). Maximum bud length was reported in stage five for genotype V_1 (35.1 mm) which was at par with V_2 and P_3, minimum in P_2 (34.9 mm). Stage six shows that maximum value of bud length in V_2 (47.7 mm) and at par with V_1, statistically superior to all other parents, and minimum bud length was found in V_3 (43.5 mm).

Stage 7 to 9: Stage seven shows maximum value of bud length in P_3 (58.6 mm) that was at par with P_2, and minimum in V_3 (54.20mm). Stage eight shows maximum value of bud length in P_3 (69.2 mm) which was at par with P_2, minimum value was found in V_3 (63.2 mm). Stage nine has maximum value of bud length in V_1 (81.9 mm), and was at par with all the species except P_1(Table 5).

Several phenological studies have concluded that changes in water availability from shifts in precipitation regimes and soil moisture are the essential proximate causes affecting phenological patterns. Tree species with similar leaf phenology often differ in the timing of their flowering and fruiting. Many deciduous tree species show flowering and fruiting during the leafless period, exhibiting wide separation between leafing and flowering phenophases. In many evergreens and in some deciduous species leaf flush and flowering occur close in time on the same new shoot.

Phenophase: Time Period for floral and vegetative bud swell and burst, leafing, fruiting, senescence and seed maturity of studied species are presented (Figure 2). Phenological characters of *Bauhinia variegata* and *Bauhinia purpurea* presented in Table 6.

Bauhinia Variegata: Bark color of this species was grey and flower color was whitish with mostly purple tinge. Its pollen vector was honey bees, ants; moth etc. Seed color of *B. variegata* was grayed orange. Its flower opening time was 6-9 am. Anther dehiscence time was 6.30 -9.30 am. Pod color was dark brown.

Bauhinia purpurea: Bark color of this species is pale grey brown and flower color was purple to white. Its pollen vector was honey bees, ants, bumble bees etc. Seed color was grayed orange. Its flower opening time was also 6-9 am. Anther dehiscence time is 7.00 -10.30 am. Pod color was dark brown.

Table 5. Floral bud length at different developmental stages of bauhinia species

Parents	Length of reproductive buds at different stages								
	Stage-1	Stage-2	Stage-3	Stage-4	Stage-5	Stage-6	Stage-7	Stage-8	Stage-9
V_1	4.8	8.7	12.3	22.2	35.1	47.5	55.1	64.0	81.9
V_2	5.0	7.6	12.1	22.2	34.9	47.7	55.5	65.4	81.7
V_3	4.5	7.6	12.4	21.4	32.2	43.5	54.2	63.2	81.5
V_4	4.3	7.9	12.6	22.0	32.5	43.8	54.3	65.0	81.3
V_5	4.3	7.4	12.0	21.5	33.0	45.1	55.6	65.4	80.5
P_1	6.6	7.8	11.5	19.5	31.6	43.7	54.3	66.0	75.3
P_2	4.5	7.6	11.8	22.0	33.3	44.4	58.2	69.1	81.7
P_3	4.6	7.7	11.9	23.0	34.3	45.2	58.6	69.2	81.0
P_4	4.9	7.7	12.1	21.0	33.2	44.8	55.0	64.1	80.1
CD (p=0.05)	0.5	0.4	0.5	0.8	1.2	1.7	1.6	1.0	1.5

Flowering and fruiting occur during the leafless period in many deciduous tree species, with a large gap between the leafing and flowering phenophases. In many evergreen and deciduous plants, leaf flush and blooming occur at the same time on the same young stem. The main pollinators for cross-pollination in *Bauhinia variegata* are Bumbus spp. and *Metasyphris conferato*r. Controlled crosses between *B. variegata* and *B. purpurea* resulted in maximum fruit and seed set after 8 hours of anthesis and developed into viable seedlings. Broeck et al (2003) observed that *Populus nigra* x *P. canadensis* and *Maughania macrophylla* x *M. chappar*. Anthesis brings about exposure of anthers and stigma to the pollen vector. Flower ordinarily opens and closes at definite hours. The present investigations revealed that the dehiscence of anthers took place between 6:30 to 9:30 am in a longitudinal fashion, maximum anther dehiscence was observed between 7.30 to 8.30 am in selected genotypes. Variation in flowering time relative to vegetative phenology, induced by a variety of factors (significant rain in winter/summer, decreasing or increasing photoperiod, or drought-induced leaf fall), results in a number of flowering patterns in tropical trees (Borchert et al 2004). In *Dalbergia sissoo*, Chauhan et al (2004) observed that stigma become responsive a few hours prior to anthesis and stay receptive a few hours following anthesis. Wani (2008) discovered anther dehiscence in the morning in *Bauhinia variegata*. Aguiara et al (2016) observed that anther dehiscence in *Cenostigma macrophyllum* occurred about 9 a.m. In Senna cana Torres et al (2008), the timing of anthesis was found to be approximately 7am. Wani and Chauhan (2008) in *Bauhinia*

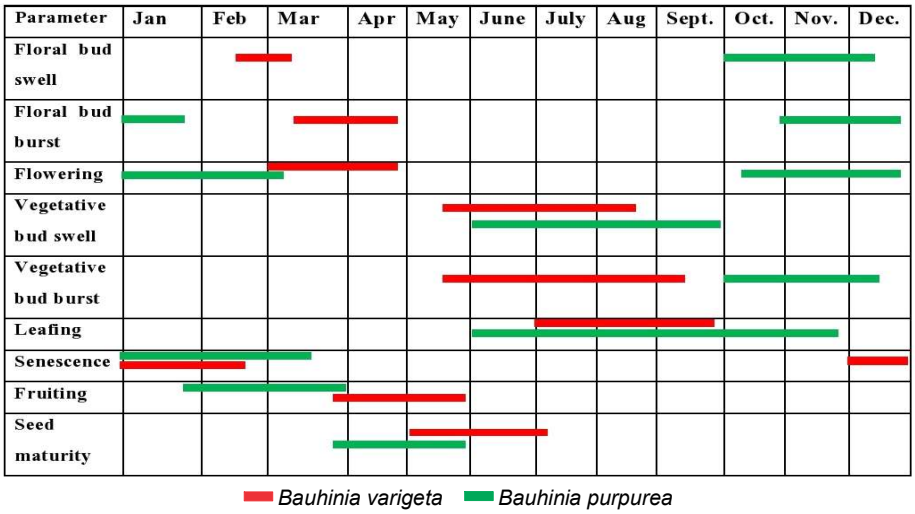

Fig. 2. Phonogram showing different phenophases in *B. variegata* and *B. purpurea*

Table 6. Various phonological characters of Bauhinia species

Parameters	*Bauhinia variegata*	*Bauhinia purpurea*
Bark color	Grey and smooth to slightly rough	Pale grey brown
Flower color	Whitish with purple tinge	Purple to nearly white or at least purple marked
Pollen size	50-60 um	55-65 um
Pollen vectors	Honey bee(Apics sps), ant, bumble bees, moth etc	Honey bee (Apices sps.), ant, bumble bees, moth etc
Seed color	Greyed orange gp. 162b to 163 c	Greyed orange gp.164b
Flower type	Entomophilous	Entomophilous
Odour	Present	Present
Flower opening time	6-9 am	5.30-9 am
Anther dehiscence time	6.30-9.30 am	6 -10.30 am
Stamens	5 (2+2+1)	5 (2+2+1)
Anther dehiscence mode	Longitudinal	Longitudinal
Pollen shape	Triangular with 3 apertures	Prolate-spheroidal, iso-pollar, tricolporate
Gynoecium	Monocarpellary, unilocular stalked, superior ovary	Monocarpellary, unilocular stalked, superior ovary
Seed dispersal	2-8 days after maturity	2-8 days after maturity

variegata and Smitha and Thondaiman (2016) observed that anthesis in *Saraca asoca* (Roxb.) occurred between 3.00 and 5.00 in the morning.

CONCLUSION

This study can uncover phenological patterns of examined species and give valuable insights into the biology of the plants involved. Maximum petal length and breath, filament length, and stigma length were all in *B. purpurea*. This study also showed the timing of vegetative and reproductive characters. It also provided a difference in seed color, flower color, bark color, pollen vectors, etc. The information from these studies is important for genetic improvement work in botany, especially in the fields of forestry and ecology.

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