Flowering and fruiting phenology of some herbs, shrubs and undershrubs from Girnar Reserve Forest, Gujarat, India

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The present study was carried out on 26 species of 13 different botanical families in Girnar Reserve Forest near Junagadh, Gujarat, India, for their reproductive phenological events, viz. flowering and fruiting from August 2008 to August 2011. Flowering and fruiting phenology varied significantly ($P < 0.01$). Mean values of percentage of species in flowering event indicated highest peak in September followed by August, for fruiting the highest peak (83.3%) was observed in December followed by January (57.7%). *Sida cordifolia* L. showed highest pooled average of 179 days for flowering. However, *Vernonia anthelmintica* L. pooled the lowest average of 33.3 flowering days. Highest and lowest pooled average number of fruiting days was recorded for *Cassia auriculata* L. and *Cassia occidentalis* Linn. with 279.7 and 35.7 days/year respectively. On basis of flowering, three species were identified with long flowering duration whereas six species were identified with short flowering duration. In the case of fruiting, five and two species were screened for long fruiting duration and short fruiting duration respectively. Average deviation in flowering among all species was ± 15.5 days for the first to second year of study; however, this was ± 15.4 days for the second to third year, resulting in overall 16.4 days of deviation for the entire study period. In the case of fruiting, the deviation was ± 20.7 and ± 17.3 days respectively, from the first to second year and second to third year, whereas the pooled deviation was 19 days in fruiting.

Keywords: Flowering, fruiting, Girnar Reserve Forest, herbs, phenology, shrubs.

PHENOLOGY is the study of the time of recurring natural phenomena in plants which deals with new foliage, leaf fall, flowering and fruiting-like events. It is the study of relationship between climatic factors and periodic phenomena in living organisms. Studying relationship between biodiversity and ecosystem functioning and characterization of plant communities and ecosystems in terms of functional types has proved to be an insightful approach. Herbs are non-woody small plants and phenology of herbs provides a clear background for obtaining detailed information on the changes occurring with time within the herb community. Different life forms such as trees, shrubs, herbs and climbers are correlated with different patterns of flowering and fruiting phenology; herbaceous plants go through reproductive phenology during the rainy season, whereas woody plants favour dry season for flowering and fruiting[1–3]. Furthermore, each plant life form shows particular association with particular climatic factors[3]. Effect of climate change on plant community was evaluated earlier[4]. It was found that phenological patterns change due to increased surface temperature, which has led to a shift in phenological activities of plant species[5]. Plant species flower mostly either as a response to dry season or phylogenic constraints, or sometimes both during summer season[6,7].

Timing of fruiting phenology is also well studied in connection with different abiotic factors, but the relationship with temperature and rainfall is given attention. A study of the phenology of Mexican Neotropical forest showed that most of the species exhibited fruiting peak in dry season and there was negative correlation between precipitation and number of species in fruiting[8]. Temperature is one of the major factors affecting flowering and fruiting phenology of any species[9]. However, there are other factors responsible for flowering and fruiting, viz. moisture[10], nutrient concentrations[11], spatial scales[12] and day length[13]. Although phenology of trees and shrubs has been studied extensively[14–16], phenology of herbs is not well studied, with a few exemptions[17–19]. The phenology of herbaceous and shrubby communities was studied together in the great Savanna[3]. In the Girnar Reserve Forest, phenological studies on trees[20,21] and shrubs[22] have been made, but herbs and undershrubs have not been studied.

Most of work done in the concerned area is not expressed in terms of time period, but only as seasonal variation. Hence, variation in the number of days for reproductive events is important. Keeping this in mind, the present study aims to: (i) evaluate flowering and fruiting patterns of 26 species group wise, including herbs, shrubs and undershrubs, as well as annuals and perennials occurring in the Girnar Reserve Forest; (ii) correlate data of flowering and fruiting with those of climatic factors and (iii) categorize statistically superior, inferior and medium plant species on the basis of flowering and fruiting duration in the Girnar Reserve Forest.

The Girnar Reserve Forest, Gujarat, Western India (70°28′–70°27′N and 21°30′–21°26′E), is well known for its biodiversity, and has been declared as a National Sanctuary by the Government of India. It is mixed subtropical deciduous forest in the Saurashtra region. On both sides, the forest is bounded by the Bhesan and Junagadh taluks, with a total spread of 182 sq. km. Dominant species of the area is *Tectona grandis* L.f., but other species such as *Butea monosperma* Lam (Thoub.), *Adina cordifolia* Roxb., *Holarrhena antidysenterica* (Heyne ex Roth) Wall., *Pithocellobium dulce* Roxb., *Randia*

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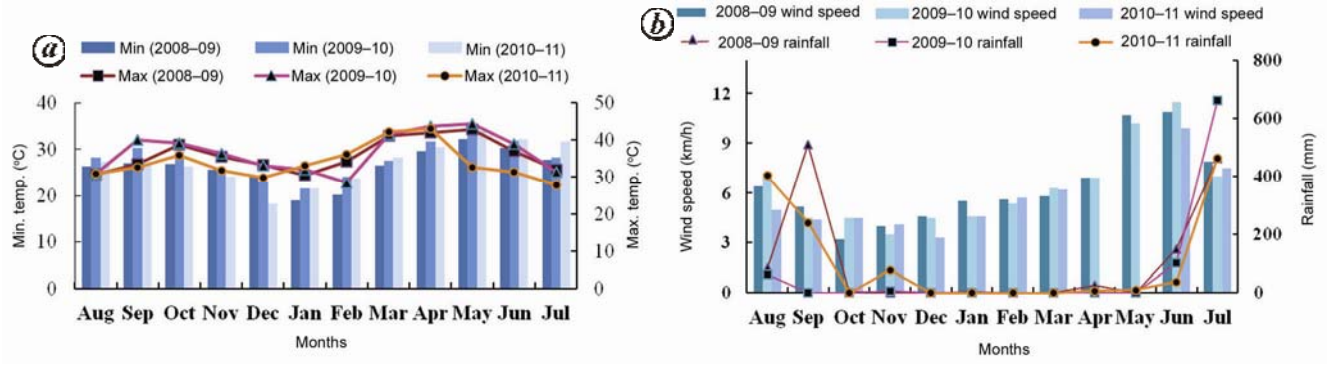

Figure 1. Climate of the study area during August 2008 to August 2011. The highest temperature of 44.5°C was recorded during May 2009, whereas lowest of 18.35°C was recorded during December 2010. Average values for rainfall were 103.05, 69.18 and 102.85 mm during 2008–09, 2009–10 and 2010–11 respectively, while wind speed showed average values of 6.39, 6.34 and 4.60 km h^{-1} during 2008–09, 2009–10 and 2010–11 respectively. There was significant negative correlation between minimum temperature and wind speed. ***a***, Month-wise minimum and maximum temperatures; ***b***, Month-wise rainfall and wind speed from August 2008 to August 2011.

spinosa (Thunb.) Bl., *Zizyphus rotundifolia* Lam and *Calotropis procera* (Ait.) R.Br. are found with other plant species. Climate is basically moist humid type with three seasons occurring in a year – winter (November to February), summer (April to mid-June) and monsoon (mid-June to September). Almost 95% of the rainfall occurs during monsoon season, with a few exceptions. Maximum and minimum temperature, along with wind speed and rain data were recorded on daily basis which were finally converted into mean value for a month. Climate of the area during the three-year study period is shown in Figure 1).

A total of 26 understorey species with 13 families, containing 5 species of Fabaceae, 4 species of Caesalpiniaceae, 3 species of Solanaceae and Malvaceae each, 2 species of Asteraceae and Convolvulaceae each and 1 species each for Euphorbiaceae, Lamiaceae, Nyctanthaceae, Plumbaginaceae, Rhamnaceae, Tilliaceae and Leeaceae were randomly selected for the study. Plants were selected from areas where micro habitat differences were small; however, these 26 plant species are common, with high density in the Girnar Reserve Forest area. Field visits were made to observe phenological events using the method of Opler *et al.*[23]. Each of plant species with 10 individuals was randomly selected and all the individuals were tagged for perennials and annuals. In case of annuals, plants were retagged after each study year in the same area. Flowering was determined by first opened flower seen on any tagged plant and considered as the first flowering day for that particular specimen of the species, while the last flowering day was when only a single flower remained on any tagged plant. In the case of first fruiting day, initiation of fruit on any tagged plant of the species was considered, whereas ripening of fruit was considered as the last fruiting day. Finally mean value of all tagged plants was converted into mean data for each species for a particular phenological trait, viz. first flowering day (FFD) and first fruiting day (FFRD).

For evaluating variation in phenology among 26 species, one-way ANOVA was performed[24]. Simple measurements like average, standard deviation, minimum and maximum were obtained using MS Excel-2010. Climate and phenological data were correlated on monthly basis. For this, percentage of species for a particular month on the basis of number of flowering and fruiting days for that month was obtained and this was correlated with maximum average temperature, minimum average temperature, average wind speed and average rainfall for that particular month. For pooled analysis of correlation, average values of all parameters for three years were calculated, and then correlation between phenological and climatic parameters was obtained. For studying variation in FFD and FFRD, the number of days after 1 June for each year was calculated. One-way ANOVA and linear correlation were performed using the software SPSS. Comparison among 4 shrubs, 10 herbs and 12 undershrubs as well as between 16 annuals and 10 perennials was carried out using average values for the number of the flowering and fruiting days. On the basis of data for three years and average plus standard deviation and average minus standard deviation, the species with highest, medium and lowest number of days for flowering and fruiting were identified. If the pooled value of species was above average plus deviation, then it was grouped under ‘species with long flowering or fruiting duration’. If the pooled value was below the average minus deviation, then it is grouped under ‘species with short flowering or fruiting duration’. The remaining species were grouped under ‘species with medium flowering or fruiting duration’.

Reproductive phenology of 26 species showed that 80.8% of the species flower in August and September while 65.4% species flower during November. In the second year, 2009–10, 80.8% of the species showed flowering in September followed by 76.9% in August, although 65.4% of the species showed flowering in October and

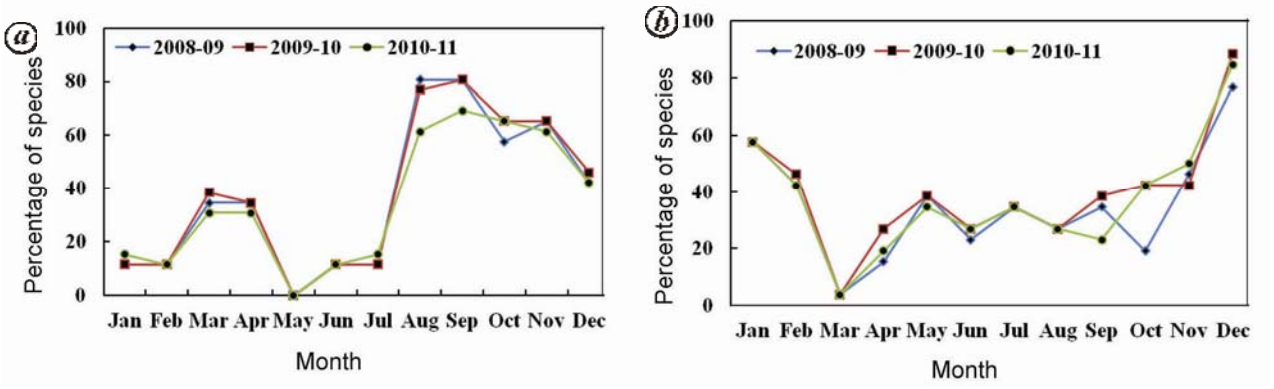

Figure 2. Phenology of flowering (***a***) and fruiting (***b***) among 26 species in Girnar Reserve Forest, Gujarat. It indicates that August and September are the best months for flowering, whereas November–December dominated in fruiting phenology among 26 species. Standard deviation was 31.4 during 2008–09, while it was 28 during 2009–10. In 2010–11, standard deviation was 40.8 for flowering. Fruiting exhibited standard deviation values of 44.7 for 2008–09, and 53.8 during both 2009–10 and 2010–11.

Table 1. Mean and deviation in reproductive phenology of herbs, shrubs and undershrubs from Girnar Reserve Forest, Gujarat

	Flowering phenology			Fruiting phenology		
Species (Family)	A	B	C	D	E	F
Abelmoschus esculentus (L) Moench (Malvaceae)	231 ± 1	223 ± 11	223 ± 11	182 ± 39	203 ± 9	175 ± 30
Acalypha indica L. (Euphorbiaceae)	53 ± 12	70 ± 1	61 ± 11	68 ± 6	70 ± 3	66 ± 3
Anisomeles indica (L.) Kuntze (Lamiaceae)	63 ± 6	76 ± 6	72 ± 12	85 ± 25	71 ± 45	53 ± 20
Argemon maxicana L. (Solanaceae)	145 ± 1	151 ± 11	152 ± 9	235 ± 18	241 ± 11	228 ± 8
Boerhavia chinensis (L.) Druce. (Nyctaginaceae)	127 ± 31	157 ± 21	135 ± 11	249 ± 59	267 ± 35	225 ± 25
Cassia auriculata L. (Caesalpiniaceae)	152 ± 11	164 ± 5	156 ± 6	288 ± 23	284 ± 28	268 ± 5
Cassia biflora L. (Caesalpiniaceae)	142 ± 11	128 ± 1	135 ± 10	107 ± 3	111 ± 3	109 ± 6
Cassia occidentalis L. (Caesalpiniaceae)	47 ± 3	41 ± 15	39 ± 12	37 ± 7	38 ± 6	33 ± 1
Cassia tora L. (Caesalpiniaceae)	141 ± 20	156 ± 17	143 ± 2	120 ± 16	113 ± 6	124 ± 10
Corchorus fascicularis Lam. (Tiliaceae)	35 ± 4	34 ± 8	32 ± 5	100 ± 18	102 ± 14	90 ± 4
Crotalaria medicaginea Lam. (Fabaceae)	61 ± 12	78 ± 0	70 ± 12	32 ± 11	45 ± 7	37 ± 18
Datura innoxia Mill. (Solanaceae)	80 ± 44	137 ± 7	106 ± 37	136 ± 22	146 ± 7	131 ± 15
Desmodium gangeticum (L) DC (Fabaceae)	14 ± 26	44 ± 11	25 ± 16	65 ± 16	55 ± 30	44 ± 15
Indigofera tinctorea L. (Fabaceae)	79 ± 5	70 ± 3	74 ± 8	41 ± 1	51 ± 16	52 ± 14
Indigofera trifoliata L. (Fabaceae)	34 ± 27	63 ± 13	44 ± 14	87 ± 21	71 ± 43	56 ± 23
Leea indica (Burm. f.) Merr. (Leeaceae)	35 ± 4	37 ± 5	34 ± 1	90 ± 4	95 ± 2	92 ± 6
Merremia turpethum (L.) (Convolvulaceae)	47 ± 3	34 ± 24	32 ± 21	44 ± 19	50 ± 10	37 ± 9
Merremia tridentata(L.) Hall. f. (Convolvulaceae)	65 ± 9	77 ± 0	71 ± 8	45 ± 45	63 ± 19	31 ± 25
Plumbago zeylanica Linn. (Plumbaginaceae)	158 ± 16	173 ± 12	161 ± 4	128 ± 39	148 ± 11	120 ± 28
Sida acuta Burm F. (Malvaceae)	96 ± 40	135 ± 24	107 ± 16	187 ± 52	197 ± 37	161 ± 15
Sida cordifolia L. (Malvaceae)	156 ± 22	191 ± 5	175 ± 27	110 ± 27	128 ± 1	109 ± 25
Tephrosia purpurea (L.) Pers.(Fabaceae)	92 ± 40	93 ± 78	65 ± 38	61 ± 14	79 ± 39	89 ± 25
Vernonia anthelmintica L. (Asteraceae)	34 ± 4	33 ± 10	30 ± 6	67 ± 37	61 ± 46	35 ± 9
Withania somniferum (L) Dunal (Solanaceae)	132 ± 25	137 ± 42	120 ± 18	129 ± 11	143 ± 8	135 ± 19
Xanthium strumarium L. (Asteraceae)	95 ± 22	81 ± 64	66 ± 42	73 ± 3	78 ± 4	76 ± 7
Zizyphus rotundifolia Lam. (Rahmnaceae)	120 ± 10	113 ± 9	120 ± 1	80 ± 4	74 ± 12	71 ± 8
Mean ± SD	94 ± 16	103 ± 15	94 ± 14	109 ± 21	115 ± 17	102 ± 14

A, mean plus or minus deviation in the number of days for flowering between first and second year; B, mean plus deviation in the number of days between second and third year of study; C, mean plus deviation in the number of days for flowering between first and third year. D–F, deviation in fruiting between first and second year, second and third year, and first and third year during the study period respectively.

November. The year 2010–11 showed highest flowering (65.38%) in October followed by (65.2%) in September. All the species showed fruiting in December followed by January. During the study years 2008–09, 2009–10 and 2010–11, the percentage of species in fruiting for December was 76.9, 88.5 and 84.6 respectively. However, January showed the same value of 57.7% species for fruiting in all the study years (Figure 2).

Pooled analysis of the data exhibited the highest average flowering (76.9%) in September; however, average highest fruiting (83.3%) was recorded in December. Average flowering days during 2008–09, 2009–10 and

Table 2. One-way ANOVA for flowering and fruiting phenology

		Number of flowering days			Number of fruiting days		
	DF	MS	*F* value	LSD (0.01)	MS	*F* value	LSD (0.01)
Block	1	29.64	0.44		11.31	0.17	
Species	25	16,264.48**	243.09	13.16	26,706.63**	393.66	13.26
Error species	25	66.91			67.84		
Year	2	5,048.31**	79.48	4.18	7,683.31**	117.69	4.24
Species × year	50	726.80**	11.44	21.31	691.15**	10.59	21.60
Residual	52	63.51			65.28		
Total	155	2,955.19			4,662.53		

DF, Degree of freedom; MS, Mean sum of square; Species × year, Interaction of species and year; **Significant level of value ($P < 0.01$).

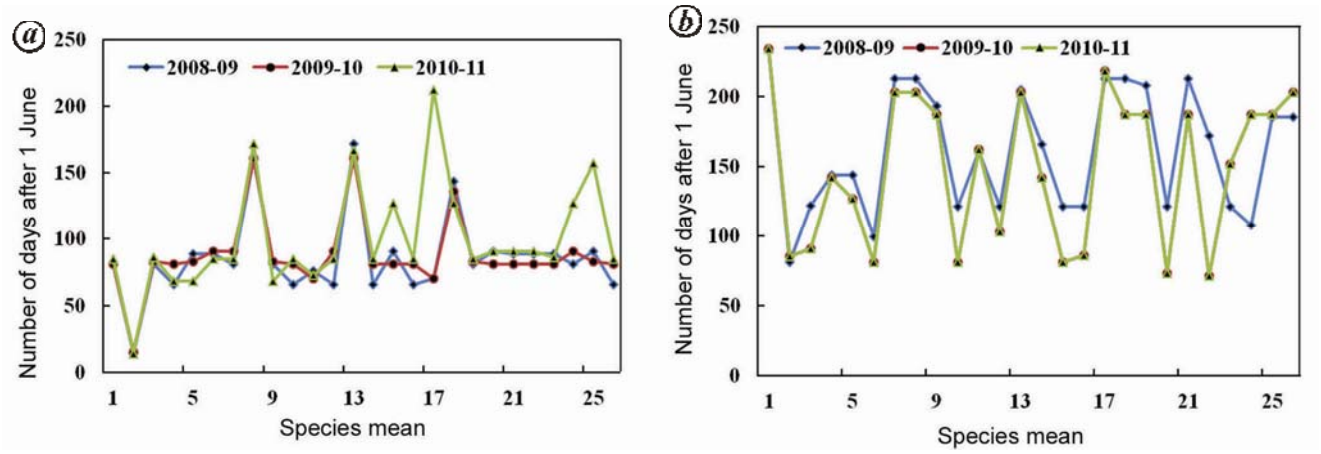

Figure 3. Variation in first flowering days (***a***) and first fruiting days (***b***) among 26 species. Variation in first flowering days (***a***) ranged from 14 to 172 days after 1 June of 2008–09, 15 to 161 days in 2009–10 and 14 to 212 days in 2010–11. In case of first fruiting days (***b***), it ranged from 81 to 233 days in 2008–09 and 71 to 234 days in both 2009–10 and 2010–11 respective years.

2010–11 were 93.62 ± 53.06, 112.65 ± 55.91 and 94.27 ± 57.62 respectively, with pooled average of 100.18 ± 53.58 for all study years. Average maximum flowering days was recorded for herb species *Abelmoschus esculentus* (L) Moench. with value of 225.7 days, while *Vernonia anthelmintica* L. exhibited mean lowest flowering days (33.3). On the other hand, for fruting phenological event, average values for 2008–09, 2009–10 and 2010–11 were 96.31 ± 63.27, 122.19 ± 74.27 and 106.81 ± 68.78 respectively, with pooled average of 108.44 ± 19.02. The highest pooled standard deviation showed significant variation within species among shrubs, undershrubs and herbs (Table 1). The timing of phenological events did not show much variation where mean highest flowering was observed during September (76.92% of the species) followed by August (73.08% of the species), which were soon replaced by fruiting for whole 3 years study. Fruiting showed a peak in December followed by January with respective values of 83.3% and 57.7% (Figure 2).

Analysis of variance indicated significant variation ($P < 0.05$) in the number of days of all phonological events studied. Furthermore, there was significant interaction between year and species (Table 2). Deviation in the number of days for flowering and fruiting for all species during the study years is shown in Table 2. FFD and FFRD exhibited significant variation ($P < 0.05$) in days after 1 June for all study years. For FFD, mean values were 86, 87.8 and 99.6 days after 1 June respectively, for the study years 2008–09, 2009–10 and 2010–11. On the other hand, mean values for FFRD after 1 June were 161.4 for 2008–09, and 148.6 days for both 2009–10 and 2010–11 (Figure 3).

Linear correlation between temperature and percentage of species for the number of days for flowering as well as fruiting was non-significant; however, average values of percentage of species irrespective of years (taking mean values for all 3 years) for flowering and fruiting showed negative significant association with minimum temperature (–0.65*) and maximum temperature (–0.58*). In fruiting phenology, percentage of species for fruiting was non-significant with minimum and maximum temperature during 2008–09, but during 2009–10 and 2010–11 there were negative significant associations between them with respective values of (–0.57*) and (–0.73**). This

Table 3. Linear correlation between percentage of species in phenological event and climatic factors

	Flowering				Fruiting			
	2008–09	2009–10	2010–11	IRY	2008–09	2009–10	2010–11	IRY
Min *T*	–0.01	–0.01	–0.36	–0.14	–0.49	–0.57*	–0.73**	–0.65*
Max *T*	–0.24	0.03	–0.04	–0.08	–0.55	–0.42	–0.53	–0.58
Rainfall	0.18	–0.29	0.24	0.05	–0.08	–0.12	–0.21	–0.16
Wind speed	–0.61**	–0.54	–0.07	–0.54	–0.21	–0.42	–0.13	–0.37

*$P < 0.05$ and **$P < 0.01$; IRY, Irrespective of years where average values of all the parameters from 2008 to 2011 were considered for correlation; Min T, Minimum temperature and Max T, Maximum temperature.

Table 4. Categorization of species on the basis of the number of days for phenological events

Group	Approx. no. of days	No. of species
Species with long flowering duration	More than 153.76 days	3
Species with medium flowering duration	53.33–151.00	16
Species with short flowering duration	Less than 46.60 days	6
Species with long fruiting duration	More than 175.99 days	5
Species with medium fruiting duration	43.33–137.33	19
Species with short fruiting duration	Less than 40.88 days	2

indicated that if there is increase in low temperature, there will be shortened fruiting in most of the species, and also decreased percentage of species for fruiting. If there is increase in maximum temperature, there will be delayed fruiting for plant species such as shrubs, undershrubs and herbs, as well as increased percentage of species for fruiting. Wind speed was non-significant with percentage of species character in flowering and fruiting during two years, 2009–10 and 2010–11, but negative significant value (–0.61*) was observed only during 2008–09 with flowering. Rainfall did not affect phenology directly, but after rain in August, flowering was started in many species (Table 3).

Among the 26 species, the 4 species showing the highest average number of days for flowering, were placed in the 'species with long flowering duration' group. These four species were *Cassia auriculata* L., *Abelmoschus esculentus* (L.) Moench., *Sida cordifolia* L. and *Plumbago zeylanica* Linn. However, six species, viz. *Vernonia anthelmintica* L., *Desmodium gangeticum* (L.) DC., *Corchorus fascicularis* Lam, *Leea indica* (Burm.f.) Merr., *Merremia turpethum* (L.) and *Cassia occidentalis* L. exhibited lowest approximate number of days, and hence were placed in the 'species with short flowering duration' group. A total of 16 species of herbs were recorded for the 'species with medium flowering duration' group. In case of fruiting phenology, five species, viz. *Sida acuta* Burm.f., *Abelmoschus esculentus* (L.) Moench., *Argemon maxicana* L., *Boerhavia chinensis* (L.) Druce. and *Cassia auriculata* Lam. showed average number of fruiting days above 180. Therefore, these were placed in the 'species with long fruiting duration' group. However, two species, viz. *Cassia occidnetalis* L. and *Crotalaria medicaginea* Lam. exhibited average number of fruiting days below 40, and hence were placed in the 'species with short fruiting duration' group. The remaining 19 species were placed in the 'species with medium fruiting duration group. Categorization of 26 plant species on the basis of flowering and fruiting days indicated that species with values above average plus standard deviation were statistically superior over the others. Furthermore, species in one group showed more or less similar phenological patterns for flowering and fruiting (Table 4).

Comparison between 16 annuals and 10 perennials indicated that the latter had highest average number of flowering days and fruiting days compared to annuals. Average values during the number of days for the flowering in perennials were 100.2, 117.6 and 93.7 respectively. On the other hand, reduced average values for the number of flowering days for annuals were, 89.5, 109.6 and 94.6 for 2008–09, 2009–10 and 2010–11 respectively. The average number of fruiting days was 115.9, 135.8 and 122.4 for perennials, while it was 84.1, 113.7 and 97.1 for the annuals for respective years. For annuals, almost the same flowering and fruiting period was found with the pooled average value of 97.9 days for flowering and 98.3 days for fruiting for the three years of study. However, in case of perennials average fruiting period was more with three years' pooled average for the number of fruiting days being 124.7 compared to three years' pooled average of 103.8 for the number of flowering days.

However, comparison among 4 shrubs, 12 undershrubs and 10 herbs showed that undershrubs as a group had long flowering duration, with pooled average value of 111.2 for three years followed by shrubs with pooled

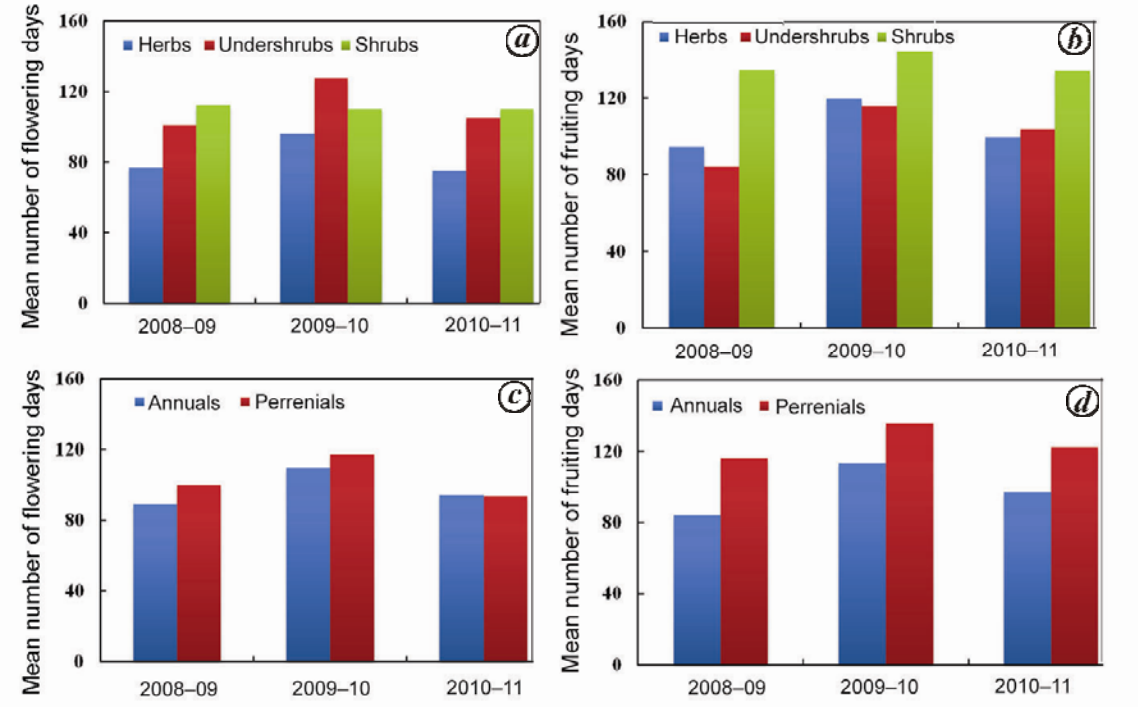

Figure 4. Diversity among different groups of plants in number of flowering and fruiting days. ***a***, ***b***, Comparison between herbs, under shrubs and shrubs: for flowering and (***b***) for fruiting. ***c***, ***d***, Comparison between annuals and perennial: (***c***) for flowering and (***d***) for fruiting. The mean number of flowering days was highest among shrubs followed by undershrubs and herbs, while mean number of flowering as well as fruiting days was highest for perennials.

average value of 110.8 and herbs with pooled average value of 82.8 for mean number of flowering days. In case of mean fruiting days for three years of study, shrubs showed highest average pooled value of 138.8 followed by herbs and undershrubs with respective average pooled values of 104.7 and 101.4 (Figure 4 *a* and *b*).

Phenology of flowering and fruiting in shrubs, undershrubs and herbs was studied mostly in August and September, whereas the second peak was also observed during March–April (spring), but the percentage was low compared to the August–September flowering. After studying 475 herbaceous and 348 arborescent species of the Eastern Ghats, South India, Sivaraj and Krishnamurthy[19] concluded that most of the herbs flower during rainy season, whereas arborescent taxa bloom during dry period irrespective of altitude and vegetation type, in agreement with the present study. Bhat and Murali[1] explained peak flowering and fruiting in post-monsoon period in herbs, and pre-monsoon period in shrubs in the Western Ghats in Uttara Kannada district, Karnataka, India, similar to the present study. In addition, they neglected the fact that, flowering in deep-rooted shrubs may have been triggered due to changes in day length and temperature, whereas among herbs species with shallow roots, moisture is mostly responsible for flowering.

Ralhan *et al.*[25] postulated two peaks in flowering, viz. one during the dry period in March–April, and another in wet warm period during August–September, among 49 shrubs species in the Kumaun Himalaya forests, similar to the present study. Duraisamy and Paulsamy[26] studied six annual herbs in Nilgiri grasslands, Western Ghats, and found that herbs flower mostly during August which is followed by fruiting. Pandey and Tripathi[27] showed for 44 aromatic species including shrubs and herbs, flowering and fruiting is seen mostly in December. According to Uppal and Singh[28], at low temperature the number of flowering days is more compared to high temperature in Himachal Pradesh.

Krishnan[29] studied 60 species including herbs, shrubs and small trees and observed that flowering and fruiting were non-uniform with dry season flowering peak and wet season fruiting peak in the wet forest of the Western Ghats. Moreover, they obtained negative correlation between rainfall and flowering; however, fruiting showed non-significant correlation with rainfall. Sundarapandian *et al.*[30] reported significant positive association between temperature and flower initiation, but obtained negative association with rainfall under deciduous conditions in the Kodayar forest, Western Ghats. Our results indirectly support the above; however, in 2010–11 there was significant negative association between minimum temperature and percentage of species in fruiting; thus low temperature leads to less fruiting period.

Joshi and Janardanam[2] found that herbs mostly flower during August–September after monsoon, whereas shrubs flower during March–April followed by fruiting in the

following months, thus supporting our results. This can be due to soil moisture availability for germination and seedling establishment during monsoon; it can also be an adaptation mechanism for animal dispersal. Several other studies[19,31–34] are in accordance with this study. However, Singh and Bhatt[35] showed that most woody plants exhibit flowering in May–June, whereas fruiting occurs during August–September and up to October.

The study of Amjad *et al.*[36] on 110 plant species, including 29 shrubs, 55 herbs, 18 grasses and 3 ferns showed that among majority of herbaceous and shrubby plants, flowering occurs during April–May in dry season, but peak is seen during May–June. This difference in the result may be due to selection of plant species, as they have given overview of all plant species. Moreover, the climate of their study region is also different. We found no clear relationship between climatic factors and flowering. Similarly, the study by Dahlgren *et al.*[37] did not show any significant relationship between environmental factors and flowering among 290 individual herbs in Sweden. Molau *et al.*[38] did not consider the fact that flowering events and phenological sequence do not change much even though variability is found in the environment. In addition, they found very little variation in the same species for first flowering days, similar to the present study which shows not much change in flowering or fruiting season each year in the study period.

We conclude that, reproductive phenology of herbs, shrubs and undershrubs was mostly characterized by two months, viz. August and September, soon followed by fruiting. The duration of flowering and fruiting was more in perennials compared to annuals. Though there is direct correlation between number of flowering and fruiting days and climatic factors; they are indirectly affected. First flowering days and fruiting days showed significant variation ($P < 0.01$). Different peaks seen during different seasons for flowering and fruiting governed adaptive mechanisms. More work is needed to understand the reproductive phenological sequence of particular area.

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