

Phenological Study of Some Selected Arid Zone Plants of Northeastern Rajasthan, India

Dr. Prashant Kumar Sharma

Associate Professor of Botany, Govt. Lohia College, Churu (Rajasthan)

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ABSTRACT

The present study was carried out on some selected arid zone plants of northeastern Rajasthan, India, for their phenological study. Phenological studies varied significantly ($P < 0.01$). Mean values of phenological event indicated highest peak in September followed by August, and also (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: phenological, flowering, fruiting, northeastern, arid zone, Rajasthan

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I. INTRODUCTION

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. Furthermore, each plant life form shows particular association with particular climatic factors. Effect of climate change on plant community was evaluated earlier [1,2]

It was found that phenological patterns change due to increased surface temperature, which has led to a shift in phenological activities of plant species. Plant species flower mostly either as a response to dry season or phylogenetic constraints, or sometimes both during summer season. Timing of fruiting phenology is also well studied in

connection with different abiotic factors, but the relationship with temperature and rainfall is given attention.



***Cassia auriculata* L**

A study of the phenology of some selected arid zone plants of northeastern Rajasthan, India, 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. Temperature is one of the major factors affecting flowering and fruiting phenology of any species. However, there are other factors responsible for flowering and fruiting, viz. moisture, nutrient concentrations, spatial scales and day length. Although phenology of trees and shrubs has been studied extensively, phenology of herbs is not well studied, with a few exemptions. The phenology of herbaceous and shrubby communities was studied together in Rajasthan. In the some selected arid zone plants of northeastern Rajasthan, India,, phenological studies on trees and shrubs have been made, but herbs and undershrubs have not been studied.[3,4]

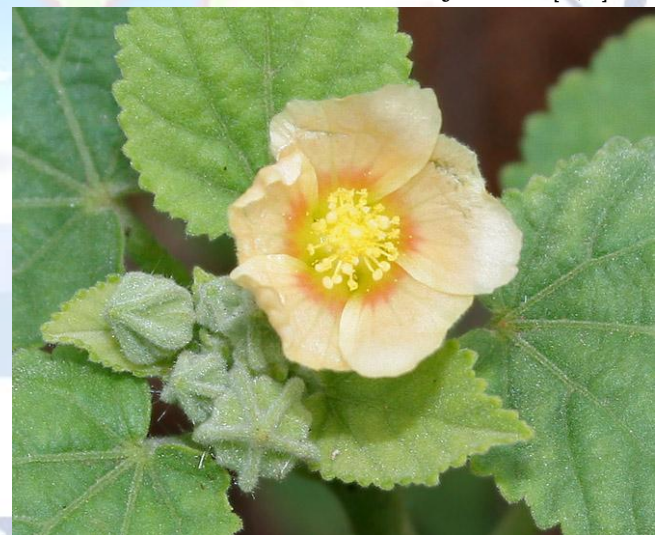
METHODOLOGY

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 some selected arid zone plants of northeastern Rajasthan, India
- (ii) correlate data of flowering and fruiting with those of climatic factors and categorize statistically superior, inferior and medium plant species on the basis of flowering and fruiting duration in some selected arid zone plants of northeastern Rajasthan, India. Northeastern Rajasthan is well known for its

biodiversity. 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 spinosa* (Thunb.) Bl., *Zizyphus rotundifolia* Lam and *Calotropis procera* (Ait.) R.Br. are found with other plant species.[5,6]

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. A total of 26 understory 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 arid zone area of northeastern Rajasthan.[7,8]



***Sida cordifolia* L**

Field visits were made to observe phenological events using the method of Opler et al. 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).[9]

DISCUSSION

For evaluating variation in phenology among 26 species, one-way ANOVA was performed. 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'. [10]

OBSERVATIONS

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 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 1.) [11, 12]

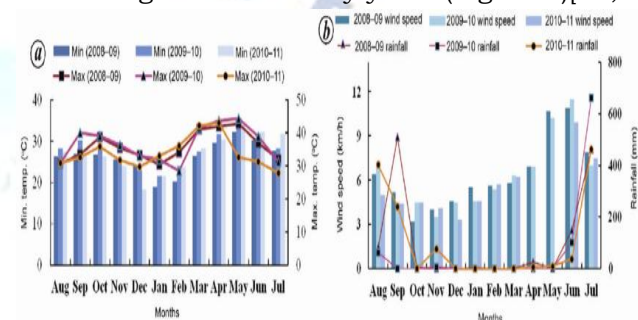


Figure 1. Climate of the study area during August 2008 to August 2011. The highest temperature of 44.5°C was recorded during May 2009, whereas lowest of 18.35°C was recorded during December 2010. Average values for rainfall were 103.05, 69.18 and 102.85 mm during 2008–09, 2009–10 and 2010–11 respectively, 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.

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 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 fruiting 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 . 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% . Analysis of variance indicated significant variation ($P < 0.05$) in the number of days of all phonological events studied.(Figure 2) [13,14]

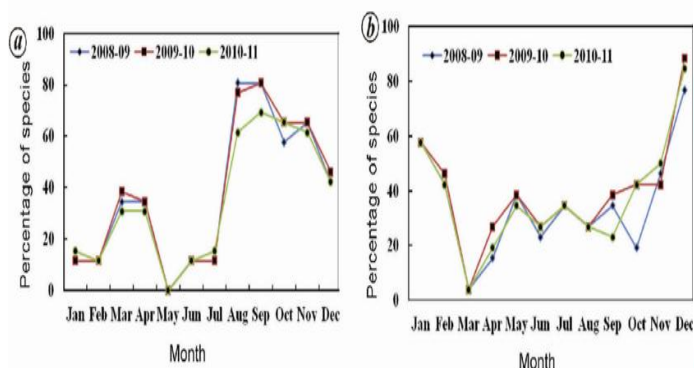


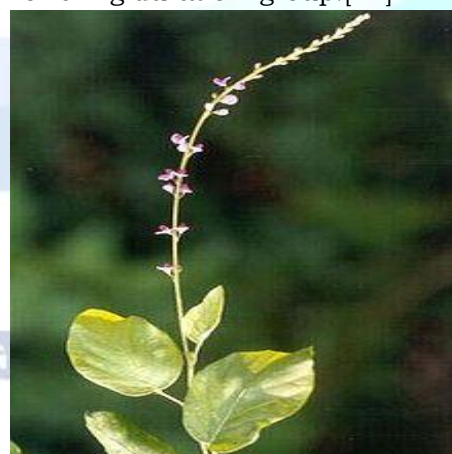
Figure 2. Phenology of flowering (a) and fruiting (b) among 26 species in arid zone of northeastern region of Rajasthan. It indicates that August and September are the best months for flowering, whereas November–December dominated in fruiting phenology among 26 species. Standard deviation was 31.4 during 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.

Furthermore, there was significant interaction between year and species . Deviation in the number of days for flowering and fruiting for all species during the study years is shown . 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 . 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 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.[15,16] Rainfall did not affect phenology directly, but after rain in August, flowering was started in many species .

RESULTS

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.[17]



Desmodium gangeticum

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., *Argemone 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. (Table 1) Furthermore, species in one group showed more or less similar phenological patterns for flowering and fruiting .[18]

Table 1. Mean and deviation in reproductive phenology of herbs, shrubs and undershrubs from arid zone of northeastern region in Rajasthan

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

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. (Figure 3) 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 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 [19] .

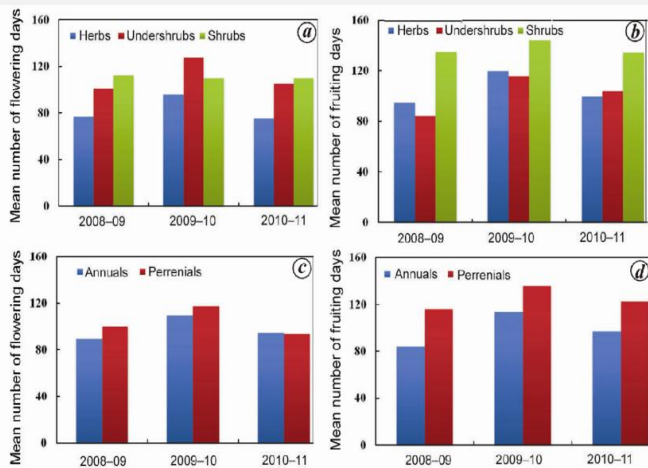


Figure 3. Diversity among different groups of plants in number of flowering and fruiting days. a, b, Comparison between herbs, under shrubs and shrubs: for flowering and (b) for fruiting. c, d, Comparison between annuals and perennial: (c) for flowering and (d) for fruiting. The mean number of flowering days was highest among shrubs followed by undershrubs and herbs, while mean number of flowering as well as fruiting days was highest for perennials.

CONCLUSION

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. It was 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. It was 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. The fruiting occurs during August–September and up to October. 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 [20].

REFERENCES

- [1] Boffa J. M. (1999). Agroforestry Parklands in Sub-Saharan Africa, FAO Conservation Guide No. 34, 230 pp. Rome: Food and Agriculture. [Describes in detail the traditions, effects, etc. of the parkland system, which is the actual forestry system in the arid zone of the world.]
- [2] Booth F. E. M. and Wickens G. E. (1998). Non Timber Uses of Selected Arid Zone Trees & Shrubs in Africa, FAO Conservation Guide No. 19, 176 pp. Rome: Food and Agriculture Organization. [Detailed descriptions of tree/shrub species in the arid zones of Africa.]
- [3] Champion H.G and Seth S.K (1968). A Revised Survey of Forest Types of India. Government of India Publication, New Delhi, 329 pp.
- [4] Doran C. J. and Turnbull J. W. (1997). Australian Trees and Shrubs: Species for Land Rehabilitation and Farm Planting in the Tropics, ACIAR Monograph No. 24, 384 pp. Canberra: Australian Centre for International Agricultural Research. [This book has all types of details about arid zone tree species in Australia.]
- [5] Dwivedi A. P. and Gupta G. N. (1993). Afforestation of Arid Land, 521 pp. Jodhpur, India: Scientific Publishers. [An edited book containing details of the management of plantations in all possible types of soils of the arid zone.]
- [6] Folliott P. F., Brooks K. N., Gregersen H. M., and Lundgren A. L. (1995). Dryland Forestry: Planning and Management, 453 pp. New York: John Wiley and Sons. [This book covers all the dimensions of arid zone/dryland forestry.]
- [7] Food and Agriculture Organization (1985). Sand Dune Stabilization, Shelterbelts and Afforestation in Dry Zones, FAO Conservation Guide No. 10, 232 pp. Rome: FAO. [This monograph mainly covers the conservation aspects of arid zone forestry in the world.]
- [8] Food and Agriculture Organization (1989). Arid Zone Forestry, FAO Conservation Guide No. 20, 143 pp. Rome: FAO. [A simplified and concise book on arid zone forestry.]
- [9] Hocking D. (1993). Trees for Drylands, 370 pp. New Delhi: Oxford and IBH Publishers. [This book is a good collection of information on the botany and utilization of tree species in the Indian arid zone.]
- [10] Houerou Le H. N. (1996). Drought tolerance and water efficient trees and shrubs for rehabilitation of tropical and subtropical arid lands of Africa and Asia. Land Husbandry 1(1–2), 43–64. [In this review paper, the selection of tree species for arid land rehabilitation and their establishment as well as their utilization are discussed.]
- [11] Tewari J. C., Bohra M. D., and Harsh L. N. (1999). Structure and production function of traditional

extensive agroforestry system and scope of intensive agroforestry in Thar desert. Indian Journal of Agroforestry 1(1), 81-94. [This review paper provides detailed information about agroforestry in the Indian arid zone.]

- [12] Boojh, R. & P. S. Ramakrishnan. 1981. Phenology of tree in sub-tropical evergreen montane forest in northeast India. *Geo-Eco-Trop* 5: 189-209.
- [13] Borchert, R. 1983. Phenology and control of flowering in tropical trees. *Biotropica* 15: 81-89. Borchert, R. 1994. Soil and stem water storage determine phenology and distribution of tropical dry forest trees. *Ecology* 75: 1437-1449.
- [14] Borchert, R. & G. Rivera. 2001. Photoperiodic control of seasonal development and dormancy in tropical stem-succulent trees. *Tree Physiology* 21: 213-221.
- [15] Borchert, R., G. Rivera & W. Hagnauer. 2002. Modification of vegetative phenology in a tropical remideciduous forest by abnormal drought and rain. *Biotropica* 34: 27-39.
- [16] Croat, T. B. 1975. Phenological behavior of habit and habitat classes on Barro Colorado Island (Panama canal zone). *Biotropica* 7: 270-277.
- [17] Dewald, L. E. & K. C. Steiner. 1986. Phenology, height increment and cold tolerance of *Alnus glutinosa* population in a common environment. *Silvae Genetica* 35: 205-211.
- [18] Elliott, S., P.J. Baker & R. Borchert. 2006. Leaf flushing during the dry season : the paradox of Asian monsoon forests. *Global Ecology and Biogeography* 15: 248-257.
- [19] Frankie, G.W., H.G. Baker & P.A. Opler. 1974. Comparative phenological studies of trees in tropical wet and dry forests in the low lands of Costa Rica. *Journal of Ecology* 62 : 881-919.
- [20] Hamann, A. 2004. Flowering and fruiting phenology of a Philippine submontane rain forest : climatic factors as proximate and ultimate causes. *Journal of Ecology* 92 : 24-31.