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Changing phenological pattern in trees and shrubs of Pune hills, Maharashtra, India

Lalitha Tilming*, Rajendra Shankar Zunjarrao
Post Graduate Research Centre in Botany, Modern College of Arts, Science & Commerce, Shivajinagar, Pune, Maharashtra, India

Abstract
Phenological studies were carried out between September 2020 and August 2022 for trees and shrubs of Vetal and Taljai hills in Pune. The vegetation is mainly dry deciduous forest and rock grasslands. Twenty plant species belonging to twelve families were observed for flowering, fruiting and leafing phenophases. Semi Quantitative Technique which includes observation of whole plant is used. The intensity score of 0 to 4 scale for different phenophases were assigned at an interval of 30 days. The study revealed high phenological diversity for different phenophases. However, leafing phenophase was almost year-round except in autumn and in early spring.

Keywords: canopy cover, phenophase intensity, phenocaster, tagging, year-round

Introduction

Phenology is the study of the timing of seasonal biological activities. This term was first introduced in 1853 by Charles Morren. It measures the timing of life cycle events in plants, animals, and microbes, and detects how the environment influences the timing of those events. In flowering plants, these life cycle events or phenophases include leaf budburst, first flower, last flower, first ripe fruit, and leaf shedding, among others. Phenophases commonly observed in animals include molting, mating, egg-laying or birthing, fledging, emergence from hibernation, and migration (Haggerty and Mazer, 2008) [7].

Phenological study is gaining attention worldwide as it is one of the implications of climate change. The data is an indicator of climate change with regard to plants, animals and ecosystem (IPCC, 2007) [8]. Climate change is affecting individual organisms, their physiology, distribution and composition of species affecting both plants and animals (Sapkota, 2019) [33]. Alternations from regular phenophase in plants and animals have negatively influenced organisms. One or more changes in phenophase duration may result in a specific phase not providing favorable conditions for herbivores seeking to maximize nutrition (Monteith *et al*., 2015) [17].

Status monitoring based phenology study is used to understand the altering phenophases in plants and with animal movements activity (Denny and Crimmins, 2014) [6]. Changes in plant phenophases could be due to alternations from regular functioning processes in abiotic and biotic components. Different urban development pattern can also influence urban plant phenology (Ju *et al.*, 2022) [9]. Species with low adaptability or dispersal capacity eventually results in increased extinction rates (Walther *et al.*, 2002) [40]. There is strong evidence that global climate change affects the start and end dates of phenological phases across a wide range of plant communities (Brown *et al.*, 2022) [3].

A number of phenological studies have been undertaken worldwide in different geographical zones and forest types using recent or modern methods which includes those in South Africa (Le Roux *et al.*, 1984) [14], in USA National Phenology Network (USA-NPN) was established in 2007 (Schwartz *et al*. 2012) [34]. Phenocams network in US makes phenology study faster and more efficient reducing the time in field work. Timesat software used to estimate SOS and EOS in Southwestern US (Browning *et al*., 2017) [4]. Phenology existing model, Growing Season Index (GSI) which is modified by adding cumulative precipitation control to better determine the relationship between weather and vegetation canopy fluctuation in Iraq in various semi-arid regions (Daham *et al*., 2019) [5]. Cool Unit (CU) and Drought Unit (DU) (Numata *et al*., 2022) [21]. Uni Chill and DDcos systems proved to be best for phenophases during spring period (Kalvāns *et al*., 2014) [11]. Phenocaster is a software package for the prediction of flowering phenology. It makes research more efficient and easy, reducing years of extensive field work. It is also species specific but such type of data collection is limited as it is available for only small numbers (Park *et. al*., 2019) [23]. The Plant Phenology Ontology (PPO) (Stucky *et al*., 2018) [37], Computer based time lapse images of plant communities conducted in Japan (Nakamura *et al*., 2018) [19].

The low cost phenology research can be done in common garden (MacKenzie *et al*., 2019) [15].

These remote sensing data often fail to parse out variation at the species level. Field observations of leaf-out times can provide species-level information. Field experiments allow researchers to disentangle and systematically investigate drivers of leaf phenology, but experiments on communities of woody plant species growing in the wild can be methodologically challenging and expensive (Primac *et al*., 2015) [30]. From the recent techniques used, as mentioned above, it is found that there is lack of knowledge at species-level observation of data. It is recommended in further research to foster understanding in various mechanisms controlling phenology and there should be standardization of methods used in observation of phenology across networks (Tang *et al*., 2016) [39].

In India considerable amount of phenological studies have been undertaken for different plant species of different forest types which includes Punjab (Kaur *et al*., 2013) [13], Uttar Pradesh (Singh and Kushwaha, 2006) [36], Northern India (Bajpai *et al*., 2012) [1], South India (Bhat and Kallur,

2001) [3], Orissa Coast (Upadhyay and Mishra, 2010) [40], Kumaun Central Himalaya (Pangtey *et al*., 1990) [22], Kumaun Himalayan forests (Ralhan *et al*., 1985) [31], North Eastern India (Shukla and Ramakrishnan, 1982) [35], Kolhapur region of Maharashtra (Kasarkar and Kulkarni, 2011) [12].

These sites are selected as it represents most of the plant diversity of other hills in Pune city. This study is of significance as phenological study in hills under the same region of different sites with more or less similar environmental conditions and except family Fabaceae, members of other families undertaken in this study were not studied earlier.

Material and methods

Site description

The study area is Pune covering 430 km^2. It is in the state of Maharashtra. Pune is located between 18.42°N to 18.62°N latitudes and 73.75°E to 73.96°E longitudes on the eastern slope of the Sahyadri range in Pune district. The type of vegetation in these hills is mainly dry, deciduous forest and rocky grasslands. Two different sites, Taljai hill and Vetal hill were selected for data collection. Taljai covering an area of 2.90 sq. km between 18.4631°N to 18.4984°N latitudes to 73.8280°E to 73.8492°E longitudes. Vetal covering an area of 2.41 sq.km between 18.5067°N to 18.5384°N latitudes to 73. 81110°E to 73.8293°E longitudes. These sites represent most of the plant diversity as compared to other hills in Pune. Figure 1 shows the location of two sites on the map of Pune. Two different types of soils are present in the study area. Taljai showed very shallow, excessively drained, loamy soils while Vetal showed slightly deep, moderately well drained, fine soils. Soil data was obtained by preparing a soil map using National Burea of Soil Survey and Land Use Planning (NBSSLUP).

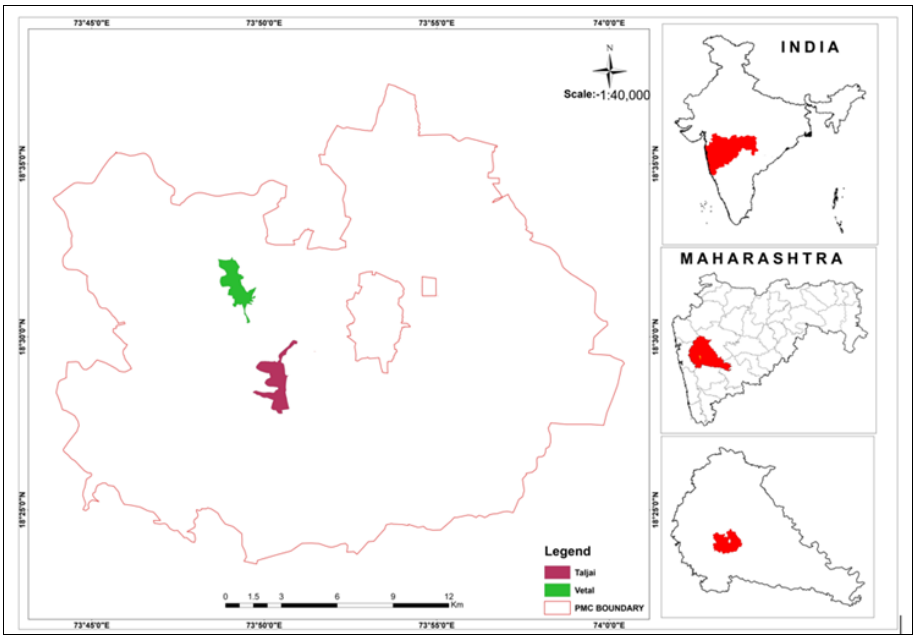
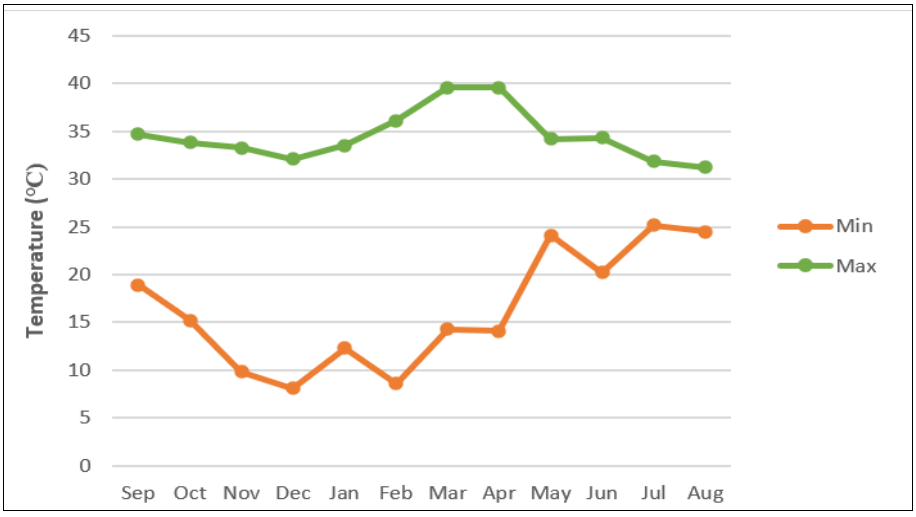


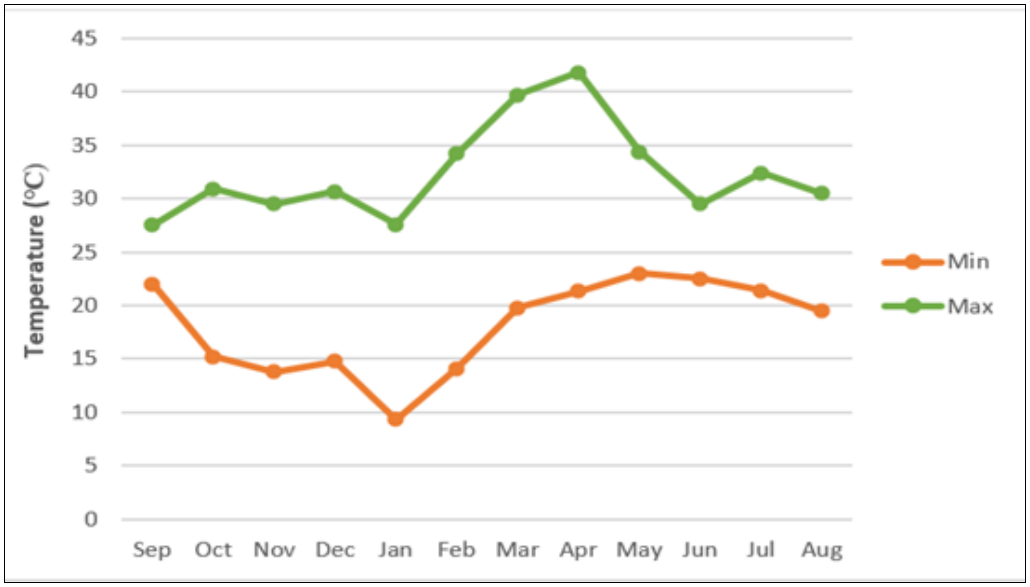
Fig 1: Map of Study area Taljai and Vetal Hill, in Pune

Climate

The maximum and minimum temperature ranges between 41.8℃ in spring and 8.1 ℃ in winter. The highest total rainfall is 367.4 mm in summer and lowest is 8 mm in spring. The above data is given for the period 2020 to 2022. Figure 2 shows temperature of Pune and Figure 3 shows rainfall of Pune in mm for the period of 2020 to 2022.



A. 2020 - 2021



B. 2021 - 2022

Fig 2: Min. and Max. temperature of Pune city. A. 2020 - 2021; B. 2021 - 2022 (Obtained from IMD, Pune).

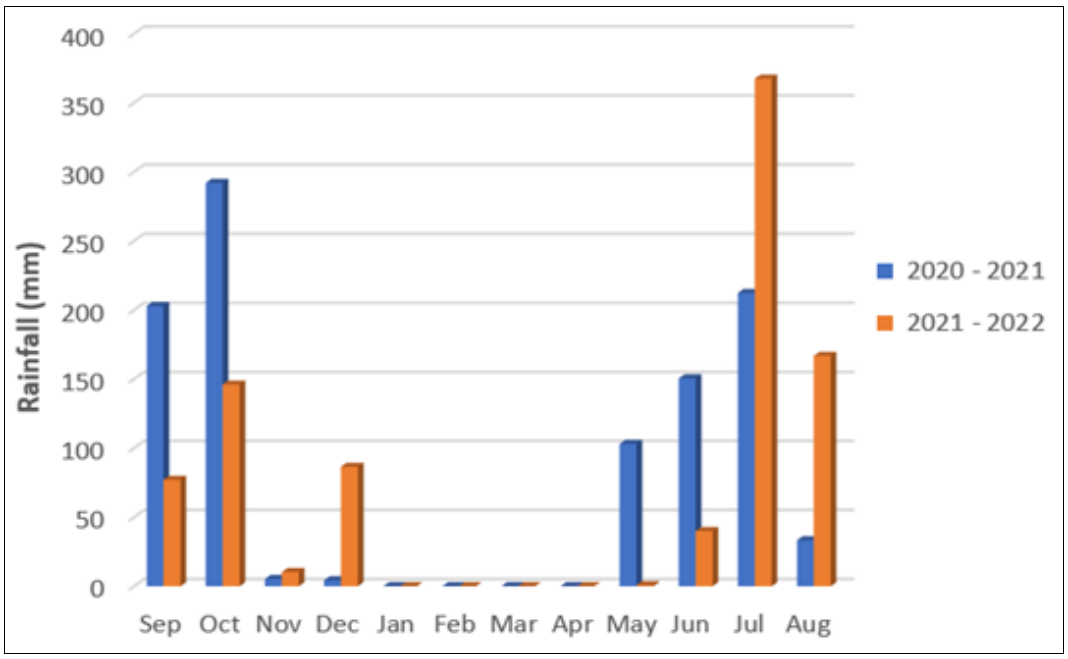


Fig 3: Rainfall in mm of Pune city during 2020 - 2022 (obtained from Mahavedh AWS Grid)

Phenological data

In the present study the penophases of flowering, fruiting and leafing of 20 tree and shrub species belonging to 12 families were studied for a period of two years between September 2020 to August 2022. Semi Quantative Technique (SQT) method is used. It includes observance of whole plant (Pilar *et. al.*, 2003) [29]. This method is quick unlike other method Quantative Techniques which includes tagging the branches for observations. Only the branches of plant species are studied and tags are put in 4 or more branches in all 4 directions. This method is time consuming and the removal of tags by natural calamities or for any reasons will hinder the further data collection. Hence SQT is considered best with less efforts and is less time consuming. Ten indivdiuals or minimum six of each species of adult and reproductive individual species were randomly selected and marked. Neighbouring individuals were selected. At an interval of 30 days the flowering, fruiting and leafing of each tree and shrub were given an intensity score of 0 (none), 1 (quarter canopy covered), 2 (half canopy covered), 3 (three-quarter canopy covered) and 4 (full canopy), based on visual estimates using digital cameras. This method of estimation of flowering, fruiting and leafing proved to provide greater detail than did a simple presence or absence system (Patel, 1997) [26].

Results

A total of 20 plant species belonging to 12 families were identified and documented in the study site. Family Fabaceae ranked first with 8 species followed by family Apocynaceae with 2 species (Figure 4).

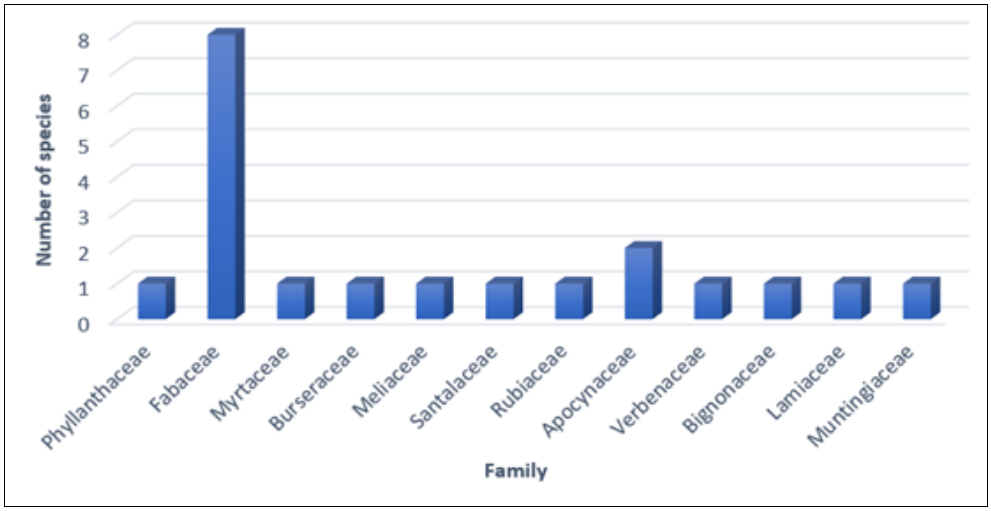
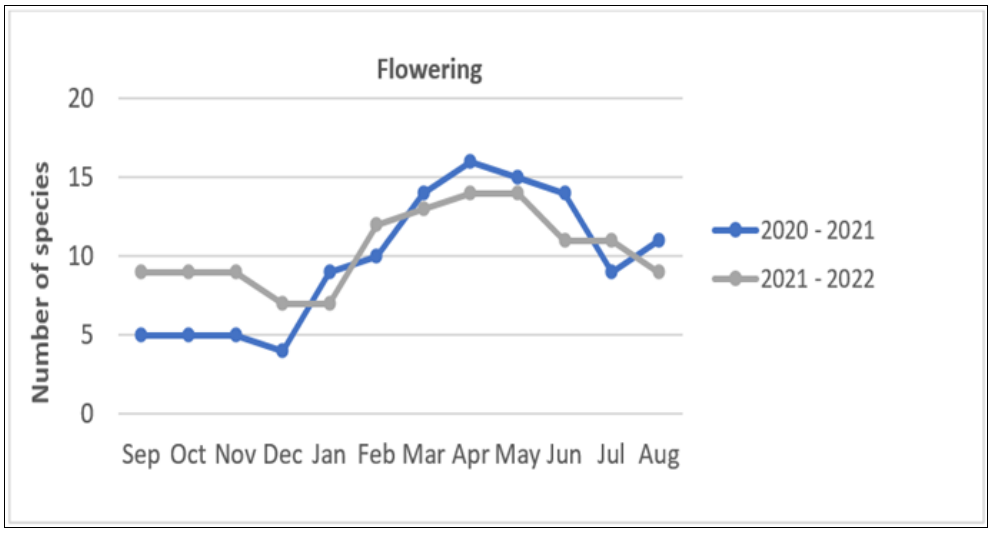
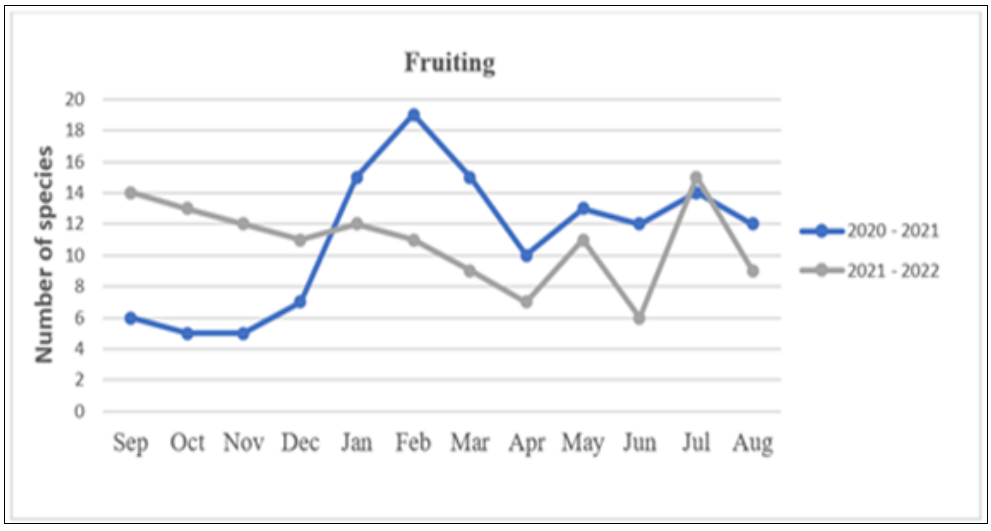


Fig 4: Taxonomy of sampled plant species

Flower formation showed peak in spring (April & May) and was 75%. Comparison of observations of flowering in different plant species occurred more often during dry than during wet months i.e. in the months of March, April, May, June, July and August (Figure 5 A). Fruiting peak observed in late winter (February) and was 95%, another peak appeared in mid- summer (July). Fruiting occurred more often in dry months in (January, February, March) and in mid-summer in (July) and early autumn in (September) (Figure 5 B). Leafing was observed almost year-round (100%) with drop in autumn (October and November) and early spring in (February & March) (Figure 5 C).



A.



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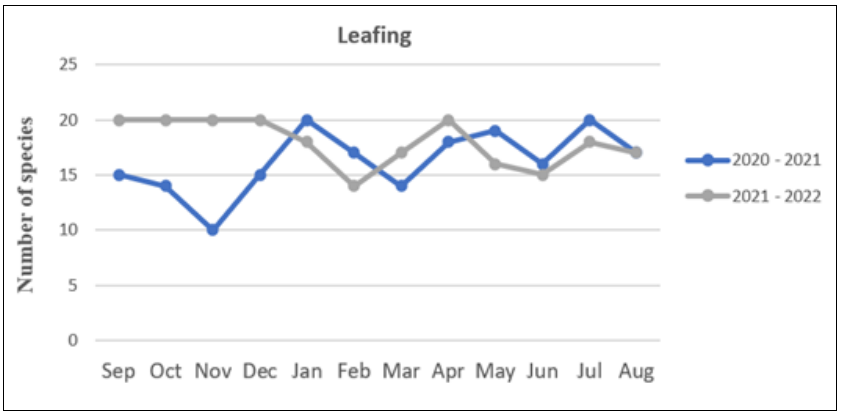

C.

Fig 5: % of plant species under study showing each phenophase during 2020 to 2022. A. flowering; B. Fruiting; C. Leafing

In (Figure 6) phenological patterns of individual plant species of twenty species studied are shown. The whole period of appearance of different phenophases flowering, fruiting and leafing for each plant species has been observed for two consecutive years. The study reveals that there is high phenological diversity for different phenophases studied among twenty plant species. However, leafing phenophase pattern reveals almost year-round leafing except in autumn and in early spring. It is observed that for the individuals of the same species, there was a significant difference in the appearance of different phenophases in different sites, for two different years in the same site the phenological pattern varied for the same species.

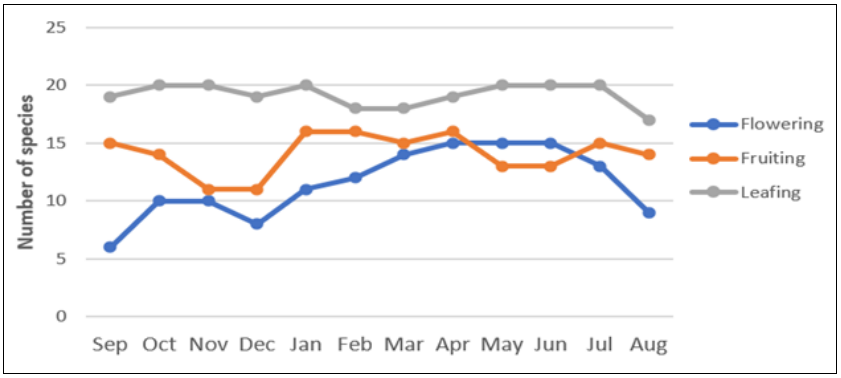

Fig 6: % of plant species under study showing each phenophase during 2020 to 2022. Flowering, fruiting and leafing

Percentage of plant species with intensity value of 3 and 4 is shown in Figure 7. For flowering most of the plant species with intensity value was observed in months of May (60%) and June (50%). Most of the plant species for fruiting with same intensity value of 3 and 4 was observed in the months of July (60%) and August (50%). For leafing most of the plant species with intensity value of 3 and 4 was observed in month of September and July (100%) and October and June (95%). This can be seen in Table 1.

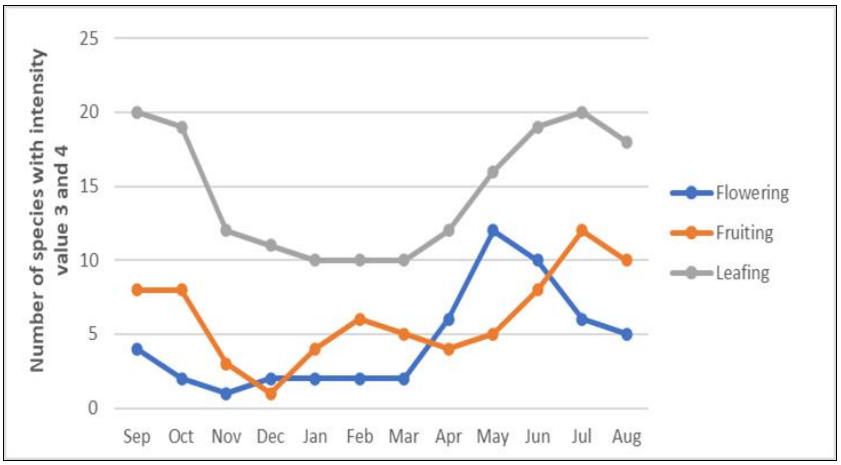

Fig 7: % of plant species under study showing each phenophase flowering, fruiting and leafing with intensity value 3 and 4 during 2020 to 2022.

Table 1: Phenological diagrams of 20 plant species belonging to 12 families. The green, yellow and orange colored bars indicate the whole period of appearance of leafing, flowering and fruiting. The values within the box indicate the intensity of different phenophases of 0 (none), 1 (quarter canopy covered), 2 (half canopy covered), 3 (three-quarter canopy covered) and 4 (full covered). F = Family, PP = Phenophases.

Sr. No	Plant Name	F	PP	Year	Site	Months											
						Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	*Phyllanthus emblica* L.	Phyllanthaceae	Leaves	2020 - 2021	TL	3	3	1	3	1	2	2	1	3	3	4	4
				2021 - 2022	TL	3	3	1	3	3	3	2	4	3	4	3	4
			Flowers	2020 - 2021	TL	0	0	0	0	0	1	2	2	3	4	0	0
				2021 - 2022	TL	0	0	0	1	1	2	2	2	3	4	0	0
			Fruits	2020 - 2021	TL	0	0	0	1	1	0	0	0	2	3	4	2
				2021 - 2022	TL	1	0	0	0	0	0	0	0	2	2	3	2
2	*Acacia catechu* (L.f.) Willd.	Fabaceae	Leaves	2020 - 2021	VL	4	3	2	1	1	0	0	1	2	3	4	3
				2021 - 2022	VL	4	3	2	1	1	1	1	1	1	1	4	3
			Flowers	2020 - 2021	VL	0	0	0	0	0	0	0	1	2	3	4	2
				2021 - 2022	VL	0	0	0	0	0	0	0	0	1	3	4	2
			Fruits	2020 - 2021	VL	0	0	0	0	0	0	0	0	0	1	2	3
				2021 - 2022	VL	3	4	2	1	2	0	0	0	0	0	3	3
3	*Albizia lebbeck* (L.) Benth	Fabaceae	Leaves	2020 - 2021	TL	3	4	2	2	1	1	3	3	4	4	4	4
					VL	3	4	2	2	1	0	2	3	2	4	4	4
				2021 - 2022	TL	4	4	2	2	0	1	2	3	4	4	3	4
					VL	4	4	2	2	0	1	2	3	4	4	4	4
			Flowers	2020 - 2021	TL	0	0	0	0	0	1	1	2	3	4	0	0
					VL	0	0	0	0	0	1	2	2	3	4	0	0
				2021 - 2022	TL	0	0	0	0	0	1	2	3	4	4	0	0
					VL	0	0	0	0	0	0	1	2	3	4	0	0
			Fruits	2020 - 2021	TL	0	0	0	0	2	3	1	2	0	0	1	1
					VL	0	0	0	0	4	4	4	4	1	1	1	1
				2021 - 2022	TL	2	3	4	2	0	0	0	0	0	0	2	0
					VL	2	3	3	2	0	0	0	0	0	0	2	0
4	*Bauhinia purpurea* L.	Fabaceae	Leaves	2020 - 2021	TL	0	0	0	0	3	3	0	3	4	4	4	4
				2021 - 2022	TL	4	4	1	1	1	0	0	0	0	0	4	3
			Flowers	2020 - 2021	TL	0	0	0	0	0	0	1	2	3	4	0	1
				2021 - 2022	TL	0	0	0	0	0	0	1	2	2	3	1	0
			Fruits	2020 - 2021	TL	1	0	0	0	3	2	0	0	0	0	0	1
				2021 - 2022	TL	1	3	1	1	1	0	0	0	0	0	1	0
5	*Butea monosperma* (Lam.)Kuntze	Fabaceae	Leaves	2020 - 2021	TL	0	0	0	0	4	1	1	3	4	4	4	4
					VT	0	0	0	0	0	0	0	0	4	4	4	4
				2021 - 2022	TL	4	3	4	3	3	2	2	1	4	4	4	4
					VT	3	3	3	3	2	0	1	4	4	4	4	4
			Flowers	2020 - 2021	TL	0	0	0	0	0	4	2	1	0	0	0	0
					VT	0	0	0	0	0	4	2	1	0	0	0	0
				2021 - 2022	TL	0	0	0	0	0	3	2	1	0	0	0	0
					VT	0	0	0	0	0	3	2	1	0	0	0	0
			Fruits	2020 - 2021	TL	0	0	0	0	0	3	4	0	0	0	0	0
					VT	0	0	0	0	0	3	4	0	0	0	0	0
				2021 - 2022	TL	0	0	0	0	0	2	3	2	0	0	0	0
					VT	0	0	0	0	0	2	4	2	0	0	0	0

6	*Dalbergia melanoxylon* Guill. & Perr.	Fabaceacea	Leaves	2020 - 2021	TL	0	0	0	0	1	0	0	1	3	4	4	4
					VT	0	0	0	0	1	1	0	1	3	4	4	4
				2021 - 2022	TL	4	2	2	2	1	1	1	1	1	1	2	4
					VT	2	3	2	2	1	0	0	0	1	1	2	4
			Flowers	2020 - 2021	TL	0	0	0	0	0	0	1	2	3	4	0	0
					VT	0	0	0	0	0	0	0	1	2	3	0	0
				2021 - 2022	TL	0	0	0	0	0	0	1	2	2	3	0	0
					VT	0	0	0	0	0	0	0	1	2	3	0	0
			Fruits	2020 - 2021	TL	0	0	0	0	0	0	1	1	2	3	4	4
					VT	0	0	0	0	0	0	1	1	2	3	4	4
				2021 - 2022	TL	4	4	0	0	0	0	0	0	0	0	4	0
					VT	4	4	0	0	0	0	0	0	0	0	4	0
7	*Delonix regia* (Bojer ex Hook.) Raf.	Fabaceaceae	Leaves	2020 - 2021	TL	3	1	1	1	1	1	0	1	2	4	4	4
					VT	3	1	1	1	1	1	0	1	1	3	4	4
				2021 - 2022	TL	4	1	1	1	1	0	1	0	1	2	3	4
					VT	3	3	3	1	1	0	1	1	2	2	3	4
			Flowers	2020 - 2021	TL	0	1	0	0	0	0	1	1	3	4	0	0
					VT	0	1	0	0	0	0	0	4	2	2	0	0
				2021 - 2022	TL	0	1	0	0	0	0	0	0	2	2	3	0
					VT	0	1	0	0	0	0	0	2	0	3	4	0
			Fruits	2020 - 2021	TL	0	1	0	0	1	2	1	0	0	2	3	3
					VT	0	1	0	0	1	1	1	1	0	1	2	3
				2021 - 2022	TL	4	2	0	0	1	2	1	0	0	0	3	1
					VT	3	4	1	0	0	0	0	0	0	0	2	1
8	*Gliricidia sepium* (Jacq.) Walp	Fabaceacea	Leaves	2020 - 2021	TL	4	3	1	1	1	0	1	1	3	4	4	4
					VL	3	3	1	1	1	0	1	1	3	4	4	4
				2021 - 2022	TL	4	3	3	1	1	0	2	1	1	2	3	4
					VL	3	3	2	1	1	0	2	1	1	2	3	4
			Flowers	2020 - 2021	TL	0	0	0	0	1	2	3	4	0	0	0	0
					VL	0	0	0	0	1	2	2	3	0	0	0	0
				2021 - 2022	TL	0	0	0	0	0	1	2	3	0	0	0	0
					VL	0	1	1	1	2	2	3	4	0	0	0	0
			Fruits	2020 - 2021	TL	0	0	0	0	0	1	2	3	0	0	0	0
					VL	0	0	0	0	1	2	2	3	0	0	0	0
				2021 - 2022	TL	0	0	0	0	0	1	2	3	0	0	0	0
					VL	0	0	0	0	1	1	2	3	0	0	0	0
9	*Leucaena leucocephala* (Lam.) de Wit	Fabaceaceae	Leaves	2020 - 2021	TL	3	2	1	3	1	2	1	1	0	3	4	4
					VL	3	3	1	2	2	2	1	2	2	3	4	4
				2021 - 2022	TL	4	2	1	3	2	2	1	0	0	1	3	3
					VL	3	3	1	2	2	2	2	1	0	0	3	3
			Flowers	2020 - 2021	TL	0	0	0	0	0	0	0	0	0	1	2	3
					VL	0	0	0	0	0	0	0	0	0	1	2	2
				2021 - 2022	TL	3	1	0	0	0	0	0	0	0	0	0	0
					VL	3	1	1	1	0	0	0	0	0	0	0	0
			Fruits	2020 - 2021	TL	0	0	0	0	0	0	0	0	0	0	2	2
					VL	0	0	0	0	0	0	0	0	0	0	0	1
				2021 - 2022	TL	4	4	4	0	0	1	0	0	0	0	4	4
					VL	4	1	1	0	0	0	0	0	0	0	4	4
10	*Eucalyptus globulus* Labill.	Myrtaceae	Leaves	2020 - 2021	TL	0	0	0	0	4	4	4	3	3	4	3	4
					VT	0	0	0	0	4	4	4	3	3	4	3	3
				2021 - 2022	TL	4	3	3	3	3	3	3	3	3	3	4	4
					VT	3	3	3	3	3	3	3	3	3	3	4	4
			Flowers	2020 - 2021	TL	0	0	0	0	1	1	0	0	0	0	0	2
					VT	0	0	0	0	1	1	0	0	0	0	0	1
				2021 - 2022	TL	0	2	0	0	2	2	0	0	0	0	0	1
					VT	2	3	2	0	0	0	0	0	0	0	2	1
			Fruits	2020 - 2021	TL	2	2	2	2	2	1	4	3	1	2	3	1
					VT	2	2	3	2	2	3	4	3	3	3	3	3
				2021 - 2022	TL	2	2	2	1	3	3	3	2	2	2	2	2
					VT	2	2	3	3	3	3	4	2	2	2	2	2
11	*Boswellia serrata* Roxb.	Burseraceaceae	Leaves	2020 - 2021	VT	0	0	0	0	1	0	0	1	3	4	4	3
				2021 - 2022	VT	2	1	1	1	2	0	0	0	0	2	2	0
			Flowers	2020 - 2021	VT	0	0	0	0	1	1	2	3	4	0	0	0
				2021 - 2022	VT	0	0	0	0	1	1	2	3	4	0	0	0
			Fruits	2020 - 2021	VT	0	0	0	0	1	3	4	4	3	1	0	0
				2021 - 2022	VT	0	0	0	0	1	2	2	3	1	1	0	0

12	*Azadirachta indica* A.Juss.	Meliaceae	Leaves	2020 - 2021	TL	3	2	2	1	1	4	3	3	4	4	4	4
					VT	3	2	2	1	1	4	4	3	3	4	4	4
				2021 - 2022	TL	3	2	2	1	2	2	4	2	2	2	3	4
					VT	3	3	2	1	2	2	4	2	2	2	3	4
			Flowers	2020 - 2021	TL	0	0	0	0	0	0	2	3	4	3	0	0
					VT	0	0	0	0	0	1	1	2	3	1	1	0
				2021 - 2022	TL	0	0	0	0	0	1	2	3	4	3	0	0
					VT	0	0	0	0	0	1	1	2	3	4	0	0
			Fruits	2020 - 2021	TL	0	0	0	0	0	0	1	1	1	2	3	4
					VT	0	0	0	0	0	0	1	1	1	1	1	2
				2021 - 2022	TL	0	0	0	0	0	0	1	1	1	1	2	2
					VT	1	0	0	0	0	0	0	1	1	1	2	3
13	*Santalum album* L.	Santalaceae	Leaves	2020 - 2021	TL	4	4	4	4	4	4	4	4	4	4	4	4
					VL	4	4	4	4	4	4	3	3	3	4	4	4
				2021 - 2022	TL	4	4	4	4	4	4	2	2	4	4	4	4
					VL	4	4	4	4	4	4	3	3	3	4	4	4
			Flowers	2020 - 2021	TL	3	2	2	2	1	0	1	1	3	4	4	2
					VL	2	1	2	2	1	0	2	0	1	4	4	3
				2021 - 2022	TL	3	2	2	2	2	2	1	1	0	1	2	3
					VL	2	1	2	2	3	1	1	0	1	1	2	2
			Fruits	2020 - 2021	TL	2	2	2	2	2	1	1	1	0	3	2	3
					VL	2	1	2	2	2	1	1	0	1	3	3	3
				2021 - 2022	TL	2	2	2	2	2	2	1	1	1	1	2	2
					VT	2	1	2	2	2	1	1	1	1	1	2	2
14	*Morinda pubescens* Sm.	Rubiaceae	Leaves	2020 - 2021	VT	4	4	3	3	3	4	4	4	1	4	4	4
				2021 - 2022	VT	4	4	3	2	2	0	1	2	4	3	4	4
			Flowers	2020 - 2021	VT	0	0	0	0	0	0	0	1	3	3	4	0
				2021 - 2022	VT	0	0	0	0	0	0	1	1	2	3	4	0
			Fruits	2020 - 2021	VT	0	0	0	0	2	4	4	4	2	4	4	4
				2021 - 2022	VT	3	3	2	2	2	0	0	0	2	0	0	0
15	*Cascabela thevetia* (L.) Lippold	Apocynaceae	Leaves	2020 - 2021	TL	4	4	4	4	4	4	4	4	4	4	4	4
				2021 - 2022	TL	4	4	4	4	4	4	4	4	4	4	4	4
			Flowers	2020 - 2021	TL	0	0	0	0	1	2	2	2	3	4	4	2
				2021 - 2022	TL	2	2	1	1	0	1	2	0	1	2	3	2
			Fruits	2020 - 2021	TL	0	0	0	0	1	1	1	1	1	2	3	3
				2021 - 2022	TL	4	2	1	1	0	1	2	1	1	0	2	2
16	*Calotropis gigantea* (L.) Dryand.	Apocynaceae	Leaves	2020 - 2021	TL	4	4	4	4	4	4	4	4	4	4	4	3
				2021 - 2022	TL	4	4	4	4	4	4	4	4	4	4	4	4
			Flowers	2020 - 2021	TL	0	0	0	0	2	3	4	4	4	0	0	0
				2021 - 2022	TL	0	2	0	0	0	0	3	4	0	0	0	0
			Fruits	2020 - 2021	TL	0	0	0	0	1	2	3	4	4	0	0	0
				2021 - 2022	TL	0	0	0	0	0	0	1	2	2	4	0	0
17	*Lantana camara* L.	Verbanaceae	Leaves	2020 - 2021	TL	4	4	4	3	2	0	0	0	3	4	4	4
					VT	2	2	2	2	2	1	0	0	3	4	4	4
				2021 - 2022	TL	4	4	4	3	2	3	3	3	3	3	4	4
					VL	2	2	2	2	1	1	2	1	3	3	2	4
			Flowers	2020 - 2021	TL	3	2	2	2	1	0	0	0	3	4	0	0
					VL	1	1	1	4	0	0	0	0	2	3	0	3
				2021 - 2022	TL	3	2	2	2	0	3	0	0	0	0	1	2
					VL	1	1	1	4	0	0	0	0	0	0	1	0
			Fruits	2020 - 2021	TL	4	3	2	1	2	0	0	0	2	3	0	0
					VL	1	0	0	0	2	3	0	0	0	2	0	2
				2021 - 2022	TL	4	3	2	1	1	0	0	1	1	3	3	2
					VL	1	0	0	0	0	0	0	0	1	1	0	0

18	*Tecoma stans* (L.) Juss. ex Kunth	Bignonaceae	Leaves	2020 - 2021	VL	4	3	3	3	2	1	1	1	3	4	4	4
				2021 - 2022	VL	4	3	3	3	1	0	0	0	1	1	4	0
			Flowers	2020 - 2021	VL	1	2	3	4	1	1	1	1	0	0	0	0
				2021 - 2022	VL	2	2	2	3	1	0	0	0	0	0	2	0
			Fruits	2020 - 2021	VL		1	2	2	3	3	2	2	0	0	0	0
				2021 - 2022	VL	1	1	2	2	2	0	0	0	0	0	1	0
19	*Tectona grandis* L.f.	Lamiaceae	Leaves	2020 - 2021	TL	4	4	2	2	1	0	0	0	3	4	4	4
				2021 - 2022	TL	4	4	2	2	1	1	0	0	1	1	4	4
			Flowers	2020 - 2021	TL	4	2	2	0	0	0	0	0	3	4	4	4
				2021 - 2022	TL	4	3	2	0	1	0	0	1	1	0	2	2
			Fruits	2020 - 2021	TL	0	0	0	0	1	1	1	1	2	2	3	4
				2021 - 2022	TL	2	2	0	0	1	0	0	0	0	0	2	1
20	*Muntingia calabura* L.	Muntingiaceae	Leaves	2020 - 2021	TL	4	4	4	3	4	4	4	4	4	4	4	4
				2021 - 2022	TL	4	4	4	3	3	3	3	4	4	4	4	4
			Flowers	2020 - 2021	TL	1	2	1	1	1	2	1	1	3	4	2	2
				2021 - 2022	TL	1	2	1	1	2	2	2	2	2	1	1	2
			Fruits	2020 - 2021	TL	3	2	1	1	1	3	2	2	4	4	4	3
				2021 - 2022	TL	3	2	1	1	2	2	4	2	3	4	3	2

Discussion

Peak flowering appeared in the beginning of summer (60%) and peak fruiting appeared at the of end of summer (66%) (Mosissa, 2019) [18]. In the present study peak flowering was observed in spring (75%) and peak fruiting was observed in late winter (95%) and in mid-summer. It can be indicated that phenophases flowering and fruiting with different plant species of same families in two different sites will vary. Variations in phenophases among individuals of the same species or different species have been linked to environmental disturbances (Suresh and Sukumar, 2011) [38]. The period of maximum activity of flowering (started at the beginning of summer and extended to the beginning of autumn) (Pilar and Gabriel, 1998) [28]. This variation in the present study is maximum during the flowering period (started at early spring and extended to the end of late summer). Flowering corresponds with leafless period in most of the species (Shukla and Ramakrishnan, 1982) [35]. This coincides with the present study.

Phenological pattern changes is attributed to varied temperature, photoperiod, frost, humidity etc. (Primack *et al.*, 2015) [30] temperature, soil moisture, nitrogen avaibility and light (Nord and Lynch, 2009) [20], adverse effects of insects pollinators as well as hervibores (Saavedra *et al.*, 2003) [32]. Phenological patterns change with plant's response to different temperature and rainfall availability have been shown to be species specific (Parmesan, 2007) [25]. The differences in phenological patterns can be attributed to difference in soil type as the sampled area in Taljai showed very shallow, excessively drained, loamy soils while Vetal showed slightly deep, moderately well drained, fine soils.

A comparison of observations on flowering time for two years under study revealed an advancement of flowering by 1- 4 months in the year 2021- 2022 for some species like *Calotropis gigantea* (L), *Cascabela thevetia* (L) Lippold, *Morinda pubescens* Sm, *Gliricidia sepium* (Jacq.) Walp, *Phyllanthus emblica* L. Many studies have shown advancement of phenological events as a result of increasing temperature (Julien and Sobrino, 2009, Menzel *et al.*, 2006, Parmesan and Yohe, 2003, Piao *et al.*, 2006) [10, 16, 24,27].

It has been suggested (Janzen, 1967) [42] that leaf flushing and flowering are separated in time to prevent competition for responses within the individual tree and to enable individuals to compete for lights through vegetative growth during the rainy season. In contrast, this study shows leaf flushing peaks are often associated with dry season and high temperature. In this study leaf flushing was observed year-round with maximum leafing in post monsoon. Post monsoon high rainfall in September and October was upto 292 mm. Monsoon periods were June, July and August with high rainfall upto 367.4 mm. In another study leaf shedding was observed in summer and in the autumn depending on the type of leaf habit of that plant species. In the present study leaf shedding or leafless period was observed in winter (January and February) and in early spring in month of March which does not coincide with the observations of (Kaur *et al.*, 2013) [13]. In another study it was found that in most of the tree species leaf fall corresponds with dry period. Leaf flushing initiated at the end of dry period. Leafless period varied in species. During wet period fleshy fruits were produced and in dry period fruits produced were mostly dry (Shukla and Ramakrishnan, 1982) [35].

Conclusion

This study revealed high phenological diversity in different phenophses studied in twenty plant species from two different sites. This study would be of significance for comparison of phenological patterns of the same plant in different geographical range with varied climatic conditions or where similar climatic conditions prevail.The studied plant species may be of great help in avenue plantations, tourism, understanding ecosystem structure and functions, understanding seasonal occurance of plant pathogens and arthropods pests, predicting the intensity of allergy season, pollen forecasting by physcians, health professionals, allergic people for wide variety of purposes for example preventive medications, planning of medicine production etc. Further, this study can be of great importance in scientific, environmental and socioeconomic disciplines.

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