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Phenological Patterns among the Vegetation of Nikyal Valley, District Kotli, Azad Jammu and Kashmir, Pakistan

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Authors' contributions

This work was carried out in collaboration between all authors. Author MSA designed the study, performed the field work, wrote the protocol, and wrote the first draft of the manuscript. Author MA managed the analyses of the study and revised manuscript. Author SKC managed the literature searches. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

Aim: The aim of this study was to report the seasonal variation in phenological pattern as a function of rain fall and temperature.
Place and Duration of Study: This study was conducted in Nikyal valley located at altitudinal range of 1500-1900 m within the longitude 74o 04′ to 10′ east and latitude 33o 26′ to 29′ north during July 2012 to June 2013.
Methodology: A phenological record of plant species was organized on the source of field trips and visits conducted every month. The plants were then classified in to different phenological stages.
Results: There were 110 plant species of 51 families consisting of 5 trees, 29 shrubs, 55 herbs, 18 grasses and 3 ferns harbouring in Nikyal valley. The investigated area had only one flowering season. Majority of herbaceous, shrubby trees species flowered from April to May and the flowering reached to the peak during May and June.
Conclusion: The variation in phenological patterns controlled by the amount and timing of precipitation inputs during the growing season.

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Keywords: Phenology; climate; environmental changes; rainfall.

1. INTRODUCTION

Phenology referred to the seasonal timing of life cycle events such as flowering, fruiting seedling and dormancy [1]. It is a periodic phenomenon in plants that are tied to periodic environmental changes [2]. A global warming led to shift in timing of plant phenology over the past half century as determined both by observations and retrospective models [3,4]. Phenological information is important in monitoring all aspects of ecosystems and is essential to understanding the dynamics of plant communities [5]. This type of study envisages a relationship between climate and growing periods of plants of an area and such type of studies are essential for planning, regeneration, forestation and conservation in rangeland and forestry [6].

Some work has been done by different workers on the phenology of plants in the various parts of the world i.e. [6,7,8,9,10,11,12,13,14,15,16,17,18,19]. Literature dealing with the phenology shows that very little work has been made in Pakistan i.e. [6,17]. The aim of the present study was to understand the vegetative as well as reproductive phenological patterns. The second major aim was to detect interrelationship between plant phenology and microclimate variables. Such relationships have been very rarely addressed in previous studies.

2. MATERIALS AND METHODS

2.1 Study Area

Nikyal Hills are situated in District Kotli, Azad Jammu and Kashmir at an altitude of 1500-1900m. They are located 30 km away from Kotli towards North. The investigated area lies within longitude 74o 04′ to 10′ east and latitude 33o 26′ to 29′ north. It is surrounded by Kotli on south, on western side by Tatapani, on Northern side by Mender and on east by Pir-Panjal [20].

The climate of Nikyal valley is of sub tropical humid type with average monthly rainfall of 95.60 mm. The maximum rainfall occurs during July amounting to 251.52 mm, while least rainfall occurs during November amounting to 14.44 mm (Fig. 1). The hot months of the year are June and July, with mean daily maximum temperature of 37.69ºC and 34.82ºC respectively and minimum temperature of 23.61ºC and 23.62ºC respectively, while the cold months of year were December and January with mean maximum temperature of 19.99ºC and 18.09ºC respectively and minimum temperature of 5.49ºC and 4.41ºC respectively (Fig. 2). The average maximum and minimum relative humidity received by the area is 79.64 and 30.82% respectively (Fig. 3). (Source: Pakistan Metrological Department Lahore).

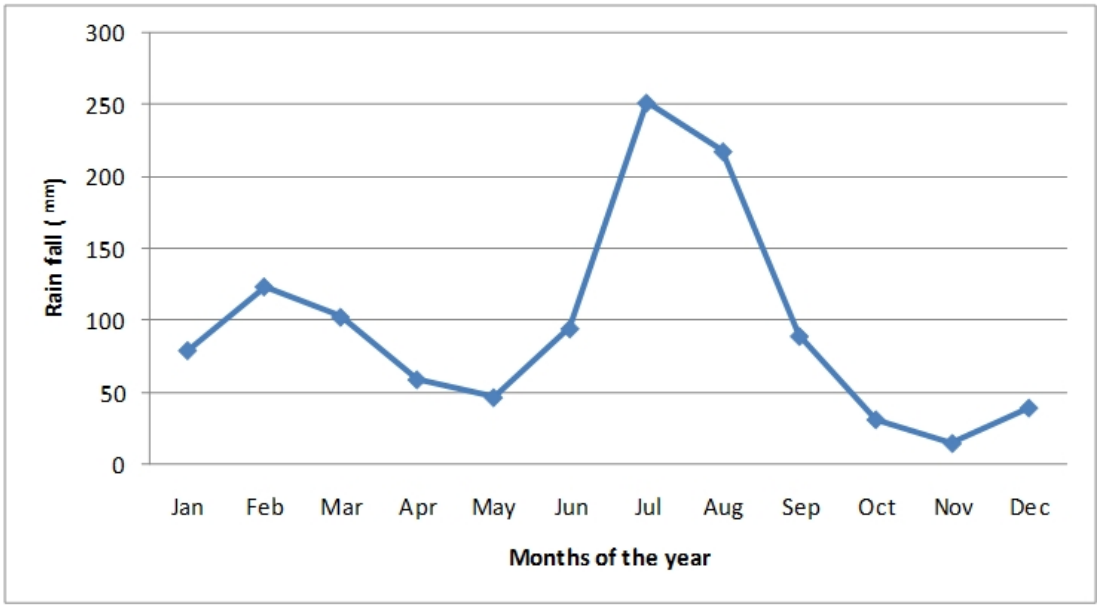

Fig. 1. Graphical representation of monthly variation in rain fall

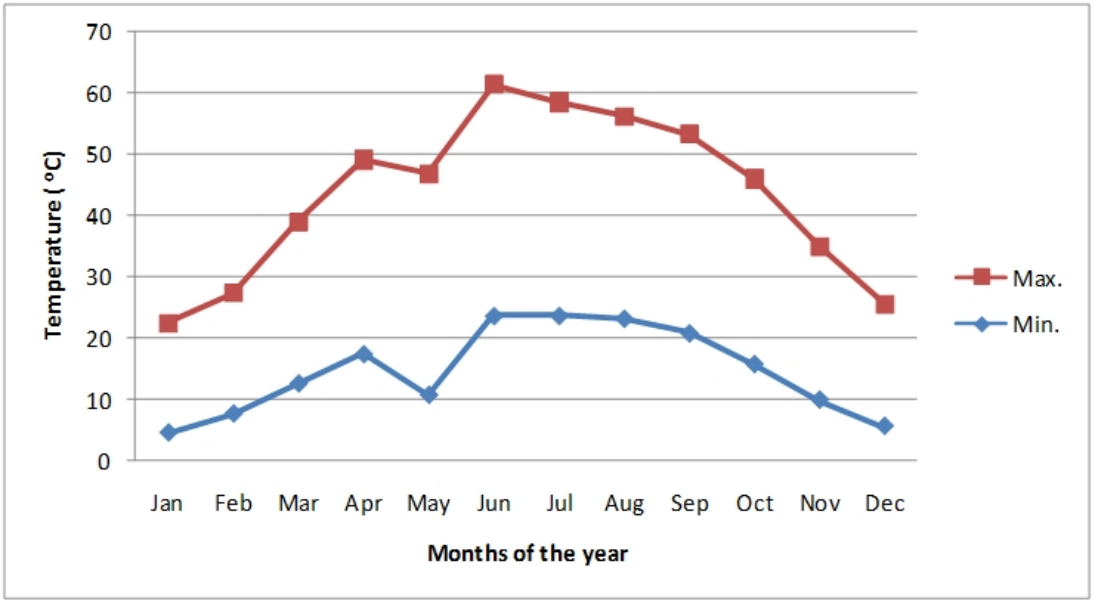

Fig. 2. Graphical representation of monthly variation in temperature

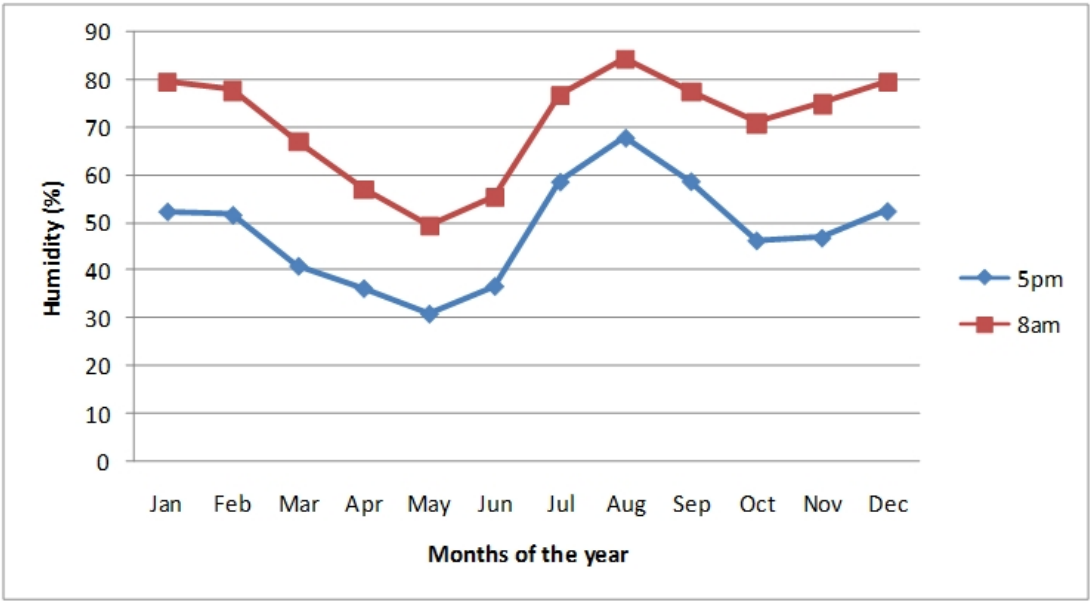

Fig. 3. Graphical representation of monthly variation in humidity

2.2 Methodology

Frequent general surveys and visits were conducted every month to report the phenological observations of 110 plant species belonging to 51 families. This was done for twelve consecutive months from July 2012 to June 2013. [6,16] The data was averaged and plants were then classified into the following four stages.

1. Seedling (vegetatively young and pre- flowering)
2. Flowering (only flowers seen)
3. Fruiting (mature where both flowering and fruiting can be seen)
4. Dormant (life cycle completed or fruiting completed)

3. RESULTS

Phenological observation was recorded from July 2012 to June 2013 (one year data).The maximum flowering occurred in the month of April (51 percent) and May (42 percent), while 3 percent plants flowered in the month of August. Very low flowering was observed in the months of February, July and August ranging from 1-2 percent (Table 2; Fig. 4).

Maximum flowering of trees (60 percent) occurred in the months of April. They included *Pinus roxburghii Prunus persica* and *Punica granatum*. While the remainig 40% trees including *Olea ferruginea* and *Qurecus dlatata* flowered in the month of May (Table 2).

Maximum Shrubs such as *Berberis lycium, Dodonaea viscosa, Elaeagnus parvifolia, Indigofera heteranth, Otostegia limbata Rubus fruticous* and *Zanthoxylum alatum* flowered in the month of April and May (96 percent) (Table 1).

Maximum herbs flowered in the month of April (51 percent), while 55 percent grasses flowered in the month of May. Maximum climbers flowered in the month of July (75 percent) and ferns sori formation started in April (Table 1).

Maximum fruiting occurred in the month of June (35 percent) which was followed by June (33 percent) and July (21 percent) respectively. August was the peak of ripening of fruit. Lowest percentage of fruiting occurred in the months of April, September and October which ranged from 2 to 5 percent (Table 2; Fig 4).

Maximum (40 percent) fruiting of trees occurred during the month of June which included *Pinus roxburghii* and *Qurecus dlatata* (Table 1).

Similarly 96 percent shrubs were at the fruiting peak in the month of May and June (i.e. *Berberis lycium, Indigofera heterantha, Myrsine africana, Nerium indicum, Rubus fruticosus* and *Ziziphus Jujube)* respectively. Herbs were at the fruiting peak in the month of May (27-61 percent) while climbers and grasses were at the fruiting peak in the month of April (Table 1). Statistical analysis showed that phenology is strongly correlated with the temperature and rainfall. (Table 3; Table 4).

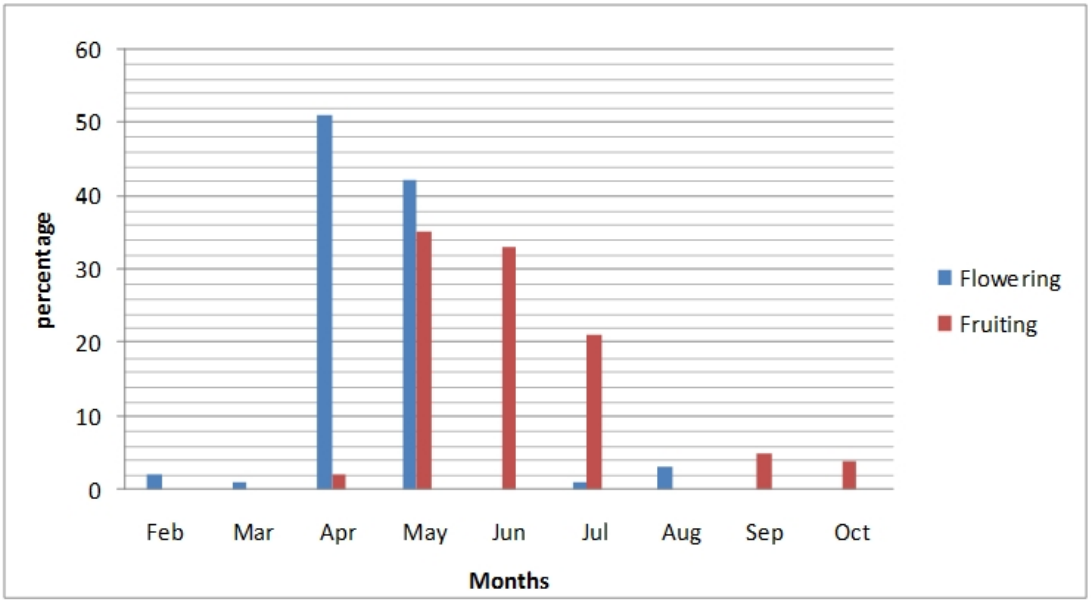

Fig. 4. Graphical representation of phenology of plants recorded from Nikyal hills during July 2012-June 2013.

Table 1. Summary of phenology recorded during 2012-2013 from Nikyal hills District Kotli

Plant species	Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Trees	Flowering %	-	-	-	60	40	-	-	-	-	-	-	-
	Fruiting %	-	-	-	-	20	40	-	20	20	-	-	-
Shrubs	Flowering %	-	4	-	48	48	-		-	-	-	-	-
	Fruiting %	-	-	-	-	48	48	4	-	-	-	-	-
Herbs	Flowering %	-	2	-	51	40	-	2	5	-	-	-	-
	Fruiting %	-	-	-		35	31	18	7	5	2	-	-
Grasses	Flowering %	-	-	6	39	55				-	-	-	-
	Fruiting %	-	-	-	5	5	22	68	-	-	-	-	-
Ferns	Flowering %	-	-	-	100	-	-	-	-	-	-	-	-
	Flowering %	-	-	-	-	100	-	-	-	-	-	-	-
Climbers	Flowering %	-	-	-	75	25	-		-	-	-	-	-
	Fruiting %		-	-	25	75	-		-	-	-	-	-

Table 2. Total percentage of phenological data

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Flowering %	-	2	1	51	42	-	1	3	-	-	-	-
Fruiting %	-	-	-	2	35	33	21	-	5	4	-	-

Table 3. Correlation between temperature and phenology

		Temperature	Phenology
Temperature	Pearson correlation	1	.352
	Sig. (2-tailed)		.262
	N	12	12
Phenology	Pearson correlation	.352	1
	P-value	.262	
	N	12	12

Table 4. Correlation between Rainfall and phenology

		Rainfall	Phenology
Rainfall	Pearson correlation	1	-.184
	Sig. (2-tailed)		.568
	N	12	12
Phenology	Pearson correlation	-.184	1
	P-value	.568	
	N	12	12

4. DISCUSSION

Phenology is the study of response of plants towards environmental changes. It is associated with plant growth rate [21], nutrient transfer [22] thermal requirement [23], plant water relationship, and even evolutionary change [24]. Small variations in climate have great effect over vegetation. While vegetation can be characterized by different patterns of phenological events [25].

In the investigated area, phenological behavior was observed during February to August. This type of study tells us about relationship between climate and growing period of an area. Such studies are used in planning age classes, conservation in forestry and rangeland. The species differed in their appearance, disappearance and flowering etc. during different time of year. The present study tells us that growing season started where few herbaceous and shrubby species start vegetative growth. The blooming of maximum plants occurred during April and May. Flowering was reduced at the end of May.

Authors [13] have reported that in sub-tropical forests of Manipur India flowering occurred during the months of April to September. Similarly in our case, maximum plant species flowered in the month of April. So our results in this regard are in accordance with them. Our findings are also supported by authors [11] who reported that maximum plants flowered in the month of April and May in May. The results are also in line with authors [12] who report that peak flowering occurred in May in different part of China.

The authors [19] reported that in Gujrat India maximum flowering occurred in the months of January and February. The difference might be due to climatic and geographical effects.

Maximum fruiting occurred in the month of May followed by June and July. Fruiting reduced in the month of October and end in November. The present findings are strengthen by author [26]. Who stated that fruiting started at the end of April and beginning of May. Fruiting

was at extreme during the dry season. According to authors [27] dry period provides the seed with intense luminosity and thus they have greater probability to germinate.

With the change in climatic conditions, flowering period of plant species can be affected. A change in temperature can cause shift in reproductive phenology of plant species in growing season [18]. In the investigated area, many herbaceous species such as *Micromeria biflora, Dicliptera roxburghiana, Imperata cylindrical* and *Poa annua* were in flowering condition.

The authors [28] observed that in alpine zone flowering period started after snow fall. In the study area, shrubs start flowering in February and trees in March. This could be due to dry conditions at the lower reaches and to some extent cold at the top.

Phenological variations are the indicator of climatic changes especially in humidity and temperature. Similarly, urbanization is also important factor which affects the global climatic changes. The uneven fluctuation in temperature due to urbanization had directly affected the phenology of plants in Canada [29]. Similarly in our case, flowering was favored during April-May due to high temperature and further rise in temperature from June to September lead to the appearance and maturation of fruits.

The authors [13,30] observed that maximum fruit maturation in eastern India occurred in the months of September to October. Climatic changes and day length variations might be responsible for differences [31].

Maximum fruiting in tree species in Gujrat India (700 28'to 700 27' north) was recorded during March, April and December by [19]. Temperature and photoperiod mainly affect fruiting in plants. In the investigated area, fruiting of tree species was at peak in the July. Our findings in this respect disagree with their study which might be due different latitude and presence of different species in Nikyal valley.

5. CONCLUSION

Several aspects of phenology and productivity such as seedling, flowering, fruiting and dormancy of different plant species varied during a twelve months of the study period, with much of the variation controlled by the amount and timing of precipitation inputs during the growing season. They are also influenced with respect to the size of the observation area, the number of observers, the duration of time observed and the type and number of species.

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COMPETING INTERESTS

The authors declare that they have no competing interests exist.

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APPENDIX

Appendix 1. Phenology of plants recorded from Nikyal hills during 2012-2013

Species	Seedling	Flowering	Fruiting	Dormant
Achillea millefolium L.	*Apr.*	*May*	*Jun.*	*Aug.*
Achyranthes aspera Wall	*Mar.*	*Apr.*	*Aug.*	*Oct.*
Adiantum venustum D.Don	*Mar.*	*Apr.*	*May*	*Oct.*
Agrostis canina auct	*Mar.*	*Apr.*	*May*	*Jul.*
Ajuga bracteosa Wallich	*Apr.*	*May*	*Jun.*	*Aug.*
Andropogon gerardii Vitman	*Apr.*	*May*	*Jul.*	*Oct.*
Arisaema jacquemontii Blume	*Mar.*	*Apr.*	*Aug*	*Oct.*
Aristida adscensionis L.	*Mar.*	*Apr.*	*Jun.*	*Jul.*
Imperata cylindrica L.	*Mar.*	*Apr.*	*Jun.*	*Jul.*
Berberis lycium Royle	*Mar.*	*Apr.*	*May*	*Jul.*
Bergenia ligulata (Str) Hot	*Mar.*	*Apr.*	*May*	*Jul.*
Biden biterata (Lour.) Merr and Sherf	*Mar.*	*Apr.*	*May*	*Jul.*
Anaphalis timmua D. Don.	*May*	*Aug.*	*Oct*	*Dec..*
Brachiaria eruciformis (J.E Smith) Griseb	*Apr.*	*May*	*Jul.*	*Aug.*
Brachiaria repans (L.) Gardner and Hubbard	*Apr.*	*May*	*Jul.*	*Aug.*
Bryophyllum pinnatm Kurz		*Feb*	*April*	
Bupleurum flacatumL.	*Apr.*	*May*	*Jul.*	*Aug.*
Androsace rotundifolia Hardw	*Mar.*	*Aug.*	*Sep.*	*Oct.*
Chrysopogon aucheri (Boiss) Stapf	*Apr.*	*May*	*Jul.*	*Oct.*
Clematis grata Wallich	*Apr.*	*May*	*Jun.*	*Aug.*
Colebrookia oppositifolia Sm.		*Feb.*	*Jul.*	*Oct.*
Commelina benghaliensis Linn.,sp. Pl.	*Apr.*	*May*	*Jul.*	*Aug.*
Contoneaster acuminatus ILinley	*Mar.*	*Apr.*	*May*	*Jul.*
Conyza canadensis L.	*Mar.*	*Apr.*	*Jun.*	*Aug.*
Conyza ambigua Hook. Arn	*Mar.*	*Apr.*	*Jul.*	*Oct.*
Cymbopogon jwarancusa (Jones) Schult.	*Mar.*	*Apr.*	*Jul.*	*Aug.*
Cynodon dactylon (L.) Pers	*Mar.*	*Apr.*	*Jun.*	*Sep.*
Cynoglossum lanceolatum Forssk	*Mar.*	*Apr.*	*May*	*Jul.*
Cyprus difformis L.	*Apr.*	*May*	*Jul.*	*Sep.*

Appendix 1 continues…….

Cyperus niveus Retz	*Apr.*	*May*	*Jul.*	*Sep.*
Cyperus rotundus L.	*Apr.*	*May*	*Jul.*	*Sep.*
Phalaris arundinacea L.	*Apr.*	*May*	*Jul.*	*Sep.*
Debregeasia salicifolia (D.Don) Rendle	*Apr.*	*May*	*Jun.*	*Aug.*
Dichanthium annulatum (Forssk).Stapf	*Mar.*	*Apr.*	*Jun.*	*Sep.*
Dicliptera roxburghiana Nees	*Apr.*	*May*	*Jun.*	*Aug.*
Dodonaea viscosa L. Jack	*Mar.*	*Apr.*	*May*	*Jul.*
Dryopteris stewartii Fress	*Mar.*	*Apr.*	*May*	*Nov.*
Cyperus globosus Forssk.	*Apr.*	*May*	*Jul.*	*Sep.*
Elaeagnus parvifolia Wall. ex Royle	*Mar.*	*Apr.*	*May*	*Jul.*
Eragrostis japonica Thunb. Trin.		*Feb.*	*Apr.*	*Jul.*
Eriophorum comosum Wall	*May*	*Jul*	*Sep*	*Nov*
Euphorbia helioscopia L.	*Mar.*	*Apr.*	*May*	*Jul.*
Euphorbia prostrata Ait	*Throughout the year*	*Apr.*	*Jun.*	*Aug.*
Euphorbia wallichii HK..f	*Mar.*	*Apr.*	*May*	*Jul.*
Ficus palmata Forrsk	*Throughout the year*	*May*	*Jun.*	*Sep.*
Fragaria nubicola Landle ex Lacaita	*Mar.*	*Apr.*	*May*	*Jul.*
Galium elegan Wall.	*Apr.*	*May*	*Jun.*	*Aug.*
Geranium rotundifolium L.	*Mar.*	*Apr.*	*May*	*Jul.*
Gerbera gossypina Royle	*Mar.*	*Apr.*	*Jul.*	*Aug.*
Grewia villosa Willd	*Apr.*	*May*	*Jun.*	*Sep.*
Hedra nepalensis K. Koch	*Throughout the year*	*Apr.*	*May*	*Jul.*
Heteropogon contortus (L.)	*Apr.*	*May*	*Jul.*	*Oct.*
Hypericum perforatum L.	*Mar.*	*Apr.*	*May*	*Jul.*
Ipomea purpureaL.	*Mar.*	*Apr.*	*May*	*Jul.*
Impatiens edgeworthii H.K.f	*Apr.*	*May*	*Jun.*	*Aug.*
Indigofera heterantha Wall.	*Mar.*	*Apr.*	*May*	*Jul.*
Ipomea cordata	*Mar.*	*Apr.*	*May*	*Jul.*
Juncus serotinus Clarke	*Mar.*	*May*	*Aug.*	*Nov.*
Justicia procumbens L.	*Mar.*	*Aug.*	*Sep.*	*Oct.*
Lespedeza juncea (L.F) Pers	*Apr.*	*May*	*Jun.*	*Aug.*
Loranthus pulverulentus Wall. in Roxb	*Mar.*	*Apr.*	*May*	*Jul.*
Malvestrum coromendelianum L.	*Mar.*	*Apr.*	*May*	*Jul.*

Appendix 1 continues…….

Medicago denticulata Willd		*May*	*Jun.*	*Aug.*
Melilotous indicus L.	*Mar.*	*Apr.*	*May*	*Jul.*
Micromeria biflora (Ham) Bth	*Mar.*	*Apr.*	*Jun.*	*Aug.*
Myrsine africana L.	*Mar.*	*Apr.*	*May*	*Jul.*
Nerium indicum Mill	*Mar.*	*Apr.*	*May*	*Jul.*
Oenothera rosea (L). Her	*Mar.*	*Apr.*	*May*	*Jul.*
Olea ferruginea Royle	*Apr*	*May*	*Sep.*	*Oct.*
Origanum vulgare L.	*Apr.*	*May*	*Jun.*	*Aug.*
Otostegia limbata(Bth) Boiss	*Mar.*	*Apr.*	*May*	*Jul.*
Oxalis corniculata L.	*Mar.*	*Apr.*	*May*	*Jun.*
Rubia tinctorum L.	*Apr.*	*May*	*Jun.*	*Aug.*
Pinus roxburghii Sargent	*Mar.*	*Apr.*	*Jun.*	*Aug.*
Plectranthus rugosus Wall.	*Apr.*	*May*	*Jun.*	*Aug.*
Poa annua L.	*Apr.*	*May*	*Jul.*	*Oct.*
Prunella vulgaris L.	*Mar.*	*Apr.*	*May*	*Jul.*
Prunus persica (L))Batsch		*Apr.*	*Aug.*	*Oct.*
Pteris cretica L.	*Mar.*	*Apr.*	*May*	*Nov.*
Punica granatum L.	*Throughout the year*	*Apr.*	*May*	*Jul.*
Quercus dilatata Lind	*Apr.*	*May*	*Jun.*	*Aug.*
Rabdopsia rugosa (Wall. ex Benth.) H.Hara	*Apr.*	*May*	*Jun.*	*Aug.*
Ranunculus muricatus L.	*Mar.*	*Apr.*	*Aug.*	*Oct.*
Rhus cotinus L.	*Apr.*	*May*	*Jun.*	*Aug.*
Rhynchosia hirta (Andrews) Meikle & Verdc.	*Apr.*	*May*	*Jun.*	*Aug.*
Rubus fruticosus Wallich.	*Apr.*	*May*	*Jun.*	*Aug.*
Rubus niveus Wallich	*Apr.*	*May*	*Jun.*	*Aug.*
Rumex hastatus D.Don	*Mar.*	*Apr.*	*May.*	*Jul.*
Rumex nepalensis D.Don	*Mar.*	*Apr.*	*May*	*Jul.*
Saccharum spontaneum L.	*Apr.*	*May*	*Jul.*	*Sep.*
Trifolium repens L.	*Apr.*	*May*	*Jun.*	*Aug.*
Sarcococca saligna (D.Don) Muel	*Throughout the year*	*May*	*Jun.*	*Aug.*
Scutellaria linearis Benth	*Apr.*	*May*	*Jul.*	*Aug.*
Solanum nigrum L	*Throughout the year*	*May*	*Jun.*	*Aug.*
Solanum surattense Burm. f.	*Mar.*	*Apr.*	*Jul.*	*Oct.*

Appendix 1 continues…….

Sonchus arvense L.	*Mar.*	*Apr.*	*May*	*Jul.*
Sonchus asper Hill	*Mar.*	*Apr.*	*May*	*Jul.*
Sorghum halepense (L)Pers	*Mar.*	*Apr.*	*Jul.*	*Aug.*
Seteria viridis Var.	*Apr.*	*May*	*Jul.*	*Oct.*
Malva parviflora L.	*Apr.*	*May*	*Jun.*	*Aug.*
Taraxacum officinale Weber	*Mar.*	*Apr.*	*May*	*Jul.*
Themeda anathera (Hack)	*Apr.*	*May*	*Jul.*	*Oct.*
Tussilogo farfara L.	*Apr.*	*May*	*Jun.*	*Aug.*
Valeriana jatamansi Jones	*Mar.*	*Apr.*	*May*	*Jul.*
Viburnum grandiflorum Wallich ex DC	*Apr.*	*May*	*Jun.*	*Aug.*
Viola odorata L.	*Mar.*	*Apr.*	*May*	*Jul.*
Woodfordia floribunda Salisb	*Mar.*	*Apr.*	*May*	*Jul.*
Polygonum aviculare L.	*Apr.*	*May*	*Jun.*	*Aug.*
Zanthoxylum alatum Roxb	*Mar.*	*Apr.*	*May*	*Jul.*
Ziziphus jujuba Mill	*Apr.*	*May*	*Jun.*	*Aug.*

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