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Research Article

PHENOLOGICAL PATTERNS OF *Erythrina variegata* and *Erythrina subumbrans* IN TWO DISTINCT PRECIPITATION REGIME IN TROPICAL FORESTS OF MIZORAM, INDIA

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Abstract- Vegetative and reproductive phenological behaviour of *Erythrina variegata* and *E. subumbrans* were studied in two distinct precipitation regimes of tropical forest (Neihbawi and Sairang) of Mizoram, North East India. Phenological variables such as timing and date, onset, duration, synchrony and amplitude were recorded and derived by following standard methodology. Hypothesis related to phenological pattern of tropics were examined in current study. Leaf fall in is mainly coincided with dry season while leaf flush is overlapped with early rainy season in both the studied species. Flowering in *E. variegata* is occurred during end of dry season while in *E. subumbrans* it exhibited during peak rainy season. Fruiting in *E. variegata* is coincided with early to peak rainy season while in *E. subumbrans* it occurred during dry season and cool climatic conditions. This study supports differential flowering and fruiting timing among related genera, which might be important to avoid competition for pollinators and driving factor for high faunal diversity in tropics. Thus, this study is rigging the hypothesis that the evolutionary limitations are more reliant than the local environment and biotic conditions.

Keywords- Phenology, leaf flush, evolutionary limitations, taxa, reproductive success.

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Introduction

Phenology refers to the study of seasonal changes that is initiation of leaf, floral bud initiation; flowering period, fruit set phase, leaf colouration and leaf drop, during the year in perpetuation with the biotic and abiotic factors of the region or locality. The phenological observations of trees are the primary information required for improvement of knowledge of natural variation for the adjustment of plant species and its interactions at community level in any ecological region. Several factors plays important role to affect the phenological process in trees at community level, which are categorized as the contiguous or decisive causes. Contiguous causes mostly consist of diminutive environmental measures, which produce phenological model, while decisive causes contain the forces of evolutionary that are accountable for these prototypes. The contiguous causes, which activate the events of phenology in tropical trees are the changes in the level of water laid up by plants [1-5] seasonal variations in rainfall [6-8], changes in temperature [9 & 10], photo period [11-14], irradiance [15] and sporadic climatic events [16]. A striking dry season in the forest transforms water availability due to physiological phenomena sharply reduce moisture level of the soil are reported as the necessary contiguous or decisive causes disturbing phenological events [1 & 2].

The studies which have assessed the contiguous or decisive causes of the events of phenology in plants under various environmental or geographic conditions are meager and the majority of studies have evaluated the communities [17-19]. The highest leaf fall was accounted during dry period in wet (La Selva) and dry forests (Comelco) of Costa Rica [17]. Therefore, the events of phenology in tropical forests are poorly recognized [17, 20-27]. The existing information on phenology in tropical forest trees is insufficient, moderately due to short of consistent expressions, and mostly because of the studies done at community level patterns and for a small period [28].

In recent times, the scientists have given focus to distinguish the significance of common patterns at community level for the species consisting a particular forest types in reference to leafing, flowering and fruiting. Comparative studies of phenological events of a tree species growing over distinct geographic locations having variation in abiotic and biotic conditions facilitate the relative significance of the events of phenology following particular hypotheses. Such evaluations will establish that the variations in climatic situation between sites may cause variation in the events of phenology or are the reaction of biological factors that is availability of pollinators and their competition within sites. Bearing to the all above logics, the current study has been established the changes in the different events of phenology of two species of *Erythrina* (i.e., *E. subumbrans* and *E. variegata*) in two tropical forest sites with varying rainfall and temperature intensity.

Materials and Methods

Study sites: the present study was carried out in two tropical forests sites of the Aizawl district in Mizoram, which differ in precipitation regime and temperature. The first site was selected as Neihbawi, located in the Northern part of Aizawl, with an altitude of 1300 m asl [Fig-1]. The average annual rainfall during the past six years was 4198.5±211.87 mm, which ranged between 3571 in 2005 and 4859 mm in 2007 [29], and a dry season consisting between November and March. This site was referred as cooler site with heavier rainfall. The second site, i.e. Sairang is located in the Western part of Aizawl with 200 m altitude [Fig-1]. This site receives 2211.17±127.74 mm average annual rainfall for past six years, which oscillated between 1661 in 2008 and 2489 mm in 2007 [29]. The common tree

species at both the studied forest sites are deciduous, leaf shed and production of flowers occurs during the dry season. This site was referred as warmer site with less rainfall. Total rainfall during 2010 at Neihbawi was recorded 4404 mm and at Sairang it was 2679 mm. During 2011 total rainfall at Neihbawi was recorded 3684 mm while Sairang received 2137 mm rainfall [35], [Fig-2].

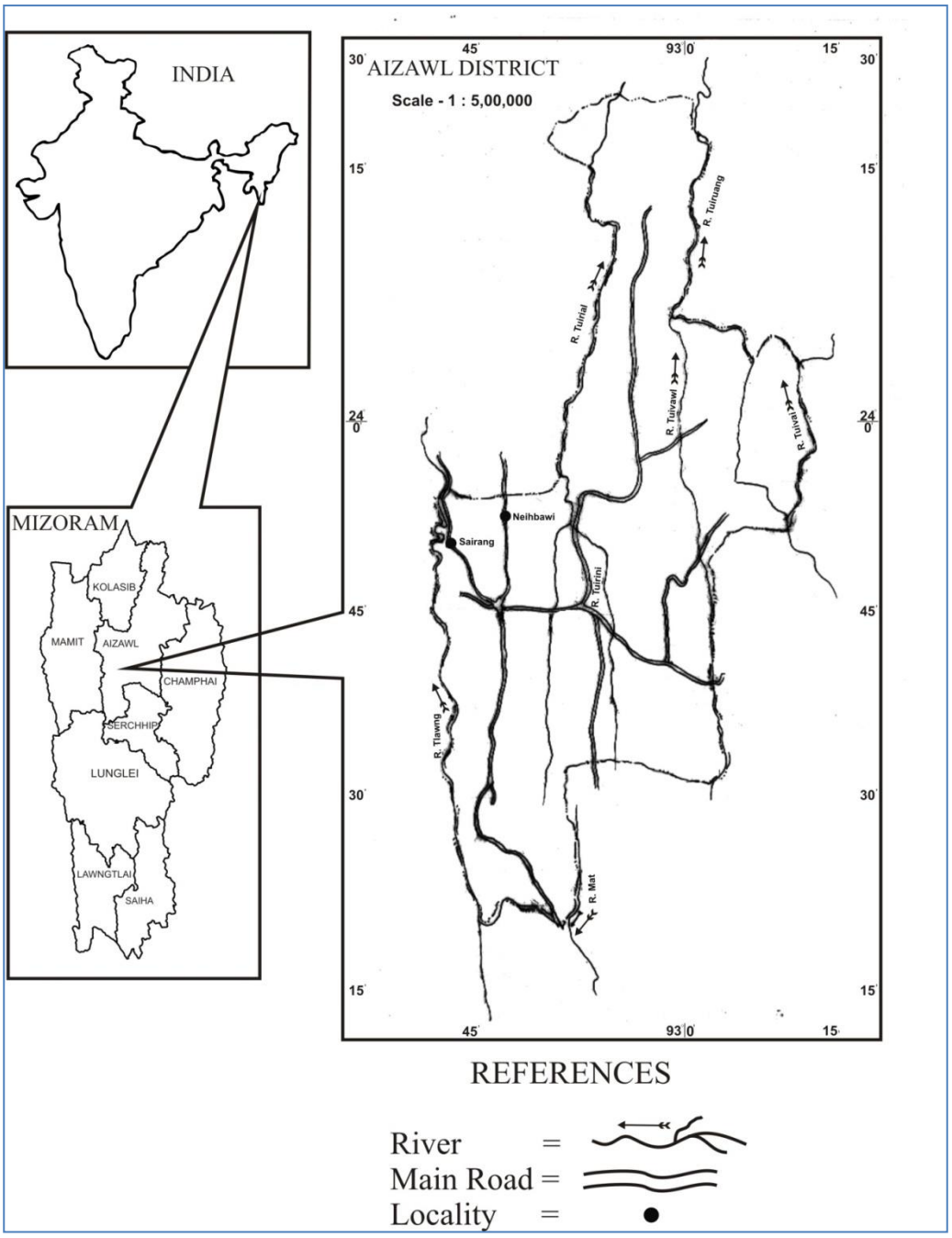

Fig-1 Location map of study sites

Study species

***Erythrina variegata* Linn. (Syn. *E. indica* Lam.):** *E. variegata,* commonly known as coral tree, is a charming deciduous tree with broad and spreading crown. The tree attains a height between 18 and 24 m and a crown spread of 6-12 m. An individual tree contains several solid branches, which produced sub-branches with black thorns resembled as tiger's claw. The long leaf stalks also contain curved spines (really more like prickles). *E. variegata* is a fast growing tree, which grows best in the region having prominent dry winter with frost free climates. The species is native to tropical Asia and has a very large natural distribution that is Taiwan, southern China, Philippines, Indonesia, Malaysia, Southeast Asia, India, and all the way to tropical east Africa.

***Erythrina subumbrans* (Hassk.) Merr. (Syn. *E. lithosperma* Miq.):** A deciduous, medium-sized tree, 5-25 m tall, trunk reaching 60 cm in diameter; crown spreading; bark whitish; trunk and branches armed with few prickles. It occurs at low and medium altitudes, in moist valleys, near streams, in open locations and secondary forest. Naturally, it is distributed from India and Sri Lanka, throughout South-East Asia (except New Guinea) to Fiji and Samoa. Bark and leaves are used medicinally. Bark decoction is used to cure spleen problem. Juice of leave is used as an eye-wash and the leaves decoction is specified for coughs. The wood is utilized in canoe and raft building [30].

Methods

The series of events of phenology were assessed in both trees species of *Erythrina* across the two study sites, marked individuals of both the species were observed for the different events of phenology at every two weeks intervals

annually. Twenty individuals of both species were marked by a metal tag on both sites. The phenological events were recorded as: (i) leaf emergence (ii) leaf maturation, (iii) leaf abscission (iv) flowering initiation (v) flower maturation (vi) flower abscission (vii) fruit setting (viii) fruit maturation and (ix) fruit abscission. Each phenological event was recorded for both species on each site by scoring dates of leaf, flower, and fruit production. The leaf flush and leaf fall dates (shedding of all leaves) have been recorded for all sampled individuals in a site. A fully leafed tree was considered between the dates of flower initiation and leaf fall. The dates of flushing of flowers, an thesis period and development of fruits were also recorded on the selected individuals. The flowering phenology was monitored weekly during flowering time. When the flower production exceeded 10% of total flower of an individual tree, the tree was monitored to be flowered. The period of flowering were categorized into (1) beginning of flower, when less than or equal to 50% of individuals in the population was bloomed (2) Peak flowering, when 51-100% of individuals in the population was blooming; and (3) end of flowering, when less than or equal to 50% of the individuals was blooming in the population. Similarly, fruiting phenology was recorded to the number of individuals selected in the population.

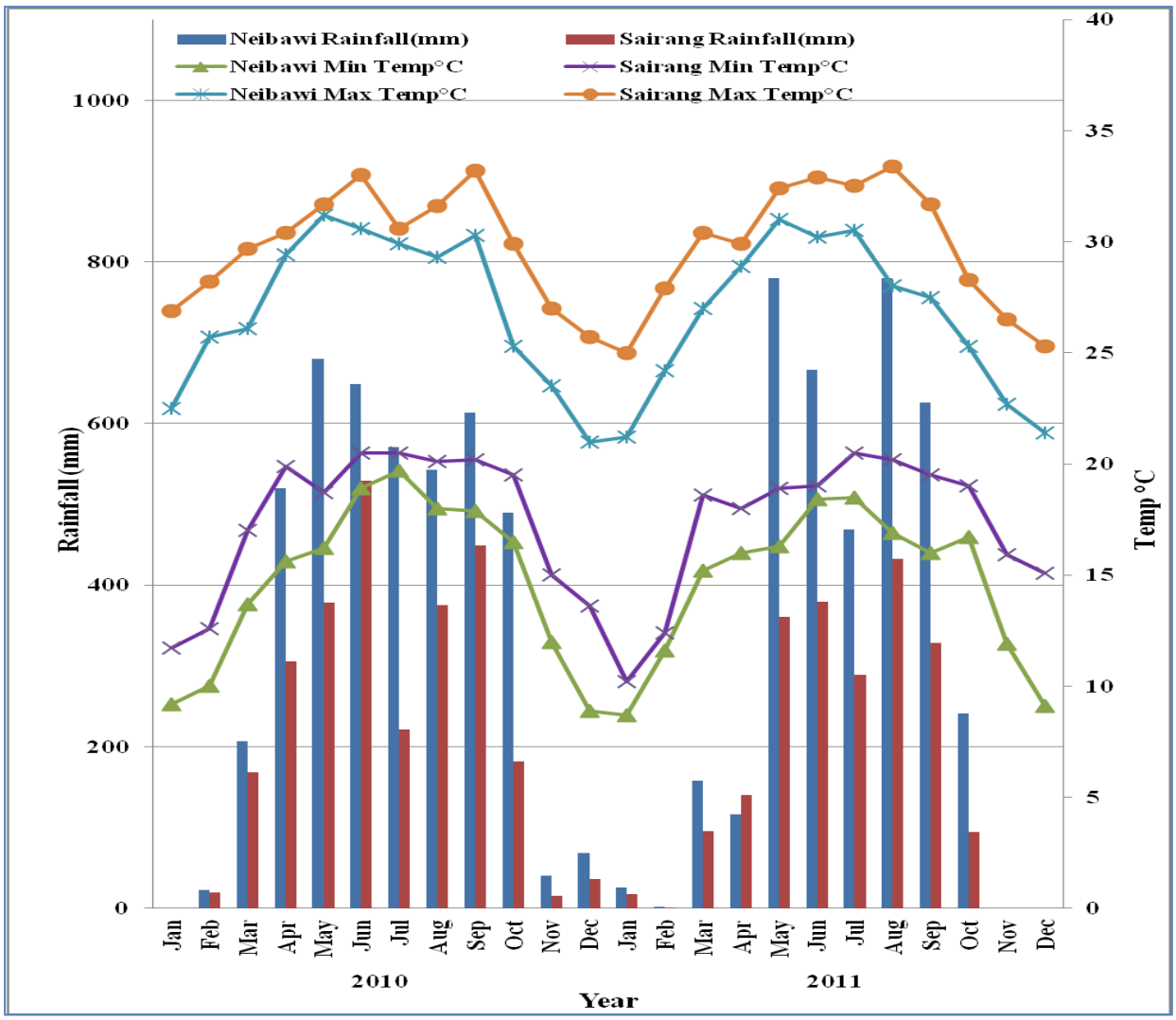

Fig-2 Mean monthly rainfall, minimum and maximum temperature distribution in study areas during study period 2010-11.

Five phenological parameters were derived from the flowering data: (i) onset (date of first flower in an thesis); (ii) duration (first and last flowering date); (iii) mean flowering date (flowering peak): the average of the dates of census in which that individual was flowering, with census of each date valued by the flowers number in that period [31]; (iv) amplitude of mean flowering (production of flowers number per unit time) [32]; and (v) synchrony (overlap of flowering among individuals in the population). All traits of flowering phenology except synchrony were estimated for individual plants as well as for the population as a whole. The synchrony of flowering within an individual tree was the degree to which period of blooming of the plant coincided the period of blooming of other all trees within the population. Synchrony was estimated as per the method used by Augspurger [33], modified by Primack [34].

Results

Leafing Phenology

Both tree species (*Erythrina variegata* and *E. subumbrans*) were observed to have peak leaf abscission during early dry season (December-January) in both sites. Leaf fall in cooler and heavy rainfall site, i.e. Neihbawi had average 16-18 days earlier leaf abscission as compared to warmer and less rainfall site, i.e. Sairang. Leaf emergence in both species coincided with early rainy season (April-May). Both species had earlier leaf flush with an average of 7-8 days in *E. variegata* and 10 days in *E. subumbrans* in Sairang compared to Neihbawi. Maturation of leaves in both studied species was reached during peak rainy season (last May-first week of June) in both forest sites [Table-1].

Flowering Phenology

Erythrina variegata exhibited peak flowering during very early rainy season (i.e. mid February to mid March) while *E. subumbrans* flowered during late rainy season (i.e. mid August to mid September). Both studied species produced young flower (onset) earlier during studied period (2010-11) in warmer and low rainfall

site i.e. Sairang as compared to cooler and heavy rainfall site i.e. Neihbawi. In case of *Erythrina variegata* it was 9 days early while in *Erythrina subumbrans* it was 7-10 days before at individual and population level in Sairang with very less inter annual variability. The flowering duration varied from 13-18 at individual level and 27-29 days at population level for *E. variegata* in both studied sites. In *Erythrina subumbrans* flowering duration varied from 16-22 days at individual level and 32-36 days at population level at both sites. Relatively narrow variation between the sites in flower duration was observed. It was of an average of 4-5 days in *E. variegata* and 5 days in *Erythrina subumbrans* at individual level at Sairang as compared to Neihbawi site. Mean synchrony was varied from 0.40 to 0.51 for *E. variegata* and *E. subumbrans*. Flowering amplitude was varied from 0.62 to 0.72 for both species during study period. Flowering phenophase was moderately synchronized within a population and was simultaneous within the individual [Table-1-3] in both the studied species.

Table-1 *Average scoring dates of phenological events from both forest study sites*

Phenophase	2010				2011			
	E. Variegata		*E. Subumbrans*		*E. Variegata*		*E. Subumbrans*	
	Neihbawi	Sairang	Neihbawi	Sairang	Neihbawi	Sairang	Neihbawi	Sairang
Leaf Emergence	28-Apr	20-Apr	2-May	22-Apr	29-Apr	22-Apr	3-May	23-Apr
Maturation of leaves	8-Jun	26-May	10-Jun	27-May	8-Jun	27-May	7-Jun	27-May
Abscission of leaves	5-Dec	22-Dec	6-Dec	23-Dec	7-Dec	24-Dec	8-Dec	24-Dec
Flowering initiation	18-Feb	8-Feb	20-Aug	9-Aug	19-Feb	8-Feb	21-Aug	9-Aug
Maturation of flower	8-Mar	26-Feb	10-Sep	29-Aug	10-Mar	26-Feb	12-Sep	29-Aug
Abscission of flower	16-Mar	5-Mar	24-Sep	14-Sep	17-Mar	7-Mar	25-Sep	12-Sep
Fruit setting	21-March	12-Mar	6-Oct	28-Sep	26-Mar	14-Mar	9-Oct	25-Sep
Maturation of fruit	2-May	28-Apr	6-Jan	2-Jan	4-May	30-Apr	8-Jan	2-Jan
Abscission of fruit	4-Jun	30-May	14-Feb	10-Feb	6-Jun	1-Jun	17-Feb	12-Feb

Table-2 *Plant and population levels data of flowering phenology in the year 2010 (Values are mean ± SE).*

Observed Variables	*E. Variegata*		*E. Subumbrans*	
	Neihbawi	Sairang	Neihbawi	Sairang
Onset (Mean plant values)	21-Feb	15-Feb	25-Aug	15-Aug
Onset (Population)	16-Feb	11-Feb	20-Aug	9-Aug
Duration (Plants)	18 ± 1	13 ± 1	22 ± 1	17 ± 2
Duration (Population)	29	27	36	33
Mean date (Plants)	1-Mar	22-Feb	5-Sep	23-Aug
Mean date (Population)	2-Mar	24-Feb	7-Sep	25-Aug
Synchrony (Plant)	0.406 ± 0.018	0.512 ± 0.030	0.405 ± 0.018	0.505 ± 0.039
Amplitude (Fls/Plant/day)	0.624 ± 0.098	0.704 ± 0.085	0.638 ± 0.093	0.720 ± 0.087

Table-3 *Plant and population levels data of flowering phenology in the year 2011 (Values are mean ± SE).*

Observed Variables	*E. Variegata*		*E. Subumbrans*	
	Neihbawi	Sairang	Neihbawi	Sairang
Onset (Mean plant values)	23-Feb	15-Feb	25-Aug	18-Aug
Onset (Population)	18-Feb	9-Feb	19-Aug	9-Aug
Duration (Plants)	18 ± 1	14 ± 1	21 ± 1	16 ± 1
Duration (Population)	28	27	35	32
Mean date (Plants)	3-Mar	22-Feb	5-Sep	26-Aug
Mean date (Population)	4-Mar	22-Feb	5-Sep	25-Aug
Synchrony (Plant)	0.41 ± 0.019	0.506 ± 0.034	0.42 ± 0.017	0.511 ± 0.035
Amplitude (Fls/Plant/day)	0.632 ± 0.095	0.698 ± 0.085	0.629 ± 0.094	0.708 ± 0.083

Fruiting Phenology

Fruiting pattern of both studied species was varied significantly with season and time. *Erythrina variegata* starts fruiting, i.e. production of fruit after a week of abscission of flower and continued for 2 months. Fruiting phase in *Erythrina variegata* coincided with early to peak rainy season (April-June). While *E. subumbrans* started fruit set 2 weeks after abscission of flower. On an average, fruiting was 8-10 days early in *Erythrina variegata* while it was 4 days before in *E. subumbrans* at Sairang as compared to Neihbawi. Fruiting phase in *Erythrina subumbrans* coincided with dry season when there was no rainfall and low temperature (December-February). Time required for maturation of fruits in *Erythrina variegata* and *E. subumbrans* varied from an average of 35-51 days during study period with little interannual variability [Table-1].

Discussion and Conclusion

Major peak of leaf fall during dry and low temperature in December and January in both species of *Erythrina* reflected the importance of rainfall, soil moisture and temperature as a proximate environmental factors regulating leaf phenology. There are studies which reflect that the beginning of winter season initiate leaf fall in the tropics [36, 37]. In dry deciduous forests, flowering and fruiting pattern are mostly influenced by soil moisture and rainfall pattern [38]. The leafless phase during dry season facilitates rehydration of the stem and twigs, which is considered as the pre-requisite for the successive flowering or leaf flushing and mechanism of maintaining shoot turgidity [39,24]. Leaf abscission in high altitude site i.e. Neihbawi was earlier than low altitude sites, this may be due to high sloping topography at Neihbawi which is prone to erosion and draining of soil water due to slope, leading to low soil moisture condition and stress stimulated by water scarcity. This may influenced the phenological attributes of tree species at both sites [40]. In tropical dry forest of South India, Murali and Sukumar [19] revealed that the variation in annual rainfall affected phenological pattern and are dependent upon the local precipitation regime of the area. Leaf flushing in both species of *Erythrina* is mainly coincided with early rainy season and end dry season, might be due to pre rain flash and increasing temperature, respectively. Similar pattern was reported from other seasonal tropical forests [17, 41-44]. Peak fruiting of *Erythrina variegata* occurred during rainy season, thus it needs high moisture level for proper fruit development compared to *E. subumbrans* in which maturation of fruits takes place during dry season. Even many of tropical fleshy fruits formed during wet season [44]. This also supports differential fruiting in tropics due to high faunal diversity.

It is very vital to study phenological behaviour of plant species in geographical and climatic conditions to explore ecological and evolutionary adaptation [44]. In global climate regime such study shall be valuable to know how plant species are going to be affected through climatic changes. Two different species of *Erythrina* distinctly varied in the flowering and fruiting phenological clock reflected the role of evolutionary limitations as an ultimate cause of phenological behaviour. Several

studies in topics have reported that flowering phenology within the evolutionary pedigrees is a conservative trait [45-47]. Both species of *Erythrina* are mainly pollinated by bird of same guilds, henceforth the competition for pollinators might be avoided by the reasons functioning on the time and duration of flowering, which is also reported by several authors from other bio-geographic regions of world [48-53, 43, & 16]. As individuals of same genus, both *Erythrina variegata* and *Erythrina subumbrans* flowered almost same duration of period with very little intra and inter annual variability despite distinct geographical and precipitation regime (i.e. Neihbawi and Sairang). Thus, this study is rigging the hypothesis that the evolutionary limitations are more reliant than the local environment and biotic conditions. Thus, the results of the study sustains hypothesis of evolutionary limitations which are highly contingent than the biotic and abiotic factors of locality, and the species of same genus have comparable patterns of phenology in spite of geographical location [45 & 47].

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Conflict of Interest: None declared

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