Certain phenological characters of the shrub layer of Kumaun Himalayan forests*

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Abstract

The phenology of 49 shrub species in five forest types occurring along an altitudinal gradient (350–2150 m) in Kumaun Himalaya has been studied. The evergreen leaf-exchanging taxa accounted for nearly half of the species, the remaining half was nearly equally divided between an evergreen continual leaf drop type and deciduous taxa. The percentage of species with lengthy leaf drop increased with elevation and finally leveled off. At each site the maximum leaf drop period coincided with the warm dry period. Percentage of species with multiple leaf flushing was low for all forests. The degree of extended leafing decreased with increasing elevation along which summer dryness also decreased. Earliest leaf initiation was observed for evergreen continual leaf drop species, followed by evergreen leaf-exchanging, and deciduous types.

For each forest, two peaks of flowering activity occurred, one during the warm dry period and the other in the warm wet period. The percentage of species with multiple flowering increased with increasing elevation. Nearly half of the species bore fleshy fruits. The mature fruit retention period for different forests ranged from about 2–3 months.

The proportion of deciduous species was similar in trees and shrubs; leaf drop was common during the summer season for trees, while it was common during the winter season for shrubs; the proportion of species with multiple leafings was greater and leaf initiation earlier in shrubs than trees; and generally shrubs showed two flowering peaks and trees only one.

Introduction

Periodicity, phenology, and other functional characters were used for describing and classifying vegetation as early as the beginning of this century (Warming, 1909). Periodic vegetation characteristics have been used in life-form systems; e.g. evergreen, rain green or summer green. However, the phenological periodicity of flowering and fruiting has generally been examined separately and presented as a specific study for a particular vegetation type (Shimwell, 1972). Loveless & Asprey (1957) analyzed certain tropical forests on the basis of a number of structural and functional features such as seasonality of flowering, pollination mechanism, evergreenness or deciduousness, etc., and emphasized the relevance of such features in characterizing the vegetation of even smaller areas.

Opler *et al.* (1980) used certain phenological characters, such as, leaf drop, leaf flushing, flowering and fruit development for characterizing the tropical forest communities of Costa Rica. Progress made in the field of phenology is encouraging (c.f. Frankie *et al.*, 1974; Beatley, 1974; Lieth, 1974;

* Nomenclature follows Osmaston (1926).

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Murray & Miller, 1982), but little information on Indian vegetation is available. Recently, Shukla & Ramakrishnan (1982) collected information on periodicities of different phenophases of subtropical humid forests in north-eastern India.

We studied tree phenology in several forests lying within 350–2150 m elevation in Kumaun Himalaya (Ralhan *et al.*, 1985) and here we report on the phenology of the shrub component of the same forests.

Study sites and climate

Five forest stands representing the major Kumaun Himalayan forest types, lying between 29° 8′ – 29° 38′ N and 79° 27′ – 79° 43′ E were studied. Important features of the sites are summarized in Table 1, and described in greater detail in Ralhan *et al.* (1985).

The basic climatic pattern is determined by the monsoonal rhythm, the year roughly being divisible into three principal seasons: (1) cool and relatively dry (mid-December to mid-February); (2) warm and dry (April to mid-June); and a (3) warm and wet (mid-June to mid-September). The climate ranges from subtropical monsoon to temperate monsoon. The sal (*Shorea robusta*) forest lies in the monsoon subtropical climate characterized by hot summer and cool winter. The two oak (*Quercus* spp.) dominated forests lie in the monsoon temperate climate, characterized by a warm summer and a cold winter. The pine (*Pinus roxburghii*) and the pine-mixed broadleaf forests, lie between the two climatic extremes (details in Ralhan *et al.*, 1985).

Incidence of burning has been high in the pine forests, intermediate in the sal forest and in forests where other species share substantial importance with pine, and negligible in mixed oak forests (Singh & Singh, 1984). While sal and oak forests form close canopies (with crown density $> 80\%$), pine, and pine-mixed broadleaf forests have relatively open canopies (with crown density $< 60\%$) (Tewari & Singh, 1983). The shrub density is highest in the forests in which oaks are the main constituents, followed by sal and is lowest in the pine forest.

Methods

Detailed phenological records for each species were made from January 1981 to December 1983, at 4 to 5-day intervals during the high activity period of the summer season and 3 to 4-week intervals during the rest of the year. At each forest site a permanent plot of one ha was established. The plot location was selected to be representative of the most typical conditions of each forest type and was protected from biotic disturbances. A total of 49 species were studied. Twenty individuals of each species were selected randomly and marked within the permanent plots for continuous phenological observations. Observations on larger populations in other similar stands were also made to supplement the information from the permanent plots.

The average leaf initiation period for a group of species (such as deciduous, evergreen, etc.) was calculated by summing up the serial number of the month of the year during which leafing was initiated in the species of that group divided by number of species.

Table 1. Site characteristics of different forests (details in Ralhan *et al.*, 1985).

Site	Altitude (m)	Annual Rainfall (mm)	Mean Annual Temperature (°C)	Forest type	Shrubs species richness	Dominant Shrubs
Chorgalia	350	2076	23.0	Sal	6	*Murraya peniculata, Clerodendron infortunatum*
Kalona	1350	2005	17.5	Pine-mixed broadleaf	21	*Myrsine semiserrata, Glochidion velutinum*
Baldiakhan	1750	2185	15.8	Pine	11	*Glochidion velutinum, Daphne cannabina*
Ranikhet	1850	1313	15.8	Mixed oak-pine	15	*Myrsine africana, Berberis asiatica*
Kilbury	2150	2488	15.0	Mixed oak-rianj	17	*Viburnum cotinifolium, Wickstroemia canescens*

Results

The species and events were categorized following Ralhan *et al.* (1985) (full data available on request).

Leaf drop

Shrubs were divisible into three categories: (i) Deciduous type – most of the leaf drop is confined to a particular season rendering the plants leafless for some time; the longevity of leaves is less than one year. (ii) Evergreen leaf-exchanging type – most of the leaf drop occurring in a particular season but because of simultaneous leafing plants are never entirely leafless; however, the amount of foliage becomes conspicuously thin during this leaf drop period; the longevity of leaves is generally of about one year. (iii) Evergreen continual leaf drop type – the leaf drop occurs the year-round but leafing is seasonal; consequently no marked thinning of the foliage occurs at any time; the longevity of leaves is generally more than one year.

Overall, the proportion of evergreen leaf-exchanging taxa was highest (Table 2), accounting for nearly half of the total species studied. The rest of the species were nearly equally divided between the evergreen continual leaf drop type and the deciduous type. The proportion of deciduous taxa tended to be slightly higher in the three forests of lower elevations (viz., sal, pine-mixed broadleaf, and pine forests) than in the remaining two forests of relatively higher elevations (viz., mixed oak-pine and mixed oak forests). The proportion of evergreen continual leaf drop type was less than 25% in all forests with the exception of the mixed oak-pine forest where 40% of the shrub species were of this type. In the sal forest none of the species showed this type of evergreenness.

Lengthy leaf drop was shown by nearly 75% of the species and was a prevalent feature in all except for the sal forest where shrubs were equally divided between lengthy and rapid leaf drop types.

In the sal forest, the species-peak for leaf drop was noted in April (a warm and dry month) (Fig. 1). In pine-mixed broadleaf forest and pine forest leaf drop was prevalent during the cool and dry period while in mixed oak-pine forest and mixed oak forests although the species-peak was not marked, more species exhibited leaf shedding during the cold and dry period than during other periods. Some evergreen leaf-exchanging type species of relatively high elevations (5 of the 17 species of mixed oak forest and 3 of the 15 species of mixed oak-pine forest) shed their leaves during the rainy season, by which time they had already produced all or a considerable part of new leaves. In the entire region, *Rhus semialata* (occurring in pine and mixed oak-pine forests) was the only species which became leafless during the rainy season.

Leaf flushing

In more than 80% of the species, in all forests except for sal and mixed oak forests, leaf initiation occurred during late winter through spring (Janua-

Table 2. a. Number of deciduous, evergreen leaf-exchanging type and evergreen continual leafdrop type in different forest communities showing different types of leafdrop behaviour (percentage of total species in respective forest types, in parentheses); r = rapid leafdrop, l = lengthy leafdrop. b. Number of species in different forest communities showing different types of leafing behaviour (percentage of total species in respective forest types, in parentheses); e = extended leaf flush, b = brief leaf flush.

Forest type	Deciduous		Evergreen leaf-exchanging type		Evergreen continual leafdrop type		Single leaf flush		Multiple leaf flush	
	r	l	r	l	r	l	e	b	e	b
Sal	2 (34)	0 (0)	1 (17)	3 (50)	0 (0)	0 (0)	2 (33)	3 (50)	1 (17)	0 (0)
Pine-mixed broadleaf	4 (19)	2 (10)	2 (10)	8 (38)	0 (0)	5 (24)	8 (38)	10 (48)	0 (0)	3 (14)
Pine	1 (9)	3 (27)	0 (0)	4 (36)	0 (0)	3 (27)	3 (27)	6 (55)	1 (9)	1 (9)
Mixed oak-pine	2 (13)	1 (7)	0 (0)	6 (40)	0 (0)	6 (40)	4 (27)	7 (47)	1 (7)	3 (20)
Mixed oak	3 (18)	1 (6)	0 (0)	10 (59)	0 (0)	3 (18)	4 (24)	11 (65)	1 (6)	1 (6)
Region	9 (18.4)	4 (8.2)	3 (6.1)	23 (46.9)	0 (0)	10 (20.4)	13 (26.5)	29 (59.2)	2 (4.1)	5 (10.2)

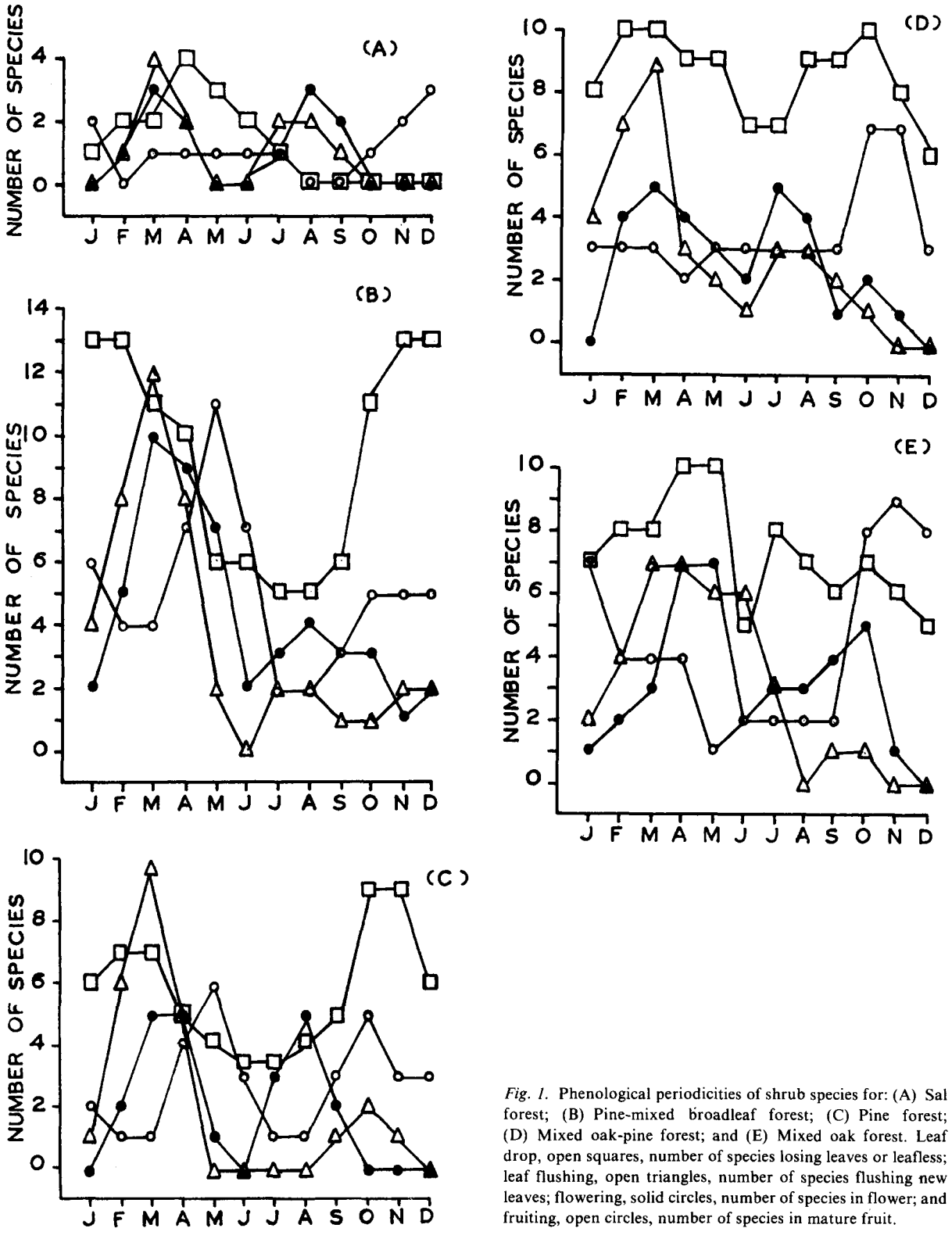

Fig. 1. Phenological periodicities of shrub species for: (A) Sal forest; (B) Pine-mixed broadleaf forest; (C) Pine forest; (D) Mixed oak-pine forest; and (E) Mixed oak forest. Leaf drop, open squares, number of species losing leaves or leafless; leaf flushing, open triangles, number of species flushing new leaves; flowering, solid circles, number of species in flower; and fruiting, open circles, number of species in mature fruit.

ry–March; Fig. 1). In sal forest, leaf initiation was clearly separated in time so that the species can be classified in two groups. Two-thirds of the species present had leaf flush during the late winter-spring period. In the other species this occurred during the rainy season. In the mixed oak forest nearly half of the species showed leaf initiation during the late winter-spring period and one-third during the summer season. No species, in the entire region, exhibited major leaf initiation during the autumn, but some of the species showed multiple leaf flushing with the second and smaller flush during this season. The average leaf initiation period across all evergreen continual leaf drop type shrubs was 1.44, that is nearly mid-February. The same was month 3 (end March) for evergreen leaf-exchanging type shrubs and month 3.4 (mid-April) for deciduous species. Only 7 of the 49 species were of the multiple leafing type and their number varied from one to four in individual forests. The proportion of shrubs with brief leafing increased with increasing elevation (Table 2). In the sal forest, shrubs were equally divided between brief and extended leafing types, while in mixed oak forests 71% of species were brief leafing types.

In nearly half of the leaf-exchanging type of species the leafing preceded leaf drop may have been induced their behaviour (Ralhan *et al.*, 1985), while in the other half of the species leaf drop was initiated earlier than the leafing.

Flowering

Generally two distinct flowering peaks were observed in each forest. The first was in the warm dry period and the second in the rainy season (Fig. 1). However, in the mixed-oak forests the second flowering peak occurred in autumn (October) instead of in the rainy season. Only five species showed multiple flowering, of which two, viz., *Myrsine semiserrata* and *Sarcococca saliqua,* flowered during both the dry periods (i.e., dry cold and dry warm) and three, viz., *Desmodium sambuensa, Myrsine africana,* and *Indigofera heterantha,* flowered once during one of the dry seasons and again during the wet season. Nearly two-third of the species in the sal forest showed brief flowering. In the rest of the forests species were roughly equally divided between brief and extended flowering types (Table 3).

Fruiting

On the average, the retention period of mature fruits in shrub species for different forests ranged from 2.2–3.1 months, the minimum for the sal forest and the maximum for the mixed oak forest (for a forest this average was calculated by summing the fruit retention period of all species divided by the number of species). In the mixed-oak forest the proportion of the species with lengthy mature-fruit retention was greater, while in the sal forest it was greater for rapid fruit retention (Table 3).

Osyris arborea (in pine-mixed broadleaf forest) was the only species with mature fruits throughout the year. As many as 11 of 49 species (including all four species of the leguminous genus Desomodium) retained mature fruits for as long as 4–7 months. None of these occurred in the sal forest, while other forests had 4–5 of these species.

The species-peak for mature fruit retention oc-

Table 3. a. Number of species in different forest communities showing different types of flowering behaviour (percentage of total species in respective forest type, in parentheses); e = extended flowering, b = brief flowering. b. Number of species in different forest communities showing different types of fruiting behaviour (percentage of total species in respective forest types, in parentheses); B = brief mature fruit retention period, L = lengthy mature fruit retention period.

Forest type	Single		Multiple		Fleshy fruit		Non-fleshy fruit	
	e	b	e	b	B	L	B	L
Sal	2 (33)	4 (67)	0 (0)	0 (0)	2 (33)	0 (0)	3 (50)	1 (17)
Pine-mixed broadleaf	9 (43)	10 (48)	1 (5)	1 (5)	7 (33)	1 (5)	9 (43)	4 (19)
Pine	5 (45)	5 (45)	1 (10)	0 (0)	3 (27)	1 (9)	3 (27)	4 (36)
Mixed oak-pine	7 (47)	6 (40)	0 (0)	2 (13)	10 (67)	2 (13)	1 (7)	2 (13)
Mixed oak	9 (53)	5 (29)	1 (6)	2 (12)	6 (35)	2 (12)	3 (18)	6 (35)
Region	21 (42.9)	23 (46.9)	2 (4.1)	3 (6.1)	20 (40.8)	4 (8.2)	14 (28.6)	11 (22.4)

curred either during the cold and dry period or during the warm and dry period (Fig. 1). In the two higher elevational forests a single species-peak during cold and dry period was evident. In mid-elevational pine forest two peaks of similar size were distinguishable; and in the forests of lower elevations one major species-peak and a second minor species-peak were observed.

Discussion

All forests in the study area have similar day length and annual rainfall regimes. The warm and wet period from mid-June to mid-September receives nearly 75% of the rainfall. The warm season is slightly drier in the lower elevation forests compared to those of high elevations. This is mainly because of elevation-related temperature differences (Ralhan *et al.*, 1985).

The two types of evergreen species account for at least about two-third of the total number of species in each forest. This proportion was comparatively higher in forests having oaks as major constituents and growing at a relatively high elevation. Regarding leaf drop periodicity, the sal forest, which occurred at the lowest elevation, was different from the rest of the forests with a prevalent summer leaf drop. The marked summer dryness in the sal forest might promote mass-scale leaf drop. In the remaining forests, all at higher elevations, summer was moister and leaf drop was promoted perhaps by the low temperatures of the winter season, together with unfavourable soil moisture conditions.

The shrubs of different forests generally fall within three broad categories with regard to the seasonality of leaf initiation: 1. late winter-spring season, 2. summer season, and 3. rainy season. In forests other than sal and mixed oak forests more than 80% of the species were of the winter-spring type, while in the mixed oak forests half of the species were late winter-spring type, one-third of summer type and the remaining of the rainy type.

The shrub species of any given type can be regarded as members of particular guild, possibly sharing common niche characters related to the temporal pattern of growth. For example, in the sal forest we have a group of the two species which show initiation of leafing during the rainy season. In the remaining four species which are of the evergreen leaf-exchanging type, leafing is initiated during late winter-spring. Singh *et al.* (1983) separated winter and summer season species in a mixed grass prairie, considering them as members of different guilds.

Species in most forests exhibit a large variation in time-separation between leaf drop and leafing. On the whole leafing began earlier in evergreen continual leaf drop type species, followed by evergreen leaf-exchanging type and deciduous type. Possibly the evergreen continual leaf drop type species require relatively lower temperatures for leaf initiation, and have a relatively greater ability to maintain photosynthetic activity during the season. There is some relationship between the time of initiation of leaves and the position of species along the deciduousness-evergreenness gradient.

A comparison of shrub phenology with that of tree phenology would aid in our understanding of the overall phenology of the forest communities. A principal difference in the environment of trees as compared with that of shrubs is the higher level of light available (Opler *et al.*, 1980).

If all the species of the region are taken into account similar proportions of deciduous species are found for shrubs and trees (27 and 33%, resp.). However, proportions differed from forest to forest. In the three lower elevation forests the part of deciduous species was greater for trees and in the three upper elevation forests, a very low proportion or none of the trees was deciduous, whereas 20–27% of the shrubs are. Further, the proportion of lengthy leaf drop was also very similar for the two growth forms.

Multiple leafing, which is common among trees (38.9%) is rare among shrubs (14.3%). Possibly shrubs could hardly afford the luxury of multiple leafing in the shaded environment given their comparatively lower photosynthate reserves.

In trees of the sal forest fruit maturation and fruit fall coincided with the beginning of the rainy season. Such a synchronization was not found for shrubs (Fig. 1A), in which fruit maturation and seed germination (Rao *et al.*, 1984) started in winter. This time-separation would reduce the initial competitive interactions between their seedlings. Evidently, the time-separation between the two growth-forms relates to the fact that the shrubs occupying the forest communities are adapted to relatively unfavourable growth conditions. But,

compared to shrubs, trees would have to devote more energy to develop chemical protection against insects whose populations are larger in summer than in winter (Singh & Singh, 1984).

Differences between shrubs and trees for many phenological activities were also found in other forests (Fig. 1B–E). As to flowering, an early summer peak was found for trees as well as for shrubs, however, for shrubs an additional peak was also found during the rainy season. As to mature fruit retention: while trees showed two peaks, one in summer and the other at the end of the rainy season, the shrubs showed a single peak at the end of the autumn season.

Evidently the two woody growth-forms often show a differential response to the climatic rhythm, complementing each other in an attempt to retain green foliage and mature fruits in the system across the year.

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