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The leaf phenology of woody plants in the gallery forests (central Black Sea region, Turkey)

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We study the interactions between leaf emergence and leaf survival in four deciduous woody species of a *Platanus orientalis* gallery forest occurring in the central Black Sea region. We found *Rubus discolor* to be a flush leaf emergence type species. However, *P. orientalis*, *Robinia pseudoacacia* and *Salix alba* are intermediate leaf emergence type. Leaf durations of all species in the study area usually varied between 210–254 days. The species that have more bud scales show a tendency toward the shortening of leaf emergence duration. The peak of leaf fall was observed between November and December. Leaf fall was strongly seasonal and statistically significant differences were observed among months, species and localities in terms of leaf number.

Key words: Gallery, forest, phenology, leaf, bud, *Platanus orientalis*, *Salix alba*, *Robinia pseudoacacia*, *Rubus discolour*, Turkey

Introduction

The study of periodically occurring natural phenomena (phenology) and their relation to climate is a central focus of several aspects of ecology (WIEDER et al. 1984). Seasonal timing events can be critical for survival and reproduction. Phenology of different populations of the same species is determined by environmental parameters and allows for genetic exchange (RATCHKE and LACEY 1985). Phenological observations also provide a background to functional rhythms of plant communities (RAWAL et al. 1991).

Phenological properties of deciduous forest species seems to be very simple at first glance; almost simultaneous budbreak in spring and also simultaneous leaf fall in autumn (KIKUZAWA 1983). However, deciduous tree species are different from each other with respect to leaf emergence and leaf fall type as suggested by KIKUZAWA (1983). In recent years phenological studies related to leaf emergence types and shedding and leaf life-span of canopy trees of understory plants have increased (CHABOT and HICKS 1982; RALHAN et al. 1985; RATCHKE 1988; UEMURA 1994a, b; GONZALES et al. 1996).

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Considering the relationships between the accumulation of forcing temperatures and the timing of spring phenological events, it is possible to say that in spring the valleys are possibly warmer and spring phenological events appear to be more advanced in valleys than in the adjacent landscape. The timing of spring phenological events in plants from temperate regions is dependent on the breaking of the winter dormancy which includes two periods of rest and quiescence. During the rest period, buds remain dormant due to intrinsic growth-arresting physiological conditions. After plants are exposed to chilling temperatures for some time, these conditions cease, and a period of quiescence starts, during which the buds do not grow, due to unfavourable environmental conditions. Bud burst and leaf unfolding occur following the accumulation of a sum of forcing temperatures. The processes involved, as well as threshold temperatures for chilling and forcing in individual species, are insufficiently known, and several models describing possible relationships between chilling and forcing have been proposed (Milan and Tichy 1998).

Gallery forests are forest formations which occur along stream margins with the canopy of trees from both margins touching each other, thus forming a gallery. They fulfil a variety of important functions. Because of their microclimate and water holding capacity they are important refuge areas, food and water resources for the local fauna. Gallery forests occur in deep valleys, with the rivers running over rocks, others develop in concave valleys with low slopes with the streams running over sand banks (Scheuber et al. 1997, Schiavini 1997).

The objective of this study is to examine the leaf emergence types, bud structures and duration of leaf emergence of three tree and one shrubby species occurring in a *Platanus orientalis* gallery forest (*Platanus orientalis* L., Platanaceae; *Salix alba* L., Salicaceae; *Robinia pseudoacacia* L., Fabaceae; *Rubus discolor* Weithe et Nees, Rosaceae). Plant phenological studies are fundamental to the understanding of the forest as a resource base for other dependent populations or communities (Sundarapandian et al. 2005).

The study area

This study has been carried out at Kurupelit, Adalar, Derebahçe and Taflan Regions (Samsun) along river valleys. The study area is characterized by V-shaped river valleys and located in the central Black Sea region, in the north of Turkey (Fig. 1).

The area has a Mediterranean climate. The mean annual precipitation varies from 664.2 to 722.08 mm and the mean temperature varies from 10.5 to 14.3 °C, the highest temperature occurring in July (24.9 °C), the lowest in January (6.8 °C), the highest precipitation occurring in November (79.49 mm), the lowest in July (33.88 mm) (Quézel et al. 1980, Kutbay and Kılınç 1995).

Alluvial and colluvial soils are widespread in the study area and they are composed of an A and a C horizon. The geological structure is represented by Neogene series. Alluvial series also occur as a derivative of the Quaternary (Kutbay and Kılınç 1995).

Materials and methods

Three to six squares of 400 m each were chosen from homogeneous vegetation and observed weekly between April 2000 and December 2000. Lower branches of the studied

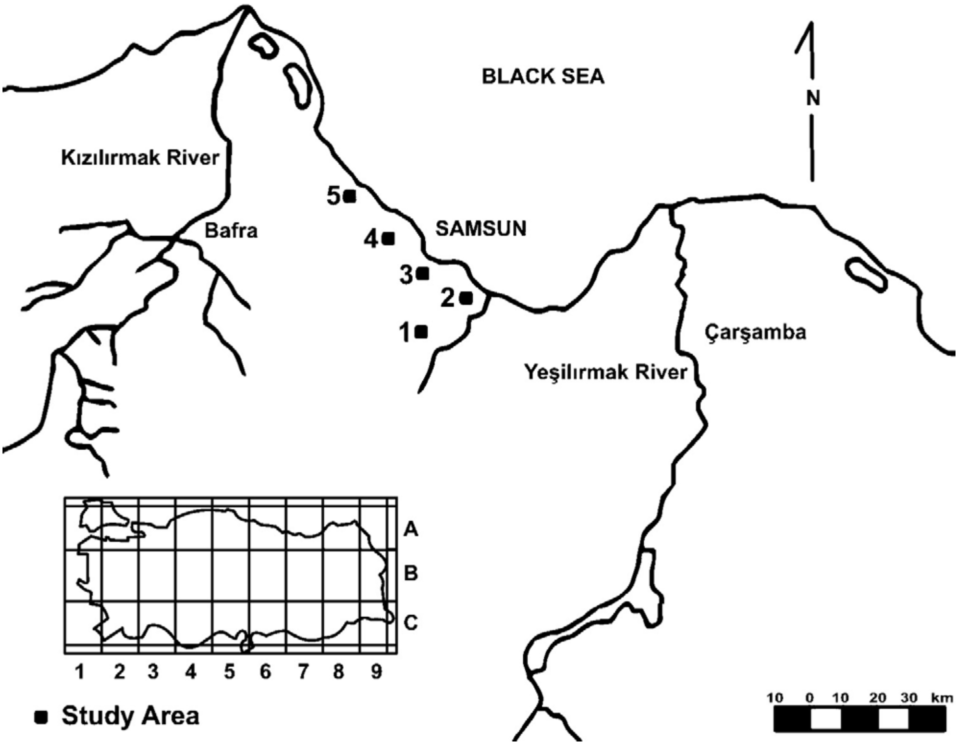

Fig. 1. Map of the study areas. 1 – Adalar, 2 – Mert, 3 – Kurupelit, 4 – Taflan, 5 – Engiz.

species within arm's reach were chosen. The twigs were labelled at the beginning of the growing season. The labelled twigs were observed from budbreak (mid-April) to leaf fall (mid-December). Leaf emergence types were determined according to KIKUZAWA (1983) and seasonal changes in leaf numbers per shoot were recorded. Leaf emergence was estimated as percent of total leaves that appeared during a given month. Leaf longevity is the number of months each leaf is retained in the canopy from bud break until fall (WILIAMS-LINERA 2000).

The numbers of bud scales were recorded and the interrelations between anatomical structure of winter bud and duration of leaf emergence were determined. The structures of winter buds were investigated under a binocular microscope by the help of longitudinal slides, and the anatomical structures of bud scales belonging to two species, which have a very remarkable structure as compared to the other species, are shown schematically.

Statistical analysis was performed using Statistical Package for the Social Sciences, version 10.0 (ANONYMOUS 1999). Three-way analysis of variance (ANOVA) test was performed to reveal whether or not months, species and localities are different from each other in terms of leaf number using the multivariate General Linear Models procedure.

Taxonomic nomenclature followed that of BRUMMITT and POWELL (1992).

Results

In some deciduous species, the one-lamina and two-stipules set is a basal unit constituting the winter bud and specialized bud scales do not exist and the structure of this type is considered to be a »homonomous« type, that is, the bud consists of like units. On the other hand, the structure of a bud with bud scales is considered to be a »heteronomous« type, that is, the bud consists of unlike components, namely bud scales and foliage leaves. All the studied species showed the »heteronomous« bud scale type. It has been reported that species with the succeeding type leaf emergence usually show a monopodial branching type, while species with intermediate flush leaf emergence type show sympodial branching type (Fig. 2).

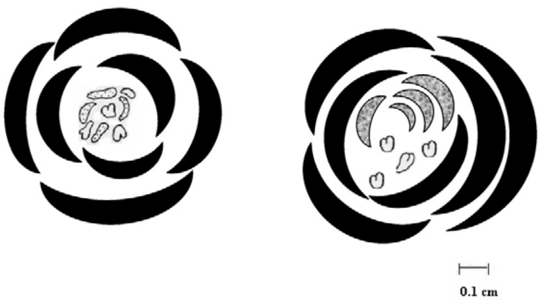

Fig. 2. Winter buds of *Platanus orientalis* and *Salix alba*. Lamina – open; stipules – dotted; bud scales – shaded.

Leaf initiation occurred in the first half of April in all of the studied species Peaks in leaf flushing occurred in August and September (Figs. 3–6). The peak of leaf fall was observed between November and December. Leaf fall was strongly seasonal and statistically significant differences were observed among months, species and localities in terms of leaf number. Mert River and Kurupelit were different from other localities in terms of leaf number. The highest and lowest leaf numbers were found in *S. alba* and *P. orientalis*, respectively (Tab. 1).

Tab. 1. The comparison of months, species and localities by using three-way ANOVA test. Significant differences at p<0.05(*), p<0.01 (**)

Source	Sum of Squares	df	Mean Square	F	Sign.
Months	14849.900	8	1856.237	998.375	**
Localities	57.078	4	14.269	7.675	**
Species	3280.739	3	1093.580	588.180	**
Months × Localities	210.822	32	6.588	3.543	**
Months × Species	1156.011	24	48.167	25.907	**
Months × Localities × Species	456.156	96	4.752	2.556	**
Localities × Species	450.844	12	37.570	20.207	**
	1004.000	540	1.859		

Tab. 2. Leaf emergence types of the studied species.

Species	Leaf emergence type
Platanus orientalis	Intermediate type
Robinia pseudoacacia	Intermediate type
Salix alba	Intermediate type
Rubus discolor	Flush type

Based on these data two different leaf emergence patterns were observed for four deciduous species as flush and intermediate types (Tab. 2). The leaf emergence duration is very short in the flush type and all of the leaves of the season emerge almost simultaneously. The leaf emergence duration of intermediate type is somewhat unclear and some of the leaves emerge almost simultaneously at first while after that the remaining leaves emerge successively.

Rubus discolor has the flush leaf emergence type. However, *Platanus orientalis*, *Robinia pseudoacacia* and *Salix alba* show the intermediate leaf emergence type (Figs. 3–6).

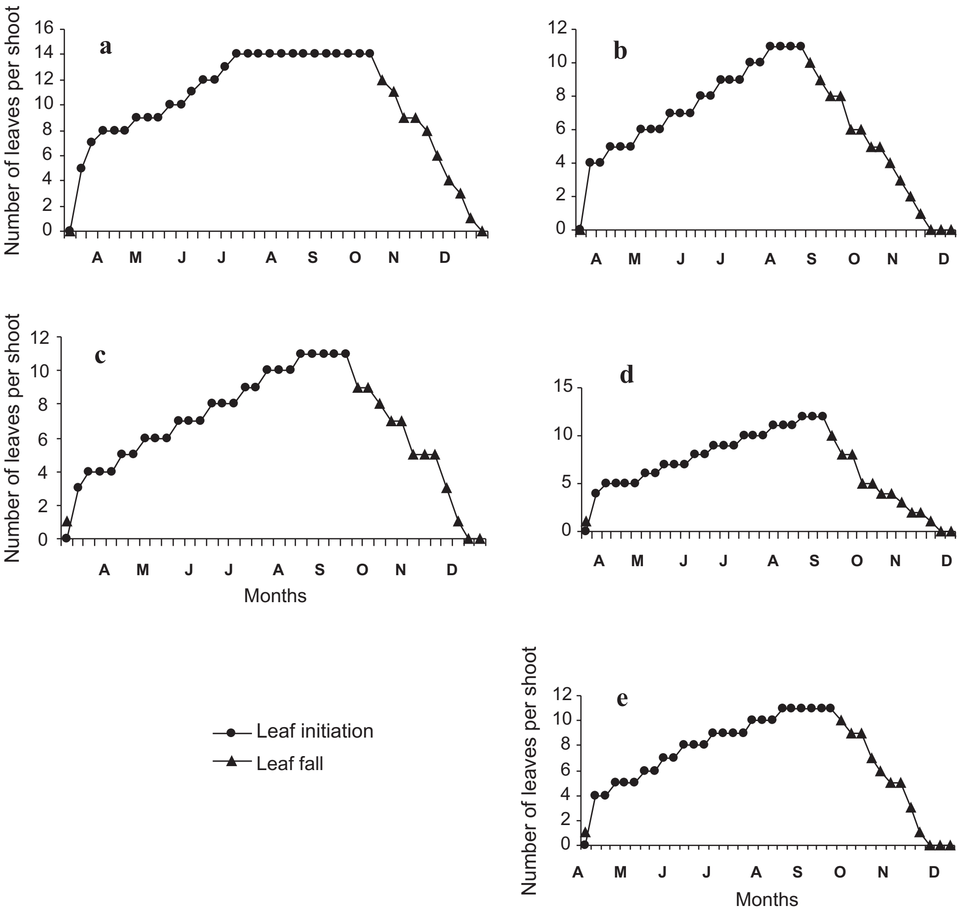

Fig. 3. Leaf initiation and fall of *Platanus orientalis* in Mert River (a), Adalar (b), Kurupelit (c), Taflan (d) and Engiz (e).

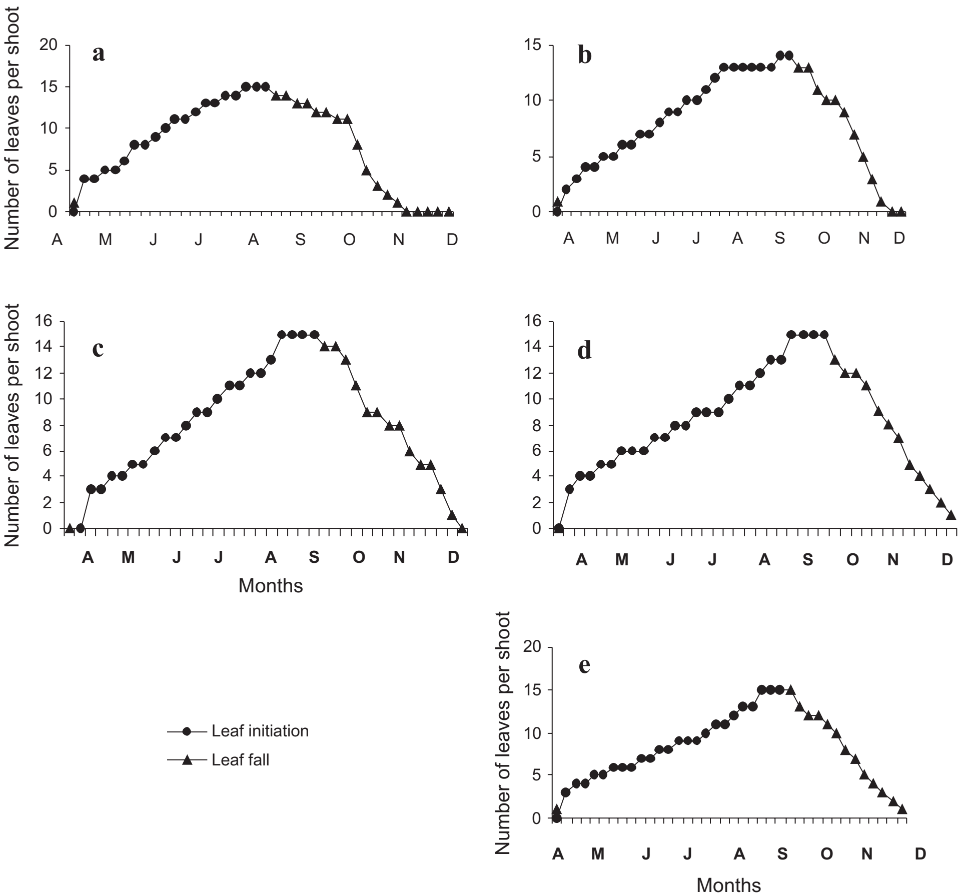

Fig. 4. Leaf initiation and fall of *Robinia pseudoacacia* in Mert River (a), Adalar (b), Kurupelit (c), Taflan (d) and Engiz (e).

The duration of leaf emergence was defined as the period from the budbreak to the end of leaf emergence. It was found that the emergence-duration of leaves was shorter with an increase in the bud-scale number (Tab. 3). The duration of leaf emergence in the present study was long in all species and varied four to five months. The emergence-duration of leaves was shorter the higher the bud-scale number (Figure 2).

Tab. 3. Number of bud scales and the duration of leaf emergence.

Species	Number of bud scales	Duration of leaf emergence
Platanus orientalis	1	116
Robinia pseudoacacia	9	102
Salix alba	7	109
Rubus discolor	12	95

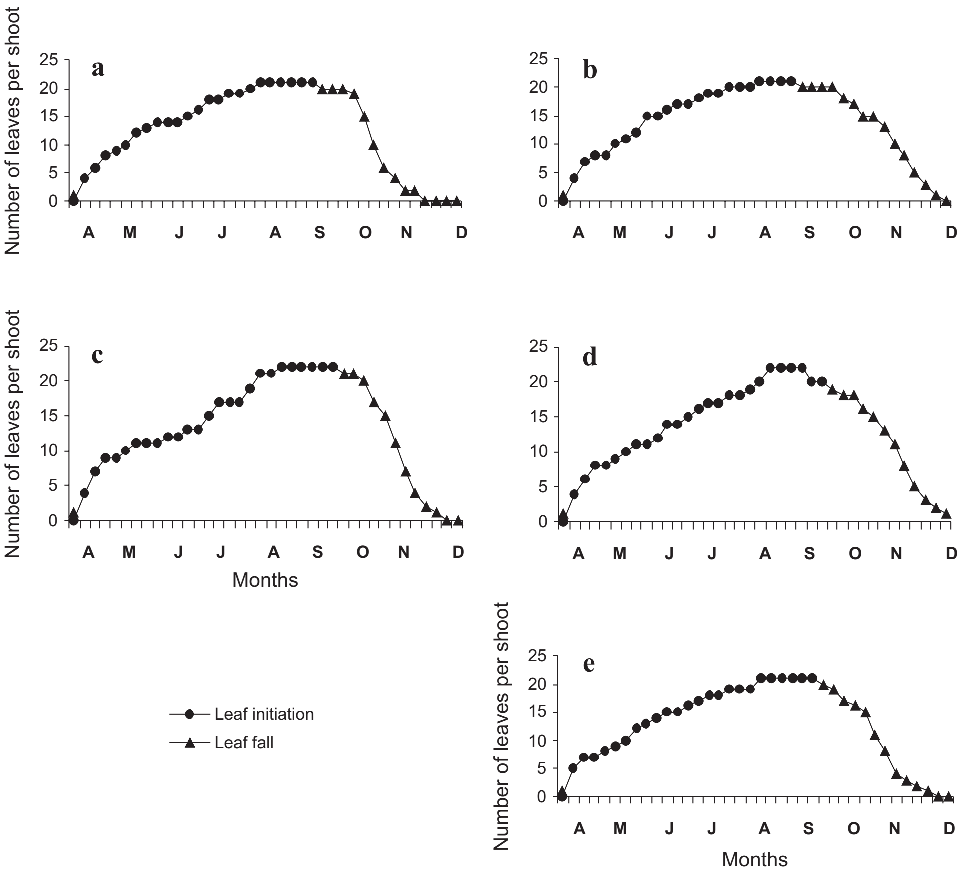

Fig. 5. Leaf initiation and fall of *Salix alba* in Mert River (a), Adalar (b), Kurupelit (c), Taflan (d) and Engiz (e).

Leaf duration was defined as the period from budbreak to the date all the leaves had fallen. Leaf durations of all species in the study area usually changes between 210–254 days.

The area surrounded by the curve of leaf survival and the abscissa (leaf number per shoot days) divided by the height of the emergence curve (leaf number per shoot), is the mean longevity of leaves (days), or the average duration of a leaf being attached to the shoot. Mean longevities of leaves in the present study varied from 95–116 days. The highest and lowest leaf longevities were obtained for *P. orientalis* and *R. discolor*, respectively.

Discussion

Budbreak was initiated mostly from the middle or end of April in our study. Deciduous species with buds protected either by woolly hairs or scales to overcome the severe winters required a considerably longer time to break out of the winter dormancy. Deciduous trees exhibit predictable annual losses of their entire canopies and subsequent homogeneous rep-

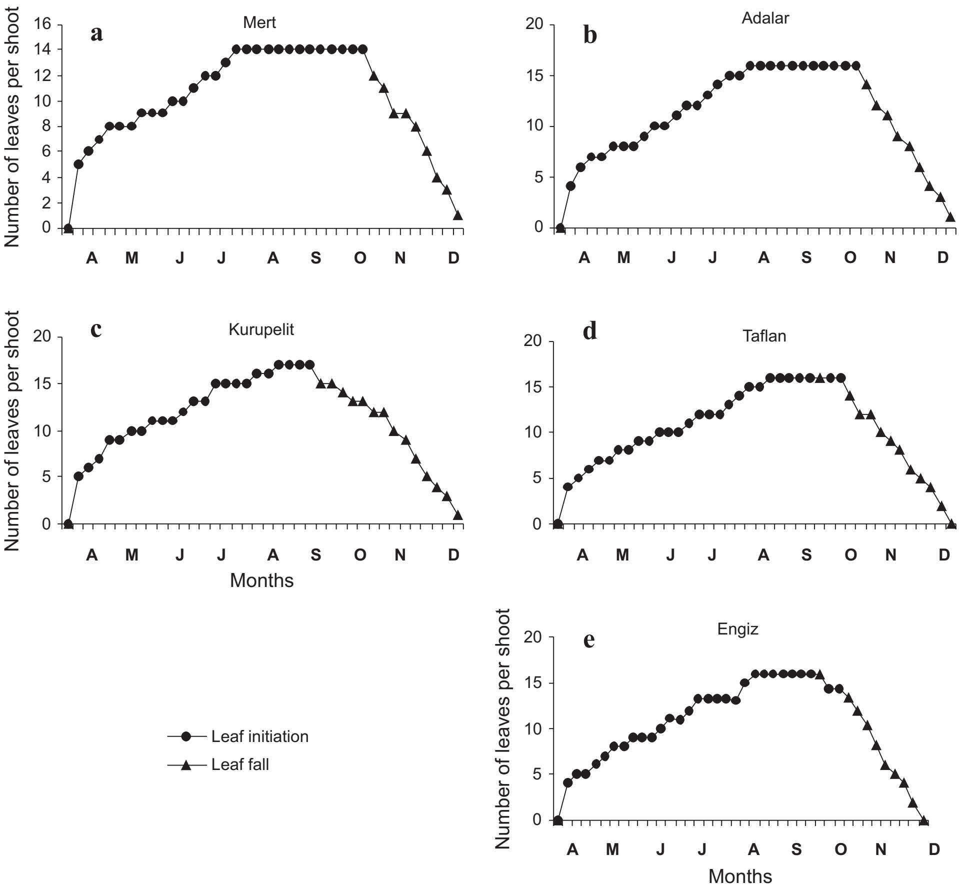

Fig. 6. Leaf initiation and fall of *Rubia discolor* in Mert River (a), Adalar (b), Kurupelit (c), Taflan (d) and Engiz (e).

lacement the following spring (LOWMAN 1992). In most temperate lowland forests in the northern hemisphere, the major part of the production of new leaves is confined to the early part of the year (WILLIAMS-LINERA 2000). In other words, leaves emerge and mature during the period with minimum rainfall, high temperature and increasing day length. The peak of leaf fall was observed between November and December when the temperature begins to decrease and day length is short, as with other deciduous species (SUNDARAPANDIAN et al. 2005).

Platanus orientalis, *Robinia pseudoacacia* and *Salix alba* show intermediate leaf emergence type, while *Rubus discolor* has flush leaf emergence type. Intermediate types are again classified into three subtypes. In the heterophyllous subtype, the early leaves of a definite number, usually one or two, emerge at first and after a short period the late leaves emerge one by one. In the Cornus subtype, the flush occurs at first and in the middle of the growing season the new leaves emerge on sylleptics or new shoots from the lateral buds of the current shoot. In the flush and succeeding subtype, at first an indefinite number of leaves emerge as a flush and after that the remaining leaves appear in succession. *Platanus* *orientalis*, *R. pseudoacacia* and *S. alba* appear to belong to the flush and succeeding subtype. In *R. discolor*, the leaves emerge successively and with a long duration of leaf emergence.

In *Salix alba* and *R. pseudoacacia* the duration of leaves was 226–240 and 226–247 days, respectively. The duration for *P. orientalis* and *R. discolor* was a bit longer, from 210–250 days and 247–254 days, respectively. Differences in leaf longevity have been evaluated in terms of nutrient-use efficiency, carbon balance and the ratio of cost to carbon gain, micro-environmental conditions in which leaves grow, as well as the emergence times (WILLIAMS-LINERA 2000).

Leaf fall was strongly seasonal in the present study. The species in the study area show synchronous leaf production. In other words, one cohort of leaves replaces or is added to a previous cohort. Many woody species operate in this mode with multiple growing points (CHABOT and HICKS 1982). Synchronous leafing may be explained as 80 % or more individuals of a species were in a given phase at one or more observation time (RAWAL et al. 1991). In the markedly seasonal temperate biomes most tree species have leaf phenologies and demographies that are usually synchronized with seasonal patterns (REICH et al. 2004).

Leaf flush and leaf fall occurred more or less simultaneously in some of the studied species (i. e. *R. discolor*) and this strategy may be advantageous because it allows the plants to utilize their mature leaves right up until the time new ones are produced (FUNCH et al. 2002).

It was found that the shortening of emergence-duration of leaves correlated with an increase in the bud-scale number. *Rubus discolor* had the highest bud scale number, and the shortest leaf emergence. This has been was explained on the basis of species whose winter buds are covered with many bud scales tending to show the flush type leaf emergence with shorter duration (KIKUZAWA 1983). Species that have more bud scales show a tendency toward the shortening of leaf emergence duration (Fig. 2). Similar results were obtained by other researchers (KIKUZAWA 1983, KILINÇ et al. 2000) in some deciduous woody species and this was interpreted by species that grow without a rest being assumed to have homonomous shoots and such a tendency was also found in tropical forest species (KIKUZAWA 1983).

Sympodial branching is seen in the studied tree species and they have also heteronomous bud-structure (Fig. 2). Deciduous species having winter buds with preformed shoots grow faster than those that produce new shoots using current photosynthate or even stored assimilate (NITTA and OHSAWA 1997).

In temperate forest plants, both the optimal leaf life-span and timing of emergence are expected to be selected by stress or by the abundance of available resources, accompanied by the habitat selection of each species (KIKUZAWA 1983, 1991; UEMURA 1994 a).

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