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Twelve Years Changes in Local Climate Factors and Annual Fluctuations of Seed Production of the *Carpinus tschonoskii* Forest in Mt. Jiri in Southern Korea

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지리산 개서어나무림에서의 12년간 지역기후의 변화에 따른 연간 종자생산량의 변동

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ABSTRACT

Changes of annual seed production related to climate change were studied for 12 years in Piagol, a riparian valley in Mt. Jiri. Sixty-four seed traps (sized 0.5 × 0.5 m^2) were set up on the forest floor of surveyed area. Seeds were collected from these traps at an interval of 15 days from September to November since 1984. Vegetation of the study area was mainly consisted of the naturally regenerated *Carpinus tschonoskii* in the tree layer. *Acer mono, Quercus serrata, Carpinus laxiflora* and *Symplocos chinensis* also appeared in the same layer. Maximum production occurred in 1984 and 1994. As a result of comparing seed production with local climate factors for 12 years, seed productivity and the year of maximum production of *Carpinus* forest were merely related with precipitation, air temperature and duration of sunshine among local climate factors. Duration of sunshine was, however, not contributed to periodically high productivity of seed of riparian valley *Carpinus* forest.

Key words: Air temperature, *Carpinus tschonoskii* forest, Climate change, Mt. Jiri, Precipitation, Riparian valley.

INTRODUCTION

The long-term climate effect is one of the disturbance factors on the spatio-temporal vegetation process and physiological control mechanism in natural ecosystems (Etherington 1982). Local climate changes also influence on vegetation change of successional forests with different regeneration strategies and disturbance regimes at the community and landscape scales (Stoutjesdijk and Barkman 1992). Consequently, climate may be considered as one of the controlling agents on tree physiology, especially in the unstable successional stage and ecosystem such as riparian valley forest (Crawford 1989).

In general, productivity of seeds is dependent upon the biological conditions such as tree physiology, flowering, pollination efficiency and insect damage and on the environmental conditions such as soil, light and climate (Grime 1979, Silvertown 1987, Watanabe 1994).

Carpinus forest often appears in the stream-sides in the riparian landscape or rocky valley of mountains. Therefore, this community is commonly consisted with some shade-tolerant species such as *Acer* and with some *Quercus* species. These species, consequently, have an ecological role as successional occupation species in a stable and conservative ecosystem like climax forest (Shibata and Nakashizuka 1995, Tanaka 1995, Park 1997). Considering that most part of Piagol had been interfered by human activities for a long time, vegetation in this valley might have been subjected to human disturbance.

According to some phytosociological studies (Jang and Yim 1985, Kim and Yim 1986), *Carpinus* forest appeares at the mid- to late successional stages on the cool temperate deciduous forest zone in Korea. Productions of seed and flower are very susceptible to habitat characteristics such as site factor and climate condition (Harper 1977, Silvertown 1987). It is therefore often difficult to measure the correct and continuous productivity of seeds and efficiency of seeding. Seed and seedling traits characterize some regeneration strategies of plant species in a special site (Grime 1979, Silvertown 1987, Hong and Nakagoshi 1998). Estimation of annual seed production is a necessary procedure to understand the whole information about pollination efficiency in the population level, and on forest regeneration and vegetation succession at the community level (Harper 1977, Rim *et al.* 1991, Shibata *et al.* 1998).

This study was carried out to determine the fluctuation of total seed production of *Carpinus* forest related to local climate change for 12 years and to estimate the indirect pollination efficiency of *Carpinus* dominated forest by comparing the annual masting fluctuation at the community level in local climatic stress.

STUDY AREA AND METHODS

Study area

This study was carried out in Piagol (Long. 127° 35′, Lat. 35°15′10″, Alt. 650 m asl.), a valley located geographically at southern part of Mt. Jiri in southern Korea, syngeographically cool temperate southern-submontane zone (Kim 1994). Tall trees of two *Carpinus* (*C. laxiflora* and *C. tschonoskii*), *Quercus serrata*, and *Acer mono* are distributed along the stream sides (Jang and Yim 1985). *Carpinus* forest is the characteristic vegetation of moist area in the stream-sides in the temperate zone in Korea and Japan (Shibata and Nakashizuka 1995, Park 1997, Shibata *et al.* 1998). It appears at the mid- to late successional stages in the warm and moist regions in southern Korea. These forests are, however, very susceptible to human interference because the forest contain major trails. According to Yim and Kim (1992), soil of this area is originated from granitic gneiss.

Seed trap and seed harvest

Sixty-four seed traps were evenly set up on the forest floor. A seed trap made of a screen bag with wire frame (0.5 × 0.5 m^2) was mounted under a thick wire. Because of large bottom stone on the forest floor, all traps were set up at the breast height (about 1.3 m) of forest. Main wire frame connected to seed trap was fixed to the trees for keeping the location of each trap against the strong wind and human disturbance (Rim *et al.* 1991). All seeds were collected from these traps at an interval of 15 days from 30 Sept. to 30 Nov. from 1984 to 1996. Collected materials were screened and divided according to the tree species, and leaf and other detritus were cleared. In the present paper, our study is focused on the total number of seeds collected from the traps without selecting species. Therefore, the data of total number of seeds were from all the tree species including *Carpinus tschonoskii*.

Analysis of climate data

Climate data of Namwon (Lat. 35°25′, Long. 127° 25′) near Mt. Jiri was analyzed from The Annual Climatological Report from 1980 to 1996. In order to examine the relationships between the annual and seasonal climate attributes and seed production according to climate change, we explored the fluctuation pattern of the maximum and minimum years of seed production for 12 years. Statistical analysis was applied to examine the relationships between the total number of seeds produced and climate data using SYSTAT (ver. 5) for Macintosh.

RESULTS AND DISCUSSION

Vegetation

Vegetation of the study area was mainly consisted of the naturally regenerated *Carpinus tschonoskii* in the tree layer. *Acer mono, Quercus serrata, Carpinus laxiflora* and *Symplocos chinensis* occurred together with *Carpinus tschonoskii* in the tree layer. *Quercus serrata* is also the characteristic species appearing at the same successional stage of *Carpinus* species (Kim and Yim 1986, Yim and Kim 1992). These *Carpinus* species were, however, not found at the shrub layer.

In the herb layer, *Sasa* and *Benzoin* were the dominants. Seedlings of *Carpinus laxiflora* were found in the herb layer, but its coverage was low. We suggest that failure of seed germination of *Carpinus* species may be related with shade-effect by the coverage of *Sasa borealis* of the herb layer (Hong and Rim, unpublished data). The role of dwarf bamboo, *Sasa* species, on the forest floor at the retrogressive process of forest regeneration is also found in other vegetation types of temperate deciduous forest and pine forest in Korea and Japan (Nakashizuka 1987, Hong *et al.* 1995, Yamamoto 1995).

Seed production and climate

Seed production of *Carpinus* forest generally showed an irregular cycle by years (Fig. 1). 1984, 1986, 1988, 1989 and 1994 were the year of seed rain of the forest. However, the heaviest production occurred in 1984 and 1994. Most seeds were dispersed in late October to early November.

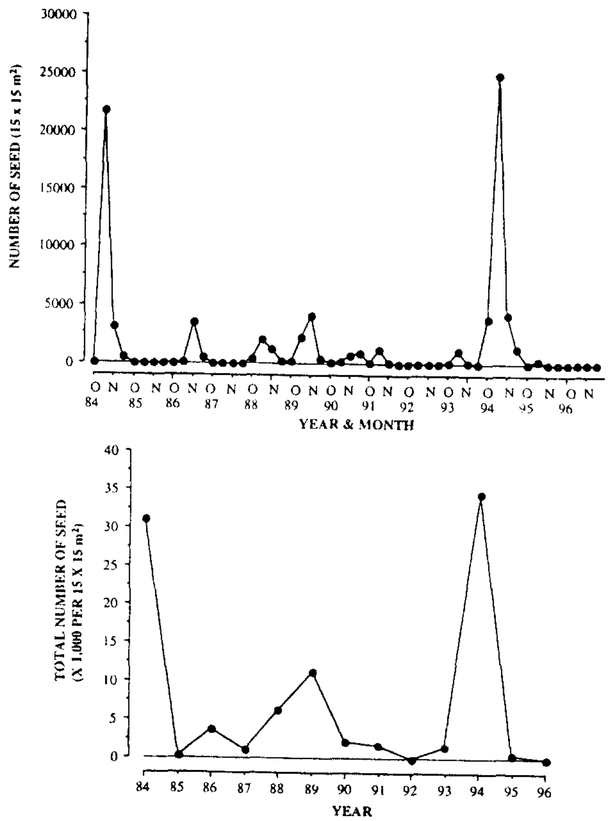

Fig. 1. Fluctuations of annual and monthly seed production of *Carpinus* forest for 12 years.

Table 1. The correlation analysis between annual seed production and climate change

Climate attributes	Correlation coefficient (r)
Annual Mean Air Temperature (℃)	0.126^{NS}
Annual Mean Maximum Air Temperature	0.154^{NS}
Annual Mean Minimum Air Temperature	0.343^{*}
Annual Maximum Air Temperature	0.349^{*}
Annual Minimum Air Temperature	0.513^{*}
Annual Mean Precipitation (mm)	0.396^{*}
Annual Mean Relative Humidity (%)	0.378^{*}
Duration of Sunshine (hr)	0.186^{NS}

* $p<0.01$

Seed production of *Carpinus* forest was significantly corelated with the annual minimum temperature (Pearson's correlation coefficient r_p = 0.513 at $p<0.01$) and annual mean precipitation (r_p = 0.396, $p<0.01$) of local climate (Table 1). Annual mean minimum temperature (r_p = 0.343), annual maximum temperature (r_p = 0.349) and annual mean relative humidity (r_p = 0.378) had also weak effect on the seed production. In this analysis, we suggest that air temperature is more important than precipitation on the seed production of *Carpinus* forest. Annual precipitation (approx. 1,400 mm/yr.) is concentrated to summer season (June to August) of seed formation stage in Korea (Hong and Nakagoshi 1998). Moreover, sometimes typhoon with heavy rain and wind attack this area in the season (Hong 1979, Seong and Shin 1979). Therefore, summer air temperature and light condition are the important factors to control vegetative and reproductive mechanisms available to seed and flower production (Grime 1979, Etherington 1982, Silvertown 1987).

In the present study, annual mean duration of sunshine was not significant in the seed production (r_p = 0.186, not significant). The duration of sunshine was, however, seasonally different (Fig. 2). Except for winter, the duration of sunshine in the season is an important factor to control the physiological mechanisms of seed maturation. There was no significant correlation between the duration of sunshine and air temperature by season. Figure 3 shows the number of days of rain and sunshine by season. Generally, annual productions of plants including fruit, rice, and vegetables are sensitively dependent on climatic attributes such as temperature and precipitation of summer season (Crawford 1989). Moreover, high temperature, long duration of sunshine and much precipitation give positive effect on tree physiology like fruiting and seed production mechanism of the sunny plants. According to Shibata *et al.* (1998), the pollination efficiency was supported as an explanation for the adaptive significance of annual fluctuation of seed production in *Carpinus* forest. In the case of shade-tolerant species at the late successional stage having

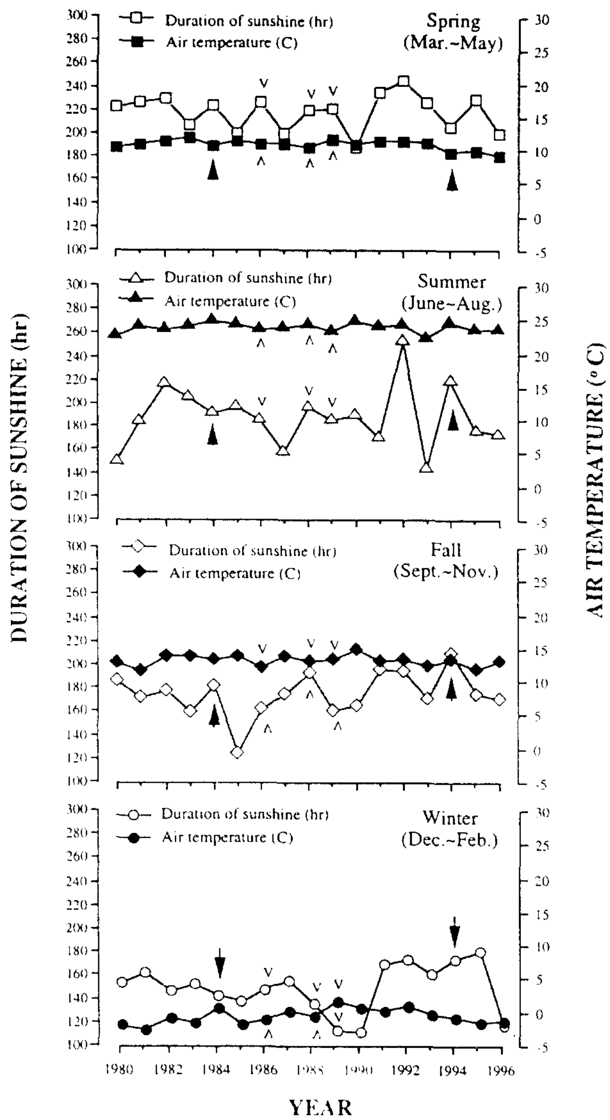

Fig. 2. Changes of the duration of sunshine and air temperature by season from 1980 to 1996 ("v" and large arrow signs mean the years of seed rain and heavy seed production, respectively).

sensitive ecosystem stability against external disturbance like climate (Grime 1979, Shibata and Nakashizuka 1995, Tanaka 1995), however, the appropriate portion of these combined climate attributes is decided to make their pollination efficiency and seed mast high (Watanabe 1994). Too much rain and strong air heat of summer season may act as a stress factor for high pollination efficiency and pro-

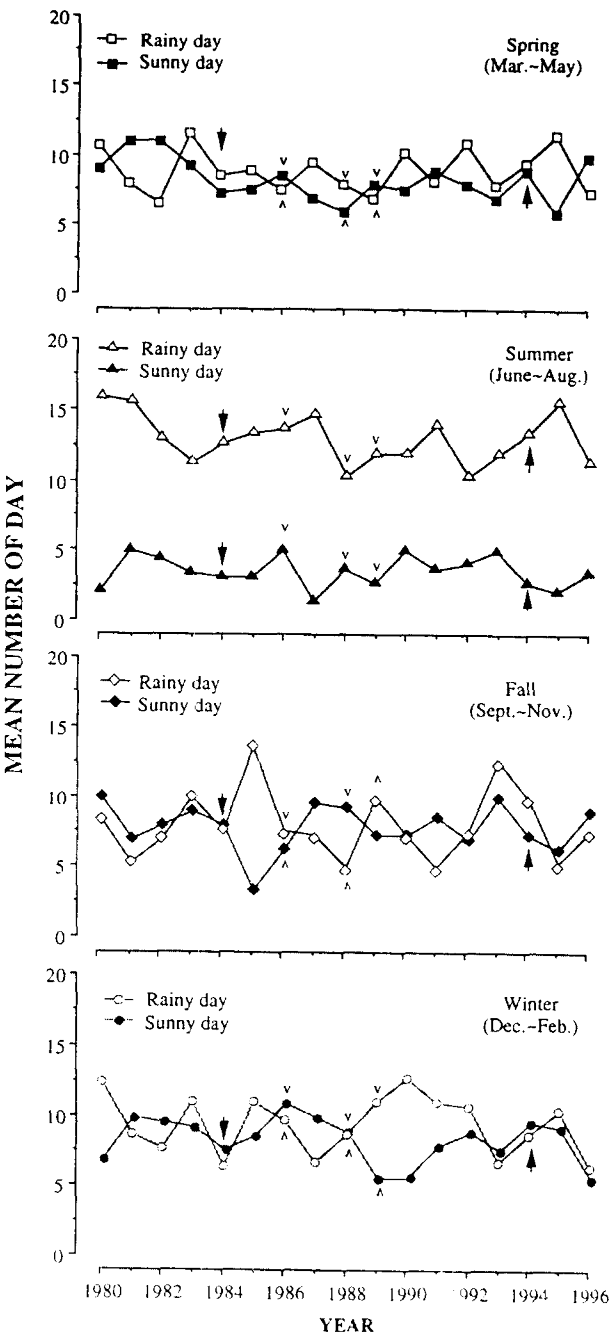

Fig. 3. Changes of the mean number of sunny and rainy day by season from 1980 and 1996 ("v" and large arrow signs mean the years of seed rain and heavy seed production, respectively).

ducing many sound seeds on the climax forest.

In the present study about the relationships between annual fluctuation of seed production and annual climatic attributes, we can suggest that the multiple causes - viz, microhabitat and microclimatic condition (Stoutjesdijk and Barkman 1992)- can operate pollination and demographic stages of the plant, and consequently it controls the seed maturation period in horizontal and vertical condition of community. To estimate the importance of climatic factors on vegetation dynamics including seed production of successional deciduous forest composed of different species in competition, we need to accumulate quantitative data about species-specific seed production of co-occurring plants appearing at the same successional stage.

적 요

이 논문은 12년간의 냉온대 활엽수림의 종자생산과 갱신에 관한 연구중 지역기후 변화에 따른 종자생산량의 변화에 대한 것이다. 본 연구는 지리산 남쪽에 위치한 하천계곡인 피아골의 개서어나무림에서 수행되었다. 식생조사와 더불어 64개의 종자채집기구를 설치하여 1984년부터 각 9월과 11월 사이에 일정간격을 두고 종자를 채집하였다. 조사지역의 식생은 주로 자연갱신된 교목성 개서어나무였다. 고로쇠나무, 졸참나무, 서어나무 및 노린재나무 등이 아교목층에서 혼생하고 있었다. 개서어나무림의 종자생산은 매년 일정한 간격으로 변동을 보였다. 그러나 이것의 최고 생산량은 1984년과 1994년에 나타났다. 12년간의 종자생산량과 지역기후 변동요인을 비교한 결과, 종자생산량과 최고생산량은 미약하나마 강우량, 대기온도 그리고 일조기간과 관계가 있었다. 그러나 이들 요인 중 계절별로 차이가 있는 일조기간은 종자생산량에 주기적인 영향으로서 작용하지 않는 것으로 생각된다.

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