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〈Short communication〉

Which Environmental Factors Caused Lammas Shoot Growth of Korean Red Pine?

Lee, Chang-Seok*, Hye-Gyung Song[1], Hye-Soo Kim[1], Bitnara Lee[1], Jeong-Hoon Pi[1], Yong-Chan Cho[1], Eun-Sil Seol[1], Woo-Seok Oh[1], Sung-Ae Park[1] and Seon-Mi Lee[1]

Faculty of Environment and Life Sciences, Seoul Women's University, Seoul 139-774, Korea

[1]Department of Biology, Graduate School of Seoul Women's University, Seoul 139-774, Korea

ABSTRACT: Lammas growth, a rare phenomenon for Korean red pine (*Pinus densiflora*), occurred in 2006. Lammas shoots showed higher frequency and longer length in Seoul's hotter urban center than in urban boundary or suburban forest sites. Frequency and length showed a close correlation with urbanization density and vegetation cover expressed in NDVI. Air temperature in the late summer of 2006 was more than 1℃ higher than an average year. Of the predominant environmental signals that modulate bud flush, only temperature changed significantly during the year. Differences in temperature between the urban centers, urban boundaries and suburban forests correlated with varying land-use density. The rise in temperature likely spurred lammas growth of the Korean red pine. Symptoms of climate change are being detected throughout the world, and its consequences will be clearer in the future. Considerate interest in the responses of ecological systems to the variable changes is required to prepare for unforeseeable crises. Monitoring of diverse ecological phenomena at Long Term Ecological Research sites could offer harbingers of change.

Key words: Climate change, Korean red pine, Lammas growth, Land use pattern, Urbanization

INTRODUCTION

In late summer, as day length begins to decrease, shoot elongation is suspended and overwintering buds begin to form in most temperate woody plants. Growth of overwintering bud occurs as temperature and day length increase in spring and is referred to as "predetermined growth."

The amount and types of shoot elongation that occur during the growing season are integral components of the annual developmental phases in plants. Rapid juvenile height growth is necessary for seedlings to survive inter- and intra-specific competition. But the developmental sequence, which begins with bud burst and ceases with cold acclimation, must be completed within the frost-free period (Dietrichson 1964, Rehfeldt 1983).

"Lammas growth," or "free growth," are shoots that form after a pause in summer growth (Kaya et al. 1994). The capacity for this second flush is a plant adaptation to favorable conditions during the growing season, the result of an ability to cease growth during periods of unfavorable conditions and resume growth when favorable conditions return (Loopstra 1984). This pressure to increase height through an extension of the shoot-growth period is balanced by the necessity to avoid damage or death from early frost or late-summer drought (Rehfeldt 1983). Lammas shoots will eventually form an overwintering bud, one less cold hardy than a normal shoot (Kaya et al. 1994). Consequently, growth initiation and cessation is associated with susceptibility to late spring and early fall frosts and is therefore important to the long-term survival and vigor of the tree (Kaya et al. 1994).

Environmental signals -such as photoperiodicity, temperature, and winter chilling- affect dormancy release, cell cycling, and elongation of meristematic tissue in the spring (Campbell and Sugano 1975, Campbell and Sorensen 1978, Steiner 1979. Bigras and D'Aoust 1993, Hanninen 1995). The signals that modulate the timing of a spring bud flush are predominately winter chilling and spring temperatures. These signals have a synergistic effect on the release of dormancy in the spring, providing the adaptive plasticity needed to survive yearly climatic fluctuations. "Winter chilling" is prolonged exposure to low temperatures, and the winter chill requirement is an elegant adaptation by a broad spectrum of woody plants (Sorensen 1983) that enables them to "sense" when winter is over, and growth can resume with minimal risk of frost damage. The ambient temperature of the air and soil in the spring is also important in the timing of dormancy release and the rate of cell expansion in the spring. In locations or years in which the winter chilling requirement is unsatisfied, warm spring temperatures and extended day length compensate, initiating the release of dormancy (Campbell and Sugano 1975).

* Corresponding author; Phone: +82-2-970-5666, Fax: +82-2-970-5822, e-mail: leecs@swu.ac.kr

Evidence of climate change is being detected throughout the world, and the most prevalent symptom is rising air temperatures. Some figures suggest that temperatures will increase in by an average of 4℃ throughout the world by 2080 (Kwadijk 1993, Middelkoop et al. 2001). This world-wide rise in temperature corresponds to a latitude difference of approximately 4˚, a significant difference because vegetation zones could change. Climate scenarios vary considerably, and there is extensive discussion within the Intergovernmental Panel of Climate Change (IPCC) about the precise rate and extent of future variations in temperature and precipitation. Therefore, it is difficult to predict the responses of biological species or ecosystems to potential changes.

In Korea, the fall of 2006 was hot compared with an average year (Fig. 3). Although lammas growth is a rare phenomenon in Korean red pine (*Pinus densiflora*), many trees formed shoots in 2006.

This study aims to clarify 1) the actual status of 2006 lammas growth in Korean red pine, and 2) the causal factors that induced growth by analyzing frequency and length of lammas shoots, temperature, land-use patterns, and vegetative cover.

MATERIALS AND METHODS

Study Site

Field survey on the lammas growth of the Korean red pine was carried out in Seoul. Thirty urban sites were chosen: 12 Gu (ward)-offices, seven universities (including one college), four public facilities, three stations, two residential areas, one elementary school, and one high school in Seoul city (Fig. 1). Five urban boundary and suburban forest sites were chosen near the foot and summits of Mt. Acha (site No. 15), Mt. Boukhan (site No. 17), Mt. Bulam (site No. 16), Mt. Cheonggye (site No. 18), and Mt. Gwanak (site No. 10). Four parks, surrounded by urban areas, were chosen for reference sites: Hakdong (site No. 22), Paris (site No. 34), and Seoripool parks (site No. 29), and Mt. Woomyeon (site No. 40).

Methods

Field survey was carried during two weeks -from January 22, 2007, to February 2, 2007- to reduce differences from lapsed survey time. Frequency of lammas growth was evaluated in reference to the total number of branches. Shoot length was measured by tape ruler with a precision of mm level for 10 branches selected randomly. Terminal shoots of each branch were chosen for measurement.

Meteorological data were obtained from the Korea Meteorological Administration (KMA 2004). Temperature at each site was obtained from the median value of temperature range extracted from the thermal band of Landsat TM satellite images.

Urbanization ratios were calculated by a percentage of urbanized land area to total area obtained from a Seoul Metropolitan Biotop Map (Seoul 2000). Total area was determined by drawing a circle 100 m in radius from the survey site. Normalized Different Vegetation Index (NDVI) as a measure of vegetation quality or thickness was calculated by analyzing Landsat TM satellite images taken in September 12, 2006. NDVI is based on the ratio between the maximum absorption of radiation in the red spectral band versus the maximum reflection of radiation in the near infrared spectral band. NDVI values range between −1.0 and +1.0 (Jensen 1996), with those approaching +1.0 indicating the presence of dense vegetation

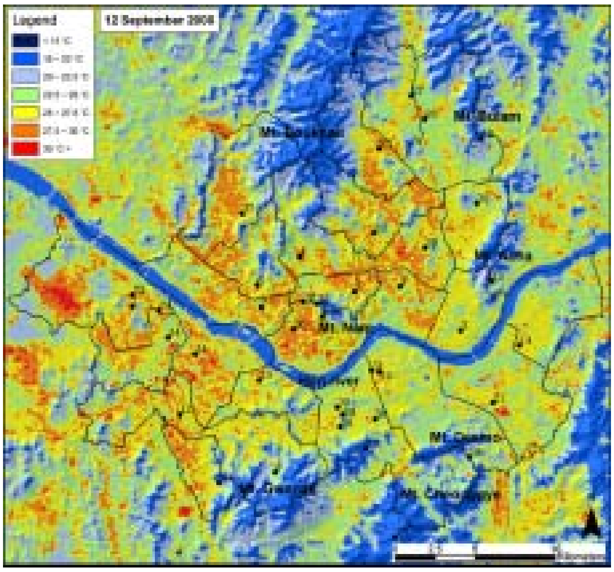

Fig. 1. A map showing the spatial distribution of temperature extracted from the thermal band of Landsat image and the study sites in Seoul, Korea. 1. Gangseo-gu office, 2. Seongdong-gu office, 3. Gwangjin-gu office, 4. Jongno-gu: Baehwa women's college, 5. Jung-gu: Dongguk university, 6. Seodaemun-gu: Yonsei university, 7. Mapo-gu: Sogang university, 8. Yongsan-gu: Yongsan 2-dong office, 9. Gwanak-gu: Seoul national university, 10. Mt. Gwanak, 11. Yeongdeungpo-gu office, 12. Guro-gu office, 13. Dongjak-gu office, 14. Gangdong-gu office, 15. Mt. Acha, 16. Mt. Bulam, 17. Mt. Boukhan, 18. Mt. Cheonggye, 19. Mt. Daemo, 20. Dongdaemun-gu: University of Seoul, 21. Songpa-gu: Garak apartment, 22. Gangnam-gu: Hakdong park, 23. Gangbuk-gu: Suyou station, 24. Gangseo-gu: Hannara party office, 25. Gangseo-gu: Gyungbok girl's high school, 26. Nowon-gu office, 27. Dobong-gu office, 28. Seocho-gu: Bangil elementary school, 29. Seocho-gu: Seoripool park, 30. Seocho-gu: Samsung leports center, 31. Gangnam-gu: Shinsa station, 32. Seocho-gu: Seorae village, 33. Sungbuk-gu: Seongshin women's university, 34. Yangcheon-gu: Paris park, 35. Yongsan- gu: Namsan library, 36. Yongsan-gu office, 37. Eunpyung-gu office, 38. Jung-gu: Seoul station, 39. Jungnang-gu office, 40. Mt. Woomyun.

cover (closed canopy forest). These values were derived using ArcView GIS software (ESRI 2005).

All statistical analyses were carried out using SAS (SAS Institute 2001).

RESULTS

The temperature in 2006 was 0.80℃ higher than the annual mean temperature of the last 30 years (Fig. 2). The difference was higher after July (1.06℃) when the wintering bud set, than previously (0.53℃). Temperature differences between the urban centers, boundaries, and suburban forests were also compared by Landsat TM image processed by thermal band (Fig. 1). Images on September 12, 2006, showed clear temperature differences among the urban centers, urban boundaries, and suburban forests. Additionally, temperatures at Yeongdeungpo and Mt. Boukhan-urban center and suburban forest sites, respectively-were compared (Fig. 3). Temperature difference between both sites maintained approximately 4℃ throughout a year.

Lammas shoot lengths were longer in the urban center and shortened as the sites shifted geographically through urban boundaries to suburban forests (Fig. 4). The frequency of lammas growth showed similar trends to shoot length (Fig. 5).

Temperature extracted from the thermal band of Landsat TM images showed a significant correlation between the frequency of lammas growth and shoot length (Table 1). Temperature also showed a

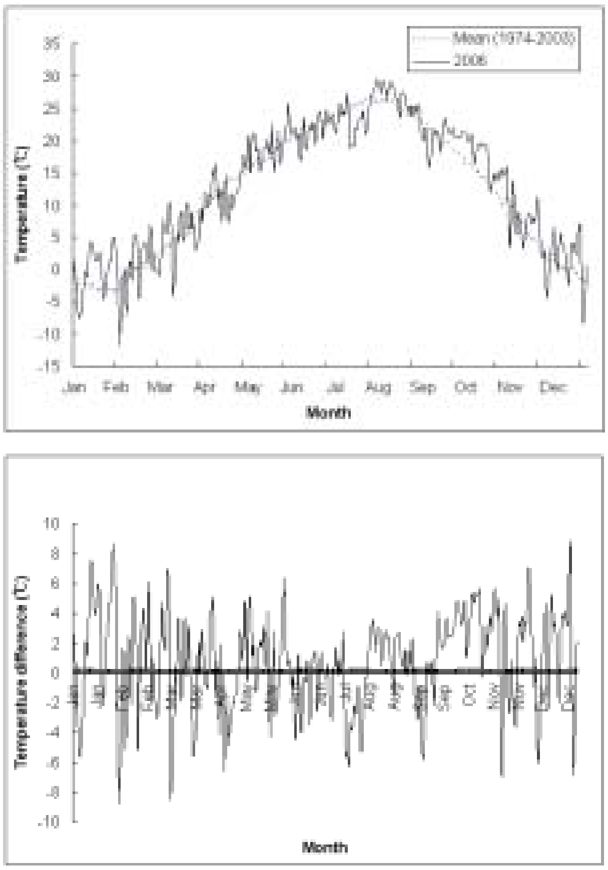

Fig. 2. Comparisons of the yearly changes in temperatures (upper) and temperature differences (lower) between the annual mean and 2006 in Seoul. On average, the temperature in 2006 was 0.80℃ higher than the annual mean of the past 30 years. Temperatures from January to June and July to December in 2006 were 0.53℃ and 1.06℃ higher, respectively, than the 30-year annual mean. Temperatures from these two periods were higher for 104 and 114 days, respectively, and lower for 78 and 70 days, respectively, than the ordinary year's temperatures.

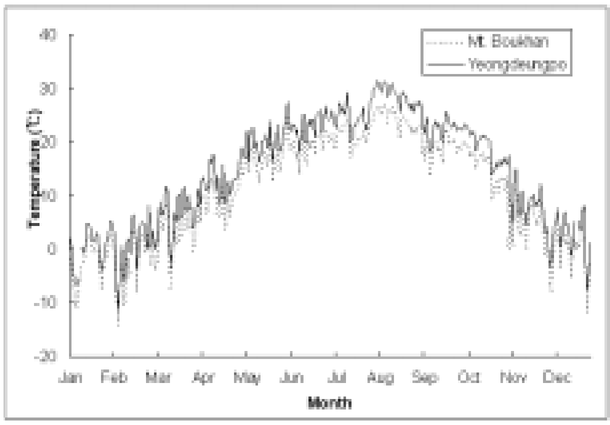

Fig. 3. A comparison of the yearly changes in temperature between Mt. Boukhan (mid-slope, Senggasa temple), a suburban forest, and Yeongdeungpo, an urban center in Seoul.

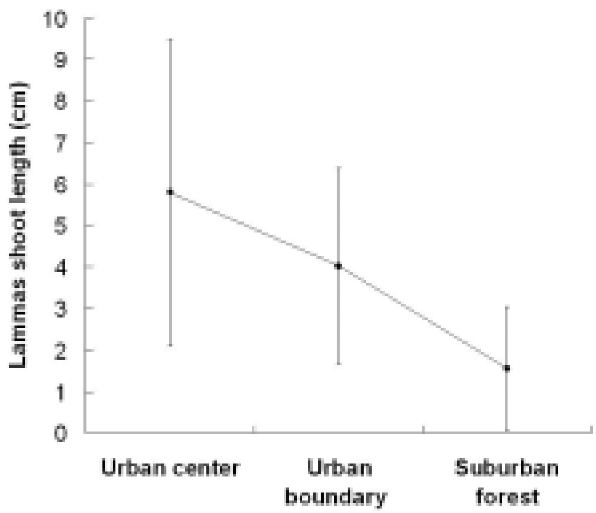

Fig. 4. Changes in lammas shoot length from urban center, through urban boundary, and toward suburban forest.

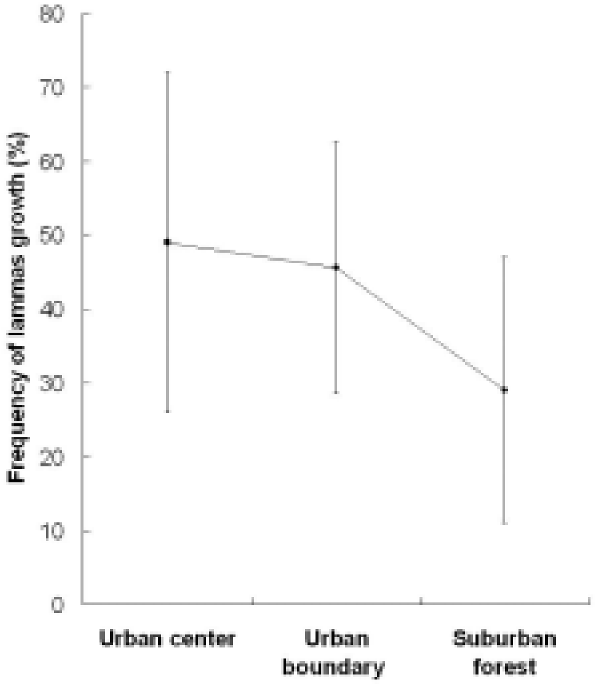

Fig. 5. Changes in frequency of lammas growth from urban center, through urban boundary, and toward suburban forest.

Table 1. Correlation coefficients between temperature from Landsat TM image, frequency of lammas growth, lammas shoot length, urbanization ratio, and NDVI

	Tempe-rature	Fre-quency	Length	Urbani-zation	NDVI
Temperature		0.35*	0.33*	0.75*	−0.77**
Frequency			0.67**	0.48*	−0.33*
Length				0.46*	−0.33*
Urbanization					−0.83**
NDVI					

close relationship to the urbanization ratio (positive) and NDVI (negative) (Table 1).

Relationships between NDVI and frequency of lammas growth and shoot length showed a negative correlation, whereas urbanization revealed a positive correlation with those factors (Table 1).

DISCUSSION

Which environmental factors caused lammas growth in the Korean red pine? We can deduce that significant temperature increases in late summer caused lammas growth. The predominant environmental signals that modulate the bud flush are photoperiodicity, temperature, and winter chilling (Campbell and Sugano 1975, Campbell and Sorensen 1978, Steiner 1979, Bigras and D'Aoust 1993, Hänninen 1995). Among these influences, only temperature experienced any change during the year.

Temperatures differed among urban centers, urban boundaries and suburban forests (Figs. 1 and 3). Lammas growth appeared with higher frequency and shoot length was longer in the hotter urban centers than in urban boundaries or suburban forests (Figs. 4 and 5). Indeed frequency and shoot length showed a close correlation to the urbanization ratio and vegetated cover of land expressed in NDVI (Table 1).

Temperature is closely related to land-use patterns. Cities are usually warmer than rural areas, especially at night, a phenomenon known as the "urban heat island" (Landsberg 1981, Atkinson 1985, Oke 1987). Within a city, substantial variation in temperature is related to topography; proximity to rivers, lakes, and oceans; the density of development; the amount of vegetated cover; and types of building materials. Land use can account for much of the temperature variation (Henry et al. 1985, Henry and Dicks 1987). The urban energy budget also controls temperature variance significantly (Grimmond 1992, Roth and Oke 1995). Built surfaces generally absorb more solar radiation than vegetation; they are also impervious, covering the soil and preventing heat dissipation from evapotranspiration (Cleugh and Oke 1986). Numerous studies have demonstrated the importance of vegetated landscapes to ameliorate the urban heat island (Landsberg 1981, Upmanis et al. 1998, Bonan 2000).

In the fall of 2006, abnormal temperature increases of more than 1℃ likely gave rise to lammas growth in Korean red pine. Considering that the spatial distribution of temperature in Seoul and its surrounding areas were in accordance with the regional land use pattern (Fig. 1) (Lee et al. 2007), intensive land use could contribute to abnormal temperatures. Alternatively, in the western United States, rainfall after a dry season caused lammas growth in Douglas-fir (Kaya et al. 1994).

Symptoms of climate change are being detected throughout the world and provide a warning message of potential ecological crises. Considerable interest in the responses of ecological systems to the variable changes are required to prepare for the future. Monitoring of diverse ecological phenomena at Long Term Ecological Research sites could offer harbingers of change. Further, this result emphasizes the necessity of discreet land use plan.

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