Characteristics of small-scale heterogeneity in light availability within a Miscanthus sinensis canopy

YANHONG TANG1* AND IZUMI WASHITANI2

1Division of Plant Ecology, National Institute for Environmental Studies, Tsukuba, and 2Institute of Biological Sciences, University of Tsukuba, Tsukuba, Ibaraki, 305 Japan

To examine the small-scale variations in light and space availability, photon flux density (PFD) at 20 cm aboveground was measured at 2 cm intervals along each of four 160 cm horizontal transects under an overcast sky condition in a Miscanthus sinensis Anderss grass canopy. Two characteristics were identified for the variation patterns of PFD penetration along transects; the predominant variations of PFD penetration prevailed at the scales usually larger than 10 cm, and the point-to-point fluctuations occurred everywhere. Spatial autocorrelation coefficients of PFD penetration along transects were highly positive (>0.5) over the lag distances from 2 to 6 cm, while those of the point-to-point fluctuations exhibited a random series. Spectrum analysis showed a higher spectrum density at the lower frequency, that is, at the higher periodicity, which indicated that the variation of PFD penetration was mainly due to the patchy distribution of grass canopy. PFD-available spans along the transects and contour maps were examined to evaluate the microsites fulfilling both PFD and space requirements in the growth of Quercus serrata Thunb. seedlings. More than 75% of the spans with PFD penetration constantly exceeding 0.04 were shorter than 8 cm, which suggests that a large proportion of high PFD spots may not be used by Q. serrata seedlings in the grass canopy because of the limitation of availability in space. The spatial heterogeneity of PFD at small scales may be of great importance in the succession of M. sinensis grass communities.

Key words: grasslands; light environment; microsite; photon flux density; spatial heterogeneity.

INTRODUCTION

Most theoretical works on the light penetration in plant canopies are based on the assumption that the plant canopy is horizontally homogeneous and extensive, plane parallel, and optically isotropic turbid medium filled densely with small scattering elements (e.g. De Wit 1965; Miller & Norman 1971). However, plant canopies are not always homogenous, such as Miscanthus sinensis Anderss. canopies that are highly heterogeneous with patches of various sizes (Iwaki et al. 1985). The heterogeneity of canopy structure would affect the spatial variation of light within plant canopies.

Recently, spatial heterogeneity of light environments at small scales from centimeters to meters within plant canopies is receiving increasing attention (Silvertown et al. 1988; Tang et al. 1990; Williams 1992). Silvertown et al. (1988) showed a marked heterogeneity in R/FR ratios in a 160 cm plot under a grass canopy and discussed its ecological implications. Within M. sinensis grass canopies, the spatial distribution of photon flux density (PFD) is highly heterogeneous (Tang et al. 1989). The light availability at the scale of individual seedlings affects remarkably the characteristics of photosynthetic induction response, biomass allocation and morphological plasticity in Quercus serrata Thunb. seedlings within the grass canopies (Tang et al. 1990; Tang et al. 1992a; Tang et al. 1993). These studies suggest that the small-scale heterogeneity of PFD seems to play an important role in the establishment of tree seedlings within grasslands. Therefore, characteristics of PFD heterogeneity at small scales, especially at the scale of individual tree seedlings, must be understood in order to reveal further their possible ecological implications in the
replacement process from grasslands to tree communities.

Since the pioneer work on the light penetration by Monsi and Saeki (1953), many studies have focused on the intensity of light within plant communities. A threshold value of light intensity has usually been set for the evaluation of a particular biological process. An average of 0.04 in light penetration, for example, has been considered as a critical value for the establishment of tree seedlings within grass canopies (Monsi & Oshima 1955). However, even if the light availability in a microsite is high enough, the microsite can not be utilized if its physical space is too small for a particular plant or for a specific biological process. Therefore, it would be insufficient or even misleading unless both the light and space availabilities are considered.

In the present study, our objective was to characterize the spatial variation of PFD at the centimeter scale on a horizontal plane and evaluate the availability of microsite from both light and spatial requirements within the grass canopy.

MATERIALS AND METHODS

Study site

Light measurements were made in the M. sinensis grassland on the southern campus of the University of Tsukuba, Tsukuba, Japan. The grassland has been developed since 1976 from an abandoned field. The main associated species in the study site were Amphicarpaea edgeworthii Benth. var. japonica Oliver, Artemisia princeps Pampan., Erigeron annuus Pers., Glycine soja Sieb. et Zucc., Imperata cylindrica P. Beauv. var. koenigii (Retz.) Durand et Schinz and Phragmites australis Trin. The aboveground biomass of the stand in late September, 1989, was 950 g m$^{-2}$ with a leaf area index (LAI) of 3.85 and a mean canopy height of about 190 cm.

Light Measurement

PFD within the grass canopy was measured with Koito quantum sensors (KOITO, IKS-25) from 6:30 to 8:00 local time on 22 July 1989. The active area of the sensor is 0.785 cm$^2$. The 90% response time of the sensor is 500 μs and the measuring range is 0–3000 μmol photon m$^{-2}$ s$^{-1}$. Before the measurement, the Koito quantum sensors were calibrated under sunlight and artificial shade against a LI-COR Model 190s Quantum Sensor. Up to 16 sensors were mounted at 2 cm intervals on a 1 m-long aluminium bar. The PFD from each sensor was recorded at 1 s interval by a data logger (Eto Denki Thermdac E), which was controlled by a personal computer (PC-9801 INS/T, NEC, Japan).

Measurement of PFD was performed within a plot of 2 × 2 m$^2$ in the M. sinensis grassland (Fig. 1). PFD at 20 cm aboveground was recorded at 2 cm intervals along each of four transects. The measuring height is approximate to the initial height of the current year seedlings of Q. serrata. The transects were located parallelly at a neighbor distance of 40 cm. The other details were described elsewhere (Tang et al. 1989). After the measurement of PFD, the grass was cut and the patch size of M. sinensis grass was measured in length and width to illustrate the horizontal distribution of grass patches (Fig. 1).

Various factors including solar elevation, sky conditions and canopy structure cause the spatial heterogeneity of light distribution within canopies. Measurements were taken under an overcast sky and windless weather conditions, when the interferences from direct solar radiation and leaf vibration caused by wind were not factors. The readings were recorded on a 3.5 inch floppy disk. The data were transferred to a Macintosh computer Ilsi for analy-

![Fig. 1. Distribution of Miscanthus sinensis patches. Each patch was measured in two orientations (North–South and East–West) and then mapped as ellipses.](image-url)