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Short Report

Spectral Estimation of Radiation Absorptance and Leaf Area Index in Corn Canopies as Affected by Canopy Architecture and Growth Stage

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受光態勢と生育段階の異なるトウモロコシ群落の光合成有効光量子束吸収能及び葉面積指数の分光反射計測による推定：井上吉雄・岩崎和雄（農林水産省農業研究センター）
キーワード：受光角度，トウモロコシ，日射吸収能，分光反射特性，葉面積指数．
Key words : Corn, LAI, Leaf angle, Radiation absorptance, Spectral reflectance.

Remotely sensed spectral measurements have been related with agronomic parameters such as leaf area index (LAI) and above-ground biomass during vegetative growth[1,5,6]. Total dry matter production, on the other hand, has been shown to be linearly correlated with the amount of radiation intercepted during that period[4]. Spectral estimation of those parameters on non-destructive and real-time basis has great potentials for crop modeling as well as for crop diagnosis[2,6]. Spectral estimation of radiation-absorptance seems effective, especially, during reproductive stage since it cannot be estimated properly by a traditional radiation-balance method because of absorption by heads and/or dead parts of plants[4]. However, influences of canopy architecture and growth stage on such spectral estimates have little been examined so far[2]. Thus, the relationships of spectral reflectance with LAI and radiation absorptance in corn canopies were examined with special regard to the effects of leaf angle and growth stage.

Materials and Methods

Field experiments were conducted during 1988, 1989 and 1990 growing seasons at Tsukuba, Ibaraki. Three varieties of forage corn (*Zea mays* L.), P3540, TH82082 and TX41 were planted at two levels of plant density (8.3 and 4.2 plants m^{-2}). Planting dates were April 15 and May 16 in 1988, April 18 in 1989, and May 15 in 1990, respectively. Plots at two extreme levels of nitrogen application (0 and 40 kg/10 a) were also included, while the others received 20 kg/10 a of nitrogen. The plot size for each treatment was 13 m × 16 m. The soil was classified as an Andosole (A-tr). The two varieties, P3540 and TH82082, were mainly used since they were the most different in leaf angle among commercially available varieties. The mean leaf angles to the stem for upper ten leaves were measured at the silking stage on each ten samples. Green leaf area index values were determined with an area meter (Hayashi Denko, A400) every week using more than five plants each time. Absorptance values of photosynthetic photon flux (APPF), obtained in 1988 and 1989, were derived from the measurements with quantum light sensors (Li-Cor, LI-190S) which were placed at the center of each plot facing upward and downward at 1 m above each canopy and also upward at the soil surface. All data were recorded every 30 seconds throughout a day. Spectral reflectance measurements were taken in 1989 and 1990 with spectroradiometer (ABE, MM2703) which was equipped with 10° field-of-view aperture and acquired data in 17 bands from 400 to 1050 nm wavelengths. The sensor was mounted at the position 1 m above each canopy with a nadiar look angle. All data were obtained within 2 h of solar noon.

Results and Discussion

The combination of various treatments for three years provided a wide range of LAIs and growing patterns. The mean leaf angles to the stem for upper ten leaves at the silking stage were 26.1±2.1° for P3540 and 57.2±2.6° for TH82082, respectively. They were slightly larger at the lower plant density. The APPF values during each day were quite consistent

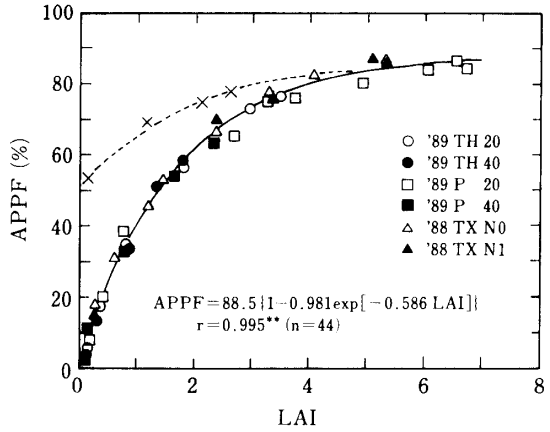

Fig. 1. Relationship between LAI and APPF in corn canopies. TH : TH 82082, P : P 3540, TX : TX 41, 40 ; 40 cm×60 cm, 20 ; 20 cm×60 cm, N 1 : 40 kg/10 a, N 1 : 0 kg/10 a. ** : Significant at 1% level. The line, ×⋯×, indicates a typical response of APPF to LAI during reproductive stage.

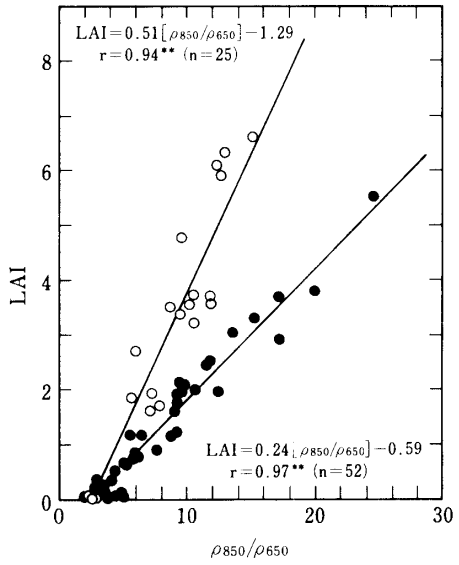

Fig. 2. Relationship between LAI and spectral reflectance ratio ρ_{850}/ρ_{650} in corn canopies. ● : vegetative stage, ○ : reproductive stage. Data are from 1989, 1990 experiments with two varieties and two plant densities. ** : Significant at 1% level.

and slightly affected by light intensity or time of measurement, which fact may allow an instantaneous estimation of APPF for a canopy. A close relationship was obtained between APPF and LAI during the vegetative stage which conformed to previously reported equations (Fig. 1)[3,4]. However, there was little difference between erectophile and planophile varieties, which suggests that such range of

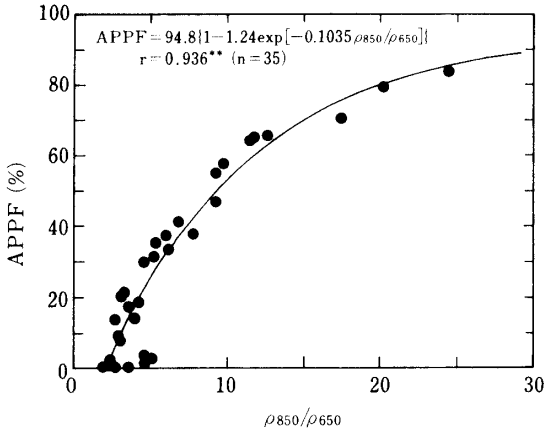

Fig. 3. Relationship between APPF and spectral reflectance ratio ρ_{850}/ρ_{650} in vegetative corn canopies. ** : Significant at 1% level. Data used are from 1989 experiment.

architectural difference in corn canopies may be neglible or unlikely to be detected by this type of methods. When LAI was around 5, approximately 85% of impinging PPF was absorbed by a canopy and the APPF value increased little with increasing LAI any more. Although the APPF value decreased with senescence during reproductive stage, it was much overestimated because of absorption by dead or non-green plant parts. The dashed line in Fig. 1 shows an example of decreasing pathway of APPF, whose final value at zero green leaf area was as high as 50%. The ratio of spectral reflectances at 850 nm and 650 nm wavelength (ρ_{850}/ρ_{650}) was best correlated with LAI among various combinations of spectral bands (Fig. 2). This ratio corresponds to the one of so-called vegetation indices originally proposed by Tucker[5], which has been shown to be correlated with green biomass during vegetative stage[1,5,6]. In the present experiment, specific regression lines were obtained not only for vegetative stage but also for reproductive stage. The relationship between LAI and ρ_{850}/ρ_{650} was affected little by the differences such as in leaf angle and plant density provided by various treatments. No close relationship, however, was found between the index ρ_{850}/ρ_{650} and above-ground dry matter (DM) during reproductive stage, while they were highly correlated with each other during vegetative development (data not shown). These results suggest that the spectral ratio is highly sensitive to LAI but insensitive to the DM. In fact, APPF and ρ_{850}/ρ_{650} values measured at the same time during

vegetative stage were well correlated with each other as shown in Fig. 3. The response of APPF to ρ_{850}/ρ_{650} after anthesis was similar to that in Fig. 1. Although it was impossible to measure the real APPF values directly during that stage, they could be calculated from the spectral ratio.

It is expected that LAI and/or APPF values in a wide range of corn varieties can be estimated from spectral reflectance measurements during an entire growth stage. The spectral estimates of LAI during mature stage, especially, is effective for providing more realistic value of absorbed PPF by a crop canopy.

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