Jpn. J. Crop Sci. 65(4) : 722—723 (1996)

Short Report

Chlorophyll Fluorescence Quenching and CO_2 Exchange Rate of Mungbean (*Vigna radiata* (L.) Wilczek) Leaves without Epidermis

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Received March 1, 1996

表皮剝離したリョクトウ（*Vigna radiata* (L.) Wilczek）個葉のクロロフィル蛍光消光と炭酸ガス交換速度：窪田文武・名田和義・平尾健二・齋藤和幸
キーワード：蛍光消失，炭酸ガス交換速度，表皮剝離，リョクトウ．
Key words : CO_2 exchange rate, Fluorescence quenching, Leaf epidermis peeling, *Vigna radiata*.

Chlorophyll fluorescence quenching and CO_2 exchange rate (**CER**) of mungbean leaf were monitored simultaneously with a partially improved measurement tool, and the effects of abaxial epidermis peeling (stomatal resistance removing) on these two factors were studied at different air temperatures.

Materials and Methods

Leaf disks of 2.5 cm diameter cut out from young expanded leaves of mungbean (var. Chinese) were used. A dark-adapted leaf disk was fixed on the central position within the vessel of a leaf disk electrode unit (LD-2, Hansatech, UK). This tool was partially improved here and used as a CO_2 assimilation chamber. Chlorophyll fluorescence from the photosystem II and CO_2 concentration in the sampled air were monitored simultaneously with a fluorimeter (MFMS-2T, Hansatech, UK) and an infra-red CO_2 gas analyzer (LI-6262, LI-COR, USA), respectively.

The atmospheric air of about 350 μL L^{-1} CO_2 concentration was pumped into the vessel of 2.7 cm^3 at 400 mL min^{-1}. The time required to transport the air from the vessel inlet through silicon tubes and a moisture absorber to the gas analyzer was 1.2 sec.

According to a fluorescence quenching analysis of Schreiber et al.[4], **Fo** (the bottom level of fluorescence yield), **(Fv)m** (the maximal fluorescence yield) and **Fv** (the fluorescence yield in a continuous illumination) were measured. **(Fv)m** was determined here upon giving an 1.5 sec saturating light pulse of 1,080 μmol m^{-2} s^{-1}. For measurement of **Fv** a light of 340 μmol m^{-2} s^{-1} was supplied continuously. During monitoring the transient of **Fv**, fluorescence yield peaks, **(Fv)s**, were determined by giving a light pulse of 1,080 μmol m^{-2} s^{-1} at about 60 sec intervals. As the light source, a light emitting diode of 660 nm was used. From these four parameters, **qE** (energy-quenching) and **qQ** (Q-quenching) were calculated.

Results and Discussion

The post-illumination transient of **CER** of a peeled leaf showed step increases at 30°C (Fig. 1A). It may be thought that the initial rapid increase is due primarily to the absence of stomatal resistance, and the subsequent slow increase depends on gradual light activation of enzymes governing the CO_2 assimilation and on the reduced pool of ribulose 1,5-bisphosphate (RuBP). On the other hand, in control leaves, **CER** was saturated at a relatively low level. This mainly depends on gas exchange restriction.

At 15°C **CER** represented an S-shaped curve with time in both peeled and control leaves. The slow light activation of enzymes related to CO_2 assimilation at the low temperature is likely responsible for the slow initial increase in **CER**.

Knowledge of the mutual relationship between the electron transport state and CO_2 assimilation is essential to the understanding of the photosynthetic utilization efficiency of energy in leaves [1,2,3]. The two components of fluorescence quenching, **qQ** and **qE**, are indicators for the electron transporting state in the photosystem, implying the photochemical quenching and non-photochemical (heat) quenching, respectively.

The initial values of **qE** determined at 30°C showed a rapid increase in both peeled and control leaves (Fig. 1B). In high light intensities the chemical energy produced by the photosystem can usually exceed the amount of

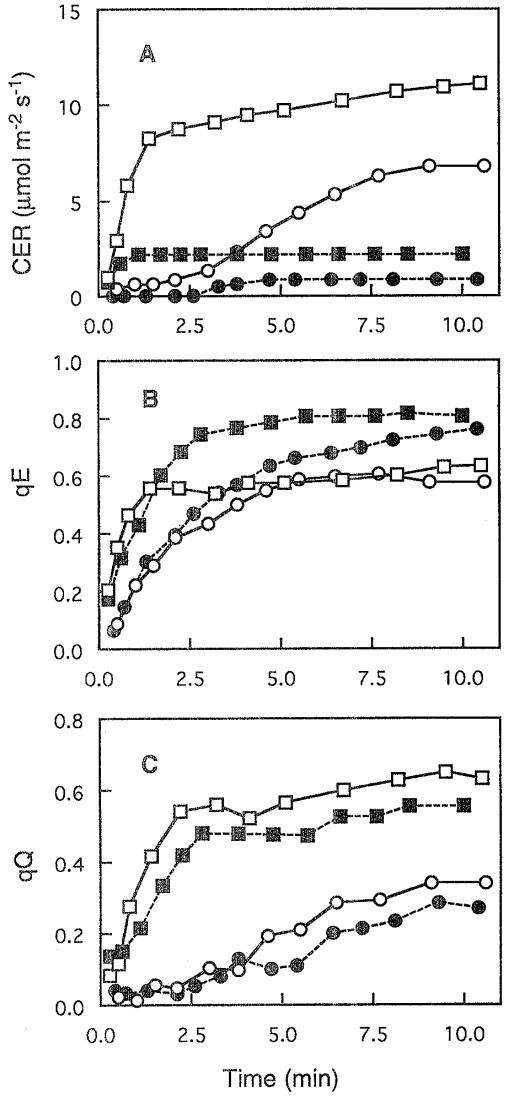

Fig. 1. Time courses of **CER**, **qE** and **qQ** of dark-adapted leaves after the initiation of illumination (340 μmol m^{-2} s^{-1}).
□, Peeled leaf at 30°C; ■, Control at 30°C;
○, Peeled leaf at 15°C; ●, Control at 15°C.

energy used by CO_2 assimilation, thus the unused energy is pooled in the photosysthetic apparatus. This may allow a rise of the ratio of adenosine 5'-triphospate to adenosine 5'-diphosphate in stroma, with a resultant increase in the transthylakoidal proton gradient. This may be regarded as a cause for energy dissipation as heat and the fast increase in **qE**.

The saturating level of qE was high in control leaves and low in peeled leaves, and was almost independent of leaf temperature difference (Fig. 1B). It may be suggested that the former depends on the chemical energy accumulation caused by restriction of the gas exchange ; on the other hand, the latter is due to a quick energy consumption by increased

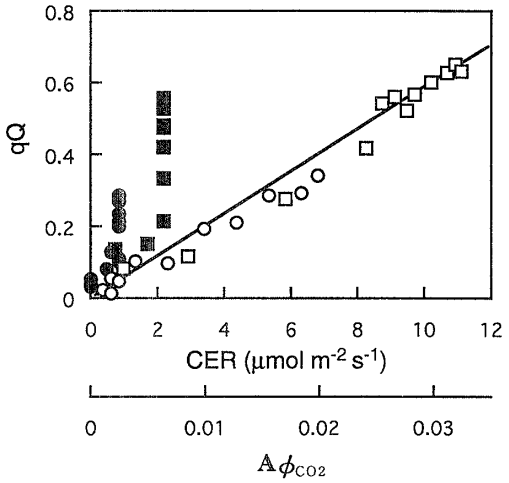

Fig. 2. Relationship between **qQ** and **CER** or $A\phi_{CO2}$. Refer to Fig. 1 for the symbols.

CER.

Time courses of **qQ** were obviously different in pattern with the measurement temperatures (Fig. 1C). A high **qQ** implies the increased energy utilization efficiency for CO_2 assimilation.

Fig. 2 shows the relationship between **qQ** and **CER** or the apparent quantum yield ($A\phi_{CO2}$) of CO_2 assimilation. $A\phi_{CO2}$ was obtained by dividing **CER** values by a light intensity of 340 μmol m^{-2} s^{-1}. **CER** and $A\phi_{CO2}$ of peeled leaves determined at both 15 °C and 30°C increased linearly ($r=0.986$) with increase in **qQ**. This relationship was also assured on 90 point measurements of peeled leaves at 15°C and 30°C (data not shown here). In control leaves such a linear relationship was not detected, **CER** and $A\phi_{CO2}$ being saturated at low levels of **qQ**. The energy partitioning to CO_2 assimilation and photorespiration is regarded as one of the causes for this phenomenon in a C_3 plant such as mungbean.

The system and technique used here can be widely applied for understanding of the mutual relationships between **CER** and the state of photochemical reaction in crop leaves.

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