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Short Report

Distinctive Response of Photosynthetic Rate and Water Use Efficiency in Three Soybean Varieties to Waterlogging and Drought-stress*

Yoshio INOUE, Shinsuke MORINAGA and Michio SHIBAYAMA
(*National Institute of Agro-Environmental Sciences, Tsukuba, Ibaraki 305, Japan*)
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湛水および乾燥条件に対するダイズ3品種の光合成速度と水利用効率の反応に見られた特異性について：
井上吉雄・森永慎介・芝山道郎（農業環境技術研究所）
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Non-optimal soil water status such as drought and waterlogging is one of the most important environmental stress factors in the world. In order to improve corp production through plant managements and breeding, we have to develop a more specific stress indicator as well as to understand the plant response to stress and their potential to acclimatize the stress, especially in the field conditions[4,5] In the present perliminary paper, we report on a distinctive response of photosynthesis and water use efficiency of soybean varieties (*Glycine max* L.) to non-optimal soil water status.

Materials and Methods

Three soybean varieties ; Enrei, Tachinagaha and Harosoy, were grown in nine lysimeter plots (3 m×3 m, 2 m depth). Before flowering stage all nine plots were under rain-fed conditions. Thereafter, all rainwater was shut out by a moving shelter which was automatically controlled with a signal from a rain detector, and three different irrigation treatments were initiated. Three plots containing the three different varieties were irrigated periodically with about 10 mm water every other day. A second group of three plots was kept without any water at all, and the third group waterlogged, during 30 days respectively. The volumetric soil moisture content at 5—10 cm depth in the furrow was determined by sampling every two days. The range of soil moisture contents in non-irrigated and periodically irrigated plots were 29.1—19.6%, and 29.3—14.4%, respectively. Transpiration rates of individual plants were measured with the hand-made stem flow gauges. Photosynthesis (Pn) and transpiration (Tr) for eight individual leaves near the the top of each canopy were obtained with a portable porometer (ADC) during solar noon ±1 hour period. Chlorophyll contents (Chl) of leaves were also measured with a chlorophyll meter (Minolta, SPAD501)

Results and Discussion

Fig. 1 shows the time course change of Pn in each variety and plot. Although such data with the light intensity greater than 900 μmol m^{-2} s^{-1} were used, day-to-day comparison of absolute values should be avoided because Pn is strongly affected by the light intensity. Relative comparison of Pn values in three plots can be useful for inferring the stress response of each varieties.

During the one-month treatment, Pn of Enrei kept lowest in the non-irrigated plot, highest in the irrigated plot, and middle in the waterlogged condition (Fig. 1a). As for Tachinagaha, Pn in both non-irrigated and waterlogged plots were much lower than in the irrigated plot for about two weeks after starting the treatment. Thereafter, however, a remarkable recovery was found in the waterlogged plot, and about 25 days after initiating the treatment Pn values in the plot reached the similar level to those in the periodically irrigated plot (Fig. 1b). On the other hand,

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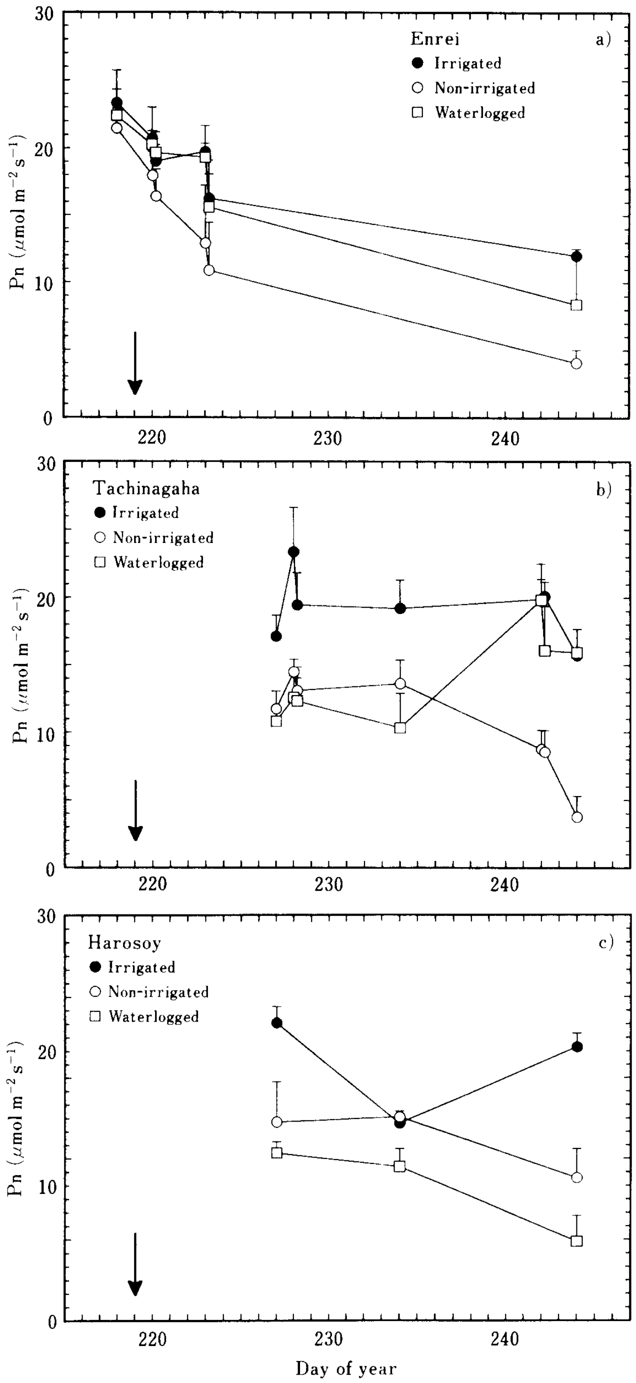

Fig. 1. Time course change of photosynthetic rates measured on leaves near the top of each canopy. Measurements were made during solar noon ±1 hour. Range of PPFD values was from 900 to 2050 μmol m^{-2} s^{-1}. Arrows indicate the initiation of the treatments. Bars indicate one-sided standard deviations.

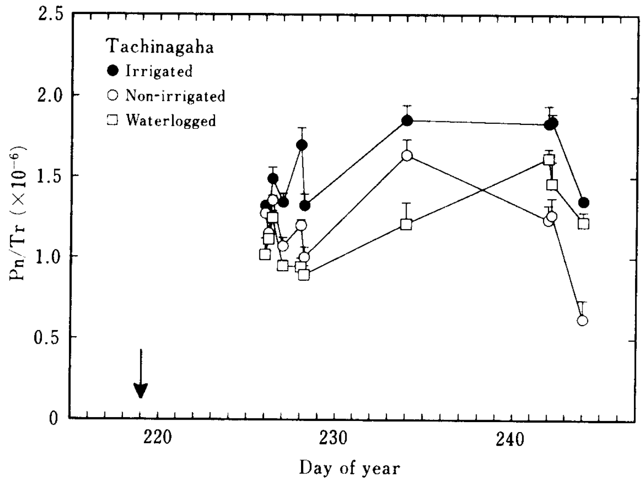

Fig. 2. Time course change of instantaneous water use efficiency (Pn/Tr) for Tachinagaha.

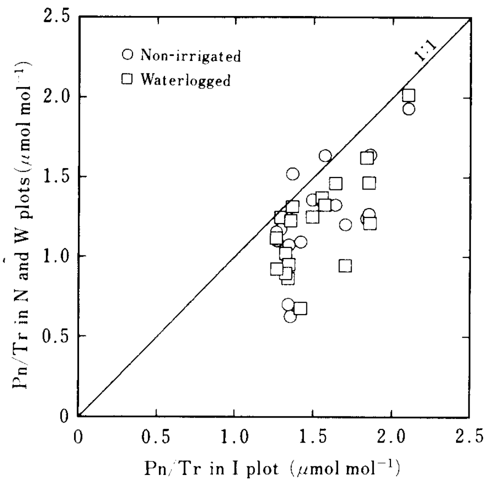

Fig. 3. Water use efficiency of three varieties in non-irrigated and waterlogged plots compared with those in irrigated plots.

the Pn value of Harosoy was consistently lowest in the waterlogged plot (Fig. 1c). After the one-month treatment, subsequently, the lowest Pn values were observed in the non-irrigated (drought) treatment for Enrei and Tachinagaha, and conversely in the waterlogged treatment for Harosoy. Each time course trend was quite distinctive of each variety, and the most noticeable phenomenon was the significant recovery in Tachinagaha under the waterlogged condition. Surprisingly, the section area at the base of a plant stem in that plot was nearly doubled (72 mm^2) in comparison with those in the other two plots (38 mm^2).

A ratio of Pn to Tr (Pn/Tr) can be a useful measure of the water use efficiency on a short term scale[2]. Fig. 2 shows that the time course response of the water use efficiency was quite similar to that of Pn in all treatments and varieties. Results suggest that Tachinagaha in the waterlogged plot may have to transpire more water to keep the same level of Pn after the recovery. In fact, the transpiration rate per individual whole plant calculated from the stem flow rate was much higher in the waterlogged plots than in the irrigated plot while Pn level was similar. Fig. 3 shows all Pn/Tr values for three varieties in the waterlogged and non-irrigated plots in comparison with those in the irrigated plot. The values of water use efficiency in drought-stressed and waterlogged conditions were always lower than those in the irrigated conditions, which was also the case for Pn values. This result suggests that the water use efficiency cannot always be increased even in the early stage of progressive drought.

It has been reported that stomatal conductance is significantly reduced just after the waterlogging remaining the leaf water potential unchanged[1]. In general, the primary effect of waterlogging is the anaerobic environment from which plants cannot obtain oxygen and the rates of water and nutrient absorption are curtailed if flooded conditions continue[3]. In accordance with these previous reports, about six days after starting the treatments, the relative Chl values against the irrigated plot were 78% for Enrei, 68% Tachinagaha, and 77% Harosoy in waterlogged plots, in contrast to the values in the non-irrigated plots; 86% for Enrei, 102% Tachinagaha, and 100% Hrosoy. However, after the one-month treatments, relative Chl values were 85% for Tachinagaha and 76% for Harosoy in the waterlogged plots, and 92% for Tachinagaha and 101% for Harosoy in the non-irrigated plots. These responses of the Chl values also well coincided with the distinctive response of Pn in each variety to waterlogging and drought-stress. Further investigation is required to understand the long-term stress response of these distinctive varieties to limited and excess water stresses for improving crop genotypes and management practices

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