Relationship between Transpiration Rate and Soil Water Content as a Tool of Estimation of Biomass Production: a Case Study in Rice

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Rice often suffers severe soil desiccation in rain fed area of South or South East Asia (O'Toole, 1982). Because water is one of the dominant limiting factors for rice yield in these areas, estimation of reduction in the biomass and grain yield under desiccated soil conditions is essential to simulate and estimate rice yield. The estimation will become furthermore to be important if rainfall instability will increase by warming climate in the future.

Dry-matter production (DMP) in crop plants is severely suppressed by soil desiccation. Many physiological factors including leaf water deficit, leaf death, stomatal closure and chemical signal derived from root system *et al.* are consider to result in reduction of the DMP (Turner, 1997). The DMP for one time interval is indicated by

$$DMP=WUE\times T/VD \quad (1)$$

where WUE is water use efficiency, T transpiration and VD vapor deficit (Tanner and Sinclair, 1983). The DMP hence may change with WUE and/or T/VD. In several rice cultivars the WUE scarcely changed with soil desiccation and was similar among cultivars but the T/VD was severely suppressed by soil desiccation (Kobata et al. 1996). There was clear cultivar difference in the T/VD under desiccated soils and the difference was resulted from that of root distribution in deep wet soil layers. The trends of the T/VD hence may highly reflect response of the DMP to desiccated soils.

Empirically there is a close curve liner relationship between normalized transpiration rate ($T_{D/I}$) and fraction of transpirable soil water (FTSW) in soybean and corn, where the $T_{D/I}$ is ratio of transpiration rate under desiccated soil to under well-irrigated condition, and the FTSW is ratio of soil water to transpirable soil water (Ray and Sinclair, 1998). Although transpiration rate is suppressed by close of stomata and reduction of leaf area caused by decrease of leaf water potential and/or hormonal signal derived from root system (Davis and Zhang 1991), the $T_{D/I}$ was indicated by an equation having a variance of FTSW. It is, however, unknown whether there is a simple relationship between $T_{D/I}$ and FTSW in diverse rice cultivars under desiccated soil conditions.

I am to clear whether the $T_{D/I}$ can be defined by an equation of FTSW and the WUE is stable for several rice cultivars having wide background under water deficit conditions in pot grown plants.

Materials and Methods

Plant Materials

Seeds of ten rice cultivars having diverse hereditary backgrounds were sown at 6 June 2001 in seedling box containing rice seedling soil and grown for three weeks in glasshouse. Two seedlings were transplanted in an 8 liter pot at 5 July 2001. The pot was filled by rice seedling soil (Andosol). 0.5 g of compound fertilizer including 14% of N, 17% of P and 13% of K was applied at the transplanting and flooded water was maintained.

Soil Desiccation Treatments

At 1 August 2001 irrigation was stopped for four pots of each cultivar while another four pots was irrigated as irrigated control under glasshouse. Pot surface was covered with a styrofoam plate and tape to protect soil evaporation. One plant was harvested from all pot, dried in 80 ℃ oven for 48 h and weigh. Pot weight was measured with electric balance every day afternoon to transpiration rate per day for three or four weeks. When transpiration rate decreases below 10 % of the irrigated control, the remained plant was harvested, dried in 80℃ oven for 48 h and weigh.

The $T_{D/I}$ for every day was calculated from ratio of transpiration rate for desiccated treatment to irrigated control. The FTSW was estimated from the following equation.

$$FTSW=(AFTSW-\Sigma Tn)/AFTSW \quad (1)$$

Where Tn is transpiration rate of day n after the start of withholding water and $AFTSW = SWC_0 - SWC_{lim}$. The SWC_0 was decided after flooded water was drained and remained for several hours and the SWC_{lim} is unavailable soil water for plants at −1.5MPa from data the relationship between soil water content and soil water potential for same soils (Andho and Kobata 2000). Air temperature and humidity were measured with a data logger to calculate vapor deficit (VD).

The WUE was calculated from the equation.

$$WUE=(DW_n - DW_0)/(\Sigma Tn/VD) \quad (2)$$

Where DW is dry matter at the end (n) and the start (0) day of withholding water and the Σ Tn accumulated transpiration.

Results and Discussion

Flooded water remained for one week or more after withholding irrigation in all pots (FTSW>1.0). The FTSW started to decrease from one week after withholding irrigation and attained at most below 0.5 during three or four weeks. The $T_{D/I}$ in some cultivar indicated near 1.0 under the flooded condition (over 1.0 of FTSW) but in another cultivar was lower than 1.0 (Fig. 1). It might be that plant size differed between control group and soil desiccated group at the start of desiccated soil treatment. To delete

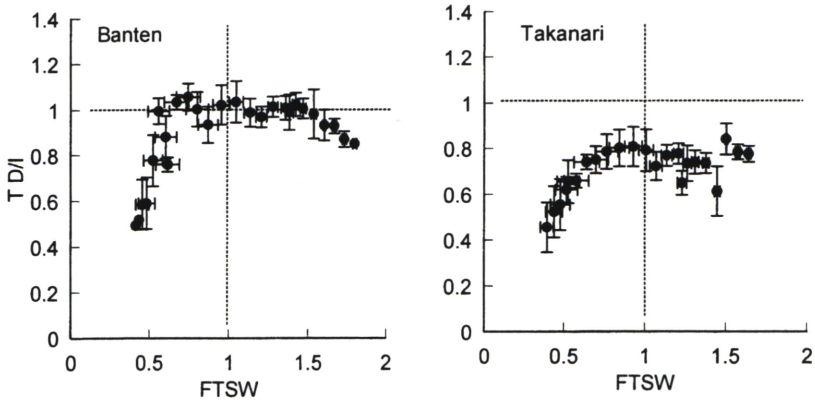

Fig. 1. Relationship between normalized transpiration rate ($T_{D/I}$) and fraction of transpirable soil water (FTSW) in two rice cultivars (Banten and Takanari)

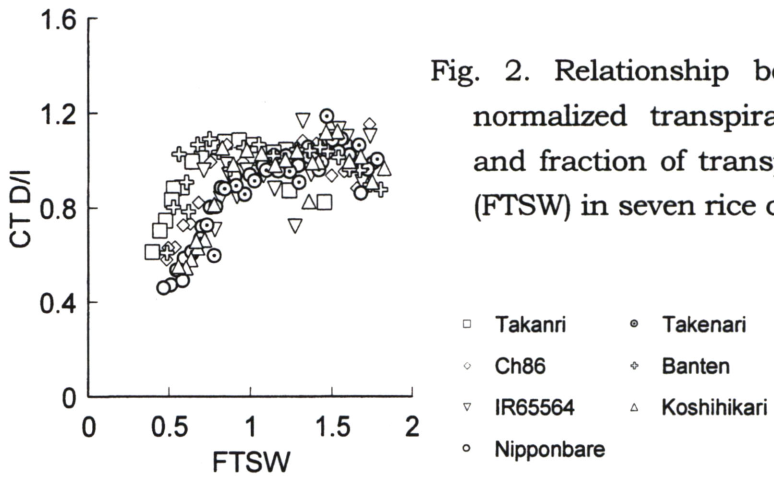

Fig. 2. Relationship between corrected normalized transpiration rate ($CT_{D/I}$) and fraction of transpirable soil water (FTSW) in seven rice cultivars

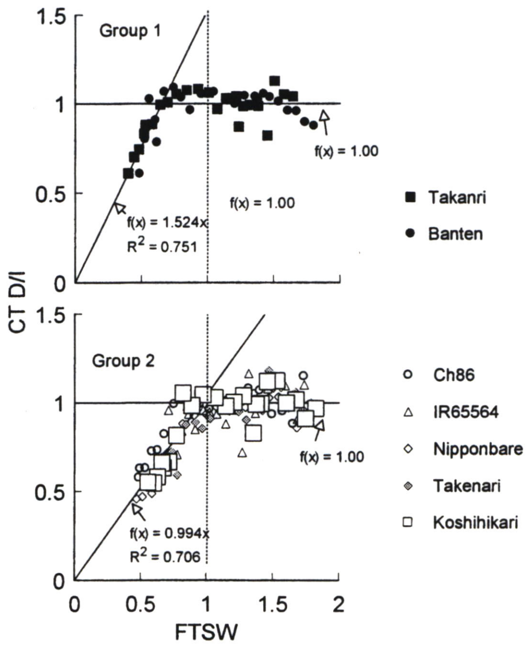

Fig. 3. Two groups of the relationship between $CT_{D/I}$ and FTSW

Table 1. Water use efficiency of seven rice cultivars under irrigated and soil desiccated conditions.

	Irrigated		Desiccated		Ratio
		($\times 10^{-2}$ g^{-1} m^{-3})			(D/I)
Takanari	2.43 ±	0.13	2.08 ±	0.06 ns	0.86
Ch86	1.75 ±	0.74	1.73 ±	0.71 ns	0.99
IR65564	1.99 ±	0.31	1.74 ±	0.43 ns	0.87
Nipponbare	2.37 ±	0.23	3.36 ±	0.08 *	1.42
Takenari	2.00 ±	0.03	2.89 ±	0.28 ns	1.44
Banten	1.99 ±	0.41	2.48 ±	0.21 ns	1.24
Koshihikari	2.40 ±	0.17	2.86 ±	0.50 ns	1.20
mean	2.13 ±	0.26	2.45 ±	0.63	1.15

Note 1. Each value is the mean ±se for 3-4 observations.
Note 2. Same letter in each cultivar does not significantly differ at 5% level.

effects of the difference on the $T_{D/I}$, the corrected $T_{D/I}$ ($CT_{D/I}$) was calculated from average of the $T_{D/I}$ during flooded conditions ($T_{D/I\text{-flood}}$).

$$CT_{D/I} = T_{D/I} \ / \ T_{D/I\text{-flood}} \quad (3)$$

When all data of the $CT_{D/I}$ were combined in one graph, while the data of some cultivars was deleted because of large variance, trends of $CT_{D/I}$ was divided into two group (Fig. 2). In one group the $CT_{D/I}$ suddenly decreased with reduction of the FTSW after the FTSW decreased less than 1.0. In another group even if the FTSW decreased less than 1.0, the FTSW was maintained near 1.0 and then decreased with reduction of the FTSW. It is not clear why there was a difference between cultivar groups in response of $CT_{D/I}$ to the FTSW and whether the differences was stable. Furthermore the cultivar differences should be investigated by several year trials.

The WUE during whole treatment periods was calculated for irrigated control and desiccated treatment plants (Table 1). The WUE in most of cultivars increased by soil desiccation but it in some cultivars decreased while significant difference was scarcely observed between control and soil desiccated treatment plant. Average in change of WUE by soil desiccated treatment was at most 1.1 and hence the change seemed to be small as the past results in rice (Kobata et al. 1996).

For typical cultivars in the responses of the $CT_{D/I}$ to FTSW stability of the relationship and equation should be investigated.

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