日本稲およびインド稲の水分消費について

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Water Consumptions in Japonica and Indica Rice Varieties*

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Water requirement is a characteristic of the efficiency of water utilization in crop plant. There have been several investigations[1,3,4,6,8,9] on the water requirement of rice plant. Few reports, however, have been published concerning differences of the water requirement among rice varieties. Present paper therefore investigates differences of characteristics of water metabolism among rice varieties, especially differences between Japonica, Indica and semidwarf Indica.

Materials and Methods

Experiment 1. Varietal differences in water consumption.

Water consumption of rice varieties was determined by lysimeter method[2] over a period of tillering to maturing stage in relation to top dry weight at harvest. Experiment was repeatedly conducted in 1982 and 1983.

Paddy field soil was placed in lysimeters ($120 \times 100 \times 90$ cm) into which water was flooded up to fixed level through a period of experiment by an auto-irrigating device constructed with a waterlevel sensor and an electromagnet-driven valve. The amount of supplied water was integrated by a water flow meter with which every lysimeter was equipped. The lysimeters were maintained rainfall-free by an automatic electromotor-driven roof which was removed on the occasion of no rainfall.

Table 1 shows varieties used in the experiment. In 1982 experiment, nine, eight and six varieties of Japonica, semidwarf Indica (including a Japonica-Indica hybrid) and Indica were used, respectively. In 1983 experiment, five, nine and six varieties of Japonica, semidwarf Indica (including three Japonica-Indica hybrids) and Indica were used, respectively. They were selected on the basis of about the same heading date in Yatabe, Ibaraki. The seeds were sown early in May in "Kabumaki pot" which was a plastic tray with square compartments of 16 mm. Twenty-seven seedlings of each variety at fifth or sixth leaf stage were transplanted to each one of the lysimeters with a seedling every hill early in June. Every lysimeter was basally fertilized with 8 g/m^2 of nitrogen, phosphate and potash, respectively, and topdressed with 1 g/m^2 of nitrogen late in July.

Determination of water consumption was begun early in July and ended late in September. The amount of water consumed through the experiment by rice plants was obtained by subtracting the integrated amount of water supplied to nonplanted plot in the lysimeters from that of planted one. At maturing stage, top of the rice plants in each lysimeter was collected, and separated into leaf blade, leaf sheath and culm, and panicle to determine the dry weight of each part.

Experiment 2. Varietal differences in water requirement.

Water requirement of rice varieties was measured in 1983 by water culture method in the same facility of moving roof used in Experiment 1. Two Japonica varieties (Nipponbare and Reihou) and two Indica varieties (Ginnen and Boro I) were used. Three seedlings of every variety grown as in Experiment 1 were transplanted to a 3 liter volume plastic pot filled with culture solution. Nutrients in the solution were N

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(NH_4NO_3) 20 ppm, P_2O_5 (KH_2PO_4) 10 ppm, K_2O (KCl) 25 ppm, MgO ($MgSO_4$) 20 ppm, FeO (Fe-citrate) 5 ppm and SiO_2 (Na_2SiO_3) 20 ppm. The culture solution was prepared with tap water by adjusting its pH with 5N H_2SO_4 to 5.0–5.5. Seedlings were placed in plastic baskets and fixed with cleaned gravels, and then the baskets were placed on the pots.

Water consumption was measured over a fourteen-day period at tillering and booting stages. Evaporation from culture solution was minimized by placing the baskets above the surface of culture solution. Total dry weight of plant materials was determined to obtain dry matter increase during the experimental period at the beginning and the end of the experiment.

Experiment 3. Varietal differences in diffusive resistance of leaf blade.

Diffusive resistance of rice leaves of the same experimental materials used in Experiment 1 was measured by porometer method[2]. Diffusive resistance of adaxial surface of leaf blade on main culm was determined with Steady State Porometer (LI-COR, LI-1600) on clear days at tillering and booting stages.

Results

Table 2 shows meteorological data during the experiments. Temperature and minimum humidity at the period of Experiment 2 and 3 were about the same value as those of August of Experiment 1. Since measurements of diffusive resistance in Experiment 3 were made on clear days, solar radiation in Experiment 3 was larger than those in Experiment 1 and 2 which were expressed by mean values over a period of two weeks or a month. In Experiment 1 and 2, however, there were several days in which the intensity of solar radiation was about the same as that in Experiment 3.

Experiment 1. Varietal differeces in water consumption.

Table 3 shows that the straw weight of Indica was remarkably large as compared with the other two ecotypes, although that of semidwarf Indica was smallest among the three ones. The weight of panicle produced by semidwarf Indica was larger than that of Japonica or Indica. Finally, total top dry weights of Indica, semidwarf Indica and Japonica were large, intermediate and small, respectively. The amount of water consumed by Indica was obviously larger than that consumed by Japonica or semidwarf Indica. Comparing Japonica with semidwarf Indica,

Table 1. Varieties used in the experiment.

Variety	1982	1983
Japonica		
Manryou (マンリョウ)	○	○
Nipponbare (日本晴)	○	○
Reihou (レイホウ)	○	○
Mangetsu Mochi (マンゲツモチ)	○	
Kusabue (クサブエ)	○	○
Tsukushibare (ツクシバレ)	○	
Kochihibiki (コチヒビキ)	○	○
Wakagoma (ワカゴマ)	○	
Harukaze (ハルカゼ)	○	
Indica, semidwarf		
Dee-geo-woo-gen (低脚烏尖)	○	○
Chen Chu Ai (珍珠矮)	○	
Nan Jing 11 (南京 11 号)	○	○
Waikyaku Nantoku (矮脚南特)	○	○
RP 9-3	○	○
BG 34-8	○	○
Bae-md-3-3	○	○
Tongil* (統一)		○
Milyang 23* (密陽 23 号)	○	○
Suweon 258* (水原 258 号)		○
Indica		
Fortana I-133	○	○
Choukoutou (長香稲)	○	○
Kairyou Toukanpaku (改良東莞白)	○	○
Ginnen (銀粘)	○	○
Boro I	○	○
Kannonsen (観音杣)	○	○

Note. * : Japonica-Indica hybrid variety.

Table 2. Weather conditions at the experiments.

No. of Exp.	Period	Temperature			Humidity Min.	Solar radiation
		Max.	Min.	Mean		
		°C	°C	°C	%	cal/cm²/day
Exp. 1	1982 July	24.8	18.0	20.9	61.2	310.7
	Aug.	29.2	22.0	25.0	58.2	362.7
	Sept.	23.1	17.2	20.2	57.9	263.6
	1983 July	25.6	18.5	21.5	61.5	303.6
	Aug.	29.4	22.0	25.1	57.3	357.3
	Sept.	24.5	18.2	20.9	59.3	251.2
Exp. 2	Tillering stage (July 25-Aug. 7)	30.7	21.7	25.5	53.6	421.1
	Booting stage (Aug. 8-21)	30.2	22.8	25.8	56.5	360.1
Exp. 3	1982 Aug. 9	29.7	22.3	25.0	48.0	462.0
	Aug. 19	30.4	21.5	25.1	55.0	456.0
	1983 Aug. 9	31.5	22.1	26.2	52.0	514.0

Table 3. Varietal differences in water consumption and top dry weight at maturing stage.

No. of variety		Dry wt. of straw (S)	Dry wt. of panicles (P)	Total top dry wt. (T)	Water consumption (W)	W/S	W/P	W/T
		g/plot	g/plot	g/plot	l/plot	l/kg	l/kg	l/kg
1982								
Japonica	9	472±38	527±56	999±88	139±19	294±29	263±27	138±13
Indica, semidwarf	8	414±45*	638±50**	1052±89	161±30	390±72**	251±38	153±25
Indica	6	563±76**	561±106	1123±147	210±37**	379±79**	377±38**	187±25**
1983								
Japonica	5	800±77	592±36	1392±103	248±19	312±42	419±44	179±21
Indica, semidwarf	9	715±77	867±95**	1582±149*	303±50*	427±82*	349±42*	191±28
Indica	6	951±109*	691±152	1643±201*	410±64**	435±86*	606±86**	250±32**

Notes. Name of varieties used in the experiment are the same as those shown in Table 1.

Water consumption was determined by the difference of the amounts of supplied water to planted and nonplanted plots.

Semidwarf Indica includes Japonica-Indica hybrid varieties.

*, ** Significant at the 5%, 1% level between Japonica and others, respectively.

the former consumed a smaller quantity of water than the latter, though not significant in the experiment of 1982.

The amount of water consumed per unit straw weight was, in consequence, significantly large in Indica and semidwarf one as compared with Japonica. The water consumption per unit panicle weight was observed larger only in Indica than in Japonica, whereas in semidwarf Indica the

Table 4. Varietal differences in water requirement.

	Variety	Tillering stage			Booting stage		
		Dry matter increase	Water consumption	Water requirement	Dry matter increase	Water consumption	Water requirement
		g/pot	l/pot	ml/g	g/pot	l/pot	ml/g
Japonica	Nipponbare	13.8	4.78	345	22.9	9.50	415
	Reihou	14.0	4.63	332	19.2	8.33	433
Indica	Ginnen	14.3	5.99	420	20.7	11.67	564
	Boro I	13.3	5.81	436	21.0	11.33	540

Note. Dry matter increase and water consumption were measured over a 14-day period.

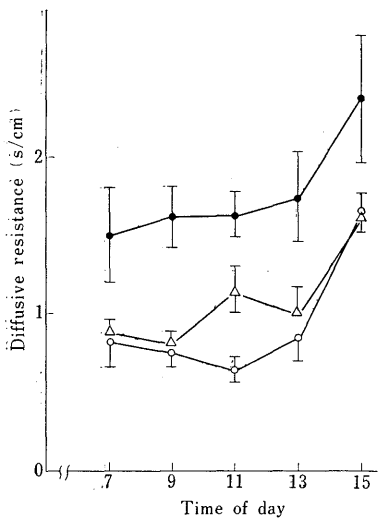

Fig. 1. Diurnal changes in diffusive resistance of leaf blade of rice plant on 19, August, 1982.
Notes. ●: Nipponbare (Japonica), △: Dee-geo-woo-gen (Indica, semidwarf), ○: Ginnen (Indica).
Each vertical line indicates the standard deviation.

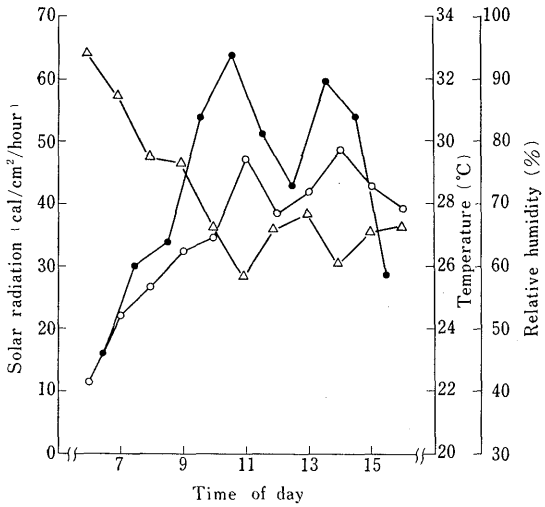

Fig. 2. Diurnal changes in solar radiation, temperature and relative humidity on 19, August, 1982.
Note. ●: solar radiation, ○: temperature, △: relative humidity.

amount of consumed water per unit panicle weight was smaller than in Japonica in 1983, but not significant in 1982. After all, Indica, semidwarf one and Japonica were large, intermediate and small, respectively, in the amount of water consumed per unit total top dry weight.

Experiment 2. Varietal differences in water requirement.

Dry matter increase of Indica was about equal to that of Japonica both at tillering stage and booting one, whereas Indica consumed obviously larger amount of water than Japonica (Table 4). Water requirement was consequently larger in Indica than in Japonica by 26% and 30% at tillering stage and booting one, respectively.

Experiment 3. Varietal differences in diffusive resistance of leaf blade.

Fig. 1 shows diurnal changes in diffusive resistance of leaf blade of three varieties, Nipponbare (Japonica), Ginnen (Indica) and Dee-geo-woo-gen (semidwarf Indica). Fig. 2 shows diurnal changes in solar radiation, temperature and relative humidity. The diffusive resistance showed similar diurnal changes among the three varieties used. It was low in the morning, remained almost the

Table 5. Varietal differences in diffusive resistance of rice leaves.

	No. of variety	Range of diffusive resistance (s/cm)										Mean
		0.4 ~ 0.6	0.6 ~ 0.8	0.8 ~ 1.0	1.0 ~ 1.2	1.2 ~ 1.4	1.4 ~ 1.6	1.6 ~ 1.8	1.8 ~ 2.0	2.0 ~ 2.2	2.2 ~ 2.4	
1982												
Japonica	9					4	1	1	1		2	1.61
Indica, semidwarf	8	2	3	3								0.72
Indica	6		2	3	1							0.88
1983												
Japonica	5							3	1	1		1.80
Indica, semidwarf	9		6	2		1						0.83
Indica	6		1	2	2	1						0.96

Notes. Numerals in the table are the numbers of variety.
Measurements of diffusive resistance were made on 9, August, 1982 and 1983.

same level till noon, and increased rapidly in the afternoon. The diffusive resistance of Ginnen and Dee-geo-woo-gen was significantly low at every time of day as compared with Nipponbare.

Varietal differences in diffusive resistance which was measured from 9 to 11 a.m. on the 23 varieties in 1982 and 20 ones in 1983 are shown in Table 5. Diffusive resistance of Japonica was about twice as high as those of Indica and semidwarf one, although very slight difference was observed between Indica and semidwarf one.

Discussion

SUGIMOTO[7,8] reported that transpiration rate per unit leaf area and water requirement of Indica were larger than those of Japonica, and suggested that the efficiency of water utilization in Indica was inferior to that of Japonica. However, there seems to be a room for further investigation in the SUGIMOTO's paper, because only five varieties were used and dry weight of root was neglected in his investigation. In the present paper, the water consumption of more than 20 varieties was repeatedly determined twice along with the top dry weight of them. Subsequently, the water comsumption and dry matter increase in whole plant of four varieties were determined with accuracy to obtain the varietal differences in water requirement. Present results corroborate that Indica is, in comparison with Japonica, characterized by large water requirement as well as water consumption in large quantity.

The present results also showed that the difference in water requirement observed between Japonica and Indica was mainly not the difference in dry matter increase but the one in water consumption. The results suggest that there is difference in transpiration rate between Japonica and Indica. Further investigations in the present paper showed that Indica and semidwarf one as compared with Japonica were conspicuously low in the diffusive resistance of leaf blade and high in the transpiration rate per unit leaf area.

KISHITANI and TSUNODA[5] reported that the transpiration rate of Indica varieties, which was measured by chamber method, was higher than that of Japonica, especially under high temperature condition. SUGIMOTO[7] also reported that the transpiration rate per unit leaf area of Indica, which was estimated by water balance method, was higher than that of Japonica. Present results corroborated them by determining the diffusive resistannce of leaf blade with porometer among rice varieties. It is therefore suggested that the difference in water requirement between Japonica and Indica is ascribed to the difference of transpiration rate per unit leaf area.

SUGIMOTO[7] reported that no difference was found in the diurnal changes of stomatal

aperture between Japonica and Indica, and suggested that the difference in the transpiration rate was attributed to a stomatal length, a stomatal frequency or a stomatal resistance. Again, KISHITANI and TSUNODA[5] reported that the photosynthetic rate of Indica was almost the same as that of Japonica, whereas the transpiration rate of the former was higher than that of the latter. It is therefore a question whether the difference in water requirement between Japonica and Indica is due to a possible difference in the ratio of transpiration rate to photosynthetic one. If it is true, a further quention arises what are the factors to cause the differences in the ratio of transpiration rate to photosynthetic one between Japonica and Indica.

Summary

Studies were undertaken to clarify the characteritics of water consumption in Japonica and Indica rice varieties.

Integrated amount of water consumed per unit top dry weight at maturing stage, which were measured by lysimeter method on 20 to 23 varieties, were observed different among Indica, semidwarf Indica and Japonica. In order of quantity of consumed water, Indica, semidwarf one and Japonica were large, intermediate and small, respectively.

Water consumption and dry matter increase in whole plant were determined twice by water culture method over a two-week period at tillering and booting stages, in order to obtain water requirement. Water requirement of Indica was obviously larger than that of Japonica. The difference in water requirement betwwen two ecotypes was mainly attributed to the difference in water consumption.

Varietal differences in diffusive resistance of leaf blade were determined by porometer method on the varieties used in the aforementioned experiment to determine water consumption by lysimeter. Diffusive resistance of Indica and semidwarf one was about one half of that of Japonica, and consequently transpiration rate of the former two ecotypes were larger than the latter one.

Obtained results suggested that there are possible differences in physiological and morphological mechanisms of water metabolism between Japonica and Indica.

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* In Japanese with English summary.
** In Japanese.

〔和 文 摘 要〕

日本稲およびインド稲の水分消費について

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日本稲，インド稲およびインド稲半矮性二十数品種を供試し，ライシメーター法によって収穫期乾物重に対する分げつ期から収穫期までの積算水消費量を検討した．地上部乾物重当たりの水消費量には明らかな品種間差異が認められ，インド稲，インド稲半矮性，日本稲の順に小さくなった（Table 3）．

次に，日本稲およびインド稲4品種を選び，ポット水耕法により分げつ期と穂ばらみ期に2週間の乾物増加量と水消費量を測定し，要水量を算出した．インド稲の要水量は日本稲と比較して明らかに大きく，その差異は水消費量に起因していた（Table 4）．

上記の結果を確認するため，ポロメーター法により葉身の蒸散抵抗の品種間差異を検討した．インド稲，インド稲半矮性の蒸散抵抗は日本稲の約半分であり，単位葉面積当り蒸散速度が高いことが確認された（Fig. 1, Table 5）．

以上の結果は，日本稲とインド稲が水分代謝の上で生理的または形態的に異なる機構を有することを示唆するものである。