Studies on Water-Consumption of Indica and Japonica Rices

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Introduction

It is well known that evapo-transpiration is the sum total of the influences of the climatic factors, while percolation is a soil factor. Evapo-transpiration is, at the same time, a varietal character and an understanding of it could be of help in breeding for the varieties that use water with greater efficiency. Age is the main factor determining the total transpiration of a variety, while, between the broad Indica and Japonica varieties there may be a considerable difference in their daily water-consumption-rates, namely, the possible achievement of water-saving through combining the daily consumption-factor and the age-factor. This idea, at the present stage, may only be a sort of speculation, but its realization is supposed to be very likely.

The aim of this study is to assess both the difference in transpiration-rates of the three varieties in the greenhouse condition and the role of evapo-transpiration in determining irrigation water requirement in the field. No pretension is made that this aim has been fully accomplished. This study is only preliminary, and more detailed investigations are required to decide exactly which variety or plant type is best suited for water economy. These experiments were conducted in Kagoshima, southern Kyushu of Japan.

Materials and Method

Experiment 1. Pot trials were conducted in the greenhouse from June to October, 1971. The surface area of pot used was 1/5000 are. Three varieties used were as follows: (1) H4 from Ceylon, Indica, long culm type. (2) IR8 released by IRRI, Indica, short culm and panicle number type. (3) Tachikara grown in southern parts of Japan, Japonica, short culm and panicle number type.

Seeds were sown in seedling box on June 7, transplanting to pots being done on June 28. Each variety had 14 pots and each pot contained one hill at two plants per hill. Two pots from each variety were placed each on a weighing balance. A separate pot filled with soil as the other ones but not planted, was kept on a balance to measure free-water-surface evaporation. In all pots, the standing water of about 4 centimeters deep was maintained. As basal fertilizer, ammonium sulphate-2 grams, potash muriate-1 gram, and calcium superphosphate-2. 4 grams were given to each

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pot. 35 days after transplanting ammonium sulphate–1 gram per pot was top dressed.

Evapo-transpiration and evaporation per pot per day were calculated from these weights. Hourly solar radiation was recorded by automatic integurator kept in the greenhouse. Plant height, tillering rate and leaf-emergence rate were recorded weekly. Samples were taken from the three varietal populations at regular intervals to obtain leaf area and dry weight.

Experiment 2. Field experiments were conducted using the same varieties as in experiment 1. Three plots, $8m^2$ each, were transplanted with the three varieties at aspacing of 25 x 30 centimeters with three seedlings per hill, at the same time as in Experiment 1. In each plot two pots filled with soil were burried at convenient positions at the row. The diameter of the surface and the depth of the pot were 20 cm and 60 cm, respectively. These pots were also planted with a hill each. A third pot, of the same dimension and filled with soil to the same depth as the other two, was burried in between the two rows for the measurement of evaporation from the field. As basal fertilizer, ammonium sulphate–200 grams, potash muriate–100 grams, and calcium superphosphate–240 grams were given to each plot. 35 days after transplanting, ammonium sulphate–100 grams per plot was top dressed.

Evapo-transpiration and field evaporation were measured by a simple self-designed device made of an inverted funnel-shaped glass tube about 5 cm in diameter with a narrow tube 60 cm long, graduated in mm. A pointer fixed on a plastic float is placed inside the narrow tube. This device is burried into the soil at a reasonable depth. When water enters the perforated funnel, the float rises along with the water level. The pointer moves in accordance with the water level and the difference due to evapo-transpiration over a definite period can be recorded. Readings in the field were taken only on the days favoured by weather.

Results and Discussion

Some Observations on Growth Characters

The three varieties come from three different sources. There are noteworthy differences and similarities in their plant types and growth characters.

From a casual observation of the three, one could figure out IR8 as a variety possessing Japonica-like as well as Indica-like characters. It was the shortest of the three showing a maximum height of 80.0 cm and 71.0 cm in the greenhouse and field, respectively, while the corresponding values for H4 were 115.0 and 121.0 and that of Tachikara, 90.0 and 90.0. The leaves of IR8 under well fertilized conditions are dark green, erect and short as well as of the Japonica type.

In the greenhouse, the maximum tiller numbers per pot of H4, IR8 and Tachikara were 30, 31 and 36, respectively; the number of bearing tillers in IR8 was 28, Tachikara being 26, H4 not heading in the greenhouse. Heading dates of Tachikara and IR8 were 70 days and 76 days after transplanting, respectively. Under field conditions, both IR8 and Tachikara had the maximum tiller number of 32 per hill while H4 had 29 per hill, the number of bearing tillers per pot of H4, IR8 and Tachikara being 16, 21 and 25, respectively. Heading dates of H4, IR8 and Tachikara were 90, 76 and 68 days after transplanting, respectively. H4 had an extended vegetative phase and headed later in the field, but the grains were perfectly filled with normal standards, at harvest.

Differences also existed in leaf longevity. Tachikara had the greatest longevity of all, while

IR8, the shortest. H4 was closer to Tachikara in this respect. These observations were made in the greenhouse. Owing to mutual shading leaf longevity may be different in the field. According to TANAKA *et al.* (7) lower leaves die faster because of mutual shading. On this basis, the leaves of H4 should have the least longevity as the mutual shading is highest. From the observations made in the greenhouse, it may be affirmed that mutual shading is not the only factor that determines leaf longevity. Leaf longevity may be in itself a varietal character which is also influenced by mutual shading. Plant height, leaf length and leaf arrangement are the main factors, along with leaf area, in determining the extent of mutual shading. As may be referred to later, the japonical plant type makes it possible for the leaves to receive maximum sunlight, yet, under these conditions, it still maintains a relatively lower transpiration rate. This perhaps is due to a balanced vegetative growth.

The amount of root produced is an indication of the degree of absorption just as much as the amount of shoot produced is an indication of the degree of transpiration. The amount of top and root produced as determined at different stages were nearly the same in the case of H4 and IR8. H4 and IR8 always maintained a higher rate of increase in root weight than Tachikara. It seems that their higher rates of transpiration necessitated larger quantities of roots to maintain correspondingly higher rates of absorption. The magnitude of vegetative growth of Tachikara was lower but it had a high top root ratio. Around noon in the greenhouse the leaves of H4 displayed signs of temporary wilting in days when light intensity was high. This perhaps was an indication that the lag between transpiration and absorption was more pronounced in the case of H4.

The relation between evaporation, evapo-transpiration and radiation in the greenhouse

Transpiration and evaporation are influenced by radiation, temperature, saturation deficit and wind. It would be preferable to take solar radiation as a fundamental climatic factor instead of air temperature (D. A. de VRIES, 10).

The three varieties H4, IR8 and Tachikara in the greenhouse from 27th June to 28th Aug. showed a high correlation of transpiration with radiation, *viz.*, 0. 90** ($Y = 2.12X+91.4$), 0. 90** ($Y = 1.97X+54.7$) and 0. 92** ($Y = 1.80X+14.5$), respectively. Fig. 1 shows that the trends of transpiration and free-water-surface evaporation for a season were similar, because both these processes were similarly affected by environmental factors. However, the relation of evaporation to transpiration is to be considered as associative and not causative, both responding to the same environmental factors but not precisely in the same way or to the same degree (BRIGGS and SHANTZ,1).

In Fig. 1, the highest of the five peaks, obtained in transpiration of the three varieties, occurred when radiation was highest. On the 15th and 16th of August the maximum transpiration per day took place, reaching the peak; exactly on the 16th the radiation per day was 380 cals/cm^2, which was the highest value recorded over the period of the experiment. This coincidentally fell around the maximum number of tiller stage of the three varieties.

High values of correlation coefficient between radiation and transpiration were obtained by BRIGGS and SHANTZ (1) in their experiment on transpiration of different crops. G. D. THOMPSON (9) working with sugar cane on evapo-transpiration obtained a value of 0. 95 for the coefficient of correlation between the measured evapo-transpiration and the calculated net radiation. As mentioned elsewhere in this paper the pot plants in the greenhouse received radiant energy from the

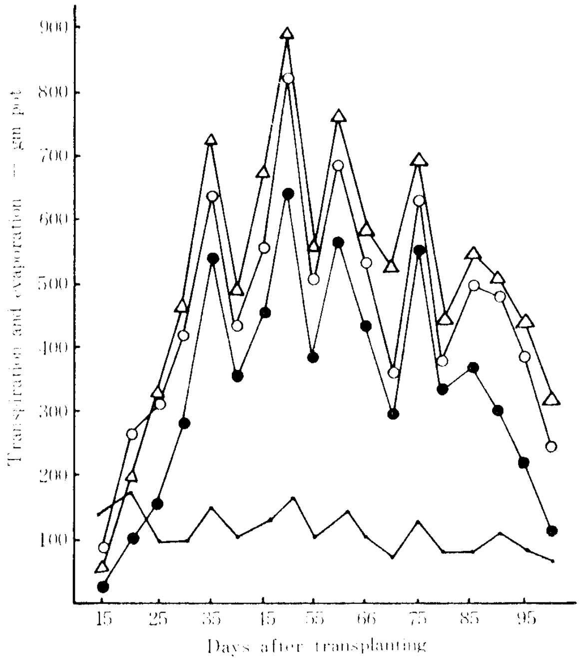

Fig. 1. Daily transpiration and evaporation in the greenhouse (5 day means)
△—△ H4 ○—○ IR8
●—● Tachikara —— Evaporation

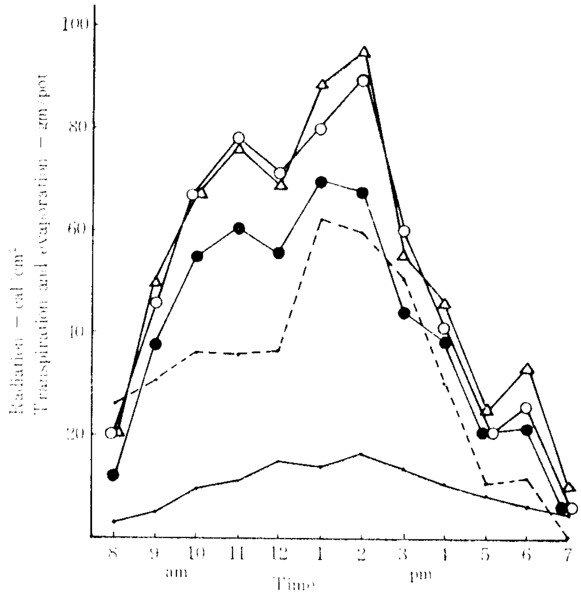

Fig. 3. Hourly transpiration, evaporation and radiation at 65 days after transplanting in the greenhouse
△—△ H4 ○—○ IR8
●—● Tachikara —— Evaporation
- - - Radiation

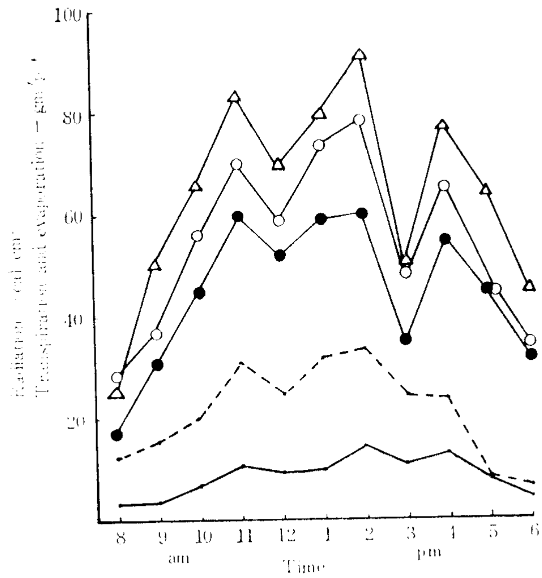

Fig. 2. Hourly transpiration, evaporation and radiation at 43 days after transplanting in the greenhouse
△—△ H4 ○—○ IR8
●—● Tachikara —— Evaporation
- - - Radiation

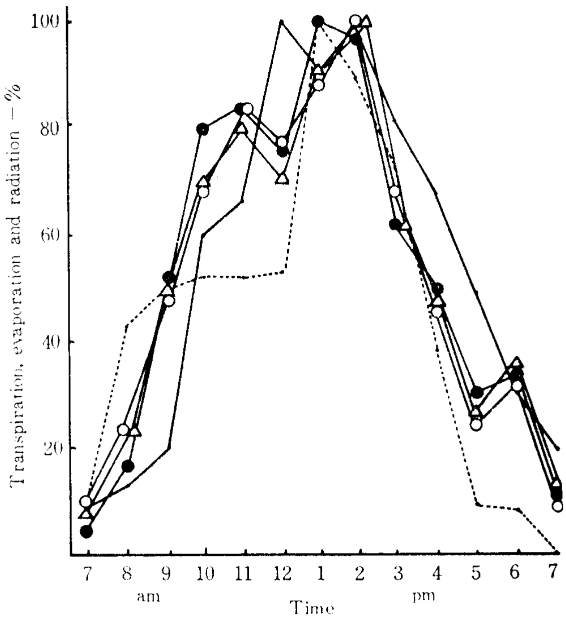

Fig. 4. Trends of hourly transpiration, evaporation and radiation at 65 days after transplanting (percentage of the maximum hourly value)
△—△ H4 ○—○ IR8
●—● Tachikara —— Evaporation
- - - Radiation

horizontal as well as vertical components. The effects of the environmental factors on the daily transpiration cycle can be more clearly illustrated by studying the hourly evapo-transpiration rates from early morning till dark. The data obtained from hourly observations on evaporation and transpiration 43 days and 65 days after transplanting are presented in Figs 2–3. From the graphs it could be noted that the trends of evapo-transpiration are influenced by the trend of radiation. It is also clear from these graphs that free water surface and plant respond, in different degrees, to the factors of radiation and temperature. To bring evaporation, transpiration and radiation data to a uniform basis, a graph was constructed, using percentage of the maximum hourly value as shown in Fig. 4. This makes the comparison of the trends of the processes involved easier. Radiation rises slightly in advance of transpiration and evaporation, and falls in advance. As radiation is the causative factor, it is understandable that it rises ahead of the other factors. In comparison with the hourly transpiration graph the evaporation graph displays some degree of symmetry, which is an indication of the fact that those two processes were not controlled in the same way by the physical factors of the environment (1).

About 50% of the total transpiration for 13 hours between 6 AM and 7 PM occurred during the 4 hours between 10 AM and 2 PM and about 72% occurred during the 6 hours between 9 AM and 3 PM. Radiation showed an identical distribution. Temperature rose to 34°C at 11 AM and continued to rise, reaching 36°C at 1 PM and falling to 34°C at 3 PM. On a fairly clear day the area of peak-water-consumption lies within the four hours from 10 AM to 2 PM. The amount of water consumed would directly be determined by the intensity of radiation. The peak consumption can be greatly affected by the degree of cloudiness, as shown in Table 2, for instance.

Both radiation and temperature show high correlation on an hourly basis with transpiration. As discussed earlier, the role of temperature is observed to be associative, not causative. Although radiation comes to nil with the onset of darkness, transpiration does not stop at that points. It is assumed that the little transpiration taking place in the absence of radiation is mainly due to temperature which falls rather gradually.

Leaf Area and Transpiration

In the greenhouse conditions, Table 1 indicates that leaf area showed a high correlation with

Table 1. Correlation coefficient between green leaf area and transpiration

Variety	Greenhouse (pot)	Field
	R value	R value
H4	0. 89**	0. 67
IR8	0. 78*	0. 50
Tachikara	0. 87**	0. 62

* and **; Significant at 5% and 1% level, respectively.

transpiration. As far as the plant factors are concerned, leaf area is a decisive factor in transpiration, as it is from the leaf that most of the transpiration takes place. In the pot trials, mutual shading was practically eliminated as the pots were widely spaced. This made it possible for the plant to receive additional energy supplied by the horizontal component of radiation, which also contributed to an increased transpiration rate. The quantity of water transpired from a certain leaf area depends on the intensity of the environmental factors, mainly radiation. Changes in radiation cause changes in transpiration irrespective of the leaf area. This could be illustrated by comparing the values of transpiration for two consecutive days, during which the leaf area is to be assumed to be constant for all practical purposes. Table 2 shows the values of transpiration and

Table 2. Transpiration and radiation in the greenhouse at 3rd and 4th, August

Date	Transpiration (gm)			Radiation	Mean air
	H4	IR8	Tachikara	(cal/cm²/day)	temperature(°C)
3rd, August	585	513	426	262	32.5
4th, August	185	205	160	97	32.0

radiation at 3rd and 4th day of August. A drastic reduction in radiation led to a drastic reduction in transpiration, showing the tremendous influence of radiation on transpiration.

Of the three values of regression coefficient in the greenhouse conditions, the one for IR8 is relatively lower. This may be due to the fact that IR8 had the highest rate of leaf emergence, as shown in Table 3, and appeared to have some amount of intra-shading, especially on the lower

Table 3. Rate of leaf-emergence in the greenhouse

Variety	Days after transplanting						
	15	25	32	45	53	64	73
H4	9.0	12.0	12.5	14.0	16.0	16.5	17.0
IR8	11.5	14.0	15.0	17.0	17.5	19.0	20.0
Tachikara	9.5	12.5	13.5	15.0	15.5	17.0	17.0

leaves. IR8 like Tachikara had dark-green, erect and short leaves but Tachikara showed a lower leaf-emergence rate and lesser number of leaves per plant. Fig. 5 shows that at the early stages 4H

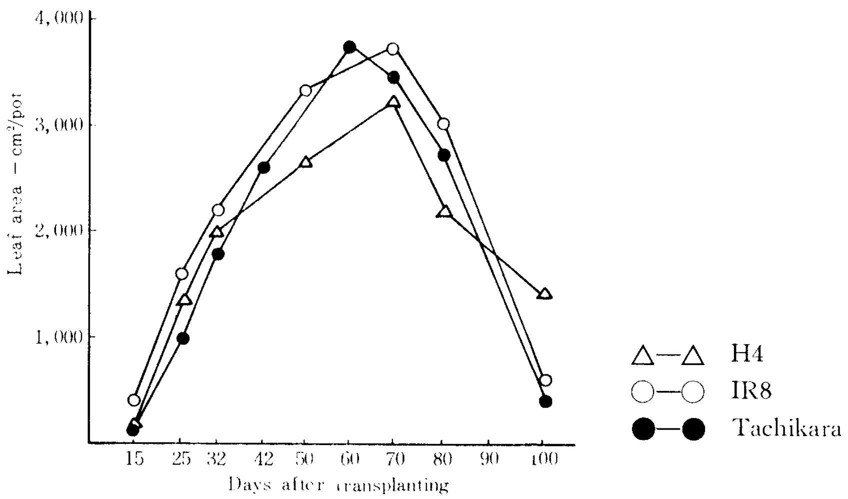

Fig. 5. Green leaf area in the greenhouse

and IR8 showed higher rates of leaf-area increase compared with Tachikara and green leaf area per pot of the IR8 was always greater than that of H4 except at the later stages when IR8 had gone into its reproductive phase, while H4 was still in its vegetative phase in the greenhouse. Although in general, greater leaf area led to greater transpiration, H4 always had the highest value for transpiration even when it did not have the highest leaf area of the three. It is also worth noting that the maxima of leaf area and transpiration did not necessarily coincide. It has been shown elsewhere that the maximum transpiration per day coincided with maximum radiation per day.

The fact that H4 is consistent in maintaining the highest rate of transpiration but not always the highest rate of leaf-area increase poses the question what other plant factors could be involved in determining the transpiration rate. There are a few probable reasons. Values of transpiration per square centimeter of leaf area were calculated from the available data. Within the same variety, there appears to be variation between values of different times in some instances. However, there seems to be no big variation if the extremes are rejected and provided that the variation is mainly due to the variation in intensity of environmental factors. It seems that H4 shows some degree of higher value for transpiration per square centimeter of leaf area than the other two. On this subject, transpiration is also looked upon as a function of leaf anatomy. As stomata are organs that are directly concerned with transpiration, the size, number and distribution of the stomata may be of importance. Microphotographs of SUMP preparates revealed the difference in size and distribution of stomata of the three varieties. Stomata of H4 were the largest in size but the fewest in number, Tachikara had the smallest but the number per unit area was greater than that of H4. IR8 was intermediate in size but had the greatest number. Due to technical limitations stomatal-count could not be made quite accurately. Due to this and due to the lack of information on the importance of size, number and distribution of stomata in transpiration of rice, no attempt is made to put forward any theory or to draw any conclusion.

There is also a possibility that the water loss from parts other than the leaves may be considerable in H4. This assumption is admittedly speculative. On the question of plant type of H4 which could be considered as a representative of the Indicas, the spreading nature of its leaves which are longer than those of Tachikara and IR8 makes it possible, under conditions obtained in the greenhouse, to obtain the maximum radiant energy available. There was not any appreciable shading of lower leaves by upper leaves. However, the consistently highest rate of transpiration of H 4 is a phenomenon that can not be explained by leaf area alone. The possibilities considered above as additional factors must be investigated.

Under field conditions, the relationship between transpiration and leaf area is not the same as that obtained in the greenhouse. Leaf area and transpiration do not increase lineally. The increase of leaf area leads to mutual shading, which cuts down the availability of solar radiation to the leaves in the lower layers. In addition, the influence of the horizontal component of radiation is negligible. Hence, the low values of correlation between leaf area and transpiration were obtained in the field, as shown in Table 1. In spite of the different degrees of mutual shading in the three different varieties, the general trends of transpiration over the whole period of growth were similar to the trends displayed by the same varieties of the pot culture in the greenhouse.

The extent of mutual shading can be represented by the light transmission ratio at 55 days after transplanting. Bottom-top ratios of light intensity of H4, IR8 and Tachikara were 50%, 62% and 67%, respectively. Another good index of mutual shading is the evaporation trends from the field, as shown in Table 4.

Table 4. Field evaporation per day at different stages

Days after transplanting	Field evaporation means (mm/day)		
	H4	IR8	Tachikara
13 – 23	4. 2	5. 4	6. 4
28 – 35	2. 0	2. 7	3. 2
36 – 50	1. 6	2. 3	2. 7
51 – 66	1. 1	2. 0	2. 0

Field evaporation trends and light transmission ratios show that Tachikara and IR8 are close to each other by virtue of their closeness in plant type. H4, due to its plant height and spreading and long leaves, showed the highest mutual shading. Nevertheless, as shown in Tables 5 and 6,

Table 5. Monthly mean evapo-transpiration and free water surface evaporation in the field

Month	Evapo-transpiration (mm/day)			Pan evaporation (mm/day)
	H4	IR8	Tachikara	
July	11. 3	11. 0	8. 7	7. 6
August	23. 1	16. 1	13. 6	9. 1
September	20. 4	15. 5	11. 0	6. 8
October	20. 7	15. 5	12. 0	5. 9

Table 6. Monthly total evapo-transpiration and rainfall in the field

Month	Evapo-transpiration totals (cm/month)			Rainfall (cm/month)
	H4	IR8	Tachikara	
July	35. 0	34. 1	27. 0	33. 9
August	71. 6	49. 9	42. 2	22. 6
September	61. 2	46. 5	31. 8	21. 0
October	62. 1	—	—	12. 1

H4 was consistent in showing the highest rate of transpiration. The influence of mutual shading on transpiration and photosynthesis is through the cutting down of radiant energy to the lower leaves. In this process, not only the leaf area but also the leaf arrangement and leaf length are equally important. Even though transpiration and photosynthesis are two dissimilar processes, a leaf that is physiologically vigorous and receiving enough of sunlight will show higher rates of both transpiration and photosynthesis (NISHIO, 5). If TANAKA's (8) concept of "active centre leaf" is extended to transpiration, then the leaf that has just completed elongation would have the highest rate of transpiration at any stage. The position of "active centre leaf" is shifted upwards as the plant grows. Dry matter accumulation was higher in H4 and IR8 than in Tachikara, which meant that activities of the "active centre leaves" of the former were higher. Transpiration followed a similar trend. The rates of transpiration of the individual leaves in a plant vary by virtue of the fact that the physiological age is different from leaf to leaf. The few fully developed young green leaves at the top contribute greater quantities toward transpiration and dry matter accumulation, in comparison with the older and lower leaves that physiologically less active and moreover receive smaller quantities of radiant energy due to mutual shading. Certain reservations should however be made. The partitioning of energy for transpiration, photosynthesis and other activities is an important factor. Are transpiration and carbon assimilation affected by mutual shading to the same degree ? This has to be clarified. LEMON (2) pointed out that of the net radiation absorbed during the day time, almost 75%-85% is used to evaporate water, 5%-10% goes into sensible heat storage in the soil and only about 5% goes into photosynthesis under ideal field conditions. Therefore, the partitioning of the radiant energy and its relation to the canopy should be considered. Such a task was beyond the scope of this study.

Transpiration Coefficient

Transpiration coefficient is defined as the quantity of water transpired for the production of 1 gram of dry matter, excluding the root. Although values of transpiration coefficient at different stages are not available for the entire growing period of this experiment, it has been established by studies elsewhere on this aspect that the transpiration coefficient is high at the early stage becomes less during the middle stage and again rises during the latter stages (MURAKAMI, 4). Table 7 gives the quantities of water consumed and dry matter produced for a period

Table 7. Transpiration and transpiration coefficient for 30-day period from 32 days after transplanting in the greenhouse

Variety	Dry matter increased (gm)	Transpiration (gm)	Transpiration coefficient
H4	66	27, 486	416
IR8	70	22, 070	315
Tachikara	58	19, 484	336

of 30 days in August in pot trials. During this period the rates of dry matter accumulation of H4 and IR8 are closer to each other and higher than that of Tachikara. However, H4 expended more water than IR8. Transpiration coefficient is a varietal character determined by two different processes, namely, rate of photosynthesis and rate of transpiration. Between H4 and IR8 on one side and Tachikara on the other it may be generalized that a higher rate of transpiration is associated with a higher rate of dry matter accumulation.

Transpiration coefficient for all growing period after transplanting is showed in Table 8. It could be stated that while within the Indica group as supported by the studies of SUGIMOTO (6) and MURAKAMI (4) there is not any great difference in the daily consumption pattern and the

Table 8. Transpiration coefficient* for all growing period after transplanting

Place	Variety	Harvested air dried weight (gm)	Growing period (days)	Total transpiration (gm)	Transpiration coefficient
Green-house (pot)	H4	—	—	—	—
	IR8	113	110	47, 234	486
	Tachikara	101	110	35, 551	409
Field	H4	120	125	69, 600 (100%)	676
	IR8	115	110	42, 570 (61. 2%)	430
	Tachikara	93	110	29, 590 (42. 5%)	370

$$*\text{Transpiration coefficient} = \frac{\text{Total transpiration in grams}}{\text{Harvested air dried plant x 0. 86}}$$

total water requirement of a crop is mainly determined by the age whereas between Indica and Japonica it is probable that there is considerable difference in daily water consumption and this difference also contributes to the total transpiration along with age.

Transpiration coefficient per day is another value that could be of use in estimating the consumptive use. MATSUSHIMA (3), SUGIMOTO (6) and MURAKAMI (4) have shown that the transpiration coefficients per day for the Indica varieties they worked with, showed a constant value for the season and from the transpiration coefficient per day the total transpiration can be calculated if the maturation period is known. MATSUSHIMA (3) obtained a value of 5. 0 grams whereas SUGIMOTO's (6) values were lower under similar Malaysian conditions. SUGIMOTO (6) attributes this difference to the method of measuring, variety and apparatus used. The values obtained in this experiment are different in the three varieties. Under field conditions IR8 has a value 3. 92 closer to Tachikara 3. 36. H4 showed a value almost 60% greater than Tachikara. H4 has a longer growing period, nevertheless, this again reveals the difference in the daily consumption pattern.

Transpiration coefficient varies not only due to the method but also due to time and place. Therefore it is important to ascertain transpiration coefficients on a seasonal basis for each agro-climatic region. Many transpiration coefficients for the season have been obtained by different workers under different conditions using differerent varieties. Moreover the method of assessment were also not identical. Values obtained by SUGIMOTO in Malaysia (6) and MURAKAMI in Ceylon (4) show that age is the determining factor of transpiration coefficient within the Indica group. Different varieties with the same maturation period do not show great variation in their transpiration coefficients within the Indica group. However the results of the present study show that between the Indicas and the Japonica used, there exists considerable difference in the daily consumption rates.

Consumptive Use and Grain Yield

In so far as rice is concerned, the ultimate justification of the water consumed by a crop over season is reflected in the quantity of grain produced. Grain yield is approximately the product of

Table 9. Grainyield and grain-straw ratio in the field

Variety	Yield per hill (gm)	Grain straw ratio	Transpiration coefficient	Growing period
H4	38.40	0.47	676	125
IR8	51.60	0.81	430	110
Tachikara	54.08	1.31	370	110

the total dry weight and the panicle straw ratio. As shown in Table 9, Indicas in general show a high rate of dry matter accumulation during the vegetative phase, however, on the basis of grain straw ratio Japonica is superior to Indicas. Although Tachikara and IR8 are closer to each other in terms of grain yield per hill, Tachikara has higher grain-straw ratio. From the point of view grain production and water utilization Tachikara seems to be the most economic and for this reason, under these conditions, it can be described as a "water economising plant type". However, for tropical conditions such a term should mean short age and drought resistance among other things.

A word of caution must be added in making all sorts of comparisons. Tachikara was performed in its own environment while H4 and IR8 were brought from different conditions. This however does not interfere with the arguments that Indicas, namely, H4 and IR8, show a higher daily transpiration rate which are in the early stages associated with higher rates of dry matter accumulation and particularly in the case of H4, such higher rates of the two processes, are not justifiable in terms of grain yield.

Summary

The present study was centred on daily evapo-transpiration rates from pots in the greenhouse and consumptive use in the field using Indica and Japonica rices. Environmental factors particularly radiation were also noted. Observations were also made on the more important growth-characters.

The following conclusions can be drawn from the observations made and the arguments presented so far:

1) Daily radiation showed very high correlation with the transpiration rates of the three varieties.

2) All three varieties displayed very similar trends as regards the daily march of transpiration from transplanting to full maturity. The peaks of all three varieties were attained exactly at the same times in pot trials, and the highest of these peaks fell around the maximum number of tiller stage. Radiation also showed maximum values during this time.

3) There was considerable difference in the daily transpiration rates between the Indica and Japonica and this contributed to the value of transpiration coefficient along with the period of maturation. The higher rates of transpiration of H4 and IR8 were accompanied by higher rates of dry matter production. However these higher rates didn't lead to higher yield.

4) The yield of H4 did not justify its transpiration coefficient when compared with Tachikara or IR8. Tachikara utilized water most efficiently producing the highest yield with the least

consumptive use.

5) The authors are inclined to think that only patterns of the leaf growth, namely, leaf age, leaf area and mutual shading, etc., is not enough to explain transpiration rates of the varieties used in this experiment and more investigations on leaf anatomy or water lost by parts other than the leaves, may be able to pave the way for the development of a concept of "water economising plant type". The breeding prospects of combining short age and low daily-transpiration-rate are also worth exploring.

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