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Determination of water use efficiency of direct seeded upland rice through gravimetric method and associated physiological parameters

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ABSTRACT

Water use efficiency(WUE) and associated physiological parameters were measured in thirty upland advanced breeding lines of rice. WUE showed an inverse trend with mean transpiration rate (r=-0.053) suggesting that stomatal control of WUE among the cultures. However net assimilation rate showed a positive relationship (r=0.79) with WUE indicating possibilities of selecting capacity type cultivars, where mesophyll efficiency would regulate WUE. WUE values of the pot experiment correlated well with those estimated in the field experiment with the same cultures utilizing specific leaf area values at 60 days after sowing. Accordingly the entries B5, B3, B11, B36, B27, B47 and the check Vandana were identified as capacity type cultivars for mining water in order to utilize it efficiently for carbon fixation.

Key words: *water use efficiency, capacity type, mesophyll efficiency, associated physiological parameters*

Assam is traditionally a rice growing state with a total area of about 25 lakh hectares. Out of this total area, summer rice (locally known as direct seeded Ahu) is cultivated over an area 6 lakh hectares and the present yield is about 1.2 t ha^{-1}. Direct seeded summer rice is grown on relatively upland condition with scanty irrigation facilities which is about 10% of the total crop area. Therefore, the summer rice has to depend totally on rainfall to meet its water requirement. Production of upland rainfed rice is constrained by moisture stress, heavy weed infestation, poor soil fertility, incidence of pests and diseases, lack of soil and water conservation practices and lack of appropriate variety. Among the various factors controlling the crop productivity, limitation of moisture is by far the most serious impediment. Water is becoming a scarce commodity even in irrigated agriculture. Genetic enhancement to improve crop productivity per unit input of water has been a research priority in crop improvement programmes all over the world. The physiological model proposed by Passioura (1986) explains the importance of water use efficiency (WUE) in influencing grain yield under water limited condition.

As per formula, Grain yield= T X TE X HI

Where T= total transpiration by the crop canopy
TE= transpiration efficiency
HI= harvest index

This relationship provides an analytical basis to explain genotypic performance under water deficit conditions and to select genotype with high levels of model parameters (T and TE). The possibility of using this as a selection trait in breeding for drought tolerance genotypes has been reported by several workers (Turner *et al*., 1984, Austin *et al*., 1978). Thus, it is important that WUE is one of the most important factor influencing crop productivity, particularly under water limited conditions (Uma 1987, Impa 2002)

At the canopy level, WUE based on evapotranspiration is difficult to measure in the field because of the lack of suitable techniques for measuring accurately the root mass and water use of the plants. WUE is often quantified at whole plant level by adopting gravimetric technique by assessing the accumulation of biomass during a definite growth period and accumulation of water transpired during the same period of growth. With the advent of this technique, significant progress was achieved in establishing the genetic variability in WUE.

MATERIALS AND METHODS

Pot culture experiments were conducted during dry season 2006-07 at Regional Agricultural Research Station, AAU, Titabar, where thirty advance breeding rice lines were used to assess differences in WUE and associated physiological parameters by gravimetric approach. Plants were grown in pots made up of 200 gauge polythene sheet of 35x80 cm filled with soil (a mixture of clay loam and cowdung) weighing about 15 kg to their capacity. Basal fertilizer (20 kg N, 40 kg P_2O_5, 40 kg K_2O) was mixed into the soil at sowing. Each genotype was planted in 3 pots and 2 plants were grown in each pot. Plants were watered daily until 30 days after sowing (DAS).

At 30 DAS, all pots were saturated with water and any excess water was allowed to drain through a drainage hole in the base of the container. Treatments were imposed from 30 DAS to 60 DAS. The exposed soil surface was covered with pieces of polythene to minimize soil evaporation. The pots were arranged in a randomized block design. The amount of water loss was determined by weighing the pots daily using an electronic balance. One pot for each replication with soil and plastic mulch, but without plants, was maintained to monitor soil evaporation in the absence of plants, The experiment was terminated at 60 DAS. The principal of determining the WUE in this technique is by assessing the increase in biomass during a particular growth period (30DAS to 60 DAS) and cumulative water transpired (CWT) during this period as per Udaya Kumar *et al.* (1998). The observation recorded during the experiment were CWT, leaf area duration (LAD), mean transpiration rate (MTR), net assimilation rate (NAR) and WUE. The biomass accumulated during the period (30 to 60 DAS) was computed as the difference in the initial and final dry matter and expressed as gram plant^{-1}.

LAD was measured as $\text{LAD} = \frac{\text{L1}+\text{L2}}{2}$ days

where, L1 is the initial leaf area and L2 is the final leaf area at the end of the treatment period. The amount of water added daily to each pot after weighing to bring back to 100 percent field capacity was summated individually for each pot during the treatment period, and was expressed as cumulative water transpired (CWT). The rate of transpiration over the entire experimental period was measured as mean transpiration rate. MTR was arrived at by computing the ratio of CWT to the LAD and expressed as ml of water dm^{-2} leaf area day^{-1}. Measurement of WUE by gravimetric approach involves the measurement of dry matter accumulated over a specific period of time and the total water transpired by the plant during the same period. Net assimilation rate (NAR) was determined as the ratio of total dry matter (TDM) during the treatment period and LAD and expressed as g m^{-2} day^{-1}. Field experiments were conducted during dry season, 2007 with the same genotypes used for pot experiments. In field experiment WUE at 60DAS was estimated utilizing actual values. For the selection of capacity type(gm) where the variability in WUE is brought about by intrinsic differences in mesophyll efficiency and WUE and T will be less dependent, the WUE and MTR values of the experiment were transformed to obtain standard normal distribution values (Z-values), after determining the standard deviation (SD) for each trait as follows.

$$Z = \frac{X - X1}{\sigma}$$

where X is the general mean for the trait across the all 30 genotypes and X1 is the mean of individual genotype and σ is standard deviation for the trait. The Z values for MTR were plotted against those of WUE.

RESULTS AND DISCUSSION

The experiments were conducted to measure WUE accurately by gravimetric method. WUE was measured by measuring daily loss of water by transpiration using a electronic balance. During the course of study, significant genetic variation was observed for WUE although the range is narrow. In the present investigation, the variation ranged from 1.09 to 3.06 g lit^{-1}. The genotypes B27 recorded the highest WUE compared to all other genotypes (Table1). The TDM accumulated during the experimental period varied significantly among the genotypes. The highest biomass of 7.36 and 7.24g plant^{-1} were observed in B19 and B3, respectively which were at par with each other, followed by B18, B5, B47, B11 and B1 which were more than the check Vandana, whereas genotype B34 recorded the lowest TDM 2.16 g plant^{-1}. The two physiological

Table 1. Cumulative water transpired(CWT), leaf area duration(LAD), mean transpiration rate(MTR), total dry matter (TDM), water use efficiency(WUE), net assimilation rate(NAR) and specific leaf area (SLA) during the treatment period of rice genotypes

Entry No.	CWT (litres plant^{-1})	LAD (dm^{2}day)	MTR (ml dm^{-2} day^{-1})	TDM (g plant^{-1})	WUE (g litre^{-1})	NAR (gm^{-2} day^{-1})	SLA (cm^2 g^{-1})
B1	3.37	519.17	6.49	6.04	1.79	1.16	351.30
B3	3.26	277.00	11.77	7.24	2.22	2.61	220.16
B5	3.33	336.10	9.90	6.92	2.08	2.06	250.60
B9	3.96	422.70	9.36	4.48	1.13	1.06	459.78
B11	2.56	314.30	8.15	6.24	2.43	1.99	200.17
B 18	3.96	273.80	14.46	6.98	1.76	2.55	367.20
B 19	3.06	263.60	11.61	7.36	2.40	2.79	208.76
B 21	2.70	287.60	9.38	3.32	1.23	1.15	448.98
B 22	2.03	237.40	8.55	2.84	1.39	1.20	420.06
B 23	1.90	266.70	7.12	2.64	1.38	0.99	389.25
B 25	1.95	242.70	8.03	2.96	1.52	1.22	400.70
B 27	2.23	151.90	14.68	6.82	3.06	3.17	189.86
B 30	2.83	221.10	12.80	3.80	1.34	1.72	392.60
B32	1.56	251.1	6.21	2.85	1.82	1.22	159.96
B 33	2.43	295.60	8.22	3.72	1.53	1.26	388.20
B 34	1.66	246.50	6.73	2.16	1.30	0.88	425.60
B 36	1.83	224.50	8.15	4.36	2.38	1.94	216.65
B 37	3.50	325.00	10.76	4.12	1.18	1.27	432.80
B 38	2.50	220.20	11.35	4.76	1.90	2.16	350.60
B 42	3.90	394.30	13.25	4.72	1.21	1.60	460.25
B 43	1.36	337.40	4.03	2.44	1.79	0.72	368.88
B 46	2.50	219.90	11.37	5.24	2.10	2.38	260.65
B 47	3.13	290.20	10.79	6.84	2.18	2.36	235.52
B 50	3.00	424.00	7.08	4.52	1.50	1.07	430.06
B 52	4.50	513.90	8.76	5.84	1.30	1.14	415.15
Annada	3.06	457.60	6.68	4.08	1.33	0.89	385.58
Rongadoria©	4.33	476.10	9.09	5.72	1.32	1.20	396.65
Vandana ©	3.00	447.50	6.70	6.04	2.01	1.35	174.80
Ahujoha©	3.26	368.70	8.84	5.28	1.62	1.43	231.70
IR 36	3.50	508.00	6.89	5.36	1.53	1.06	396.60
Mean	2.96	328.27	9.41	4.95	1.77	1.55	333.32
SEm	0.03	0.82	0.36	0.03	0.02	0.04	0.09
CD	0.06	2.10	1.01	0.07	0.04	0.11	3.12

traits namely transpiration rate regulated by stomatal factors and the primary carboxylation mechanism that determines the total biomass significantly controls the differences in WUE. Depending upon the extent of control by either of these parameters genotypes can be classified as conductance (gs) and capacity (gm) types (Udaykumar *et al.,*1998a, Farquhar and Llyod 1993). Because of the interrelationship between transpiration rate and WUE, selection for high WUE for conductance type would be counter productive. On the other hand, capacity types will have a weaker relationship between transpiration and WUE, selection from such type does not accompany a reduced TDM and are desirable. In order to understand which one of these parameters control the difference in WUE in those tested genotypes, the relationship of WUE with MTR and NAR were examined. Total transpiration is a function of intrinsic difference in transpiration rate

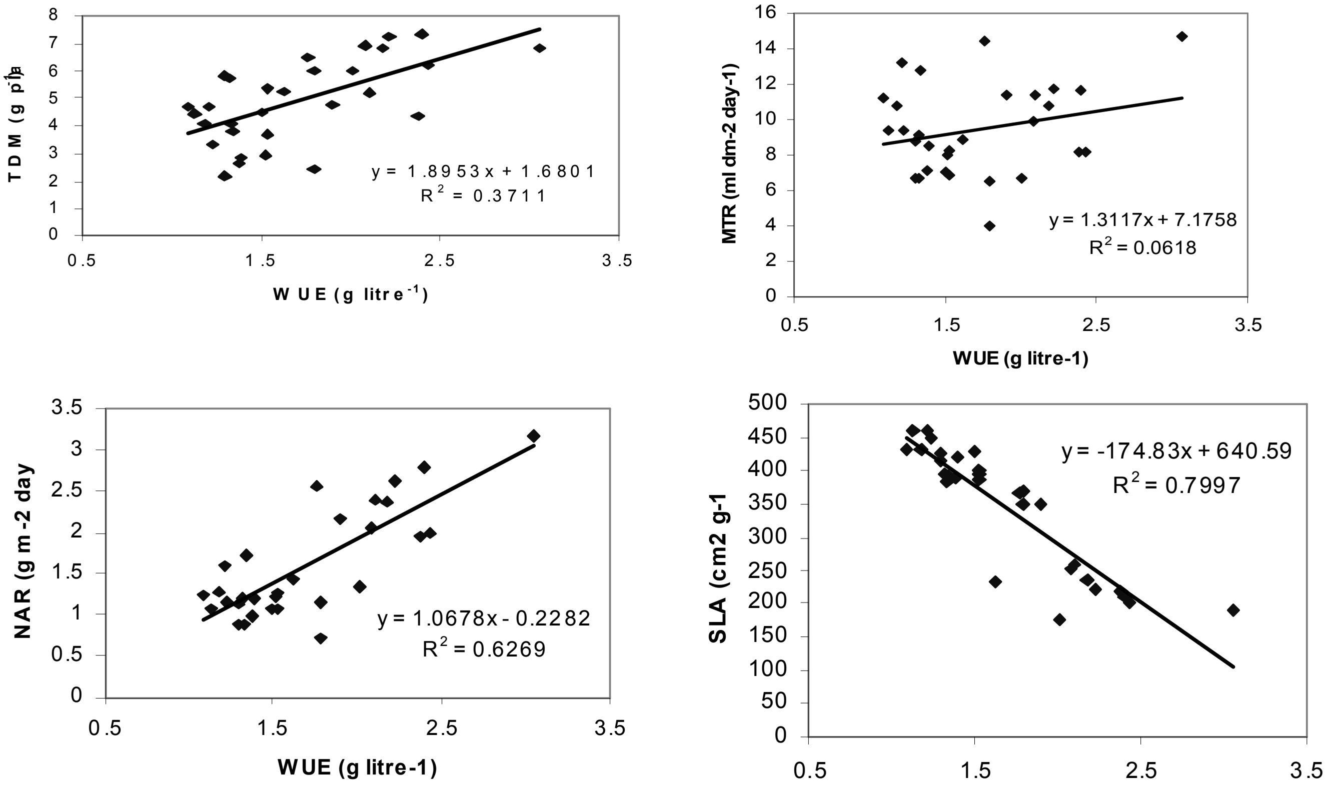

Fig1. Correlation between WUE and associated physiological parameters

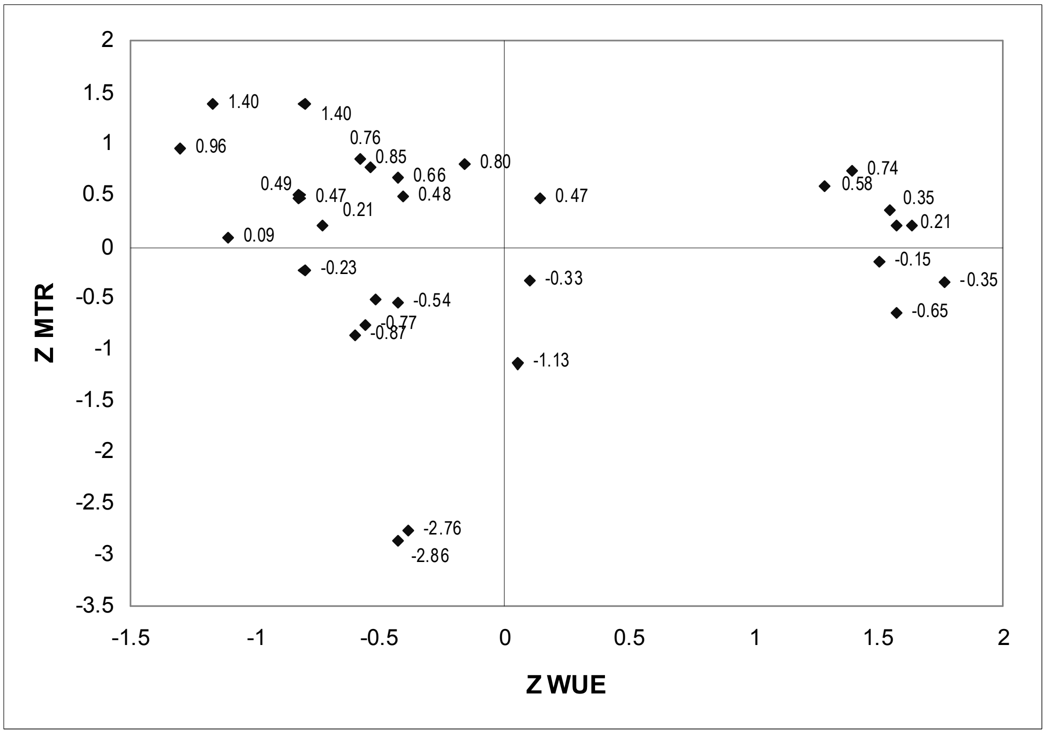

Fig2. Standardized normal distribution (Z) plot between MTR and WUE of 30 rice genotypes

controlled by stomatal factors and leaf area. The functional leaf area of plant canopy (LAD) over the experimental period was determined and a significant genetic variability was noticed (Table 1). The LAD ranged from 151.9 dm^2 day in B27 to 519.17 dm^2 day in B1. Leaf area of the canopy besides determining the total transpiration, is also associated with total biomass. The stomata that regulate the transpiration rate also control the total influx of CO_2 for photosynthesis. Therefore, total biomass and total transpiration can be expected to be interdependent. As expected a highly significant positive relationship between the total water transpired during the experimental period and the total biomass was observed (r=0.47) (Table2). Net assimilation rate (NAR) varied significantly from 0.72 gm^{-2} day^{-1} in B43 to as high as 3.17 gm^{-2} day^{-1} in B27. Similarly MTR that integrates the diurnal variation in stomatal conductance over the entire experimental period showed a significant genetic variability. B27 followed by B18 recorded the highest MTR of 14.68 and 14.46 ml dm^{-2}day^{-1} respectively followed by B42, B30, B3, B19, B38 and B46. On the other hand, MTR as low as 4.03 ml dm^{-2}day^{-1} was noticed in B43. The relationship between WUE and MTR is not significant. However, NAR showed a positive relationship with WUE (r=0.79) among these genotypes. This indicates that there are possibilities of selecting distinct genotypes where the mesophyll efficiency (gm type) would regulate WUE. WUE values of the pot experiment correlated well with those estimated in the field experiment with the same genotypes utilizing specific leaf area (SLA) values at 60 DAS as per Wright *et al.,* (1993). It has been observed that SLA values are closely and negatively correlated with WUE (r=-0.89) indicating that the genotypic ranking for SLA in field and WUE in pots were just opposite to each other i.e. lower SLA values indicate more water use efficient and vice-versa (Fig.1) The findings were in close conformity with Impa (2002). The Z values for MTR were also plotted against those of WUE (Fig. 2). Genotypes with similar deviation for MTR but significantly differing in WUE were identified. Such genotypes showed Z values close to Zero. Negative Z values for WUE indicates higher WUE compared to the general mean. Such types in the figure are selected as high capacity types (gm type). Accordingly. The entries B5, B3, B11, B36, B27, B47, B46 and the check Vandana were selected as capacity type indicating these genotypes have a distinct inherent capacity for mining water in order to utilize it efficiently for carbon fixation.

Table2. Correlation among different parameters

	WUE	TDM	MTR	NAR	SLA	CWT
Mean	1.7000	4.9187	9.4057	1.5870	343.3723	2.963333
SD	0.4839	1.5262	2.5542	0.6526	94.6046	0.831796
Std. Error	0.0883	0.2786	0.4663	0.1191	17.2724	0.151865

	r values with WUE		r values with CWT	
TDM	0.60232	**	**0.53592**	**
MTR	0.248505	ns	0.350732	
NAR	0.791753	**	0.01921	
SLA	-0.894247	**	0.20216	

	WUE	*TDM*	*MTR*	*NAR*	*SLA*	*CWT*
WUE	1					
TDM	0.60232	1				
MTR	0.248505	0.486115	1			
NAR	0.791753	0.71843	0.760121	1		
SLA	-0.894247	-0.635699	-0.152999	-0.688433	1	
CWT	-0.321568	0.53592	0.350732	0.01921	0.20216	1

	WUE	TDM	MTR	NAR	SLA
Mean	1.7000	4.9020	9.4057	1.5870	333.3213
SD	0.4839	1.5055	2.5542	0.6526	120.9660
Std. Error	0.0883	0.2749	0.4663	0.1191	22.0853

	r values with WUE	
TDM	0.609181	**
MTR	0.248505	ns
NAR	0.791753	**
SLA	-0.22882	ns

	WUE	TDM	MTR	NAR	SLA
WUE	1				
TDM	0.609181	1			
MTR	0.248505	0.470136	1		
NAR	0.791753	0.711406	0.760121	1	
SLA	-0.22882	-0.038077	0.128426	-0.016051	1

REFERENCES

Austin RB, Morgan CL and Blackwell RD 1978. contributions to grain yield from the anthesis assimilation in tall and dwarf barley phenotypes in two contrasting seasons. Ann. Bot. 45: 309-319

Farquhar GD and Llyod J1993. Carbon and oxygen isotope effects in the exchange of carbon dioxide between terrestrial plants and the atmosphere. In: Stable isotopes and plant carbon/water relations. Academic press Inc., pp.47-70

Impa SM2002. stable isotopic approach to identify gs and gm types in rice and their analysis using RAPD markers. M. Sc. Thesis, submitted to UAS, Bangalore, India

PassiouraJB1986, Resistance to drought and salinity. Avenues for improvement. Aust. J. plant Physiolol. 13: 191-201

Turner N C, Jordon WR and Sinclair TR 1984. Crop water deficits. A decade of progress. Adv. Agron. 39:1-51

Udaykumar M, Sheshshayee MS, Nataraj KN, Bindu Madhava H, Devendra R, Aftab Hussain IS and Prasad, T.G. 1998a.hy breeding for WUE has not been successful. An analysis and alternate approach to exploit this trait for crop improvement. Current science.74 (11) : 994-1000

Uma S 1987. Transpiration quotient and WUE in different C_3 and C_4 species and its relationships with biomass and productivity under stress conditions. M. Sc. Thesis, submitted to UAS, Bangalore, India

Wright GC, Hubick KT, Farquhar GD and N Rao 1993. Genetic and environmental variation in transpiration efficiency and its correlation with carbon isotope discrimination and SLA in peanut. In stable isotope and plant carbon water relations. (Eds, J.R. Ehleringer, A.E. Hall and G.D. farquhar) pp. 247-267