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SHORT COMMUNICATION

VARIABLE RADIATION USE EFFICIENCY IN RICE CULTURES GROWN AT DIFFERENT LOCATIONS

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Variation in radiation use efficiency (RUE) amongst 81 rice cultures was assessed at Hyderabad, Maruteru and Pattambi locations. The RUE was computed for each culture at panicle initiation stage (RUE_pi) and at physiological maturity (RUE_m) for each location. RUE_pi and RUE_m differed significantly amongst cultures and also between locations. The interaction between location and cultures was also found to be highly significant. The mean RUE_pi for all the cultures was 1.08, 0.56 and 1.22 g MJ^{-1}, respectively, for HYD, MTU and PTB. The average RUE_m estimated was 0.37, 0.60 and 0.93, respectively, for HYD, MTU and PTB. Out of the 81 rice cultures, very few entries consistently showed high RUE at all the three locations and at both the stages. The cultures IET 21023 and IET 20986 recorded higher, though not the highest, RUE, at panicle initiation and maturity stages at all the three locations and produced TDM and grain yield higher than the mean TDM and grain yield for all the test cultures.

***Key words*: ORYZA model, radiation use efficiency, rice**

Radiation use efficiency (RUE) is important in understanding and modeling the relationship between plant growth and the physical environment. Plant dry matter accumulation depends on the total C fixed during photosynthesis and the fraction of the carbon converted into dry matter. A number of crop growth simulation models have been developed using the RUE concept to forecast crop growth and yield at different environments (Brisson *et al.* 2003). Analysis of crop growth should consider total dry matter (TDM) as a product of the amount of photosynthetically active radiation (PAR) intercepted by the crop, multiply by an efficiency factor. Such analysis suggests that radiation utilization efficiency is a conservative quantity (Monteith & Elston 1983), whilst the amount of radiation intercepted is the variable that determines the crop yield. PAR depends on the location and time of year while seasonal *fraction (f)* is affected by the duration and the area of the canopy. The RUE (biomass produced per unit of radiation energy intercepted) of rice is low, even among C_3 crops, and this is a major limitation to yield potential. Although rice is the most important food crop in the world, little field-scale, season-long studies on RUE has been conducted (Campbell *et al.* 2001). At present, very few studies with rice have analyzed crop performance in terms of radiation interception and utilization. The objective of this trial was to identify rice cultures for efficient dry matter production with high radiation use efficiency.

Seeds of 81 rice cultures from the Initial Evaluation

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Trials (IET) of AICRIP-2008 along with three released varieties (Table 1) were planted at Hyderabad (HYD), Pattambi (PTB) and Maruteru (MTU) during wet-season of 2008. Plant samples were collected at tillering and at physiological maturity and dry weights were determined. Leaf area was recorded with a leaf area meter (LI 3100C, LICOR, USA) and leaf area index (LAI) was computed. Oryza 2000 model was used to estimate the

Table 1. Details of 81 rice genotypes along with the days to flowering and maturity (mean of three locations)

Cultures	Days to flowering	Days to maturity	Cultures	Days to flowering	Days to maturity
IET 20964	96	127	IET 21005	101	138
IET 20965	94	124	IET 21006	99	130
IET 20966	85	118	IET 21007	87	121
IET 20967	100	132	IET 21008	98	126
IET 20968	79	137	IET 21009	106	138
IET 20969	95	125	IET 21010	104	135
IET 20970	95	126	IET 21011	87	115
IET 20971	88	120	IET 21012	86	116
IET 20972	89	122	IET 21013	93	123
IET 20973	99	129	IET 21014	90	119
IET 20974	98	128	IET 21015	93	121
IET 20975	88	122	IET 21016	100	126
IET 20976	92	124	IET 21017	107	130
IET 20977	100	136	IET 21018	106	140
IET 20978	93	123	IET 21019	92	127
IET 20979	104	139	IET 21020	84	113
IET 20980	95	125	IET 21021	91	121
IET 20981	93	125	IET 21022	106	139
IET 20982	95	126	IET 21023	89	125
IET 20983	90	122	IET 21024	86	119
IET 20984	97	127	IET 21025	93	124
IET 20985	97	129	IET 21026	96	127
IET 20986	100	131	IET 21027	99	125
IET 20987	100	132	IET 21028	98	129
IET 20988	102	135	IET 21029	99	130
IET 20989	104	137	IET 21030	101	134
IET 20990	103	133	IET 21031	102	135
IET 20991	97	133	IET 21032	99	128
IET 20992	100	137	IET 21033	90	121
IET 20993	101	134	IET 21034	91	123
IET 20994	94	123	IET 21035	91	121
IET 20995	93	126	IET 21036	91	123
IET 20996	106	136	IET 21037	99	130
IET 20997	100	126	IET 21038	104	135
IET 20998	94	125	IET 21039	94	126
IET 20999	99	134	IET 21040	96	127
IET 21000	101	132	IET 21041	100	131
IET 21001	104	138	IR 64	99	131
IET 21002	112	142	PR 113	92	119
IET 21003	105	137	Aiswarya	89	117
IET 21004	101	137			

daily total radiation (RDD) and shortwave radiation was calculated by the product of daily total radiation with the ratio of actual effective sine of solar inclination (SinB) over the integral of effective SINB (DSINBE). Fraction of PAR was calculated from the fraction of diffused radiation which is calculated from the atmospheric transmission. This radiation flux at Earth's surface, assuming 100% atmospheric transmission, was calculated from the solar constant, which is the radiation flux perpendicular to the sun rays, multiplied by the sine of the solar inclination (SinB), which changes during the day. The absorbed PAR was estimated as follows.

$$\text{Short wave radiation (TMPR1)} = \frac{\text{RDD*SINB*(1.0+0.4*SINB)}}{\text{DSINBE}}$$

PAR =TMPR1*fraction of PAR (0.5)
Absorbed PAR=PAR*40%

Day wise total radiation (RDD)KJ m^{-2} d^{-1} and APAR was calculated for the whole crop growing period. From this data APAR (MJ m^{-2}) for PI and maturity period was calculated. RUE (g MJ^{-1}) was computed as RUE_pi = TDM at PI/ΣAPAR from sowing day to PI and RUE_m = TDM at maturity/ΣAPAR from sowing to maturity. Software was developed using Microsoft Access with Visual Basic code to calculate culture wise and replication wise RUE for three locations. The data was analyzed using DSAASTAT Ver 1.02 software as single factor RCBD for multi-locations.

Significant differences were noticed amongst cultures for days to flowering and days to maturity at all the three locations (Table 1). Similarly, the grain yield, TDM and HI differed significantly amongst cultures and between locations (Table 2) and the interaction between cultures and locations was significant. In our study, we used the Oryza 2000 model to compute APAR and the RUE was computed for each culture at panicle initiation stage (RUE_pi) and at physiological maturity (RUE_m) for each location. Radiation-use efficiency differed significantly (*p=0.001)* amongst cultures and between locations (Table 3). The interaction between location and cultures was found to be highly significant. At HYD the mean RUE_pi was 1.08 g MJ^{-1} with a minimum value of 0.50 (Aiswarya) and a maximum of 2.36 (IET 20998) (Table 2). IET 21001, IET 20997, IET 20992 and IET 21003 are other cultures with high RUE whereas IET 20981, IET 21005 and IET 21035 cultures recorded low RUE_pi. At maturity, the RUE_m varied between a maximum of 0.53 (IET 21019) to a minimum of 0.24 (IET 21013) with a mean value of 0.37 g MJ^{-1}. At MTU centre, the mean RUE_pi for all the cultures was 0.56 with a range of 0.0312 (IET 20968) to 0.96 (IET 21010). At maturity, the mean RUE_m was 0.61 g MJ^{-1} with a range of 0.36 (IET 21029) to 0.97 (IET 20979). At PTB centre, the mean RUE estimated at PI stage was 1.22 g/MJ with a minimum value of 0.59 (IET 21020) and a maximum of 2.09 (IET 21030). The RUE_m varied between a maximum of 1.8 (IET 21028) and minimum of 0.60 (IET 20978) with a mean value of 0.94 g/MJ. Wide variation in RUE of rice has been widely reported. Kiniry *et al.* (1989) reported mean RUE as 2.2, 2.2 and 2.8 g MJ^{-1} IPAR for sunflower, rice and wheat. Farell *et al*. (1998) reported that the average

Table 2. Means of radiation use efficiency and other important parameters of rice cultures estimated for different locations

Character	HYD		MTU		PTB	
	Mean	Range	Mean	Range	Mean	Range
RUE_pi (g MJ^{-1})	1.08	0.50-2.36	0.56	0.30-0.96	1.22	0.59-2.09
RUE_m (g MJ^{-1})	0.37	0.24-0.53	0.60	0.36-0.97	0.93	0.60-1.82
Grain yield (g m^{-2})	541	380-860	530	275-775	214	109-327
Total dry matter (g m^{-2})	1036	687-1493	1098	659-1502	650	326-933
Harvest index (%)	52	39-53	48	38-52	49	41-59
Days to flowering	106	93-117	83	71-103	100	79-123
Days to maturity	135	121-141	118	97-138	131	108-155

Table 3. Mean sum of squares of total dry matter, grain yield, harvest index and RUE of 81 rice genotypes at three locations

Effect	d.f.	Total dry matter ($g\ m^{-2}$)	Grain yield ($g\ m^{-2}$)	Harvest index (%)	RUE_pi	RUE_m
Location	2	21581590	5572923	933	16.584	12.996
Replication (Location)	3	7057	906	42.59	0.1736	0.0043
Cultures	80	50562**	18897**	61.04**	0.2342	0.0486
Cultures x Location	160	48679**	17271**	45.06*	0.2194**	0.0523**
Residual	240	32217	10697	33.47	0.0234**	0.00024**
Total	485	129381	37095	45.6	0.1920	0.0790

YEARS/LOCATIONS: fixed effect

RUE of the released Australian varieties was 1.08 g MJ^{-1} while the average of the international lines was 1.25 g MJ^{-1}.

Similarly, wide variation in RUE of rice for locations has been reported and the largest value is twice as great as the smallest (Kiniry *et al.* 1989). Costa *et al.* (2000) reported a value of 0.45 g MJ^{-1} for rice crop grown at eight different regions in Minas Gerais, Brazil. Zhang *et al.* (2009) calculated the RUE as the ratio of above ground biomass accumulated at maturity and intercepted radiation during the entire growing period and reported an average RUE value of 1.38 g MJ^{-1} across different locations. RUE estimated in our study at maturity was lower than at panicle initiation stage. Out of the 81 rice cultures, very few entries consistently showed high RUE at all three locations and both the stages. IET 21023 exhibited higher, though not the highest, RUE both at panicle initiation and at maturity stages at all three locations. This entry produced high TDM at harvest too and higher grain yield which was higher than the mean TDM and grain yield for all 81 entries. The entries identified with high RUE could be used in crop improvement program to develop rice genotypes with high biomass accumulation and grain yield.

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