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Absorption of photosynthetically active radiation (PAR) and its effect on yield and dry matter production of rice at different dates of transplanting

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ABSTRACT

A two year experiment was conducted on rice (Var. Satabdi) at the C- Block Farm (Incheck), B.C.K.V, W.B. (Lat 22^{0}56' N; long 88^{0}E), during 2007 and 2008 kharif seasons. The crop was transplanted on 5 dates (D_1-6th July, D_2 – 13th July, D_4 – 27th July and D_5 – 3rd August). The Absorbed Photosynthetically Active Radiation (APAR), total dry matter production at tillering, panicle initiation, panicle emergence and 50% anthesis were recorded. The results showed that absorption of PAR was high under D_1 or D_2 transplanting. The dry matter accumulation was the highest under D_1 transplanting; and reduced with the delay in transplanting. Both the dry matter accumulation and grain yield were significantly affected by the absorption of PAR. Absorption of PAR at tillering and panicle initiation was positively related to yield production and 36 and 65 percent of yield variation due to PAR absorption could be explained in two years of experiment.

Key words: Absorption, PAR, rice, dry matter, yield

The crop modifies the mechanism of energy and mass exchange processes between the Earth's surface and the atmosphere creating an environment in which it lives from germination to maturity. Growth, development and yield of a crop are substantially affected by the canopy microclimate as well as by weather conditions (Uchijima, 1976; Russel *et al.*, 1989). The dry matter production in rice is linearly related to intercepted PAR (Haloi and Dey, 2000; Tomar *et al.*, 2004, Ahmed *et al.*, 2008; Ning *et al.*, 2008). Absorption of PAR may have also significant contribution to the dry matter production in rice, however sufficient information is not available in case of transplanted rice grown in the *kharif* season in the Gangetic plain zone of West Bengal. West Bengal is a principal rice growing state of the country. Transplanting of rice is frequently delayed for a number of reasons viz. non-availability of adequate rainfall, late harvesting of *pre-kharif* crops (like sesamum, mungbean, blackgram etc). The delay in transplanting causes yield reduction because of macro- and micro climatic influences on the crop. Among the macroclimatic parameters, both the maximum and minimum temperatures have a profound effect on the crop by influencing the duration of different phenophases in cereal crop (Parya *et al.*, 2010), whereas absorption of PAR by the crop is an important micro-climatic parameter which influences the yield of rice. Therefore it is necessary to investigate the pattern of absorption of PAR by a popular rice variety of W.B., transplanted on five different dates in 2007 and 2008 *kharif* seasons and its effect on dry matter production and productivity of rice crop.

MATERIALS AND METHODS

The field experiment was carried out on rice (var. Satabdi) at the C- Block Farm, Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India during *kharif* seasons of 2007 and 2008. The Farm is located at 22°56'N latitude and 88°32'E longitudes at an elevation of 9.75 m above mean sea level. The zone is classified as having a tropical humid climate with three distinct seasons divided into winter (November to February), *Pre-kharif* (March to May) and *kharif* (June to October). The annual rainfall generally varies from 1400-1500 mm, most of which is received from June to September during active SW monsoon, the onset and departure of which have been remarkably shifted in the present days. January is the coldest month with a mean temperature of 10.2^{0}C. The atmospheric mean temperature begins to rise from the end of February and reaching maximum during the month of May (37.7 ^{0}C). The mean relative humidity remains high (82-95%) during June to October and reaches at 70% in January. Soil of the experimental site is classified as sandy loam, Aerie Haplaquept. Basic chemical properties of the surface (0-15 cm) soil were pH 6.80 organic carbon 5.4 g kg^{-1}, available N, P_2O_5 and K_2O as 85, 15.3 and 40 kg ha^{-1}, respectively.

The experiment was set up in Randomized Block Design (RBD) and the rice crop (var. Satabdi) was transplanted on five dates (D_1- 6th July, D_2- 13th July, D_3- 20th July, D_4 - 27th July and D_5 - 3rd August). Each treatment was replicated four times and distributed randomly to a RBD plot having the plot size of 20 m^2 to minimize the effect of difference between the plots. Each treatment was repeated in the same plot during successive years of the experimentation. The Photosynthetic Active Radiation (PAR) was measured at 11:30 h. during tillering, panicle initiation, panicle emergence and at 50% anthesis using line quantum sensor (APOGEE Logan UT, UK).

From the measured PAR values, absorbed PAR was calculated by using the following formula (Gallo and Daughtry, 1986): Absorbed PAR (APAR)

$$= [PAR_{(0)} + RPAR_{(S)}] - [TPAR + RPAR_{(C)}]$$

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Where,
PAR $_{(0)}$ = Incident PAR above the canopy
RPAR$_{(S)}$ = Reflected PAR from soil
TPAR = Transmitted PAR through the canopy to the soil surface
RPAR$_{(C)}$ = Reflected PAR from the crop

The dry matter (g m^{-2}) accumulated in the crop was estimated from the destructive samples taken from 1 m^2 area of each plot. The measurement was done on the same days as in the case of PAR.

The statistical differences in case of dry matter production and grain yield among the different treatment combinations were tested for a RBD design. The relationship among absorption of PAR, dry matter production and grain yields were worked out through Multiple Regression Analysis technique (Gomez and Gomez, 1984). The statistical measurements of coefficient of determination (R^2) were determined to indicate the degree of association between the three variables over the phenological stages.

RESULTS AND DISCUSSION

Dry matter production

Dry matter production at the tillering stage was maximum when the crop was transplanted on 6th July in both the years (Table-1) with a delay for seven days, dry matter accumulation in rice reduced gradually recording the lowest accumulation under D_5 transplanting (3rd Aug); the difference was significant in 2007 at each week, however, no such level of significance was found to be observed in 2008.

In 2007, the percentage reduction in dry matter production were 9.86, 27.79, 41.52 and 51.74 when transplantings were done on 13th, 20th and 27th July and 3rd August respectively; in 2008, the same were 12.04, 19.84, 23.37 and 26.01 percent respectively for the above dates of transplanting.

Dry matter production at the PI stage was also maximum in 2007 when the crop was transplanted on D_1 (6th July), however in 2008, dry matter production was highest when the crop was transplanted on D_2 (13th Aug), but the later dates of transplanting recorded a gradual reduction in dry matter production.

Dry matter production was reduced significantly with the delay in transplanting during panicle emergence as well as 50% anthesis in 2007, a little deviation was observed in 2008 during panicle emergence. The reduction in delayed transplanting was because of slow transport of photosynthates during heading stage (Xie, *et al.*, 1996). Moreover delayed transplanted crop might have to face the adverse temperature during reproductive phase.

Absorption of PAR:

Absorption of PAR was reduced when the crop was transplanted on D_2 and D_3 in 2007 whereas the absorption was reduced continuously with the delayed transplanting during tillering stage. The discrepancy observed during tillering might be due to cloudy sky observed during peak monsoon season. During panicle initiation and panicle emergence stages, maximum absorption of photosynthetically active radiation was found in D_1-transplanted crop in 2007; however in 2008, PAR absorption did not show any variation during PI or panicle emergence stages. During 50% anthesis, no definite trend in PAR absorption by rice crop was observed (Table 2). Absorption of PAR significantly contributed to the dry matter production of rice irrespective of the phenological stages (Fig. 1) when the crop was transplanted on 6th July, 58 or 63 percent variation in dry matter production could be ascribed to the absorption of PAR. In 2007, strength of association (R^2 value) reduced when the crop was sown on 13th July but the 20th July transplanted rice recorded a strong association. Beyond D_3- transplanted crop, strength of association gradually reduced with the delay in transplanting in 2008, significant relationship between absorption of PAR and dry matter production was observed but the closeness of association was depressed when the crop was transplanted on D_3 and D_5. The relationship worked out in this experiment conclusively showed that the reduction in dry matter production was related to the absorption of PAR.

Table 1: Dry matter production in rice at the different phenophases, transplanted at different dates

	2007				2008			
	Tillering	**Panicle initiation**	**Emergence**	**Anthesis 50%**	**Tillering**	**Panicle initiation**	**Emergence**	**Anthesis 50%**
D_1	333.6	652.5	1329.6	1557.3	283.3	671.7	1336.3	1473.1
D_2	300.7	504.1	1091.0	1376.7	249.2	713.8	1138.6	1443.4
D_3	240.9	427.8	981.7	1131.6	227.1	617.2	1387.7	1433.7
D_4	195.1	486.4	893.0	784.9	217.1	492.8	1002.3	1116.7
D_5	161.0	354.0	636.1	852.3	209.6	303.7	783.1	1016.5
SEm(±)	**8.0**	**8.1**	**17.2**	**14.2**	**8.9**	**17.9**	**13.8**	**17.5**
LSD(0.05)	**23.8**	**24.2**	**51.5**	**43.2**	**26.8**	**53.8**	**41.4**	**52.6**

Table 2: Absorption of PAR by the rice crop at the different phenophases, transplanted at different dates

	2007				2008			
	Tillering	Panicle initiation	Emergence	Anthesis 50%	Tillering	Panicle initiation	Emergence	Anthesis 50%
D_1	131.3	166.9	167.8	172.8	121.7	127.2	136.6	142.8
D_2	125.0	151.2	166.3	153.4	122.0	127.1	138.5	149.9
D_3	111.9	128.6	163.0	177.7	96.1	113.9	138.5	113.0
D_4	129.5	152.9	155.0	156.8	98.2	128.7	168.5	126.8
D_5	138.9	144.9	164.8	178.7	94.8	123.9	99.5	98.4

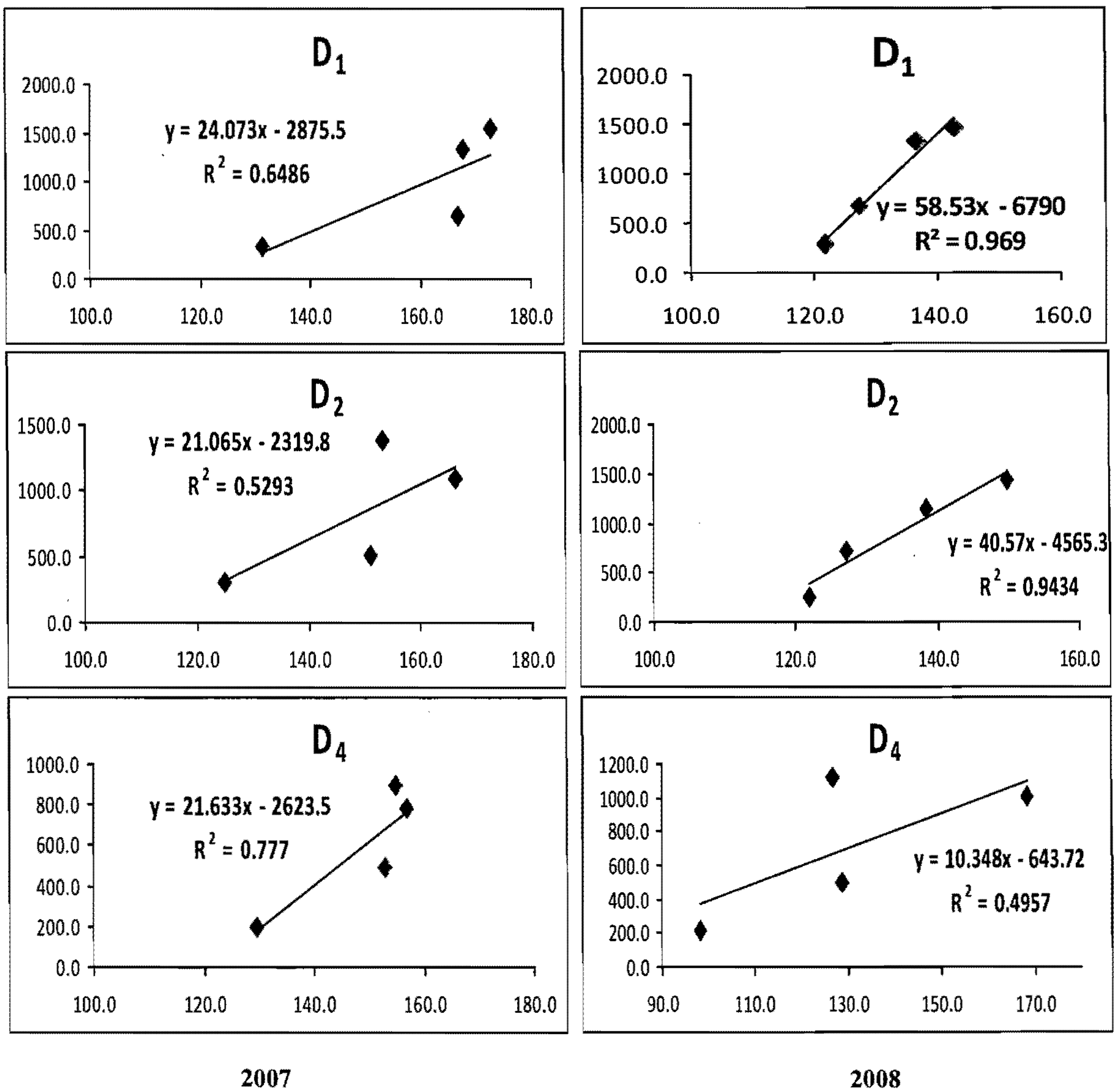

Fig.1: Relationship between dry matter production and absorbed PAR on different dates of transplanting

Dry matter accumulation in rice depends on leaf and tiller production during vegetative phase. Murata and Togari (1972) did not observe any close correlation between average daily solar radiation and tiller number.

However Uchijima (1976) argued that the radiant energy impinging on leaf surfaces played a decisive role in plant evaporation and canopy photosynthesis which actually helps in the processes of dry matter accumulation. In the present experiment, absorbed PAR definitely contributed to the dry mater production with a linear trend but the strength of the association declined due to delay in transplanting, because the delay would shift the vegetative phase to September which remains more cloudy than July or August in West Bengal. Because the dry matter production increases with increasing light intensity (Nyarko and De-Datta, 1993) the PAR received by rice crop may be helpful to augment the photosynthetic process by absorption as well as interception (Ahmed *et al.*, 2008).

Dry matter production and grain yield

Dry matter production during different phenological stages significantly affected the grain yield in rice (Table-3). Pooled analysis of dry matter production over the years showed that dry matter production during anthesis stage significantly explained the variation in grain yield in rice. About 80 and 86 percent variation in grain yield could be explained through the variation in dry matter production during emergence and anthesis stages respectively (Table 3). This is because of the fact that the growth of vegetative organs *viz.* tillers, new leaves and roots slows down after panicle initiation, therefore the tillering stage is primarily responsible for development of biomass (Murata and Matsushima, 1975; Ahmad *et al.* 2008) but its development during the emergence and anthesis period played a crucial role in the transfer of photosynthetates from source to sink during the post anthesis period.

Table 3: Relationship between yield and dry matter production at different phenological stages over different dates of sowing during different crop growing seasons

Phenological stages	Pooled	
	Equation	R^2
Tillering	y = 7.454 Till + 2195.7	0.57
PI	y = 3.084 PI + 2386.8	0.70
Emergence	y = 1.831 Emerg + 2061.2	0.80
Anthesis 50%	y = 1.716 Anthe + 1906.17	0.86
Harvest	y = 0.210 Harv + 180.0	0.80

**(y)- Yield; (Till)- Tillering; (PI)- Panicle Initiation; (Emer)- Emergence; (Anthe)- Anthesis 50%; (Harv)- Harvest.*

Table 4: Grain yield of rice (cv. Satabdi) during different crop growing seasons

	Yield (kg ha^{-1})		
	2007	2008	Pooled
D_1	4429.7	4921.8	4675.7
D_2	4071.8	4344.5	4208.1
D_3	3735.5	4283.5	4009.5
D_4	3348.3	3894.4	3621.3
D_5	3314.5	3634.8	3474.7
SEm(±)	**93.1**	**45.6**	**53.4**
LSD(0.05)	**279**	**136.6**	**160**

Grain yield of rice decreased with the delay in transplanting (Table 4); the maximum grain yield was observed when the crop was transplanted on 6th July. In 2007, no significant variation in grain yield was observed when crop was transplanted on D_4 and D_5; similarly the grain yield did not vary between D_2 and D_3 transplanting in 2008. The pooled data show that there was no significant variation in grain yield when the crop was transplanted on D_4 and D_5. The extent of the reduction in grain yield was found to be 66.8, 95.17, 150.63 and 171.57 kg/ha for a delay of 7, 14, 21, and 28 days from 6th July transplanting.

The step-wise regression analysis showed that the cumulative absorbed PAR during tillering and panicle initiation stages significantly affected the grain yield.

The cumulative absorption of PAR during panicle initiation stage, in 2007, had a significant positive impact on grain yield whereas; PAR absorption during tillering had a negative impact on grain yield.

$Yield_{2007} = 3016.24 + 21.90\ PI^{**} - 19.62\ Till^{**}$

$R^2 = 0.36^{**}$, Adjusted $R^2 = 0.30$, S.E. (est) = 388.59

However, in 2008, the reverse impact was observed, i.e, cumulative absorption of PAR during tillering had a significant positive effect on grain yield.

$Yield_{2008} = 4335.73 + 31.09\ Till^{**} - 27.65\ PI^{**}$

$R^2 = 0.65^{**}$; Adjusted $R^2 = 0.62$ S.E. (est) = 281.78

The strength of association in the latter year was more than the former year, i.e. about 65% variation in grain yield could be explained through the variation in cumulative absorption of PAR at the tillering and panicle initiation stages.

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