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Photosynthetically active radiation variation in across the different phonological phases and its effect on boro rice yield in new alluvial zone of West Bengal

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Abstract
Interception of photosynthetically active radiation (PAR) by the rice crop at different phenophases is important for growth and yield variation through radiation utilization by the crop. Identification of intercepted PAR at a particular time point is necessary for understanding the role of PAR. An experiment on boro rice the cultivar Shatabdi, Heera and Triguna was conducted at 'D' block farm, B.C.K.V, West Bengal, India. The 32 days age of seedling and 25 days age of seedling were transplanted on 27th January 2017-18 and 2018-19. The intercepted PAR was measured at 11:30hr morning at taken observation from tiller initiation, tillering, panicle initiation, panicle, flowering, milk and physiological maturity. The dry matter, yield and PAR use efficiency were estimated. The age of seedling 25 days reduced the dry matter. The PAR use efficiency ranged from 2.57 to 5.10 MJ^{-1} in 32 days age of seedling with Triguna variety. The yield attributes and grain yield were reduced 25 days age of seedling with Heera variety. The PAR use efficiency for grain production was drastically reduced 25 days age of seedling with Heera variety. The interception of PAR at 11:30hr had significant contribution for dry matter and grain yield of boro rice in the new alluvial zone of West Bengal. It was using appropriate and proper age of seedling i.e. 32 days age of seedling ideal and suitable for transplanting.

Keywords: PARUE, interception, rice, dry matter, grain yield

Introduction
Rice is the most important edible cereal in the world. The dry matter accumulation and yield of crop depend on the solar radiation received by the canopy. Interception of light by the rice canopy depends on the transmissivity and the reflectivity of the rice canopy and its leaf inclination (Maruyama *et al.*, 2007) [13]. The relationship between the intercepted radiation and dry matter is known as radiation use efficiency (RUE). The estimation of RUE involves the total solar radiation whereas a certain fraction of the total electromagnetic spectrum is used for photosynthetic purpose. The PAR fraction cannot be estimated from total solar radiation simply by a multiplication factor because the appropriate multiplication factor depends on canopy leaf area index (LAI).
Therefore, it is essential to measure the PAR interception directly and RUE should be estimated with this intercepted PAR. The effect of temperature on rice growth is well established (Shimono and Ishii, 2012; Dutta *et al.*, 2012) [8, 16].
The growth of crop is a complex process and is the resultant effect of canopy radiation capture, photosynthesis and the conversion of photosynthesis to the biomass (Shimono *et al.*, 2002) [17]. During the vegetative and reproductive periods, the limited leaf area and canopy radiation interception were the major reasons for reduced dry matter increase in rice (Shimono *et al.*, 2002) [17]. Ahmad *et al.*, 2008) [1] recorded a linear relationship between the total dry matter accumulation and intercepted PAR in rice crop. The investigations on the impact of intercepted PAR on dry matter accumulation yield and PAR use efficiency (PARUE) at the different growth stages as well as the interception of PAR at a particular time point of a day is still not well documented. Shimono and Ishii (2012) [16] suggested that the variation in grain growth could not be fully explained by temperature and solar radiation during ripening stage. Therefore, we hypothesized that the identification of intercepted PAR at a particular time point of a day is essential for better dry matter production in rice crop, which will give better yield as an ultimate effect and the present investigation was undertaken.

Materials and Methods

A field experiment was conducted during *boro* seasons of 2017-18 and 2018-19 at the District Seed Farm (D block farm) of Bidhan Chandra Krishi Viswavidyalaya, at Kalyani in Nadia district (Latitude 22°58′ N, Longitude 88°31′ E and Altitude of 9.75 meter above mean sea level), West Bengal, India.

The experimental site falls under tropical sub-humid climate and experiences three distinct seasons-March to June as summer, June to September as rainy season and October to February as winter; the summer season is humid and receives rainfall with thunderstorm occasionally. The mercury reaches at its maximum during the month of May, whereas the coldest day is usually observed during January. Nor-Western shower comes during March, April or May and the area experiences dry spell for long period with concomitant high air temperature.

The experiment was laid out in factorial randomized block design (FRBD) with three varieties (V_1) Triguna, (V_2) Shatabdi and (V_3) Heera three spacing (S_1) 20 cm x 15 cm, (S_2) 20 cm x 20 cm and (S_3) 15 cm x 15 cm and two age of seedlings (A1) 32 days age of seedling and (A_2) 25 days age of seedling with two replications.

The rice seedling was transplanted on 27th January in season 2017-18 and 2018-19. The treatments were replicated two times with a net plot size of 3m x 3m.The recommended dose of fertilizer for short duration variety (80:40:40 Kg N, P_2O_5 and K_2O ha^{-1}) and for medium duration variety for (120:60:60 Kg N, P_2O_5 and K_2O ha^{-1}) was applied uniformly to all the treatments.

Five hills were selected from the 2nd row and plants were cut from the ground level. The leaves, stems and roots were separated and dried in hot air oven at 60°C temperature for 72 hours. The summation of the dry weight of stems, leaves and roots gave total dry matter accumulation which was then calculated in terms of g m^{-2}. The final grain yield from 1 m^2 area were collected for yield estimation and yields from 1 m^2 area were converted on hectare basis.

Photosynthetic active radiation was measured with the help of Line quantum sensor (APOGEE Logan UT, Model no. MQ-301). The observations were recorded at 11.30hr, on each phenophases to get a picture of temporal variation of the same.

Intercepted PAR was calculated with the help of following the expression

$IPAR = PAR_{(o)} – TPAR–RPAR_{(c)}$ (Dhaliwal *et al.,* 2007) [7]

Where,

$PAR_{(o)}$ = the portion of the incident PAR above the canopy

TPAR = transmitted portion of the PAR through the canopy to the soil surface

$RPAR_{(c)}$ = reflected PAR from crop (reflected PAR value at the uppermost layer of the rice canopy).

PAR Use efficiency (PARUE)

The PAR use efficiency (PARUE) indicates the potentiality of the crop to produce photosynthates per unit of incoming radiation falling over the crop canopy.

$$\text{PAR use efficiency (PARUE) in g/ MJ} = \frac{\text{Total dry matter accumulation / grain yield (g / m}^2\text{)}}{\text{Accumulated intercepted PAR (MJ / m}^2\text{)}}$$

Statistical analysis

Statistical analysis was done by using the standard procedures of split-split plot design (Gomez and Gomez, 1984) to draw a valid conclusion on sole and interaction effect of all the variables.

Results and Discussion

The interception of PAR during the panicle phase was maximum at 11.30hr. Generally the interceptions increased in 11.30hr. in most of the cases, thereafter flowering phase its declined (Figure 1).The temporal variation in the general trend was observed due to cloudless appearance during the boro season. During panicle phase, mean interception varied from 85 to 90% under different variety, spacing and age of seedlings. The mean interception was minimum when the age of seedling 25 days. During tiller imitation the interception (80%), was minimum at 11.30hr under different variety, spacing and age of seedlings. Interception generally increased with the increase in solar elevation angle. In this latitude, the sun remains at the Zenith at 11.30h, thus, the crop receives maximum insolation (Chakraborty *et al.*, 2008; Jena *et al.*, 2009) [4, 11]. The definite increasing trend of interception was found during panicle initiation and flowering because of the clear sky with better bright sunshine hours in March and May.

Dry matter accumulation in gradually increased from tillering to physiological maturity (Table 1). The Triguna variety with age of seedling 32 days in transplanting, dry matter accumulation was minimum in Heera variety with age of seedling 25 days. Therefore, it could be suggested that the dry matter accumulation was significantly and positively dependent on intercepted PAR on, 11.30 h during the different phenophases. Ishikawa *et al.,* (2003) [10], Al-Khaffaf *et al.,* (2003) [2] obtained a significant relationship between solar radiation and dry matter accumulation.

Photosynthetically active radiation use efficiency as influenced by the different phonological phases of rice with the variety and age of seedling was presented in the (Table 1)**.** The PARUE was increased with the progress of crop growth phases wise. The highest PARUE was observed in Triguna variety in complete panicle phase 5.10 and 5.22 MJ in both the crop growing season. The PARUE was found in the 2.55 and 2.57 MJ in physiological maturity phase of Triguna cultivar in both the year 2017-18 and 2018-19. The PARUE was observed in lowest at Heera variety in complete panicle phase at 4.37 and 4.27 MJ and lowest was observed in physiological maturity phase in 2.29 and 2.31 MJ in the year 2017-18 and 2018-19. When, decline in photosynthetically active leaf area also contributed to the reduction in PAR use efficiency during reproductive phase as rice leaves senesced at high rate after 100% flowering, but leaf tissue whether live or dead considered equally in the measurement of intercepted PAR. The age of seedling was 545.39 and 564.67 grain yield g/m^2 was presented in the (Table 2)**,** the highest PARUE was recorded with 32 days age of seedling 1.26 yield PARUE (gmJ^{-1}) and 1.31 yield PARUE (gmJ^{-1}).

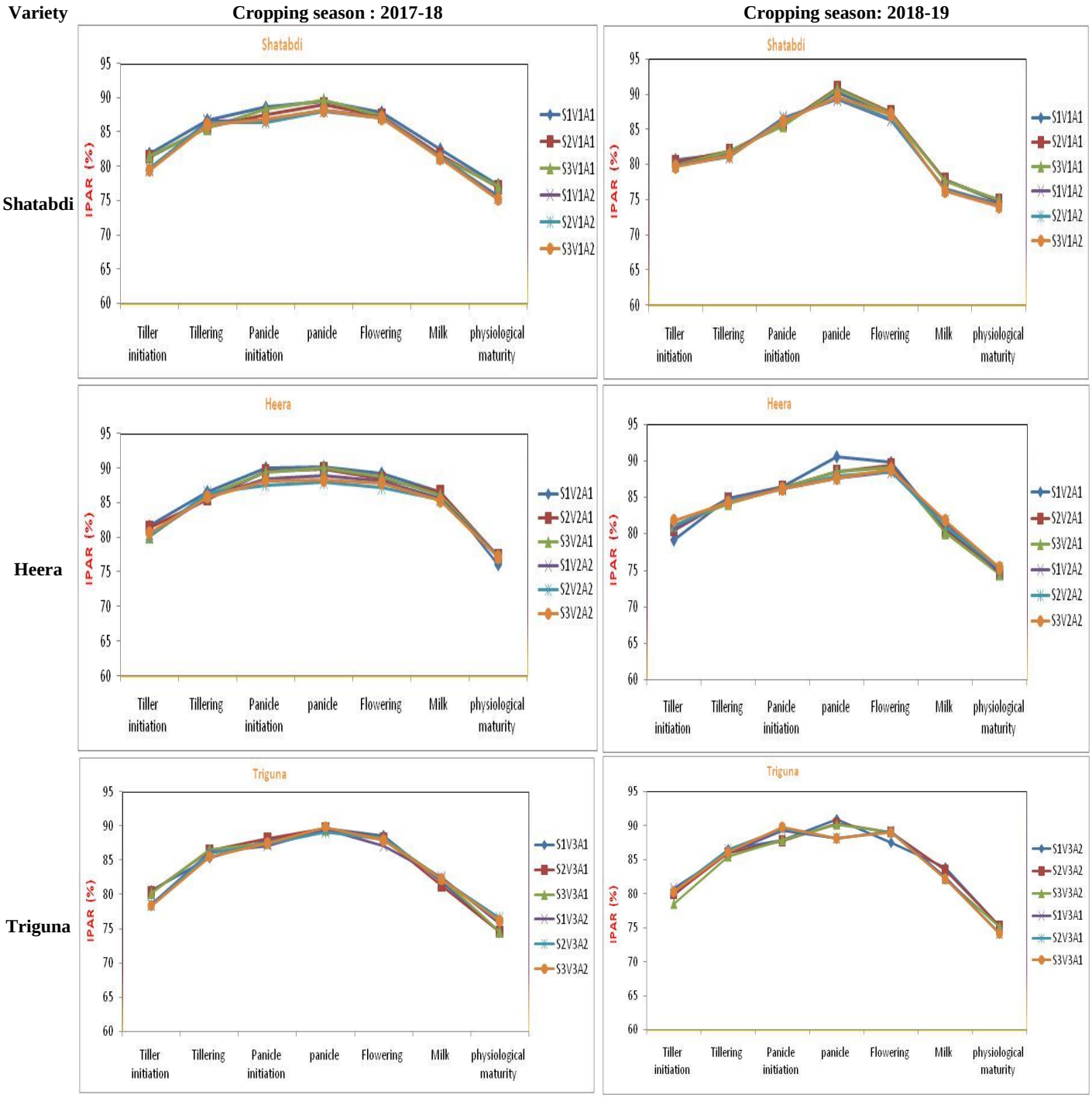

Fig 1: Temporal variation of IPAR (%) for different phenological phases for two consecutive the boro rice seasons in the year 2017-18 and 2018-19 in respect to two age of seedlings and three variety, three spacing

Table 1: Variation of PAR utilization efficiency (g/MJ) and different major phenological phases (g/m^2) in variety and age of seedling of boro rice grown in the year 2017-18 and 2018-19

PARUE (g / MJ)							
Year	**Phenological phases**	**Shatabdi**		**Heera**		**Triguna**	
		Age of seedling 32	**Age of seedling 25**	**Age of seedling 32**	**Age of seedling 25**	**Age of seedling 32**	**Age of seedling 25**
2017-18	Tiller initiation	2.59	2.54	2.41	2.35	2.66	2.59
	100 % Tillering	4.60	4.48	3.87	3.83	4.94	4.84
	Compete Panicle	4.97	4.90	4.37	3.99	5.10	4.91
	100 % Flowering	2.55	2.41	2.35	2.30	2.72	2.65
	Physiological maturity	2.45	2.38	2.29	2.25	2.55	2.47
PARUE (g / MJ)							
2018-19	Tiller initiation	2.63	2.58	2.43	2.38	2.70	2.64
	100 % Tillering	4.66	4.56	4.15	3.98	4.96	4.88
	Complete Panicle	5.00	4.93	4.27	4.13	5.22	5.05
	100 % Flowering	2.57	2.47	2.37	2.32	2.73	2.64
	Physiological maturity	2.47	2.39	2.31	2.26	2.57	2.48

Table 2: Yield attributes, grain yield and PAR use efficiency for grain production in rice under Different variety and age of seedlings during 2017-18 and 2018-19

Treatment	Grain Yield g/m^2		Yield PARUE (gmJ^{-1})	
	2018	2019	2018	2019
V1 (Shatabdi) (S)	509.25	512.42	1.20	1.19
V2 (Heera) (S)	390.83	398.83	0.95	0.96
V3 (Triguna) (M)	602.00	629.42	1.39	1.43
S.E (m), (±)	0.81	0.87	-	-
CD at 5%	2.41	2.56	-	-
A1 (32 Days)	545.39	564.67	1.26	1.31
A2 (25 Days)	456.00	462.44	1.10	1.11
S.E (m), (±)	0.66	0.71	-	-
CD at 5%	1.97	2.10	-	-

The yield of rice was also significantly and positively affected by the interception of PAR during 100 % tillering and complete panicle stage at 11.30hr (Table 1).

Triguna cultivar 602 and 629.42 grain yield g/m^2, yield PARUE 1.39 (gmJ^{-1}) and 1.43 (gmJ^{-1}) yield PARUE in both the year 2017-18 and 2018-19. The PARUE was observed in lowest at Heera variety in combination with the three varieties namely as Shatabdi, Heera and Triguna. The linear relationship was observed different phenological phase's wise biomass and accumulated intercepted PAR in the boro rice growing season of 2017-18 and 2018-19.

Conclusion

In conclusion, the results show that rice cultivar Triguna should be transplanted with 32 days age of seedling was obtained the higher PARUE. The interception of PAR at 11.30hr has a significant and positive contribution for dry matter as well as grain yield of rice. The PAR use efficiency during the tiller imitation is lower than the 100% flowering.

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