Environment and Ecology 41 (1B) : 416—420, January—March 2023
ISSN 0970-0420

Studied Over Rice Crops for Radiation Interception, Extinction Coefficient and Radiation use Efficiency in Two Growing Seasons in Odisha, India

M. K. Beck, H.V. Puranik

Received 3 October 2022, Accepted 9 December 2022, Published on 6 March 2023

ABSTRACT

At the ICAR-IIWM, Deras Farm, Bhubaneswar, Odisha, a field experiment was carried out. Examine the radiation use efficiency, extinction coefficient and IPAR in rice during the *kharif* season under two growing seasons (2018 and 2019). With a line quantum sensor equipment, the PAR values of incident PAR and transmitted PAR at the field were measured after (30 DAT) canopy development at 15 day intervals till maturity from 8 am to 5 pm each day. For all growth stages, LAI was linearly correlated to IPAR, with the highest PAR interception occurring around midday; however, the lowest PAR interception occurring during the morning and evening may be influenced by the sun's longer path to the earth's surface. Extinction coefficient is a measure of the canopy's efficiency to intercept light and a distribution of PAR within the plant canopy. The second growing season exhibited higher RUE values (1.46 g/MJ IPAR) as a consequence of different radiation interception caused by changes in canopy surface and LAI.

Keywords Rice, Intercepted photosynthetically active radiation, Extinction coefficient, Radiation use efficiency, LAI.

INTRODUCTION

Crop canopy cover significantly depends on the crop cultivars and its physiological characters. Crop canopies represent an integrated photosynthetically and biomass production system, the crop canopy cover plays an important role in the function. Crop canopy cover, which is directly related to the ability of within canopy light interception, is the most important factor influencing light radiation distribution and light use efficiency (Liu *et al.* 2011) and LAI distribution also the principal factors that determine light radiation distribution and leaf physiological characters in crop canopies. The beers law for the describing the distribution of light in a crop canopy of different hight to predict light transmission, many studies have focused on beer law on canopy light transmission in crops, such as wheat, rice, maize and cotton (Liu *et al*. 2011 and Tang *et al.* 2011). The most dynamic approach is utilizing the extinction coefficient (K) and cumulative LAI values to simulate vertical light distribution in the crop canopy, when the larger LAI, the larger K under the same conditions and the canopy intercepted more sun light. K value are affected by many other factors, such as structural parameters and also elevation angle.

M.K. Beck[1]*, H.V. Puranik[2]
[1]PhD Scholar, [2]Associate Professor,
Department of Agrometeorology, IGKV, Raipur 492012, India
Email : beck.manoj05a@gmail.com
*Corresponding author

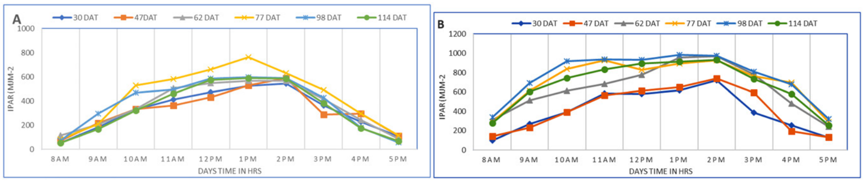

Fig. 1. Comparing diurnal variation of IPAR from 8 am to 5 pm at different growth stages on two rice growing seasons (A) and (B).

Under potential conditions, with adequate moisture and fertility, radiation plays the role of a decisive factor for crop growth and development. The present investigation was undertaken to assessing the effect of radiation interception, Leaf Area Index and Light extinction coefficient of rice crop growth development in Bhubaneswar condition.

MATERIALS AND METHODS

Weather condition

The experimental site is in the tropical Eastern plateau and Hills Agro-climatic zone-VII" Agro-climatic zone. About 1384.2 mm and 1540.9 mm of rain fell during the 2018 and 2019 *kharif* seasons, spread over 46 and 55 wet days, respectively. In 2018 and 2019, the weekly mean maximum and lowest temperatures during the crop growing period varied from 34.8 to 29.8°C and 26.3 to 15.9°C respectively. Similar mean relative humidity (RH) ranged from 96 to 88% and 96 to 86% in the morning and from 87 to 53% and 84 to 43% in the afternoon, respectively, in the years 2018 and 2019. Similar to the above, mean bright sunshine hours in 2018 and 2019 ranged from 1.2 to 8.5 hr and 1.3 to 7.5 h, respectively.

Measurement and observations

In both the year, data collection was started at 30 DAT and continued upto maturity with 15 days interval. In every observation day, where randomly selected plants of the crop always maintained a distance from the previous observation area to avoid edge effects. Observations on growth parameters plant height, phenological stages, biomass, yield and yield attributes were recorded throughout the growing period.

During the growth period, diurnal and seasonal variation of incident and transmitted PAR were also measured at 15 days interval starting from 8 am to 5 pm with a gape of one hour. A line quantum sensor was used manually to record the radiation on surface and different canopy level.

Different indices calculation

Based on the measurement of LAI and PAR data amount of light extinction coefficient of the crop was determined using the beer low.

$$k = \left[\frac{-\ln\left(\frac{PARt}{PARi}\right)}{LAI} \right]$$

PARt = Transmitted PAR at bottom of canopy

PARi = Incoming PAR at top of the canopy

LAI = Leaf Area Index

The intercepted PAR (IPAR) was measured following relationship :

$$I_i = I_0 - I_{re} - I_t + I_{rg}$$

$$I_i \text{ (\%) by the canopy} = (I_i/I_0)*100$$

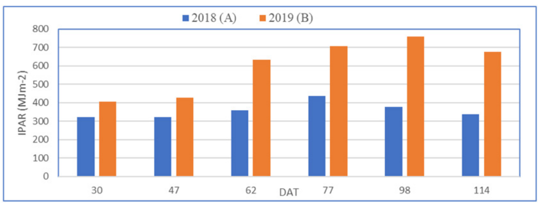

Fig. 2. Comparing seasonal variation of average IPAR on two rice growing seasons (2018 and 2019).

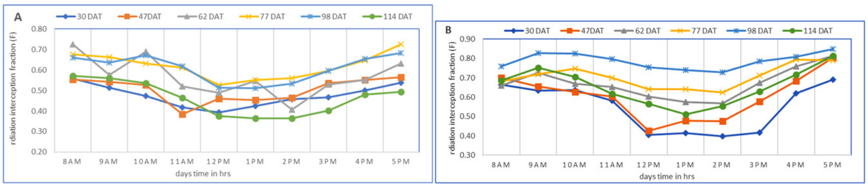

Fig. 3. Comparing diurnal variation of radiation interception fraction (F) from 8 am to 5 pm of two rice growing seasons (A) and (B).

Where,

I_i = Intercepted photosynthetic active radiation (PAR) by the canopy

I_0 = Incident PAR on the canopy

I_{re} = Reflected PAR by the canopy

I_t = Transmitted PAR through the canopy

I_{rg} = Reflected PAR from the ground.

Similarly for the fraction of photosynthetic active radiation intercepted was calculated as :

$$F = \frac{IPAR}{PAR}$$

Where,

IPAR = Intercepted photosynthetic active radiation

PAR = Photosynthetic active radiation above the canopy.

Radiation use efficiency was calculated from the cumulative IPAR on cumulative dry biomass obtained from the sequential sampling (Kar *et al.* 2014).

RESULTS AND DISCUSSION

Intercepted photosynthetically active radiation (IPAR)

The diurnal variation on hourly basis Fig.1 shown of IPAR range varies from 53 to 544 MJm^{-2} and 102 to 719 MJm^{-2} at 30 days after transplanting (DAT), at 47 DAT from 72 to 591 MJm^{-2} and 135 to 742 MJm^{-2}, at 62 DAT from 87 to 567 MJm^{-2} and 240 to 970 MJm^{-2}, at 77 DAT from 85 to 762 MJm^{-2} and 294 to 927 MJm^{-2}, at 98 DAT 59 to 598 MJm^{-2} and 320 to 983 MJm^{-2}, at 114 DAT 52 to 589 MJm^{-2} and 254 to 932 MJm^{-2} in two seasons respectively. The highest interception of PAR noon hours but lowest interception morning and sunset hours may be due to the increase path length of the sun from earth surface.

The seasonal variation Fig. 2 shows that a day of mean IPAR varies from 322, 322.7, 358.6, 436.1, 377.2, and 337.5 MJm^{-2} in first season (A) and 404.1, 426.7, 632.8, 707, 758.2 and 676.1 MJm^{-2} in second season (B) on 30 DAT, 47 DAT, 62 DAT, 77 DAT, 98 DAT and 114 DAT respectively. The lowest IPAR recoded at morning and sunset hrs and the highest intercepted photosynthetically active radiation have recorded during noon hrs were as highest at crop reproductive stages under days after transplanting in both the year and second season (2019) IPAR was reported high as compare to first season (2018). These results indicated that IPAR increases as surface canopy increased. Similar results show that the PAR interception increased with increased LAI (Basu *et al.* 2014).

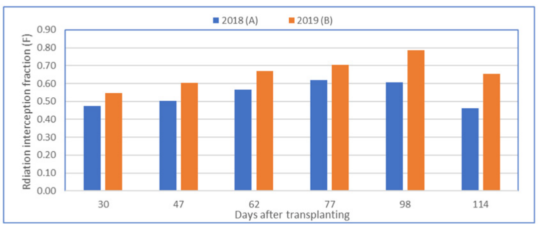

Fig. 4. Comparing seasonal variation of average radiation intercepted fraction (F) at different growth stages on two rice growing seasons 2018 (A) and 2019 (B).

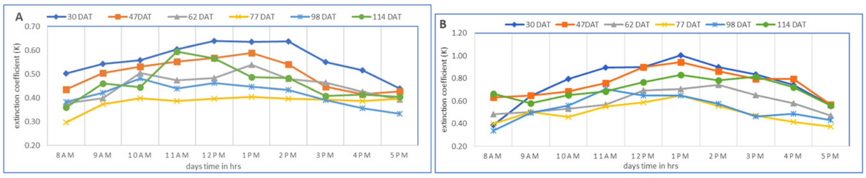

Fig. 5. Comparing diurnal variation of extinction coefficient (K) from 8 am to 5 pm on *kharif* rice of two seasons (A) and (B).

Radiation interception fraction (F)

The temporal variation of radiation intercepted fraction (F) of rice crop for two seasons are presented in Fig. 3 the F is highest at sun rise and sunset during a day time variation and lowest at noon hrs were is varies from 0.39 to 0.56 and 0.40 to 0.69 from 30 days after transplanting, at 47 DAT varies from 0.38 to 0.56 and from 0.43 to 0.80, at 62 DAT varies from 0.41 to 0.72 and from 0.57 to 0.81, at 77 DAT varies from 0.53 to 0.72 and from 0.62 to 0.79, at 98 DAT varies from 0.51 to 0.68 and at 114 DAT varies from 0.36 to 0.57 and from 0.51 to 0.81 in two seasons respectively. The lowest fraction was resulted at reproductive stages of both the crop seasons it may be due to depends on the inclination of the solar rays and overall highest fraction was resulted at second season of rice crop. The highest value of F during morning and evening hours were therefore due to solar rays being more inclined i.e., low angle making with respect to horizontal surface of the crop and at the noon hours they are make almost vertical inclination and that inclination causes the rays/radiation to be spread over a large area and hence more interception per square unit area (Basu *et al.* 2014).

The Fig. 4 is showing seasonal variation of radiation fraction from 0.47, 0.50, 0.57, 0.62, 0.61, 0.46 and 0.55,0.60, 0.67, 0.70, 0.79, 0.65 at 30, 47, 62, 77, 98 and 114 days after transplanting in 2018 (A) and 2019 (B) seasons. Where is found lowest at developing phases and relatively decrease at maturity phases but highest radiation interception fraction was found at reproductive stages in both the season and highest radiation fraction in second season (B) was resulted. The radiation interception fraction varied from tillering to maturity stages. The figure is showing parabolically. It may be due to highest leaf canopy surface and full growth of leaf area.

Light extinction coefficient (K)

The daytime variation of extinction coefficient an hourly change on rice crop of two seasons (A) and (B) are presented in Fig. 5 the profile (K) behaves parabolic changes during both the crop season. Because of the extinction coefficient changes diurnally with changing sun's azimuth angle. The maximum (K) value was found noon hours of the day and at early growth stages were varies from 0.44 to 64 and 0.39 to 1 at 30 DAT, 0.42 to 0.59 and 0.57 to 0.94 at 47 DAT, 0.38 to 0.54 and 0.47 to 0.74 at 62 DAT, 0.30 to 0.41 and 0.38 to 0.65 at 77 DAT, 0.33 to 0.48 and 0.34 to 0.71 at 98 DAT, 0.36 to 0.59 and 0.56 to 0.83 at 114 DAT in both season respectively. The lowest extinction coefficient (K) was resulted at reproductive stages of both the crop seasons and as compare to first season the highest (K) value was resulted at second season of rice crop.

The seasonal variation of extinction coefficient (K) is showing Fig. 6 from 0.56, 0.50, 0.45, 0.38, 0.41, 0.46 and 0.77, 0.76, 0.59, 0.50, 0.54, 0.71 at 30, 47,

Table 1. Radiation use efficiency (RUE) and heat use efficiency (HUE) to obtain various growth intervals in rice under two growing seasons (2018-2019 and 2019-2020).

Crop season	30	45	60	75	90	Maturity	Mean
				RUE (g/MJ)			
2018	0.52	1.29	1.27	1.33	1.53	1.39	1.22
2019	0.64	1.47	1.55	1.53	1.87	1.72	1.46
Mean	0.58	1.38	1.41	1.43	1.70	1.55	1.34
				HUE (g/m^2/^{0}C day)			
2018	0.36	0.47	0.52	0.64	0.68	0.58	0.55
2019	0.37	0.49	0.62	0.66	0.71	0.65	0.58
Mean	0.37	0.48	0.60	0.65	0.69	0.62	0.56

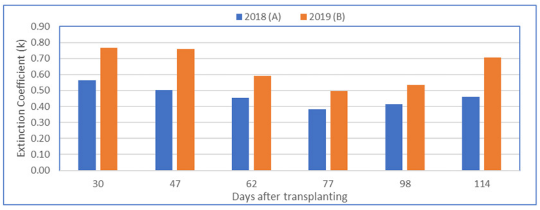

Fig. 6. Comparing seasonal variation of average extinction coefficient (K) at different growth stages on *kharif* rice in 2018 (A) and 2019 (B) seasons.

62, 77, 98 and 114 days after transplanting in 2018 (A) and 2019 (B) seasons. Where is found highest at developing phases and relatively decrease at maturity phases but lowest extinction coefficient (K) was found at reproductive stages in both the season and also, highest extinction coefficient (K) in second season (B) was resulted. It may be due to highest leaf area index at reproductive stage. At maturity stage (K) value sharply deceased due to senescence by (Basu *et al.* 2014). The highest (K) value determine it determine strong light absorption but reduced (K) value determine important for allowing better light penetration into leaf canopies (Kar *et al.* 2014) (K) value determine based on cultivars, orientation of leaf, planting pattern and value may vary from 0.3 to 1.5 (Samanta *et al.* 2019).

Radiation use efficiency (RUE)

Radiation use efficiency of rice variety recorded in different seasons at different growth stages varied considerably as shown in the Table 1. Higher RUE (1.46 g/MJ) was observed in 2nd season as compare to 1st season. All growth intervals showed higher values of RUE in 2nd season as compared to 1st season. RUE was increased from 30 days of crop growth to 90 days of crop growth and it decreases due to leaf senescence in both the season of rice crop. RUE variation might be due to the differential dry matter production in two seasons while intercepting different amount of radiation because of variation in canopy surface and the LAI. According to Samanta *et al*. (2019), RUE levels vary with plant species, climatic conditions, measuring method and plant characteristics. The difference observed between both experiments clearly shows the effect of weather on the radiation use efficiency due to the direct relation between biomass accumulation and its CO_2 assimilation rate (Saha *et al.* 2015 and Pradhan *et al.* 2018).

CONCLUSION

The intercepted PAR pattern as crop growth advanced has been widely investigated. It can be derived after this experiment that estimating the PAR interception pattern and LAI at various growth stages throughout the growing season can diagnose the light extinction coefficient, f IPAR value and radiation use efficiency, designed to allow one must evaluate and keep track of the potential growth of crops is also beneficial for further scientific study.

REFERENCES

Basu SS, Maji SK, Dutta S, Jena RN, Chakraborty PK (2014) Impact of PAR interception at different time points on total dry matter production in rice (*Oryza sativa* I.) crop transplanted on different dates. *J Food Agric Environ* 12 : 285—291.

Goyal A, Das DK, Sehgal VK, Vashisth A, Datta SP, Mukherjee J, Pradhan S, Singh J, Singh R (2018) Effect of row direction and cultivar on micrometeorological and biophysical parameters of oil seed brassica. *J Agrometeorol* 20 (Special Issue I) : 85—91.

Kar G, Kumar A, Sahoo N, Mohapatra S (2014) Radiation utilization efficiency, latent heat flux and crop growth simulation in irrigated rice during post-flood period in east coast of India. *Paddy Water Environ* 12 : 285—297.

Liu RY, Huang WJ, Ren HZ, Yang GJ, Xie DH, Wang J (2011) Photosynthetically active radiation vertical distribution model in maize canopy. *Trans Chin Soc Agric Engg* 27 : 115—121.

Pradhan S, Sehgal VK, Bandyopadhyay KK, Panigrahi P, Parihar CM, Jat SL (2018) Radiation interception, extinction coefficient and use efficiency of wheat crop at various irrigation and nitrogen levels in a semiarid location. *Ind J Pl Physiol* 23 (3) : 416—425.

Saha S, Sehgal VK, Chakraborty D, Pal M (2015) Atmospheric carbon dioxide enrichment induced modifications in canopy radiation utilization, growth and yield of chickpea (*Cicer arietinum* L.). *Agric Forest Meteorol* 202 : 102—111.

Samanta S, Banerjee S, Mukherjee A, Patra PK, Chakraborty P (2019) Deriving PAR use efficiency of wet season rice from bright sunshine hour data and canopy characteristics. *Mausam* 70 (2) : 347—356.

Tang L, Li YD, Zhang YP, Zhu XC, Liu XJ, Cao WX, Zhu Y (2011) Simulation of canopy light distribution and application in rice. *Rice Sci* 4 : 427—434.