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Effect of Transplanting Dates, Cultivars and Irrigation Regimes on Microclimate and Yield of Rice

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Abstract

A field experiment was conducted at BCKV, Kalyani, West Bengal (Latitude 22°59'13'' N, Longitude 88°27'20'' E) to evaluate the performance of different rice cultivars grown during *kharif* season of 2017. The experiment was laid down in a split split-plot design where four dates of transplanting (16th June, 30th June, 14th July and 28th July) were allotted in main plot, three rice cultivars (Nayanmani, Satabdi, Swarna) in sub-plot and two irrigation regimes (Optimum and Deficit) in sub-sub plot. Result revealed that the grain yield (4365 kg ha^{-1}) was recorded in 16th June transplanting, highest which significantly declined by 15%, 31% and 36% respectively with delay in transplanting. Deficit irrigation resulted 851 kg ha^{-1} less grain yield compare to optimum irrigation condition (3915 kg ha^{-1}). Grain yield under different variety was in the order of Nayanmani (4495 kg ha^{-1}) > Swarna (3008 kg ha^{-1})>Satabdi (2965 kg ha^{-1}).The highest magnitude (0.98 g MJ^{-1}) of radiation use efficiency was noted under D_1, which decrease gradually with delay in transplanting time (0.79 g MJ^{-1}>0.64 g MJ^{-1}>0.58 g MJ^{-1}). The highest magnitude (0.87 g MJ^{-1}) of RUE was noted under optimum irrigation, which was 0.15 g MJ^{-1} less under deficit irrigation. Among the varieties, the highest magnitude (1.10 g MJ^{-1}) of RUE was recorded under Nayanmani, which was 0.40 g MJ^{-1} less under Satabdi. The lowest RUE (0.48 g MJ^{-1}) was noted under Swarna.

1. Introduction

Agricultural productivity is influenced mainly by cultural practices followed and prevailing weather conditions. Rice is the predominant cereal crop in east India including the state of West Bengal. The total cultivated area of rice in India is 43.2 million ha and the country produced 110.2 million tons of rice in 2016-17. West Bengal is the largest rice producing state in India. Almost half of its arable land is under rice cultivation. In the fiscal year 2016, the state produced about 15.75 million tonnes of rice over 5.46 million hectare cultivable area (Anonymous, 2019). Rice requires a mean temperature range of 17 to 33 °C and solar radiation range of 300 to 600 calories cm^{-2} day^{-1} in its growing areas and seasons. Rice is a water loving plant requiring a heavy rainfall of 125 cm during its vegetative period and an annual rainfall of 100-200 cm (Prasada Rao, 2008). To improve production it is imperative to understand the weather at both macro and micro-levels as weather directly influences the crop growth

and development. For higher productivity, rice requires higher light intensity. For enhancing crop productivity its exposure to sunlight and utilization efficiency are important so as to produce dry matter. The rate of photosynthesis is dependent upon the availability of photosynthetically active radiation intercepted by the leaves. The ultimate capacity of a plant to produce dry mater depends on degree of exposure to sunlight and its radiation use efficiency. There is a need to know the microclimate variations particularlyair temperature, canopy temperature, radiation in rice crop for optimum crop production. Hence, the present investigation was carried out to screen suitable planting dates, varieties and irrigation regimes considering optimum microclimatic parameters.

2. Materials and Methods

2.1. Study site

Field experiment was conducted during the *kharif* (July-October) seasons of 2017 in the 'C' Block Farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, (Latitude 22°59'13'' N, Longitude 88°27'20'' E and altitude 10.8 m above mean sea level), West Bengal, India. The experimental site characterized as hot, sub-humid climate. The study site receives an average annual rainfall of 1600 mm out of which 1300 mm (81%) occurs during monsoon period (June to September). May is the hottest with 27.6 to 31.1 °C average temperature, whereas the coldest day experiences during January (15.5 to 21.3 °C). The soil of the experimental site is Entisol with sandy loam texture.

2.2. Experimental design and treatments

The experiment was arranged in a split-split plot design with four dates of transplanting [DOT, D_1: 16.06.2017, D_2: 30.06.2017, D_3: 14.07.2017 and D_4: 28.07.2017) as main plot treatment, three rice cultivars (V_1: Nayanmani, V_2: Satabdi (IET4786) and V_3: Swarna (MTU 7029) in sub-plot treatment and two irrigation management (I_1: Optimum and I_2: Deficit irrigation) as sub sub-plot treatment. Size of the individual plot was 4.5×5.0 m^2 with spacing 20 cm (RxR) and 15 cm (PxP).

In I_1, a continuous water level of 3 cm was maintained up to milking stage. However, in I_2, 150-200 mm water was applied only during transplanting process. Thereafter no irrigation was applied and the crop was grown with the help of rainwater only.

During land preparation, synthetic fertilizer was applied @ 80N (Urea), 60P_2O_5 (SSP), 60K_2O (MOP) kg ha^{-1}. Full dose of phosphate, potassium and 50% nitrogen were applied at land preparation and rest 50% nitrogen was applied in two equal splits; 21 DAT and before panicle initiation stage.

2.3. Harvesting

The crop was harvested at physiological maturity stage. The grain yield was recorded after proper sun drying and threshing of the crop.

2.4. Observation and measurement

2.4.1. Measurement of microclimatic parameters of the crop stand

The microclimate of a crop stand is largely influenced by photosynthetically active radiations (PAR) interception, relative humidity and canopy temperature within and above crop canopy. Air temperature within canopy has direct effect on physiological process such as photosynthesis, transpiration and respiration. It also determines thermal environment within the crop stand. The measurements of microclimatic parameters were done at 08.00, 10.00, 12.00, 14.00 and 16.00 hours during various phenological stages (tillering, panicle initiation, 1st Anthesis, flowering, milking, dough and maturity).

2.4.1.1. Photosynthetically active radiation

The diurnal cycles of photosynthetically active radiation (PAR) was recorded with the help of a line quantum sensor (Model: APOGEE/MQ-301). Measurements of PAR were made placing the line quantum sensor across the row. The incident PAR (PAR_0) was measured placing the sensor horizontally 100 cm above the crop height and the PAR reaching to the ground through canopy (transmitted PAR) was measured by placing the sensor 50 cm above the soil surface horizontally. The reflected PAR from canopy and ground surface was measured by just inverting the sensor towards the canopy and ground surface respectively. The output of the instrument was given in µmol m^{-2} s^{-1}. The output was converted to W m^2 by a conversion factor of 4.57.

2.4.1.1.1. Component of the photosynthetic active radiation

The following components of the PAR were calculated as Follows:

(i) Intercepted photosynthetically active radiation (IPAR) was computed as

IPAR=Incident PAR- Reflected PAR-Transmitted PAR ……. (i) (Dhaliwal et al., 2007)

IPAR (%)=(IPAR×100)/ PAR_0 ……………… (ii)
TPAR (%)=(IPAR×100)/ PAR_0 ……………… (iii)
R_CPAR (%)=(R_CPAR×100)/ PAR_0 …………… (iv)
R_SPAR (%)=(R_SPAR×100)/ TPAR …………… (v)
Where

PAR_0=Incident PAR above the rice canopy
TPAR=PAR transmitted through the rice canopy to the ground
R_CPAR=Reflected portion of PAR from the canopy
R_SPAR=Reflected portion of PAR from the soil

(ii) Absorbed photosynthetically active radiation (APAR)

Absorbed PAR (APAR) was calculated by the equation proposed by Gallo and Daughtry (1986)

APAR=[PAR_0+ $PARR_S$] − [TPAR+ $PARR_C$]……….(vi)
APAR (%) (APAR×100)/PAR_0 ………… (vii)

2.4.1.2. Radiation use efficiency

RUE=(Total grain yield of rice/Total accumulated absorbed PAR)

2.4.1.3. Canopy temperature

The canopy temperature was measured with the help of infrared thermometer (MODEL: R-tek, RT/SRG550). The infrared thermometer was targeted to the canopy from east, west, north and south side of the each plot at an angle of 45°. The mean value of the four values considered as the canopy temperature value for each plot. Unit of the recorded temperature was °C.

2.4.1.4. 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.

3. Results and Discussion

3.1. Photosynthetic active radiation

Flowering stage is the most important stage among different crop growth stages of rice, during which is flowering stage, weather elements along with photosynthetic active radiation plays pivotal role towards seed formation, development and finally to yield. In the present manuscript diurnal variation of PAR is being discussed only for flowering stage and variation of other micrometeorological parameter along with PAR is also being discussed considering all the phenological stages.

3.1.1. Diurnal variation

3.1.1.1. Flowering stage

Irrespective of all the treatment combination, the higher R_CPAR (4.8%) was recorded at 8 hrs which decrease gradually and reached its lowest level (4.0%) at 12 hrs followed by a steady increase upto 16 hrs (Table 1). Higher angle of incident radiation resulted at higher reflection at morning and afternoon time. R_CPAR from the crop canopy indirectly indicates the physiological condition of the crop. In Table 1, the diurnal variation of R_CPAR clearly shows that it ranged from 3.8 to 5.4% across DOTs. Gates (1981) recorded that reflectance from the 'high sun' is lower than the 'low sun' in different crop species. Jean et al. (2009); Biswas et al. (2011) and Maji et al. (2015) reported PAR reflection from mung bean, sesamum and potato during early and late hours of the day respectively.On an average the highest magnitude was recorded in D_4 (5.4%) followed by D_1 (4.6%), D_3 (4.4%) and the lowest in D_2 (3.8%). Among the three varieties, the average value of R_CPAR was in the order of V_3 (5.0%)>V_2(4.6%)>V_1(4.0%). Stress plant under I_2 reflected 20.83% more PAR compare to non-stress plant (I_1).

Irrespective of all the treatment combination, the diurnal variation of R_SPAR showed that the highest magnitude was observed at 16 hrs (9.0%) and the lowest magnitude was seen at 12 hrs (5.0%) (Table 1). This is due to increases solar elevation angle and Jean et al. (2009), Biswas et al. (2011) and Maji et al. (2015) recorded similar observation in different crops. Variation of reflected soil (R_SPAR) from soil among the

Table 1: Variation of reflected PAR from crop and soil, transmitted PAR and absorbed PAR during flowering stage of rice under different dates of transplanting, different cultivars and irrigation regimes

Treatment	8 hr	10 hr	12 hr	14 hr	16 hr
R_CPAR					
D_1	5	4	4	5	5
D_2	4	4	3	4	4
D_3	5	5	4	4	4
D_4	6	5	5	5	6
V_1	4	3	4	4	5
V_2	5	4	4	5	5
V_3	5	5	4	5	6
I_1	4	3	4	4	4
I_2	5	4	4	5	6
R_SPAR					
D_1	7	5	5	8	13
D_2	6	5	5	6	7
D_3	6	6	5	6	7
D_4	7	6	5	6	8
V_1	6	4	5	6	7
V_2	6	5	5	7	9
V_3	8	8	5	7	13
I_1	6	6	5	7	8
I_2	7	6	5	6	9
TPAR					
D_1	8	12	17	8	6
D_2	13	20	32	15	13
D_3	10	12	20	14	20
D_4	10	11	17	10	10
V_1	12	20	31	15	15
V_2	11	16	21	14	13
V_3	8	6	13	6	5
I_1	9	10	19	7	10
I_2	10	17	22	14	14
APAR					
D_1	88	85	80	88	89
D_2	83	77	67	82	84
D_3	86	84	77	82	77
D_4	85	85	79	86	84
V_1	84	78	67	82	81
V_2	85	81	76	82	82
V_3	88	90	84	89	90
I_1	87	87	78	90	87
I_2	85	79	75	82	81

different dates of transplanting showed that the peak value was obtained by D_1 (7.6%) followed by D_4 (6.4%), D_3 (6.0%) and the lowest value was seen under D_2 (5.8%). The highest magnitude of R_SPAR among the different varieties was found under V_3 (8.2%) followed by V_2 (6.4%) and lowest in V_1 (5.6%). Among the irrigation regimes, it showed a similar pattern as that of R_CPAR where highest magnitude was recorded in I_2 (6.6%) and the lowest in I_1 (6.4%). Dry soil under I_2 result more reflection of PAR (Table 1).

The diurnal variation showed the highest magnitude of TPAR was recorded at 12 hrs (21.3%) and the lowest magnitude was recorded at 8 hrs (10.1%) (Table 1). Similar observation also recordedin rice by Chakraborty et al. (2017), in mung bean by Jean et al. (2009a, 2010b), in sesamum by Biswas et al. (2011) and in potato by Maji et al. (2015). The transmitted PAR (TPAR) shows an opposing pattern as portrayed by R_CPAR among the different dates of transplanting. The highest (18.6%) magnitude of TPAR was recorded under D_2 followed by D_3 (15.2%), D_4 (11.6%) and the lowest value in D_1 (10.2%). The highest magnitude (18.6%) and lowest magnitude (7.6%) of TPAR was recorded respectively in V_1 and V_3. Similar trend was observed in the values of TPAR as that of R_CPAR and R_SPAR where it peak value was seen in I_2 (15.4%) and lowest value in I_1 (11%) (Table 1).

The diurnal pattern of APAR showed a highest value at 8 hrs (85.7%) and the lowest value at 12 hrs (75.9%) (Table 1). Absorbed PAR determines the amount of radiation absorbed by the canopy. The results in Table 1 shows that the highest APAR was arranged in decreasing order among the different dates of planting as D_1 (86%)>D_4 (83.8%)>D_3 (81.2%)>D_2 (78.6%). Among the different varieties, peak value of APAR was seen under V_3 (88.2%) followed by a decrease in V_2 and V_1 by 7.8% and 17.9% respectively. Amidst the irrigation regimes the peak value was found in I_1 which was decreased by 6.8% in I_2.

3.1.1.2. Stage wise variation

Temporal variation of absorbed PAR shows an increasing trend from tillering to panicle initiation stage and remain static afterwards till harvesting. The maximum magnitude of APAR (49-88%) was found under D_2 followed by D_1, D_3 and D_4 (Figure 1). Mukherjee et al. (2013) also observed that highest PAR absorption in rice was noted under D_2 (i.e. transplanting in end of July) followed by D_3 and D_1. In general, APAR under deficit irrigation (I_2) showed superiority over optimum irrigation (I_1). The maximum magnitude of APAR (33-87%) was found in deficit irrigation condition (I_2) compare to optimum irrigation condition (I_1). The maximum magnitude of APAR (22-89%) was found under V_3 followed by V_2 (21-84%) and lowest magnitude was noted under V_1 (26-79%).

3.2. Absorbed photosynthetically active radiation

Photosynthetically active radiation (PAR) is the most important natural resource, which is assimilated through photosynthesis process, and the energy is stored in grain as
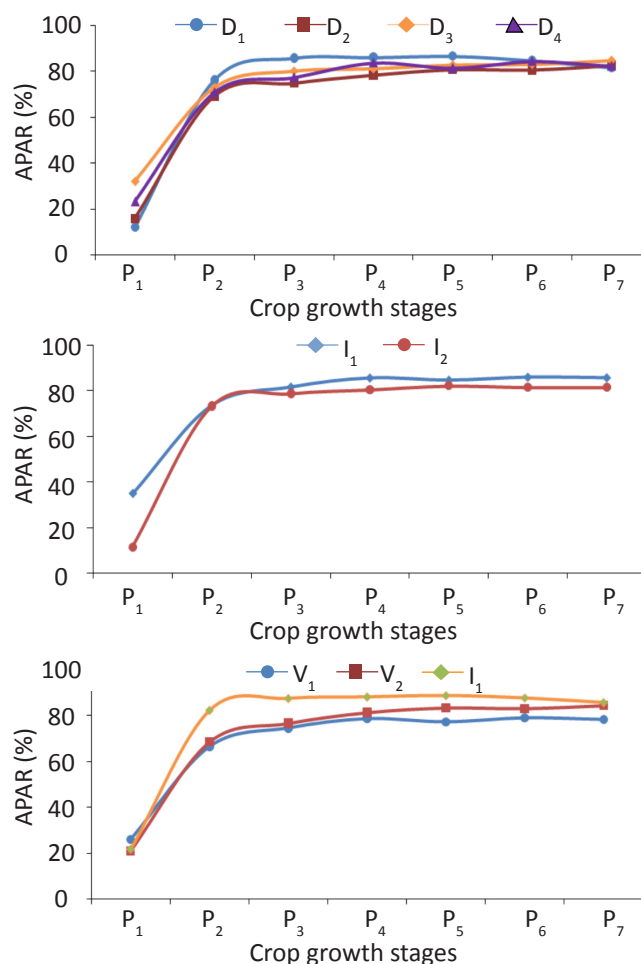

Figure 1: Variation of absorbed PAR during different crop growth growth stages (P_1: Tillering; P_2: Panicle Initiation; P_3: 1st Antheis; P_4: Flowering; P_5: Milking); P_6: Dough) and P_7: Maturity) under different (a) DOTs (b) irrigation regimes and (c) rice cultivar

starch material. More the absorption means more production of photosynthates thus more the dry mater production. Absorption of PAR directly regulates the total biomass production as well as economic yield of any crop. In this study, it has been observed that due to variation in crop duration and magnitudinal difference in radiation intensity, the total amount of PAR absorbed by rice crop during its entire life cycle, varied under different dates of transplanting, variety and irrigation regimes. The amount of APAR was at the lowest level (479 MJ) under D_1, which increased gradually with progress of transplanting time. It was 19 and 20 MJ more under D_2 and D_3 respectively. The magnitude of APAR was at its highest peak (529 MJ) under D_4 (Table 2). The duration of crop did not vary significantly between optimum and deficit irrigation regimes as the crop received good amount of rainfall during entire cropping period. However, the water stress which encountered by the crop grown under deficit irrigation in general matured 3 to 4 days earlier than optimum irrigation condition. Thus, the total APAR value was 14 MJ

Table 2: Impact of date of transplanting, cultivars and irrigation regimes on total absorbed PAR, grain yield, straw yield and radiation use efficiency (RUE) of rice

Treatments	APAR (MJ)	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	RUE (g MJ^{-1})
DOT				
D_1: 16.06.2017	479	4365	6500	0.98
D_2: 30.06.2017	498	3721	6700	0.79
D_3: 14.07.2017	499	3043	7300	0.64
D_4: 28.07.2017	529	3023	7700	0.58
Irrigation				
I_1: Optimum	506	3915	7570	0.82
I_2: Deficit	492	3064	6500	0.67
Variety				
V_1: Nayanmani	411	4495	4000	1.10
V_2: Satabdi	454	2965	6600	0.66
V_3: Swarna	633	3009	10500	0.48

less under I_2, compared to I_1 (506 MJ). Different crop varieties are distinct from each other in-terms of their varietal traits, growing duration and adaptability to different resources. Among the variety, the lowest (411 MJ) APAR value was noted under V_1 followed by V_3 (454 MJ). Being a short duration crop Nayanmani got minimum days to mature thus it accumulated lowest APAR value. The highest magnitude of PAR was absorbed (633 MJ) by Swarna, which is predominantly a long duration variety (Table 2).

3.3. Radiation use efficiency

Radiation use efficiency is an important index, which represent the capacity of a crop to utilize the solar radiation. In this study, the RUE value under all the treatment combination ranged from 0.48 to 1.10 g MJ^{-1}. Irrespective of irrigation regimes and variety, the highest magnitude of RUE (0.98 g MJ^{-1}) was noted under D_1, which decrease gradually with delay in transplanting time. The RUE value arranged for other DOT is as D_2 (0.79 g MJ^{-1})>D_3 (0.64 g MJ^{-1})>D_4 (0.58 g MJ^{-1}) (Table 2). Similar findings have been reported by Chakraborty et al. (2018), Dutta et al. (2011), Ahmed et al. (2008) in rice, Tabarzad et al. (2016) in barley and Sun et al. (2013); Reynolds et al. (2005) in wheat. The total APAR value was gradually increasing with date of planting. Incontrast, completely reverse trend in grain resulted decreasing trend in RUE with delay in transplanting. In general, the crop grown under delayed transplanting faced more daily maximum and minimum temperature during its critical stages compared to early date of transplanting. Exposure to such higher temperature in late transplanting compelled the crop to consume more photosynthates through photorespiration. Thus, even though the APAR was more, but accumulation of photosynthates to the grain was less in delayed transplanting treatments.The highest magnitude (0.82 g MJ^{-1}) of RUE was

noted under optimum irrigation regimes and it was 0.15 g MJ^{-1} less under deficit condition.In conformity Chakraborty et al. (2018), Sun et al. (2013), Reynolds et al. (2005) and Gomez-Macpherson and Richards (1995) also found reduction in RUE due to late sowing not only caused by high temperature but also the moisture content in soil and demand for photosynthates during grain filling. Among the varieties, the highest magnitude (1.10 g MJ^{-1}) of RUE was recorded under Nayanmani, which was 0.40 g MJ^{-1} less under Satabdi. The lowest RUE (0.48 MJ^{-1}) was noted under Swarna.

3.4. Canopy-air temperature difference

During flowering and milking stage, crop under I_1, was under more water condition which is inferred from lowest negative CATD value compare to I_2. Similarly, Dalil and Ghassemi-Golezani (2012), recorded the largest difference in leaf and air temperature (CATD) under the lowest water supply in maize crop.The CATD value from the Figure 2 showed that except tillering there were always negative CATD value for V_1. In terms of negative CATD value the varieties are arranged in the order V_1>V_2>V_3, which indicate that V_1 was in more comfortable condition compared to V_2 and V_3. In terms of negative CATD value of the DOTs are arranged in the order D_1>D_4>D_2>D_3.

3.5. Grain and straw yield

Irrespective of irrigation regimes and variety, the highest grain yield (4365 kg ha^{-1}) was obtained when the crop was transplanted on middle of June (D_1). A significant reduction in yield by 644 and 1322 kg ha^{-1} were recorded when transplanting was delayed by 15 days (D_2) and 30 days (D_3) respectively (Table 2). The lowest (3023 kg ha^{-1}) grain yield was recorded when the crop was transplanted during end of July (D_4). Temperatures above 35 ^{o}C cause different types of heat injury to rice crop, depending on the cultivar and growth stage. Anthesis is the most sensitive stage of rice to high temperatures (Yoshida, 1981) and the heat-sensitive processes of anthesis are anther dehiscence, pollination, pollen germination, and to a lesser extent pollen tube growth (Ekanayakeet al., 1989). Temperatures above 35 ^{o}C at anthesis can result in up to 40–60% sterility (Krishnan et al., 2011). In our experimentation, the maximum temperature under D_3 and D_4 was higher level up (>37 ^{o}C) to flowering stage and it was at lower level under D_2 and D_1. Crop grown under D_4 and D_3 produce more number of chaffy grain compare to D_1 and D_2 treatment. Higher air temperature during panicle imitation, flowering stage and grain filling may be the probable causes for having such result. Zhang et al. (2007) have same observation in rice.

Rai and Kushwaha (2008) reported 15.3% more grain yield under 15 June sown crop than 15 July sowing, which might be due to optimum conditions available for growth and development resulted in more storage of photosynthates in the grain in early sown crop. Reduction in grain yield under delayed transplanting owed to reduction in favorable growing period (low air temperature) leading to poor grain filling and
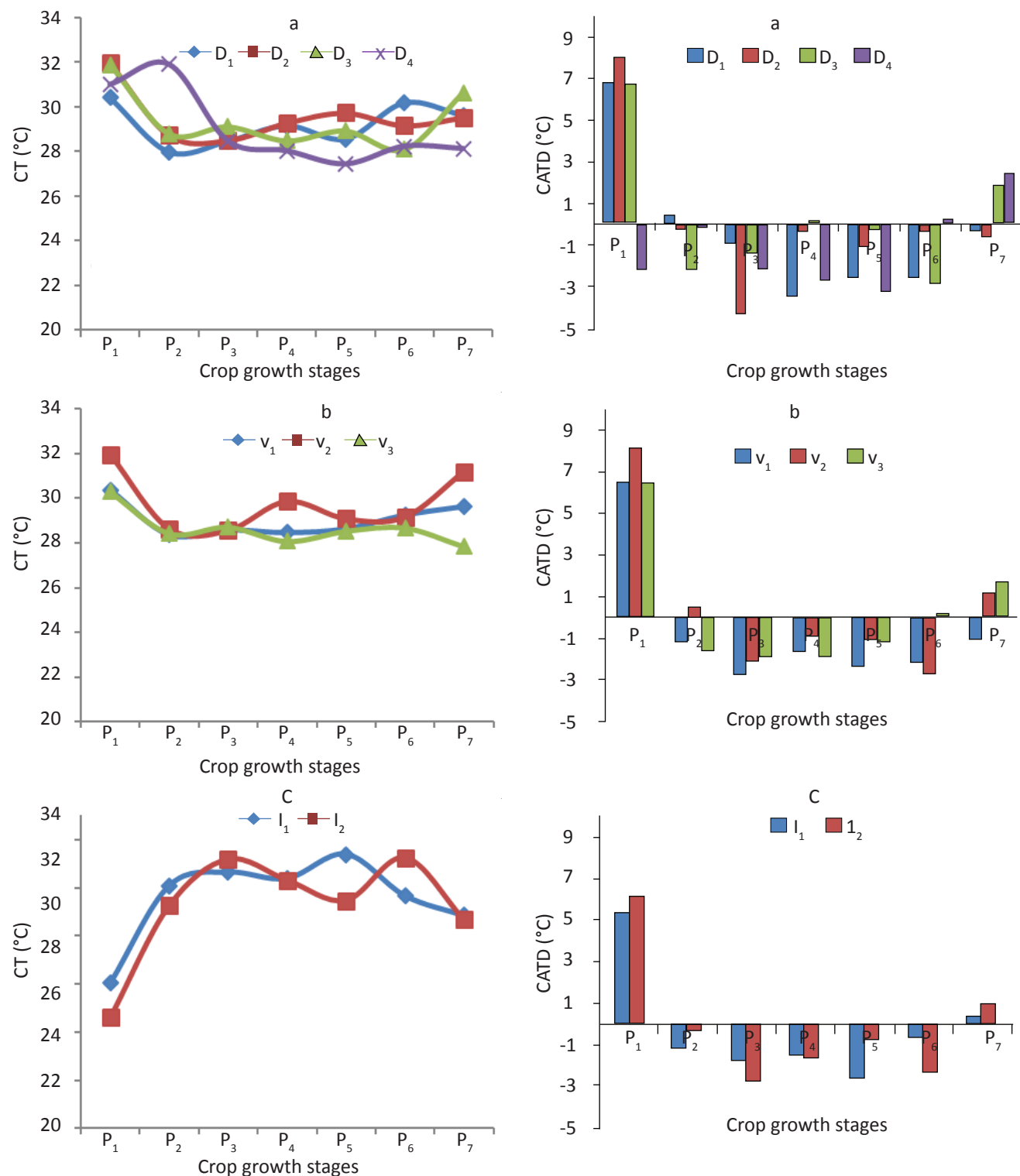
Figure 2: Variation of canopy temperature (CT) and canopy air temperature difference (CATD) under different (a) DOTs (b) rice cultivar and (c) irrigation regimes

low yield. (Gill et al., 2006). Statistically significant variation in yield was recorded between water stress and non-stress treatments. The highest productivity of rice (3915 kg ha^{-1}) was observed when crop was grown under optimum irrigation condition, which reduced by 21.73% under water deficit condition. In I_2, average CATD (-0.1 °C), CADT at tillering (+6.2 °C) and flowering stage (-0.8 °C) which were more compare to I_1 (Figure 2) and this is the probable cause of lower grain

yield in stress condition. Water stress at critical crop growth stages (tillering, flowering) is responsible for achieving lower grain yield under water stress treatment (Basha et al., 2017). Significantly, higher (4495 kg ha^{-1}) grain yield was recorded under Nayanmani compared to this 33.0% and 34.0% lower grain yield was produced by Swarna and Satabdi respectively because of Satabdi grown under more stress (Average CADT +0.4, tillering (-1.1) and Flowering stage (+8.2) than Swarna and Nayanmani. The effect of CADT on important growth stages showed a negative correlation and great yield reduction with the increased CADT. If the magnitude of CADT is positive the crop in stress. Patel et al. (2001) also reported significant negative correlation with CADT and different growth stages in pigeon pea. Erdem et al. (2006) noticed similar relation in potato.

Irrespective of irrigation regimes and variety, the highest straw yield (7700 kg ha^{-1}) of rice was obtained under D$_4$, which reduced significantly and gradually with early dates of transplanting. The lowest (6500 kg ha^{-1}) straw yield during middle of June (D$_1$). Straw yield was significantly governed by irrigation pattern. The highest productivity of straw (7570 kg ha^{-1}) was observed when crop was nurture under optimum irrigation condition (I$_1$). Scarcity of water forced to lower down the production of straw biomass by almost 13.3%. Due to varietal differences, crops took various time periods to mature. Thus, the total amount of PAR interception is different for every cultivar which determines the crop biomass. Due to this, Swarna produced highest (10,500 kg ha^{-1}) straw biomass. Rest of the two varieties produced 37% (Satabdi) and 62% (Nayanmani) less straw biomass throughout the crop period.

4. Conclusion

Rice should not be transplanted beyond 15th of July in eastern Gangetic plains of West Bengal for better productivity based on CATD, absorbed and reflected pattern of PAR by the rice canopy.

5. Acknowledgement

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