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Short Communication

Thermal use efficiency for determining optimum date of transplanting and water regime in *Boro* rice

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The productivity of rice is largely affected by a set of weather variables among which rainfall, solar radiation and temperature play a significant role. West Bengal farmers generally prefer to grow *Boro* rice for higher return, which requires huge amount of irrigation water. Deficit irrigation during the vegetative phase affects the growth process and productivity of rice plants (Mishra, 2012). The crop duration under different dates of transplanting are greatly influenced by temperature and may be estimated by accumulated heat units (Gouri *et al.*, 2005). Aggarwal *et al.* (2016) also evaluated the heat utilization for rice productivity. Under deficit irrigation the total dry matter accumulation during the period of crop growth is affected because of small leaf size and lower number of tillers. The impact of temperature and bright sunshine hour (BSS) on growth and yield of rice crop, transplanted under different dates under deficit irrigation, may differ with the normal practice of cultivation. However, a very few information is available at present. The aim of the research is to identify a suitable window for dates of transplanting along with irrigation regime for optimizing grain yield in *Boro* rice based on heat use efficiency(HUE) and helio-thermal use efficiency (HTUE).

A field experiment was conducted at the university research farm, Kalyani (22°56´N, 88°32´E, 9.75 MSL) during the *Boro* season of 2014 and 2015. The soil is *entisol* having 0.07% nitrogen, 24.06 kgha^{-1} available phosphorous, 187.45 kgha^{-1} available K, 0.78% organic carbon with pH 6.92. Thirty five (35) days old rice seedlings (cv. *Shatabdi*) were transplanted on 24th January (D_1), 7th February (D_2) and 21st February (D_3) under four ponding regimes. The design was strip-plot where the main plot and sub plot treatments were dates of transplanting and the ponding regimes respectively, with a plot size of 8m×3.5m. The four sub plot treatments are continuous ponding (I_1); intermittent ponding (I_2) during 20 to 65 DAT (irrigation applied 3 days after disappearance of standing water); irrigation depth is 5 cm; intermittent ponding (I_3) during 20 to 65 DAT (irrigation applied 5 days after disappearance of standing water); irrigation depth is 5 cm and shallow depth deficit irrigation (I_4) during 20 to 65 DAT; irrigation depth is 3cm. I_1 treatment received 9 to 10 number of irrigations during 20 to 65 DAT. Whereas I_2, I_3 and I_4 received 3 to 4; 2 to 3 and 6 to 9 numbers of irrigation respectively during 20 to 65 DAT for D_1 transplanted crop. I_1, I_2, I_3 and I_4 treatments received 8 to 11, 6 to 7, 2 to 3 and 8 to 9 numbers of irrigation respectively for D_2 transplanted crop. Similarly for D_3, I_1, I_2, I_3 and I_4 treatments received 8 to 12, 3 to 5, 2 to 4 and 7 to 9 numbers of irrigation respectively. In case of I_2 and I_3 irrigation water was applied after 3 and 5 days disappearance of standing water respectively. All standard agronomic procedures were adopted for raising the rice crop. The temperature and bright sunshine hour data were collected from the adjacent meteorological observatory. The GDD, HTU were computed on 30, 45, 60, 75 and 90 days after transplanting (DAT). The cumulative GDD was computed as,

$$\text{Cumulative GDD (day °C)} = \Sigma\,(T_{mean} - T_b)$$

Where T_{mean} is daily mean air temperature in °C = $(T_{max}+T_{min})/2$; T_b is the base temperature considered as 10°C. The helio-thermal unit (HTU) is obtained by multiplying the GDD with bright sunshine hours as follows;

$$\text{The helio-thermal unit (HTU)} = \text{GDD} \times \text{BSS}$$

The heat use efficiency (HUE) and helio-thermal use efficiency (HTUE) were computed through dividing the above ground biomass or grain yield by cumulative GDD and HTU respectively. HUE and HTUE for above ground biomass on 90 DAT and grain yield have been presented for brevity.

Changes in cumulative GDD and cumulative HTU

The cumulative GDD and HTU gradually increased with the progress of growth irrespective of dates of

Table 1: Changes in cumulative GDD and cumulative HTU for *Boro* rice with the progress of growth under different dates of transplanting.

DAT	D_1		D_2		D_3	
	1st year	2nd year	1st year	2nd year	1st year	2nd year
Cumulative GDD(day °C)						
30	290	352	358	445	439	503
60	739	860	910	1003	1064	1115
90	1378	1474	1567	1607	1753	1735
Maturity	1640	1659	1657	1740	1801	1832
Cumulative HTU(day °C h)						
30	2209	2281	2627	3245	3455	4439
45	3658	4355	4689	5660	6015	6531
60	5705	6809	7327	7702	8800	8726
75	8390	8823	10131	9888	11744	10922
90	11271	11016	13036	12079	15063	13063
Maturity	13581	12336	13753	12788	15483	13904

Table 2: Thermal use efficiency for biomass production of *Boro* rice on 90 DAT under different dates of transplanting and irrigation regime.

DOT	Irrigation regime	Above ground biomass (gm^{-2})			HUE (gm^{-2} day^{-1} C)			HTUE (gm^{-2} day^{-1} C h)		
		1st year	2nd year	Mean	1st year	2nd year	Mean	1st year	2nd year	Mean
D_1	I_1	1061.7	1002.6	1032.2	0.77	0.68	0.73	0.09	0.09	0.09
	I_2	934.2	947.1	940.7	0.68	0.64	0.66	0.08	0.09	0.08
	I_3	793.2	800.1	796.7	0.58	0.54	0.56	0.07	0.07	0.07
	I_4	855.9	876.9	866.4	0.62	0.59	0.61	0.08	0.08	0.08
D_2	I_1	900.3	837.6	869.0	0.57	0.52	0.55	0.07	0.07	0.07
	I_2	1140.0	1174.5	1157.3	0.73	0.73	0.73	0.09	0.1	0.09
	I_3	1011.6	1114.8	1063.2	0.65	0.69	0.67	0.08	0.09	0.08
	I_4	963.9	998.1	981.0	0.62	0.62	0.62	0.07	0.08	0.08
D_3	I_1	1137.3	1109.4	1123.4	0.65	0.64	0.64	0.08	0.08	0.08
	I_2	990.9	1060.5	1025.7	0.57	0.61	0.59	0.07	0.08	0.07
	I_3	950.7	989.1	969.9	0.54	0.57	0.56	0.06	0.08	0.07
	I_4	839.1	897.6	868.4	0.48	0.52	0.5	0.06	0.07	0.06

transplanting and year of experiment (Table 1). The cumulative GDD upto 30 DAT ranged from 299 to 503 day °C under different dates and years, highest being under late transplanting (D_3). Similar trends were observed in all the DAT and years. At maturity cumulative GDD ranged from 1640 to 1832 degree days.In case of HTU, upto 60 DAT, the results were similar to that observed with GDD, however, after 75 DAT, the cumulative HTU in second year were less than the first year, mainly due to lower BSS.Singh *et al.* (2010) and Praveen *et al.* (2013) observed gradual decline in cumulative GDD and cumulative HTUwith delay in transplanting. In the present experiment the trend was reverse because transplanting dates and subsequent growth phases were shifted from low to high temperature regime.Sandhu *et al.* (2013) did not obtain any regular trend in cumulative GDD and cumulative HTU with the gradual delay in transplanting of rice.

Table 3: Thermal use efficiency for grain yield of *Boro* rice under different dates of transplanting and irrigation regimes.

DOT	Irrigation regime	Yield (tha^{-1})			HUE			HTUE		
		1st Year	2nd Year	Mean	1st Year	2nd Year	Mean	1st Year	2nd Year	Mean
D_1	I_1	6.63	6.82	6.72	0.40	0.41	0.41	0.05	0.06	0.05
	I_2	6.22	6.70	6.46	0.38	0.40	0.39	0.05	0.05	0.05
	I_3	4.95	5.47	5.21	0.30	0.33	0.32	0.04	0.04	0.04
	I_4	5.37	5.75	5.56	0.33	0.35	0.34	0.04	0.05	0.04
D_2	I_1	5.66	5.97	5.81	0.34	0.34	0.34	0.04	0.05	0.04
	I_2	6.46	6.57	6.51	0.39	0.38	0.38	0.05	0.05	0.05
	I_3	5.29	5.43	5.36	0.32	0.31	0.32	0.04	0.04	0.04
	I_4	5.84	6.13	5.99	0.35	0.35	0.35	0.04	0.05	0.05
D_3	I_1	5.20	5.27	5.23	0.29	0.29	0.29	0.03	0.04	0.04
	I_2	5.14	5.02	5.08	0.29	0.27	0.28	0.03	0.04	0.03
	I_3	4.97	4.57	4.77	0.28	0.25	0.26	0.03	0.03	0.03
	I_4	4.58	4.30	4.44	0.25	0.23	0.24	0.03	0.03	0.03
Irrigation	SEm(±)	0.03	0.05							
	CD at 5%	0.13	0.20							
DOT (D)	SEm(±)	0.02	0.03							
	CD at 5%	0.10	0.17							
DXI	SEm(±)	0.06	0.05							
	CD at 5%	0.23	0.17							

HUE and HTUE for biomass production

The mean biomass accumulation, HUE and HTUE on 90 DAT were maximum under D_2 and I_2 treatment and minimum when date of transplanting was delayed by 15 days (Table 2). On 90 DAT the HUE for biomass production ranged from 0.57 to 0.64 gm^{-2}day^{-1}under different dates of transplanting. Sharp reduction in HUE under D_3 was observed. Singh *et al*. (2010) reported that the TUE for dry matter accumulation reduced gradually with the delay in transplanting. The mean HTUE on 90 DAT ranged from 0.07-0.09gm^{-2}day^{-1}°C h under D_1 and D_2, 0.06-0.08*gm^{-2} day^{-1}* h under D_3 transplanting (Table 2). The HTUE under different irrigation treatments followed the similar pattern as observed in case of HUE.

HUE and HTUE for grain yield

The grain yield, HUE and HTUE for grain yield are presented in Table 3. The mean grain yield was highest in I_1 treatment under D_1, in I_2 treatment under D_2 with no significant difference in the second year. In both the years I_2 treatment recorded maximum grain yield. The mean HUE and HTUE followed similar trend to that of grain yield.Singh *et al*. (2010) also observed a gradual decline in HUE for grain yield with the delay in transplanting of rice.

It can be concluded that the date of transplanting should be confined within 7th February and I_2 irrigation (where irrigation water was applied 3 days after disappearance of water) regime might be adopted based on HUE and HTUE for optimum grain yield.

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