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Studies on accumulated thermal unit, thermal use efficiency of different rice genotypes at different phenological stages

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Abstract
A field experiment was conducted during *Kharif* season of 2019 at Student Instructional Farm of A.N.D.U.A. & T, Kumarganj, Ayodhya (U.P.) Studies on accumulated thermal unit, thermal use efficiency of different rice genotypes at different phenological stages. Experiment was conducted with in Randomized Block Design and replicated four times. The treatments comprised of 3 crop growing environment i.e. 5^{th} July (D_1), 15^{th} July (D_2) and 25^{th} July (D_3) with 3 genotypes i.e. NDR-97 (V_1), SARJOO-52 (V_2) and BPT-5204 (V_3). The results revealed that Crop growing environment of 5^{th} July (D_1) took more days to reach harvest stage in all genotypes. With respect to the heat units *viz*., growing degree days, photo thermal unit, helio- thermal unit, the first growing environment of rice on 5^{th} July (D_1) is giving more values over after growing environment i.e. 15^{th} July (D_2) and 25^{th} July (D_3). Maximum thermal use efficiency (TUE) was recorded in crop growing environment on July 5^{th} (0.60 $g/m^2/^0C\ days^{-1}$) at milking the stage, followed by July 15^{th} (0.39$g/m^2/^0Cdays^{-1}$) and July 25^{th} (0.41$g/m^2/^0Cdays^{-1}$).

Keywords: Crop growing environment, GDD, HUT, PTU, genotypes, thermal use efficiency

Introduction
Rice (*Oryza sativa* L.) is one of the most Staple cereal crops, cultivated in 114 countries across the world (150 million hectares, 11% of total area) (Pathak *et al.*, 2018) [6]. Rice belongs to the Poaceae family originated from South East Asia. Out of 24 species of rice only two species *Oryza glaberima* and *Oryza sativa* are cultivated. Weather and climate greatly affect agricultural productivity in any region. Agricultural production of any region is being regulated by the prevailing climate of that the area through temperature, rainfall, light intensity, radiation, sunshine duration etc. (Sastri *et al.*, 2010) [9]. Crop phenology can be used to specify the most appropriate date and time of a specific development process. The growing degree day (GDD), helio-thermal unit (HTU), photo-thermal unit (PTU), and phenothermal index (PTI) are some simple tools to find out the relationship between plant growth, temperature, bright sunshine hours, and day length. However, the impact of temperature, bright sunshine hour, as well as daylength on the growth habits of rice crop, are not well documented. Agricultural production and productivity of any region is being regulated by the prevailing climate of that area through temperature, rainfall, light intensity, radiation, sunshine duration, etc. (Goswami *et al.*, 2006) [3], Thermal use efficiency i.e., which indicates the amount of dry matter produced per unit of growing degree days or thermal time.

Materials Methods
To carry out the research output of the investigation entitled "Studies on accumulated thermal unit, thermal use efficiency of different rice genotypes at different phenological stages", an experiment was conducted during kharif seasons of 2019 at Student Instructional Farm of ANDUA&T, Narendra Nagar, Kumarganj, Ayodhya (U.P.). The geographical situation of experimental site lies at latitude 26° 47'North longitude 82° 12' East and altitude of 113 meter from mean sea level in the Indo -genetic alluvium of Eastern Uttar Pradesh. The experiment was carried out in Randomized Block Design (Factorial) and replicated four times. The experiment comprised of three crop growing environment i.e. 5^{th} July (D_1), 15^{th} July (D_2) and 25^{th} July (D_3) with three genotypes i.e. NDR-97 (V_1), SARJOO-52 (V_2) and BPT-5204 (V_3).

The fertilizers were applied as per the requirement of crop. 100:60:60 kg ha^{-1} N: P_2O_5: K_2O was applied in the form of Urea, SSP and MOP, respectively. At higher mean temperatures (25-32 °C), early flowering is induced by reducing the growth duration; whereas the mean low temperature (<15 °C) forces the crop to remain dormant with no flowering. Therefore, a day temperature of 25 °C to 33 °C and night temperature of 15 °C to 20 °C is preferable. Rice crop needs a hot and humid climate. The heat unit or GDD was proposed to explain the relationship between growth duration and temperature. This concept assumes a direct and linear relationship between growth and temperature. The heat units, i.e. Growing Degree Day (GDD) were computed using a base temperature of 10 °C during the various crop growth stages for rice genotypes.

Accumulated thermal unit/GDD (°C days)

The heat unit or GDD was proposed to explain the relationship between growth duration and temperature. This concept assumes a direct and linear relationship between growth and temperature. The heat units, i.e. Growing Degree Day (GDD) were computed using a base temperature of 10 °C during the various crop growth stages for rice genotypes.

Accumulated thermal unit of different phenophases were calculated by using following formula.

$$\text{ATU} = \sum_{i=1}^{n} \text{G.D.D.}$$

Where, i= 1, 2, 3…….. n is the number of days.

$$\text{Accumulated thermal unit} = \frac{\text{T max} + \text{Tmin}}{2} - \text{Base temp.}$$

Base temperature for rice crops is 10 °C.

Accumulated photothermal unit (day °C hour)

Photothermal unit (PTU) = GDD x DL

Where,

DL = Day length (Possible sunshine hours: from dawn to twilight).

Accumulated helio-thermal unit (day °C hour)

Heliothermal unit (HTU) = GDD x BSSH

Where,

BSSH = Bright sunshine hours

Thermal use efficiency (g/m²/°C days)

Thermal use efficiency i.e., which indicates the amount of dry matter produced per unit of growing degree days or thermal time

Thermal use efficiency (HUE) was calculated by per following formula

$$\text{TUE} = \frac{\text{Total Dry matter}(\text{g/m}^2)}{\text{Accu.thermal unit (°C days)}}$$

Results & Discussion

The data pertaining to total dry matters accumulation as of rice genotypes recorded at different stages of crop as influenced by various treatments have been presented in Table 1 and fig. 1. The total dry matter (gm^{-2}) accumulation differs significantly with respect to different growing environment at all the growth stages. From table it was revealed that maximum total dry matters (gm^{-2}) accumulation was recorded at July 5th (1177.15) followed by July 15th (1065.72) and July 25th (947.92) at harvest, respectively. Among the genotypes SARJOO-52 attained maximum total dry matters (gm^{-2}) accumulation (1230.08) at harvest followed by genotypes BPT-5204 (1139.88) at harvest and NDR-97 (820.83) at the harvest. It is also evident that genotypes significant among each other for total dry matters (gm^{-2}) accumulation at 15 DAT, 30 DAT, 45 DAT, 60 DAT, 75 DAT, and 90 DAT and at harvest.As the weather became free in most of the days of September–October, the crop growth became faster under D3 lesser accumulation of dry matter has been observed due to short plant and cold spell at night. The results are in conformity with the findings of Salam *et al.* (2004) [8].

The accumulated growing degree days (GDD) computed for different rice genotypes under various date of crop growing environment from tillering to harvest stage are shown in Table 2. Highest accumulated GDD was observed under 05th July (D_1) crop growing environment in all the genotypes followed by 15th July (D_2) crop growing environment and 25th July (D_3) crop growing environment, respectively. In genotypes NDR-97 observed the highest GDD at harvest with D_1 crop growing environment (1788.7) followed by D_2 crop growing environment (1710.5) and D_3 crop growing environment (1617). In genotypes SARJOO-52 the highest GDD was recorded at harvest stage with D_1 crop growing environment (2197.7) followed by D_2 crop growing environment (2128.7) and D_3 transplanting crop growing environment (2010). Similarly, in genotypes BPT-5204 highest value of GDD was recorded at harvest stage with D_1 crop growing environment (2566.95) followed by D_2 crop growing environment (2427) and D_3 crop growing environment (2300). Similar results were reported by Halder *et al.*, 2010 [4]. In general, the accumulated growing degree day values decreased with delayed sowing due to early maturity of crops because of high value of temperature at maturity. These results are in general agreement with the findings of Sreenivas *et al.* (2010) [11] and Chopra and Chopra (2004) [2]. Paul and Sarker (2000) [7] also reported that requirement of GDD decreased for different phenological stages with delay in sowing. Decrease in heat units with delay in transplanting has also been reported by Singh and Pal (2003) [10]. Abhilash *et al*. (2017) [1] reported that accumulated GDD were higher under early transplanting.

The observed value of Thermal use efficiency (TUE) (g/m²/°C $days^{-1}$) at harvest stages of different genotypes of rice under various crop growing environments is given in the Table 3. Highest accumulated TUE was observed under 05th July (D_1) crop growing environment in all the genotypes followed by 15th July (D_2) crop growing environment and 25th July (D_3) crop growing environment.

In genotype NDR-97 observed the highest TUE at milking stage with D_1 transplanting (0.60) followed by D_2 at harvest stage crop growing environment (0.53) and D_3 at milking stage crop growing environment (0.41). In genotype SARJOO-52 the highest accumulated TUE was found at dough stage with D_1 crop growing environment (0.57) followed by D_2 crop growing environment (0.51) and D_3 crop growing environment (0.47). In genotype BPT-5204 the highest accumulated TUE was found at milking stage with D_1 crop growing environment (0.58) followed by D_2 crop growing environment (0.51) and D_3 crop growing environment (0.47). Similar result was reported by Nayak *et al*., 2017 [5].

Table 1: Total dry matters accumulation as affected by different growing environment of different rice genotypes

Treatments	Total dry matter (gm^{-2})						
Growing environment	**15 DAT**	**30 DAT**	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**At Harvest DAT**
5th July	129.60	216.00	356.59	524.40	708.64	1012.35	1177.15
15thJuly	127.80	213.00	322.83	474.76	641.56	916.52	1065.72
25th July	124.20	207.00	287.15	422.28	570.65	815.21	947.92
SEm±	2.27	3.83	5.95	8.54	11.77	16.51	18.47
CD (5%)	6.65	11.19	17.39	24.93	34.36	48.19	53.93
Varieties							
NDR-97	125.40	209.00	248.65	365.66	494.14	705.91	820.83
Sarjoo-52	129.00	215.00	372.62	547.97	740.51	1057.87	1230.08
BPT-5204	127.20	212.00	345.30	507.80	686.21	980.30	1139.88
SEm±	2.27	3.83	5.95	8.54	11.77	16.51	18.47
CD (5%)	6.65	11.19	17.39	24.93	34.36	48.19	53.93

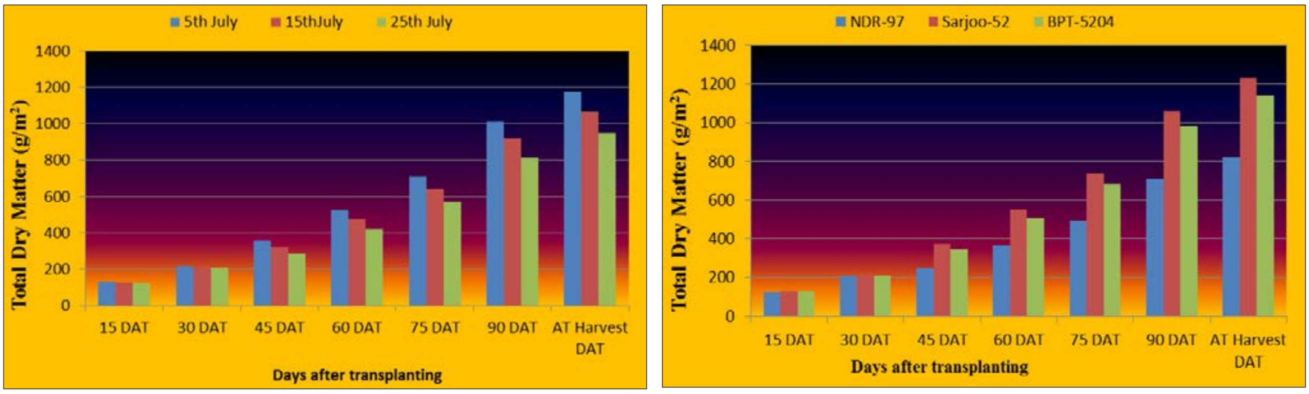

Fig 1: Total dry matters accumulation as affected by different growing environments of different rice genotypes

Table 2: Accumulated growing degree days (°C day) at different rice genotypes at different phenological stages

Transplanting Date	Tillering	Panicle Initiation	Days to 50% Flowering	Milking	Dough stage	Harvest stage
NDR-97						
05-Jul-19	819.50	1259	1531.75	1685.95	1747.2	1788.7
15-Jul-19	741.8	1179.3	1468.2	1610.5	1670.2	1710.5
25-Jul-19	617.8	1019.8	1288	1390.5	1509.5	1617
Sarjoo-52						
05-Jul-19	948.5	1278.25	1624.2	1829.95	2059.2	2210.20
15-Jul-19	857.5	1199.3	1570.2	1768.2	1940.5	2095.7
25-Jul-19	819	1185.7	1509.5	1764.5	1858.2	2010
BPT-5204						
05-Jul-19	999.25	1479	1849.7	2179.7	2367.95	2566.95
15-Jul-19	939	1446.7	1768.2	2060.7	2279.5	2427
25-Jul-19	901	1370.7	1703	2059.5	2247	2300

Table 3: Thermal use efficiency (TUE) (g/m^2/˚C days at different rice genotypes at different phenological stages

Transplanting Date	Tillering	Panicle Initiation	Days to 50% Flowering	Milking	Dough stage	Harvest stage
NDR-97						
05-Jul-19	0.43	0.41	0.46	0.60	0.57	0.56
15-Jul-19	0.29	0.40	0.44	0.39	0.38	0.53
25-Jul-19	0.33	0.28	0.32	0.41	0.37	0.35
Sarjoo-52						
05-Jul-19	0.37	0.41	0.43	0.55	0.57	0.53
15-Jul-19	0.38	0.39	0.40	0.51	0.47	0.50
25-Jul-19	0.35	0.35	0.37	0.46	0.43	0.47
BPT-5204						
05-Jul-19	0.35	0.47	0.54	0.58	0.49	0.45
15-Jul-19	0.34	0.44	0.51	0.51	0.46	0.43
25-Jul-19	0.31	0.30	0.47	0.46	0.42	0.41

Conclusions

Conclusively, With respect to the heat units *viz.*, growing degree days, photo thermal unit, helio thermal unit, the first growing environment of rice on 5th July (D_1) is giving more values over after growing environment i.e. 15th July (D_2) and 25th July (D_3).With respect of optimum growing environments thermal use efficiency are found better under D_1 (5th July) as compared to 15^{h} July (D_2) and 25th July (D_3) growing environments. Based on above findings (D_1) 5th July is best suited growing environments for new selection genotypes of rice based on yield attributes, yield and heat units. Maximum thermal use efficiency (TUE) was recorded in crop growing environment on July 5th (0.60 $g/m^2/^0C$ days) at milking the stage, followed by July 15th (0.510$g/m^2/^0C$ days) and July 25th (0.509$g/m^2/^0C$ days).

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