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Studies on accumulated thermal unit and thermal use efficiency at different phenophases of rice varieties under different crop growing environment

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Abstract
A field experiment was conducted during kharif season of 2018 entitled "Studies on accumulated thermal unit and thermal use efficiency at different phenophases of rice varieties under different crop growing environment" at N.D. University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.). The experiment consisted of nine treatment combinations viz. three crop growing environment *viz.* July 15th, July 25th and August 04th and three varieties viz., NDR-97, NDR-2064 and BPT-5204. Results reveal that maximum accumulated thermal unit (2203.1°C days) was recorded in crop growing environment of July 15th followed by the July 25th (2089.8°C days). Among the varieties, maximum accumulated thermal unit in variety BPT-5204 (2367.2°C days) followed by NDR-2064 (2113.7°C days). Maximum thermal use efficiency of (0.51g/m^2/°C days) was recorded in July 15th at Physiological Maturity followed by July 25th (0.475g/m^2/°C days). NDR-2064 possess maximum TUE of 0.535g/m^2/°C days at Physiological Maturity followed by BPT-5204 (0.505g/m^2/°C days).

Keywords: Thermal unit, thermal use efficiency, growing environment, rice

Introduction
Rice is one of the most important cereal crop belong to the family *Poaceae.* It is the staple food for half of the world's population. Among the crop production tools, proper time of transplanting is the prerequisites that allow the crop to complete its life phase timely and successfully under a specific agro-ecology. In rice, the optimum leaf areas for seedlings, optimum leaf shapes to maximize photosynthetic efficiency, deep, well developed root systems, leaf area index (LAI) at flowering and crop growth rate (CGR) during panicle initiation have been identified as the major determinants of yield. Growth and grain yield reductions have been widely observed when traditionally flooded rice fields were subjected to water saving irrigation measures, where a continuous flood water layer is avoided.

Rice is very much sensitive to photo thermal regimes and the crop growth is influenced largely by the growing environmental conditions. Among them temperature plays a significant role in physiological, chemical and biological processes of plants. It is an important environmental factor influencing the growth and development of crops. During growth and development of a cereal, several growth stages are distinguishable in which important physiological processes occur. Influence of temperature on phenology and yield of crop plants can be studied under field condition through accumulated heat units. Plants have a definite temperature requirement for attainment of certain phenological stages. The duration of each phenophase determines the accumulation and partitioning of dry matter in different parts as well as crop responses to environmental and external factors. The occurrence of different phenological events during crop growth period in relation to temperature can be estimated by using accumulated heat units or growing degree days (GDD).

Growing degree days are based on the concept that the real time to attain a phenological stage is linearly related to temperature in the range between mean temperature and base temperature. A degree day or heat unit is the departure from the mean daily temperature above the minimum threshold temperature. The heat unit concept assumes that a direct and linear relationship between growth and temperature is advantageous for the assessment of yield potential of a crop in different weather conditions. Keeping above facts in view present investigation was under taken.

Materials and Methods

The field experiments was conducted at N. D. University of Agriculture & Technology, Kumarganj, Ayodhya (U.P.) during *kharif* season of 2018 situated at a distance of about 40 km. away from Ayodhya district headquarter on Ayodhya Raibarelly road. 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 inthe 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. 15th July, 25th July and 04th August with three varieties i.e. NDR-97, NDR-2064 and BPT-5204. Fertilizers were applied @120:60:60 N: P_2O_5: K_2O $kgha^{-1}$. 1/3rd of Nitrogen and total phosphorous and potash were applied as basal application just before puddling and incorporated in the top 15 cm soil. Remaining dose of nitrogen was applied as top dressing in two equal doses at tillering and at panicle initiation stages. The soil of the experimental field was silty loam in texture and medium in fertility having pH 8.5.

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 day.

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

Base temperature for rice crops is 10 °C.

Thermal use efficiency (HUE) was calculated as per following formula**;**

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

Results and Discussion

Accumulated thermal unit

Maximum accumulated thermal unit (2203.1 ˚C days) was recorded in crop growing environment of July 15th followed by July 25th (2089.8 ˚C days) due to fulfillment of required thermal unit in longer duration and lowest was recorded in August 04th (1965. 5˚C days) growing environment due to occurrence of less duration of crop. Among the varieties, Accumulated thermal unit was recorded maximum in variety BPT-5204 (2367.2 ˚C days) followed by NDR-2064 (2113.7˚C days) mainly due to optimum growth of treatment caused by longer duration. Similar results were reported by (Halder *et al.*, 2010 and Khavse *et al.*, 2015) [2, 3].

Thermal use efficiency

Maximum thermal use efficiency of 0.51g/m^2/˚C days was recorded with crop growing environment of July 15th at Physiological Maturity followed by July 25th (0.475g/m^2/˚C days). This is possibly due to accumulation of higher dry matter per unit of thermal regime. Among the varieties, NDR-2064 possess maximum thermal use efficiency of 0.535g/m^2/˚C days at Physiological Maturity, followed by BPT-5204 (0.505g/m^2/˚C days) mainly due to higher dry matter production. Similar result was reported by (Nayak *et al*., 2017 and Meena *et al*., 2015) [5, 4].

Table 1: Accumulated thermal unit as affected by different crop growing environment of rice varieties.

Treatments	Accumulated thermal unit (˚C days)					
	Tillering	Panicle Initiation	Days to 50% Flowering	Milking	Dough stage	Physiological Maturity
Crop growing environments						
15th July	925.3	1393.6	1641.2	1881.9	2054.9	2203.1
25th July	885.2	1337.8	1572.4	1802.8	1962.2	2089.8
04th August	769.8	1233.4	1448.3	1647.2	1813.1	1965.5
Varieties						
NDR-97	780.9	1176.9	1325.2	1505.9	1636.5	1777.5
NDR-2064	859.5	1269.1	1469.6	1729.3	1965.8	2113.7
BPT-5204	939.9	1518.7	1867.1	2096.7	2227.9	2367.2

Table 2: Thermal use efficiency at different phenophases as affected by crop growing environment of rice varieties.

Treatments	Thermal use efficiency (g/m^2/˚C days)					
	Tillering	Panicle initiation	Days to 50% Flowering	Milking	Dough stage	Physiological Maturity
Crop growing environments						
15th July	0.344	0.430	0.470	0.502	0.500	0.510
25th July	0.324	0.378	0.435	0.463	0.470	0.475
04th August	0.311	0.367	0.399	0.458	0.457	0.459
Varieties						
NDR-97	0.320	0.350	0.352	0.388	0.442	0.440
NDR-2064	0.357	0.417	0.459	0.522	0.529	0.535
BPT-5204	0.330	0.409	0.457	0.479	0.491	0.505

Conclusions

Maximum accumulated thermal unit (2203.1˚C days) was recorded in crop growing environment of July 15th. Maximum thermal use efficiency of 0.51g/m^2/˚C days was recorded with crop growing environment of July 15th at Physiological Maturity, followed by July 25th (0.475g/m^2/˚C days). Accumulated thermal unit was maximum in variety BPT-5204 (2367.2˚C days). The variety NDR-2064 possesses maximum thermal use efficiency of 0.535g/m^2/˚C days at Physiological Maturity followed by BPT-5204 (0.505g/m^2/˚C days).

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