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Studies on thermal use efficiency, heliothermal unit and photothermal unit of rice (*Oryza sativa* L.) cultivars under varying crop growing environment

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Abstract
A field experiment was conducted during *kharif* season2018 entitled "Studies on thermal use efficiency, heliothermal and photothermal unitof rice (*Oryza sativa* L.) cultivarsunder varying crop growing environment." in sandy loam soil of N.D. University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.). The experiment consisted of nine treatment combinations comprised of three transplanting dates *viz*. July 15th, July 25th and August 04th and three varieties viz., NDR-97, NDR-2064 and BPT-5204. Results reveal that different phenophases of rice markedly varied with only dates of transplanting but also different weather variables which ultimately create the different crop growing environment to harvest the yield accordingly. Highest thermal use efficiency (TUE) was recorded in crop growing environment on July 15that all the stage, followed by July 25th, among the cultivars highest thermal use efficiency was recorded with BPT-5204, followed by NDR-2064.Maximum heliothermal unit was recorded in crop growing environment on July 15th at both the stages vegetative and reproductive stage followed by July 25th. Maximum photothermal unit was recorded in crop growing environment on July 15th at both the stages, followed by July 25th at vegetative and reproductive stage and among the cultivars in BPT-5204.

Keywords: Thermal use efficiency, heliothermal unit, photothermal unit, rice

Introduction
Rice is the most consumed cereal grain in the world constituting the dietary staple food of more than half of the world population. Apart from food rice is intimately involved in the culture as well as economy of many societies. Rice a member of the family *Poaceae* originated from South East Asia and in Asia where more than 90 per cent of world's rice is produced and consumed with two countries, China and India, growing more than half of the total crop. Thus rice is immensely important to food security of Asia. Crops sown on different dates are exposed to different solar duration during the season and this may influence Radiation use efficiency through its effect on radiation transmission (Khichar *et al.,* 2000) [2]. The duration of growth stage of any particular species was directly related to temperature and it could be predicted using the sum of daily air temperature. Temperature is an important environmental factor that influences the growth and development, phenology and yield of crops (Bishnoi *et al.,* 1995) [1]. Heat use efficiency (HUE), i.e., efficiency of heat utilization in terms of dry matter accumulation, depends on genetic factors, crop type and sowing time and has great practical application (Rao *et al.,* 1999) [3]. The effects of meteorological factors on crop production and yield can be assessed in two different ways (Van Keulen 1987) [4].

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 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. 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.

Thermal use efficiency (TUE)

Heat use efficiency is also represented by thermal time use efficiency (TUE), which indicates the amount of dry matter produced per unit of growing degree days or thermal time. This was computed by using the following formula:

$$\text{TUE} = \frac{\text{Total dry matter (g/m}^2\text{)}}{\text{Thermal unit (°C days)}} \times 100$$

Heliothermal units (HTU)

The product of the growing degree day and the corresponding actual bright sunshine hours had been termed as heliothermal units (HTU) and expressed as ^{0}C days hrs. (Chakravarthy and Sastry, 1985). Heliothermal unit was calculatedby using following formula:

$$\text{HTU} = \sum_{i=1}^{n} \text{Thermal unit} \times \text{B. S. S. (hrs.)}$$

Where,

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

Photo thermal units

The product of the growing degree day and the length of the day in hours accumulated over a given period is termed photo thermal units and expressed as ^{0}C days hrs. Photothermal units was calculatedas by using following formula:

$$\text{PTU} = \sum_{i=1}^{n} \text{Thermal unit} \times \text{day length (hrs.)}$$

Table 1: Thermal Use efficiency as affected by different crop growing environment of rice cultivars

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	0.355	0.380	0.440	0.471	0.543	0.554
25th July	0.337	0.349	0.373	0.446	0.496	0.510
04th August	0.319	0.336	0.360	0.423	0.489	0.502
Cultivars						
NDR-97	0.338	0.381	0.407	0.442	0.445	0.448
NDR-2064	0.346	0.371	0.408	0.449	0.566	0.551
BPT-5204	0.345	0.352	0.389	0.443	0.498	0.593

Table 2: Accumulated heliothermal unit as affected by different crop growing environment of rice cultivars.

Treatments	Phenophases/Stage	
Crop growing environment	Heliothermal unit (^{0}C days hrs.)	
	Vegetative	Reproductive
15th July	8973.5	13004.9
25thJuly	8295.0	12765.7
04th Aug.	8262.4	12553.0
Cultivars		
NDR-97	5488.5	7706.2
NDR-2064	7374.8	11859.2
BPT-5204	7821.8	13190.4

Table 3: Accumulated photothermal unit as affected by different crop growing environment of rice cultivars

Treatments	Phenophases/Stage	
Crop growing environment	Photothermal unit (^{0}C days hrs.)	
	Vegetative	Reproductive
15th July	22075.1	28492.2
25thJuly	21143.7	28011.9
04 Aug.	17775.9	23600.7
Cultivars		
NDR-97	17482.1	22813.5
NDR-2064	19754.5	27793.7
BPT-5204	22898.8	28286.6

Results and Discussion

Thermal use efficiency

Thermal use efficiency of rice cultivars at different growing environment has been depicted in table no.1 it was revealed that maximum thermal use efficiency (0.554 g/m^2/°C days) was recorded at growing environment on July 15th, followed by July 25th (0.510 g/m^2/°C days). Among the cultivars, BPT-5204 possess highest thermal use efficiency (0.593 g/m^2/°C days) followed by NDR-2064 (0.551 g/m^2/°C days).

Heliothermal unit (^{0}C days hrs.)

Data pertaining to heliothermal unit as affected by different crop growing environment of rice cultivars have been presented in table no.2 it was revealed that highest heliothermal unit (13004.9 ^{0}C days hrs.**)** was recorded in crop growing environment on July 15th,followed by July 25th.Among the cultivars highest heliothermal unit (13190.4 ^{0}C days hrs.) was recorded at reproductive stages in cultivars BPT-5204, followed by NDR-2064.

Photothermal unit (^{0}Cdays hrs.)

Data pertaining to photothermal unit as affected by different crop growing environment of rice cultivars have been presented in table no.3it was revealed that highest photothermal unit (28492.2 ^{0}C days hrs.) was recorded in date of transplanting on July 15th at reproductive stages, followed by July 25th and August 04th.Among the cultivars highest photothermal unit (28286.6^{0}C days hrs.) was recorded at reproductive stages in variety BPT-5204, followed by NDR-2064 and NDR-97.

Conclusions

Based on the above findings it was concluded that thermal use efficiency, heliothermal unit and photo thermal unit were recorded maximum in crop growing environment on July 15th and among the cultivars with BPT-5204. The application of heat units provides a scientific basis for determining the effect

of temperature, radiation and photoperiod on phenological behavior of a standing crop.

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