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Effect of heat use efficiency and thermal unit at different phenophases of rice (*Oryza sativa* L.) cultivars

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Abstract
A field experiment was conducted during kharif season of 2017 on the topic entitled "Effect of heat use efficiency and thermal unit at different phenophases of rice (*Oryza sativa* L.) cultivars." in sandy loam soil of N.D. University of Agriculture and Technology, Kumarganj, Faizabad (U.P.). The experiment consisted of nine treatment combinations comprised of three transplanting dates viz., July 5th, July 15th and July 25th and three varieties viz., NDR-97, NDR-3112 and BPT-5204. Results reveal that Highest Heat use efficiency (HUE) was recorded in growing environment of July 25th transplanting at all the stage followed by July 15th and July 5th transplanting while among the variety NDR-3112 recoded highest HUE followed by BPT-5204and NDR-97.

Keywords: Phenophases, HUE, thermal units

Introduction
Rice (*Oryza sativa* L.) is one of the important foods for most people living in India. It is being grown under diverse agro-climatic condition at wide range of latitudes. It is essential to human diet in India as it is a richest source of carbohydrates and adds the proteins component in human diet too. Generally 6.8% protein, 78.2% carbohydrates, 0.5% fat and 0.6% mineral matters are found in rice hence it is primarily used as a staple food crop. Rice production is influenced by a set of meteorological variables such as temperature, rainfall etc Ji, B. *et al.* (2007) [4]. The climate extremities, particularly high temperatures affect the plant growth and reduce the rice yield significantly Satake, T. and Yoshida, S. (1978) [7]. The crop growth response is influenced largely by the microclimate environment in the crop. Microclimate in the crop varies from top of the canopy to the soil surface and affects crop development and yield. Various environmental factors influencing crop growth are interception of photosynthetically active radiation, air and leaf temperatures, relative humidity, prevailing wind speed, CO2 concentration and soil moisture availability. Temperature and light play a key role in influencing the crop production. Thermal time is an independent variable to describe plant development Dwyer, L.M. and Stewart, D.W. (1986) [3]. It can be used as a tool for characterizing thermal responses in different crops. Knowledge of accumulated GDD can provide an estimate of harvest date as well as crop development stage Ketring, D.L. and Wheless, T.G. (1989) [5]. Heat use efficiency (HUE), i.e., efficiency of utilization of heat in terms of dry matter accumulation, depends on crop type, genetic factors and sowing time and has great practical application Rao *et al.* (1999) [6]. Initiation as well as duration of crop phenophases is an essential component of weather based dynamic crop growth and yield simulation models. Crop phenology can be used to specify the most appropriate date and time of specific development process. The duration of each phenophase determines the accumulation and partitioning of dry matter in different organs Dalton, L.G. (1967) [2]. Wang, J.Y. (1960) [8] reported that the duration of a particular stage of growth was directly related to temperature and this duration of particular species could be predicted using the sum of daily air temperature. Temperature is an important environ- mental factor influencing the growth and development of crop plants. It influences the crop phenology and yield of crop Bishnoi *et al.* (1995) [1]. Plants have a definite temperature requirement to attain phenological stages. Hence, it becomes imperative to have knowledge of the exact duration of phenological stages in a particular crop-growing environment and their impact on yield of crop. In the present study, an attempt is made to predict the growth and yield of rice (*Oryza sativa* L.) with agroclimatic indices viz. growing degree days (GDD), heliothermal units (HTU), photothermal units (PTU) and heat use efficiency.

Materials and Methods

An experiment was conducted during kharif 2017 at the Agrometeorology Research Farm of N.D. University of Agriculture& Technology, Kumarganj, Faizabad (U.P.) on the topic entitled "Effect of heat use efficiency and thermal unit at different phenophases of rice (*Oryza sativa* L.) cultivars." The experimental site is located in the main campus of NDUA&T, Kumarganj, (Faizabad) situated at a distance of about 42 km. away from Faizabad district headquarter on Faizabad Raibarelly road. The experiment was conducted in Randomized Block Design (RBD) and replicated the three times. The different growth parameters studied were rice as Phenophases, HUE, Thermal units (BSS, HTU, PTU).

Results

Days taken to attain maturity as affected by different growing environment of rice cultivars have been presented in (Table-1). A perusal of data showed that different growing environment influenced rice cultivars. Maximum days taken to maturity (116 days) were recorded when crop was transplanted on July 5th followed by July 15th and July 25th. The minimum days taken to maturity was recorded (104 days) on 3rd date of transplanting. Among the varieties days taken to maturity were affected by different cultivars. The maximum days taken to maturity were recorded with BPT-5204 (122 days) followed by NDR-3112 (106 days) and NDR-97 (100 days). Heat use efficiency (HUE) ($g/m^2/^0$days) of rice cultivars at different growing environment has been depicted in (Table-2). From table it was revealed that maximum Heat use efficiency HUE ($g/m^2/^0$days) (0.491) was recorded at 1st date of transplanting on July 5th at 105 DAT followed by July1 5th (0.469) and July 25th (0.453). Among the varieties, BPT-5204 possess highest Heat use efficiency (0.529) at 105 DAT followed by NDR-3112 (0.491) and NDR-97 (0.398).

Bright sunshine (hrs.) of rice cultivars at different growing environment has been depicted in (Table-3). From table it was revealed that highest bright sunshine (hrs.) was recorded at 1st date of transplanting on (650.6) July 15th followed by (593.1) July 25th and (546.7) July 25th respectively. Among the varieties bright sunshine hours were recorded highest in cultivar BPT-5204 (583.4) followed by NDR-3112 (479.5) and NDR-97 (435.2). Heliothermal unit as affected by different growing environment of rice cultivars have been presented in (Table-4). From table it was revealed that heliothermal unit was recorded highest in 1nd date of transplanting on July 5th (^{0}days hours) followed by July 15th and July 25th. Among the varieties highest heliothermal unit at vegetative and reproductive stages were recorded in cultivars BPT-5204 followed by NDR-97 and NDR-3112.

Photothermal unit as affected by different growing environment of rice cultivars have been presented in (Table-5). From table it was revealed that photothermal unit was recorded highest in 1st date of transplanting on July 5th, at vegetative and reproductive stages as followed by July 15th and July 25th. Among the varieties highest photothermal unit at vegetative and reproductive stages was recorded in variety BPT-5204, followed by NDR-3112and NDR-97.

Table 1: Days taken to phenophases as affected by different growing environment of rice cultivars

Growing Environment	Phenophases		
	Days to panicle initiation	Days to 50%Flowering	Physiological Maturity
5th July	73	83	116
15thJuly	70	80	111
25th July	68	77	104
Varieties			
NDR-97	61	80	100
NDR-3112	63	79	106
BPT-5205	75	91	122

Table 2: Heat use efficiency (HUE) as affected by different growing environment of rice cultivars

Treatments	Heat use efficiency ($g/m^2/^0$days)						
Growing environment	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	105 DAT
5th July	0.389	0.342	0.331	0.353	0.430	0.489	0.491
15thJuly	0.384	0.341	0.327	0.348	0.422	0.461	0.469
25th July	0.349	0.306	0.297	0.316	0.390	0.446	0.453
Varieties							
NDR-97	0.360	0.317	0.298	0.317	0.386	0.439	0.386
NDR-3112	0.384	0.337	0.346	0.369	0.448	0.509	0.529
BPT-5204	0.377	0.333	0.311	0.331	0.409	0.448	0.491

Table 3: Accumulated of Bright sunshine hours as affected by different growing environment of rice cultivars

Treatments	Phenophases/Stage	
Growing environment	Bright sun shine (BSS) (hrs.)	
	Vegetative	Reproductive
5th July	371.2	650.6
15thJuly	326.3	593.1
25th July	320.9	546.7
Varieties		
NDR-97	186.5	435.2
NDR-3112	199.1	479.5
BPT-5204	285.0	583.4

Table: 4 Accumulated heliothermal unit as affected by different growing environment of rice cultivars

Treatments	Phenophases/Stage	
Growing environment	Heliothermal unit (^{0}days hrs.)	
	Vegetative	Reproductive
5th July	5369.76	9507.30
15thJuly	4972.44	9045.80
25th July	4636.69	8388.67
Varieties		
NDR-97	3651.54	8545.47
NDR-3112	3896.44	8957.60
BPT-5204	5674.81	9977.37

Table: 5 Accumulated photothermal unit as affected by different growing environment of rice cultivars

Treatments	Phenophases/Stage	
Growing environment	Photothermal unit (^{0}days hrs.)	
	Vegetative	Reproductive
5th July	176673.3	54893.0
15thJuly	172102.1	50228.6
25th July	164872.4	41665.3
Varieties		
NDR-97	137341.5	55111.0
NDR-3112	144648.1	60797.3
BPT-5204	207734.4	64554.5

Conclusion

It is concluded that study in highest photohermal unit was recorded with growing environment on 5th July at vegetative (176673˚days hrs.) and reproductive stages (54893.0˚days hrs.) which was superior growing environment 15th July & 25th July. In the varieties maximum photothermal unit was recorded by BPT-5204 which was superior over NDR-3112 and NDR-97.

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