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Assessment of GDD, PTI and HUE of Maize crop sown under different growing environment in Ayodhya (U.P.)

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Abstract

A field experiment was carried out at Agrometeorological Research Farm, Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya (U.P.) during *kharif* season of 2021-23. In this research, Assessment of GDD, PTI and HUE of Maize crop sown under different growing environment. The experiment comprised nine treatment combinations and conducted in Randomized block design and replicated four times. Treatment consisted of three crop growing environment viz. 1st July, 11th July and 21st July with three cultivars viz. Shweta, Type-41 and Tarun. Results reveal that meteorological parameters such as Photo thermal index ($^{\circ}\text{Cdays/day}$), Heat unit (Growing degree days) & Heat use efficiency ($\text{g/m}^2/^{\circ}\text{day}$) recorded highest with the crop growing environment on 1st July (36°C) followed by 11th July date of sowing. Lowest values of all were recorded in 21st July (34.5°C) of crop growing environments. Among the varieties, Shweta took relatively longer duration and ultimately matured 4 days delayed over Tarun and Type-41 when it was sown on 1 July crop growing environment. This study may help to select the suitable sowing time under climatic condition of eastern Uttar Pradesh.

Keywords: Maize, growing environment, yield, phenophase, heat unit, photo thermal index, heat use efficiency

Introduction

Maize (*Zea mays* L.), a member of the poaceae family, After Rice and Wheat is one of the world's third most significant cereal crops. It is one of the main food crops in the globe, providing sustenance for both people and livestock (Tahir *et al.*, 2008) [21]. Because of its unique qualities, such as its carbon pathway (C_4), superior transpiration efficiency, high versatility utilization, etc., maize is referred to as the "Queen of Cereals" (Ramasamy *et al.*, 2017) [16].

As a result, it serves as both a significant source of carbohydrates for human consumption and as animal feed (Undie *et al.*, 2012) [24]. According to (Kumar *et al.*, 2020) [10] maize seeds have 10% protein, 4% oil, and 2-3% crude fiber. A variety of products made from maize, including starch, glucose, dextrose, sorbitol, dextrin, high fructose corn syrup, malto dextrin, germ oil, germ meal, fiber, and gluten products, are made using maize as a raw material. Compared to other cereal crops, maize has a far higher output potential and greater adaptation to a variety of agroclimatic situation.

Worldwide, it is cultivated on nearly 150 Mha in about 160 countries, representing diverse soil, climate, biodiversity, and management practices and contributes 36% (782 million tonnes) of global grain production (Singh *et al.*, 2017) [20]. USA is the major producer of maize (31.08%), followed by China (23.42%), Brazil (9.27%), European Union (5.89%), Argentina (4.49%), Ukraine (3.22%), India (2.8%) and others (16.45%) (Anonymous 2022) [3].

In our country maize is farmed throughout India from the dry region of Chitradurga, Karnataka, to the warm, humid plateau of Chindwara, (M.P.). In India, the area of maize during 2020-21 the area of maize was 9.86 million hectares with a production of 31.51 million tons and productivity was 3195 kg/ha (Directorate of Economics and Statistics, 2022) [5]. The predominant maize growing states that contributes more than 80% of the total maize production are Andhra Pradesh (20.9%), Karnataka (16.5%), Rajasthan (9.9%), Maharashtra (9.1%), Bihar (8.9%), Uttar Pradesh (6.1%), Madhya Pradesh (5.7%), Himachal Pradesh (4.4%) (Murdia *et al.*, 2016) [13].

Apart from these states maize is also grown in Jammu and Kashmir and North-Eastern states.

The heat unit or growing degree day (GDD) concept assumes that there is direct and linear relationship between growth of plants and temperature. The scientific way of assessing and qualifying the effect of temperature and photoperiod on plant growth, development and yield by applying GDD theory which advocates that the plants have a definite temperature requirement to pass through a certain growth portion or phenophase. (Kiniry *et al.*, 1983) [9] and yield (Shukla and Vasuniya, 1998) [19]. Plants have a definite temperature requirement before they attain certain phenological growth stages and to forecast the phenology and crop production attributes. (Jones *et al.* 2003) [8]. Though maize is a day neutral plant, flowering and maturity of genotypes are dependent on available temperature and sunshine hours. (Rao *et al.* 2000) [17]. Hence the knowledge on the calculation of the heat units *i.e.*, Growing degree days (GDD), Photothermal index (PTI) and heat use efficiency (HUE) are the basic principles to understand the phenology and follow proper planting dates for different genotypes over temporal and spatial separations. Tao *et al.*, (2003) [22] described that changes in temporal and spatial pattern of precipitation in the growing season may directly impact the crop water cycle and could induce water stress during crop development. The crop growth that reduces the time between planting and grain development limiting the yield (Lobell and Field, 2007) [11]. High temperature at flowering (tasseling and silking) inhibited the pollination and grain development. Warmer environmental condition accelerates the pollen shedding and delay in silking (Basra, 2009, Amin *et al.*, 2017) [4, 2]. Heat stress at silking and tasseling reduced the grain yield by 7% for every day after exposure to stress (Lobell *et al.*, 2011) [12].

Materials and Methods

The experiment was conducted at Agro-meteorological Research Farm of Acharya Narendra Deva University of Agriculture & Technology, Narendra Nagar (Kumarganj), Ayodhya (UP), India, which is geographically situated between 26° 47' N latitude and 82° 12' E longitude and at an altitude of 113 meters above mean sea level. The average annual precipitation is about 1001 mm of which 85-90 percent received during monsoon period during May by summer monsoon. The experiment was conducted in Randomized Block Design with four replications. Nine treatment combinations comprised three Crop growing environments *viz.* July 1st (D1) (33 °C), July 11th (D2) (31.75 °C) and July 21st (D3) (30.5°C) along with three cultivar *viz.* Shweta

(V1), Type-41 (V2) and Tarun (V3) were used under this investigation. The experimental field was prepared thoroughly by ploughing twice with country plough followed by blade harrow to achieve fine tilth.

Photo thermal index (°C days/day)

Photo thermal unit was measured at different sowing dates were calculated as per following formula:

$$\text{Photo thermal index} = \frac{\text{GDD between two phenophases}}{\text{No. of days between two phenophases}}$$

Heat unit (Growing degree days): as per (Nuttonson, 1995): Growing degree days (GDD) at different phenological stages were calculated by using following formula:

$$GDD = \sum_{i=1}^n \text{heat unit (HU)}$$

$$\text{Heat unit} = \frac{T_{\max} + T_{\min}}{2} - (T_b)$$

Where, T_b is base temperature

Base temperature is 10.0 °C.

Heat use efficiency (g/m²/°day)

Heat use efficiency (HUE) is the dry matter production per unit of heat unit use by the crop. Heat used efficiency (HUE) may be calculated as following-

$$HUE = \frac{\text{Total dry matter (gm}^{-2}\text{)}}{\text{Heat unit (}^{\circ}\text{days)}}$$

Results and Discussion

Photo Thermal Index requirement of *kharif* maize varieties at different phenophases as affected by different dates of sowing/weather variability have been presented in Table 1. The maximum Photo Thermal Index (PTI) requirement from sowing to maturity was recorded by Shwetha cultivars *i.e.* 19.0 & 18.3 °C days/day at 1st July (36 °C) dates of sowing, while minimum Photo Thermal Index from sowing to maturity is 18.5 & 16.4 °C days/day was observed under 21st July (34.5 °C) dates of sowing during the experimental year 2021 and 2022 respectively, followed by Tarun and significantly superior over Type-41 variety under same crop growing environment.

Table 1: Photo Thermal Index at different phenophases as affected by different dates of weather variability in maize varieties

Sowing Date	Photo Thermal Index at different phenophases (°C days/day)						
	Emergence	Knee high stage	Tasseling	Silking	Milking	Dough Stage	Maturity
Shwetha							
1 st July (36 °C)	27.01	20.55	20.55	20.01	19.9	19.75	18.65
11 th July (35 ⁰ C)	25.85	19.75	19.65	19.75	19.65	18.75	18.45
21 st July (34.5 °C)	23.75	19.42	19.05	18.85	18.45	18.31	17.45
Type-41							
1 st July (36 °C)	26.70	20.45	19.55	19.70	19.70	19.30	18.15
11 th July (35 ⁰ C)	25.85	19.65	19.10	19.15	19.10	18.30	17.70
21 st July (34.5 °C)	23.75	19.25	18.90	18.55	18.01	18.10	16.70
Tarun							
1 st July (36 °C)	20.6	20.55	19.75	19.90	19.85	19.70	18.25
11 th July (35 ⁰ C)	19.90	19.75	19.25	19.60	19.31	18.65	17.85
21 st July (34.5 °C)	19.64	19.42	19.20	18.90	18.61	18.55	17.15

Pooled data of year 2021-22

Accumulated Heat unit (GDD) requirement at different phenophases: Accumulated Heat Unit (GDD) requirement of *kharif* maize varieties at different phenophases as affected by different dates of sowing/weather variability have been presented in Table 2. The maximum heat Unit (GDD) requirement from sowing to maturity were recorded 1984.55 and 1950.25 °C days at 1st July (36 °C) dates of sowing by Shwetha

cultivars, while minimum accumulated growing degree days from sowing to maturity 1750.1 and 1664.5 °C days was observed under 21st July (34.5 °C) dates of sowing during the experimental year 2021 & 2022 respectively, followed by Tarun and significantly superior over Type-41 variety under same crop of maize.

Table 2: Accumulated Heat Unit (GDD) requirement of *kharif* maize varieties at different phenophases as affected by weather variability

Sowing Date	Accumulated Heat unit requirement at different phenophases						
	Emergence	Knee high stage	Tasseling	Silking	Milking	Dough Stage	Maturity
Shwetha							
1 st July (36 °C)	105.37	802.50	975.87	1145.88	1323.13	1517.20	1967.41
11 th July (35 °C)	131.37	743.01	933.50	1110.75	1249.08	1466.35	1876.90
21 st July (34.5 °C)	118.87	644.12	874.87	994.375	1174.70	1453.30	1707.30
Type-41							
1 st July (36 °C)	105.37	682.62	878.50	1052.75	1223.63	1461.5	1881.65
11 th July (35 °C)	131.37	666.12	840.37	1011.25	1170.13	1409.95	1789.65
21 st July (34.5 °C)	118.87	605.50	795.25	915.375	1121.83	1361.11	1638.90
Tarun							
1 st July (36 °C)	105.37	721.12	936.12	1092.00	1283.25	1481.11	1931.20
11 th July (35 °C)	131.37	704.25	879.62	1030.88	1210.38	1448.35	1842.50
21 st July (34.5 °C)	118.87	624.37	834.87	954.125	1137.83	1397.55	1677.40

Pooled data of year 2021-22

Heat use efficiency: Data pertaining to requirement of *Kharif* maize at different phenophases as affected by dates of sowing/weather variability have been presented in Table 3 The maximum heat use efficiency requirement from sowing to maturity was recorded with (0.65 and 0.68 g/m²/°Cdays) at 1st July (36 °C) dates of sowing while minimum heat use efficiency

from sowing to maturity (0.60 and 0.63 g/m²/°Cdays) was observed under 21st July (34.5 °C) dates of sowing while among the varieties Shweta obtained higher Heat use efficiency in compared with Tarun and Type-41 variety during the experimental year 2021 & 2022.

Table 3: heat use efficiency at different phenophases as affected by dates of weather variability in maize

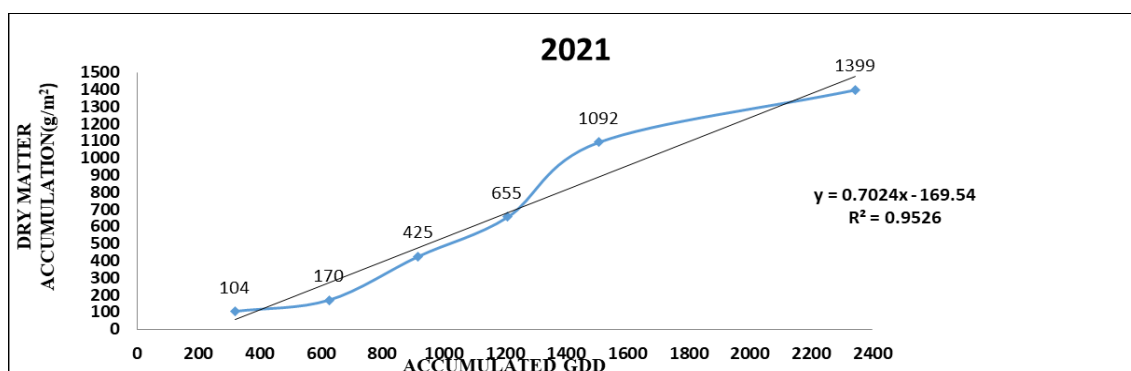
Treatments	Heat use efficiency (g/m ² /°C days)				
	Emergence	Knee high stage	Tasseling	Silking	Maturity
Dates of sowing/Weather variability					
1 st July (36 °C)	0.150	0.201	0.295	0.561	0.665
11 th July (35°C)	0.145	0.185	0.281	0.525	0.625
21 st July (34.5 °C)	0.141	0.175	0.265	0.510	0.615
Varieties					
Shweta	0.155	0.191	0.31	0.570	0.645
Type -41	0.135	0.175	0.26	0.495	0.571
Tarun	0.141	0.175	0.29	0.535	0.625

Pooled data of year 2021-22

Relationship between Accumulated Heat Unit (GDD) and Dry Matter Accumulation of *kharif* maize sown at 1st July Date of Sowing during 2021 and 2022

Relationship between accumulated heat unit (GDD) and dry matter accumulation of *kharif* maize has been depicted in Fig. 1

and Fig 2. It is quite obvious from the fig. that increase in accumulated heat unit (GDD) increased the dry matter accumulation of *kharif* maize with $R^2 = 0.95$ during both the year of investigation



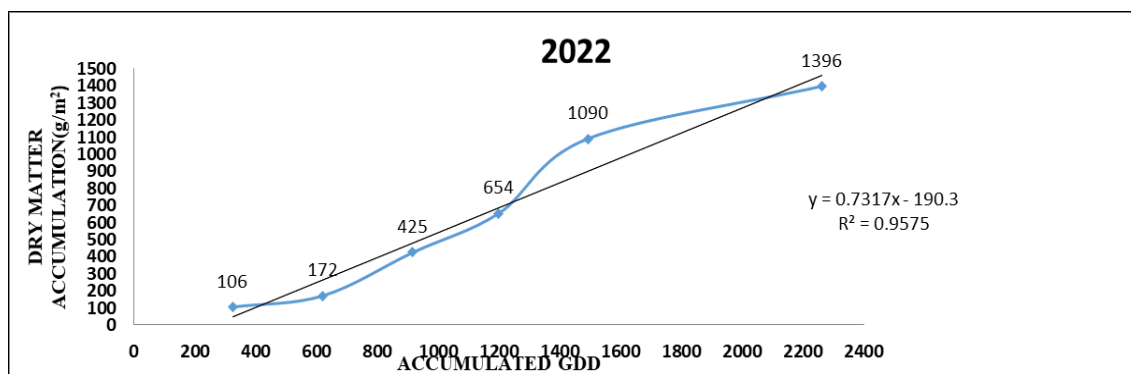


Fig 1: Relationship between accumulated heat unit (GDD) and dry matter accumulation of *kharif* maize in 2021 and 2022

Conclusion

The heat assessment parameters like Photo thermal index, Accumulated Heat unit (GDD) requirement at different phenophases and Heat use efficiency of the crop were highest in crop growing environment on the 1st July (D₁) followed by July 11th (D₂). Lowest values of all were recorded on 21st July (D₃). Higher accumulated heat unit of 804.75, 1327.5 and 1525.4 °C-days during knee high stage, milking and dough stage, respectively were recorded in the timely sown (1st July) crop during experimental year 2021 as compared to subsequent delayed sowing for achieving higher dry matter production. The decrease in accumulated heat unit was recorded with delay in sowing. The results also revealed that the Shweta recorded higher yield as compared to other varieties. Shweta experienced achieved minimum temperature 26.5 °C, 22 °C and 20 °C during tasseling, milking and dough stages, respectively which optimum for achieving higher yield of maize. Maximum temperature of 36 °C, 28.5 °C and 27 °C during emergence, tasseling and dough stage, respectively were favoured to get higher yield and yield attributing characters of maize. Among the varieties 28.5 °C, 35 °C and 27 °C during tasseling, Silking and dough stages of variety Shweta were recorded optimum, maximum, and minimum temperature for achieving higher yield as compared to other varieties.

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Authors contribution: P. Singh: Conceptualization, Methodology, Data collection, Data Analysis, Visualization, Writing-original draft; N. Singh: Conceptualization, Writing review and editing.

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