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Phenology and Climate Indices of Maize Hybrids under North Western Himalayan Region of Temperate Kashmir

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In the Kharif season of 2021, a field experiment was conducted at the crop research farm of the Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir. The primary objective of the study was to investigate the phenology of maize hybrids in relation to agrometeorological indices. The experimental design included two factors: Factor A, representing different irrigation regimes at various growth stages (I_1 to I_6), and Factor B, consisting of two maize hybrid varieties (Shalimar Hybrid-2 and Shalimar Hybrid-3). The irrigation treatments ranged from early vegetation stage to rainfed conditions. The experiment

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followed a split plot design with three replications. Results indicated that the treatment I_5 (Irrigation at IW/CPE ratio of 0.8) and Shalimar Hybrid-3 exhibited the highest values for key agrometeorological indices, including GDD, HTU, PTU, and HYTU. These findings provide valuable insights into optimizing irrigation practices and selecting suitable maize hybrids for enhanced phenological performance.

Keywords: Maize hybrids; phenology; GDD; HTU; PTU; HYTU.

1. INTRODUCTION

Maize (*Zea mays* L.), belonging to the family Poaceae, is the most versatile crop among cereals concerning its adaptability, types, and uses. Maize, being a "C4 and day-neutral plant," has a very high yield potential and is known as the "queen of cereals." It is the second most widely grown crop globally, cultivated in tropics, sub-tropics, and temperate climates, with several types such as field corn, sweet corn, popcorn, and baby corn. Among the maize-growing countries, India ranks 4thin area and 7th in production, representing around 4 percent of the world's maize area and 2 percent of total production. In India, maize is cultivated on an area of 9.86 million hectares (mha) with a production of 31.51 million tonnes and a productivity of 3.19 t ha-1 [1]. In Jammu and Kashmir, maize is the second most important cereal crop after rice [2], cultivated over an area of about 3.08 lakh hectares with a production of 5.12 lakh tons and a productivity of 1.7 t ha-1 [3].

Weather variables like temperature, rainfall, light intensity, radiation, sunshine duration etc. are the important prevailing parameters that influence growth and productivity of crop however, temperature is among the most important factor that effectsphenology, growth and yield of field crops [4]. A crop has a definite requirement of temperature for reaching various phenophases and the time interval between the different developmental stages is decided by the accumulation of heat units or GDD at the respective stage [5].The growing degree day (GDD), heliothermal unit (HTU), photothermal 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 [6].These indices aid farmers in making informed decisions regarding planting, crop development, and harvesting. GDD, PTU, HTU, and HYTU serve as key indicators of the thermal and hydrological conditions that directly influence crop growth and development, andadequate availability of nutrients during entire growth phase is essential for exploiting the weather conditions in a better way [7].Monitoring these indices allows farmers to optimize crop schedules, assess potential risks related to temperature and water availability, and implement suitable agronomic practices. By incorporating agrometeorological indices into decision-making processes, farmers can enhance crop productivity and resource utilization, contributing to sustainable agriculture.

2. MATERIALS AND METHODS

A field experiment was conducted during *Kharif* season 2021 on the experimental site situated in the north western Himalaya's temperate region. Fig. 1 shows the average meteorological data of the Meteorological Observatory at Wadura collected from experimental site for the experimentation period during the *Kharif* season of the year 2021. The total precipitation during the cropping season was 227 mm, and the annual rainfall was found 821 mm.Number of days taken by the crop to various phenological stages were recorded from the experimental plot. The readings were recorded once the plants had reached 50% completion of the specific stage. The various agro-meterological observations recorded were:

2.1 Growing Degree Days (GDD)

The growing degree days were calculated from sowing date till completion of harvest. This was determined by using the following formula:

$$GDD\ (oC) = \frac{(Tmax\ +\ Tmin)}{2} - Tbase$$

Where**,**

T_{max} = Daily maximum temperature (^{o}C)
T_{min} = Daily minimum temperature (^{o}C)
T_{base} = Base temperature (^{o}C)

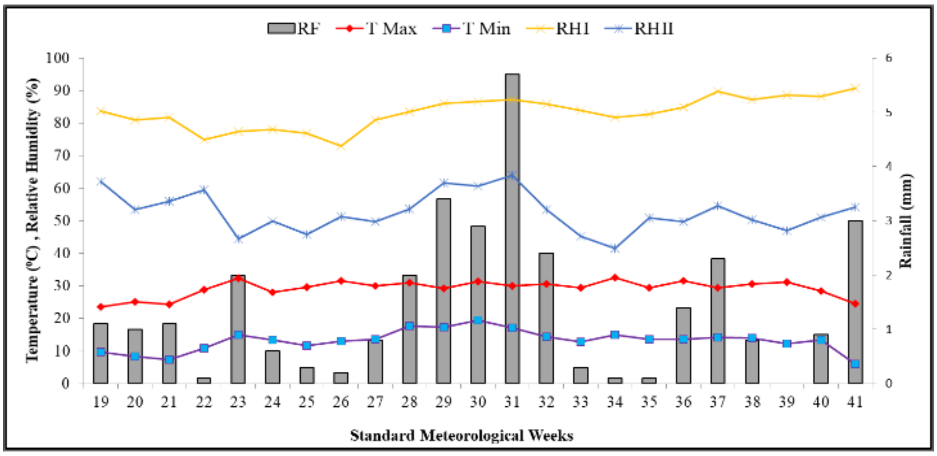

Fig. 1. Weather conditions during the *Kharif* season 2021

2.2 Photo Thermal Units (PTU)

The product of the growing degree days and the length of the day in hours accumulated over a given period were the photo thermal units and expressed as °C days^{-1} hours^{-1}.

Photo thermal units (PTU) = GDD x day length

2.3 Heliothermal Units (HTU)

Helio thermal units were estimated by the product of growing degree day and the corresponding actual bright sunshine hours and were expressed as °C day hours $^{-1}$.

Helio thermal units = GDD x Actual bright sunshine hours

2.4 Hydrothermal Unit (HYTU)

Hydrothermal units were calculated by multiplying GDD with the daily mean value of relative humidity.

Hydrothermal units= GDD x RH (%)

3. RESULTS AND DISCUSSION

3.1 Growing Degree Days (GDD)

Various developmental stages as well as harvest date of crop can be estimated from the knowledge of accumulated GDD. Growing degree days accumulated at different phenophases were calculated during crop seasons (Table 1). Irrigation schedule produced a pronounced effect on GDD accumulation. The maximum number of growing degree days were accumulated by irrigation scheduled at IW/CPE ratio of 0.8 at all phenophases. The minimum GDD accumulation was recorded under control. The reduction in GDD accumulation was due to reduction in number of days taken to attain any phenological stage under water stress conditions. Similar results were reported by Brar et al. [8], Dar et al. [9], Kaur et al. [10]. Shalimar Hybrid-3 consumed more heat units or GDD as compared to Shalimar Hybrid-2 to reach different phenological phases (Table 1). The differential behaviour of maize hybrids to heat unit requirement, could be ascibed to their genetic makeup. Besides, it was also due to longer duration of Shalimar Hybrid-3 to complete its growth in field as compared to Shalimar Hybrid-2. The results were also in agreement with the findings of Taruna *et al*. [11], Naik et al. [12], Fayaz et al. [13].

3.2 Photothermal Units (PTU)

Different irrigation schedulings and varieties showed a significant effect on Photothermal unit accumulation (Table 1). The maximum Photothermal units were accumulated under IW/CPE ratio of 0.8 at all phenophases. The minimum PTU were accumulated under control because under decreased irrigation frequency there is higher canopy temperature which induces early maturity in crop, therefore short duration of phenophases. Similar results were reported by Kaur et al. [10]. Shalimar Hybrid-3 consumed more Photothermal units as compared to Shalimar Hybrid-2 to reach different phenological phases (Table 1). This might be due to difference in their genetic makeup. Similar result reported by Fayaz et al. [13].

3.3 Heliothermal Units (HTU)

Different irrigation scheduling and varieties showed a significant effect on Heliothermal unit accumulation (Table 2). The maximum

Table 1. Growing degree days (GDD) and Photo thermal units (PTU) requirement of maize varieties at various phenophases underdifferent irrigation scheduling

Agrometerological Indicies	GDD	PTU	GDD	PTU	GDD	PTU	GDD	PTU
Growth Stages / Treatments	Knee height		Tasseling		Silking		Harvest	
I_1	491.15	6,746.27	954.38	12,923.38	1,017.93	13,742.47	1,557.91	20,240.49
I_2	481.66	6,617.03	933.61	12,657.04	991.08	13,396.78	1,526.37	19,913.74
I_3	468.91	6,442.94	895.16	12,158.78	948.67	12,849.92	1,496.12	19,576.64
I_4	444.17	6,104.25	890.41	12,096.47	955.02	12,932.52	1,456.41	19,114.13
I_5	510.38	7,008.37	981.96	13,279.28	1,048.61	14,136.35	1,570.24	20,354.42
I_6	404.80	5,565.19	839.43	11,426.90	904.50	12,279.52	1,426.70	18,765.28
SE(m)±	9.13	125.01	3.95	51.60	8.622	111.11	7.70	88.49
CD (p≤0.05)	**29.14**	**399.03**	**12.62**	**164.71**	**27.519**	**354.64**	**24.60**	**282.44**
Varieties								
V1	454.22	6,241.61	904.86	12,281.24	965.86	13,071.42	1,497.19	19,567.77
V2	479.47	6,586.40	926.79	12,566.04	989.41	13,374.44	1,514.06	19,753.80
SE(m)±	5.44	74.56	1.73	22.43	7.05	90.97	6.26	72.47
CD (p≤0.05)	**16.97**	**232.30**	**5.39**	**69.89**	**21.96**	**283.43**	**18.62**	**218.41**

I_1: Early Vegetative, Knee Height, Flowering and Grain Filling Stage, I_2: Knee Height, Flowering and Grain Filling Stage, I_3: Flowering and Grain Filling, I_4: Flowering, I_5: IW/ CPE Ratio, I_6: Rainfed, V_1: Shalimar Hybrid-2, V_2: Shalimar Hybrid-3

Table 2. Helio thermal units (HTU) and Hydrothermal units (HYTU) requirement of maize varieties at various phenophases underdifferent irrigation scheduling

Agrometerological Indicies	HTU	HYTU	HTU	HYTU	HTU	HYTU	HTU	HYTU
Growth Stages / Treatments	Knee height		Tasselling		Silking		Harvest	
I_1	4,032.09	26,952.04	7,159.97	57,830.89	7,735.70	61,654.33	11,704.50	97,451.20
I_2	4,023.81	26,261.89	6,977.20	56,483.49	7,497.23	60,101.50	11,496.85	94,692.15
I_3	3,980.94	25,410.14	6,696.96	54,065.90	7,108.14	57,451.31	11,283.08	92,380.84
I_4	3,820.65	23,955.49	6,650.99	53,781.80	7,184.00	57,843.92	10,966.98	89,626.90
I_5	4,155.57	28,069.05	7,420.69	59,505.55	7,995.07	63,424.88	11,767.90	98,694.56
I_6	3,474.62	21,971.32	6,146.81	50,867.46	6,750.48	54,698.87	10,743.44	87,584.34
SE(m)±	72.19	508.08	36.39	250.00	74.38	524.088	60.68	534.25
CD (p≤0.05)	**230.42**	**1,621.71**	**116.17**	**797.95**	**237.43**	**1,672.77**	**193.69**	**1,705.21**
				Varieties				
V1	3,845.42	24,679.24	6,744.02	54,738.42	7,279.09	58,491.37	11,269.11	92,754.53
V2	3,983.81	24,194.07	6,940.18	56,106.61	7,477.78	59,900.23	11,385.13	94055.47
SE(m)±	43.617	304.65	15.623	109.83	61.80	425.31	49.05	443.62
CD (p≤0.05)	**135.885**	**949.12**	**48.671**	**342.19**	**192.54**	**1,325.03**	**148.32**	**1332.52**

I_1: Early Vegetative, Knee Height, Flowering and Grain Filling Stage, I_2: Knee Height, Flowering and Grain Filling Stage, I_3: Flowering and Grain Filling, I_4: Flowering, I_5: IW/ CPE Ratio, I_6: Rainfed, V_1: Shalimar Hybrid-2,V_2: Shalimar Hybrid-3

Heliothermal units were accumulated under IW/CPE ratio of 0.8 at all phenophases. The minimum HTU were accumulated under control. The results were also in agreement with findings of Kaur et al. [10]. Among different varieties Shalimar Hybrid-3 consumed maximum Heliothermal units as compared to Shalimar Hybrid-2. The differential behavior of the varieties to HTU could be due to their genetic makeup. Also, due to short duration of Shalimar Hybrid-2 in field to complete its growth as compared to Shalimar Hybrid-3. Similar results were opined by Fayaz et al. [13].

3.4 Hydrothermal Units (HYTU)

Different irrigation scheduling and varieties showed a significant effect on Hydrothermal unit accumulation (Table 2). The maximum Hydrothermal units were accumulated under IW/CPE ratio of 0.8 at all phenophases. The minimum HYTU were accumulated under control as there was reduction in GDD accumulation due to short duration of phenophases. Similar results were reported by Kaur et al. [10]. Shalimar Hybrid-3 consumed more Hydrothermal units as compared to Shalimar Hybrid-2 to reach different phenological phases (Table 2). This might be due to difference in their genetic makeup. Similar result reported by Fayaz et al. [13].

4. CONCLUSION

The study shows that when the irrigation water to crop potential evapotranspiration (IW/CPE) ratio is 0.8, it leads to maximum values for important agrometeorological indices including Growing Degree Days (GDD), Heat Thermal Units (HTU), Potential Thermal Units (PTU), and Hybrid Thermal Units (HYTU).Additionally, the Shalimar Hybrid-3 variety demonstrated superior performance, recording the highest values across these key parameters. These findings underscore the significance of precise irrigation practices and highlight the specific strengths of the Shalimar Hybrid-3 variety in achieving optimal agrometeorological conditions for enhanced crop development. Further research may delve into the broader implications of these results for agricultural practices and crop selection strategies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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