Original Research Article

Temperature-Based Agrometeorological Indices for Indian Mustard (*Brassica spp*. L.) under Different Growing Environments in Prayagraj condition.

ABSTRACT

Field studies were carried out during the winter season at the Research Farm of the College of Forestry, SHUATS, Prayagraj (25°45'N, 81°84'E, and 98.2 m amsl) during *rabi* season 2022. to compute the temperature-based agrometeorological indices for Indian mustard (*Brassica spp*. L.) sown under different growing environments. The experiment was laid out in the FRBD method with three different dates of sowing 17 Oct, 03 Nov, and 17 Nov., and four varieties of mustard (Jhalak, Sriram, Kalasona, and Ratna). The third date of sowing crop (D_3) had significantly higher agrometeorological indices (HU, PTU, and HTU,) values over the first (D_1) and third date (D_3). Among the varieties, Jhalak performed better with respect to agrometeorological indices. HU (1886.2), HTU (6569.08), PTU (11747.87) clearly suggesting there by the significant effect of these indices on the mustard crop. These indices can therefore very well used as indicators of crop performance, once these relationships are quantified and tested**.**

Keywords: HU – Heat Unit, PTU-Photothermal Unit, HTU -Heliotherml Unit.

INTRODUCTION

Mustard crops are greatly affected by climatic conditions due to their specific characteristics. Changes in weather parameters can significantly impact the growth and productivity of mustard, making it sensitive to climate change. The purpose of this study was to analyze the thermal requirements of mustard crops and how they affect its growth stages and yield in different environments. The research also focused on evaluating the performance of various mustard varieties under proper irrigation and recommended cultural practices, specifically during the rabi season. The decline in mustard yield since 1997 can be attributed to unfavorable monsoon conditions, leading to moisture stress and increased temperatures. High temperatures during early sowing and crop growth resulted in poor initial growth and reduced plant population (Kumar, 2005).

Furthermore, abnormal weather conditions during the establishment phase, including cold spells, fog, frost, leaf wetting, and intermittent rains during flowering and pod formation, have become concerning in major mustard-producing states such as Punjab, Haryana, Rajasthan, and Uttar Pradesh. Additionally, mustard crops in India face yield losses caused by physiological disorders and the spread of pests and diseases like aphids, white rust, downy mildew, and stem rot. In Uttar Pradesh is the fourth largest producer of mustard in India, after Rajasthan, Haryana, and Madhya Pradesh. In 2022-23, the state produced 1.6 million tonnes of mustard, accounting for about 11% of the country's total production. The area under mustard cultivation in Uttar Pradesh is about 2.2 million hectares. The major mustard-growing districts in the state are Hardoi, Rae Bareli, Sitapur, Unnao, Lucknow, and Prayagraj. India is also expected to produce a record 115.25 lakh tonnes of mustard in 2022-23, up from 109.5 lakh tonnes in 2021-22. The prevailing climate in an area, including

temperature, rainfall, light intensity, radiation, and sunshine duration, regulates agricultural production and productivity. Temperature, in particular, significantly influences field crops' phenology, growth, and yield. Agrometeorological indices such as heat units, photo-thermal units, helio-thermal units, photo-thermal, and heat use efficiency have been widely used to assess crop phenology, growth, and yield based on temperature. These indices consider the timing of biological processes in crops and provide more accurate predictions than calendar dates. Winter crops, including mustard, are highly sensitive to temperature, as variations affect the duration of different growth stages. However, limited information is available regarding the impact of temperature, day length, and bright sunshine hours on mustard yield in the region. Therefore, the main objective of this study was to determine the optimal thermal conditions for mustard crops using various temperature-based agrometeorological indices and assess their impact on phenology and yield for three mustard varieties in different growing environments in Prayagraj, under sub-tropical conditions. The main aim of the present study was to determine optimum thermal regimes for the mustard crops in the form of different temperature-based agrometeorological indices and as the sess impact thereof on the phenology and yield of three mustard varieties under differentgrowing environments under Prayagraj conditions.

MATERIAL AND METHODS

The present field study was conducted at Research Farm of College of forestry, SHUATS, Prayagraj (25°45'N,81°84'E and 98.2 m amsl) during *rabi* season 2022.
The experiment was laid out in split plot and consisted of three growing environments imposed through different sowing dates (D_1: Oct. 17, 2022; D_2: Nov. 03, 2022; and D_3: Nov. 17, 2022) in the main plots and four mustard variety (V1: Jhalak, V2: Kalasona and V3: Sriram V4: Ratna) in sub- plots and replicated three timeThe weather data recorded at Agrometeorology Observatory of college of forestry, SHUATS and observations on crop phenology, seed and biological yield have been used to compute temperature based agrometeorological indices and establish their relationship with phenology, seed and biological yield of mustard at Prayagraj. The crop phenology was recorded by visual observation in experimental plots on every alternate day during the crop growing period and the number of days taken for occurrence of different pheno-phases viz., P_1: Emergence, P_2: four leaf stage, P_3: Early vegetative phase, P_4: 50 % flowering, P_5: 50 % pod development, P_6: Start of seed filling, P_7: End of seed filling,P_8: Physiological maturity**.**

Temperature Based Agrometeorological Indices.

Growing degree days (GDD)/Heat unit (HU) at different phenological stages were determined by summing the daily mean temperature above base temperature (T_b), expressed in °C Day. For *Brassica* species, T_b is considered as 5°C following Morrison (1996). This was calculated by using the following formula:

$$\text{HU (°C day)} = \sum_{i}^{j} \frac{\text{Tmax}+\text{Tmin}}{2} - \text{T}_\text{b}$$

Were,

T_{max} = Daily maximum temperature (°C)
T_{min} = Daily minimum temperature (°C),
T_b = Minimum threshold/base temperature(°C).

Cumulative photo-thermal units (PTU) were determined by multiplying the HU to the maximum possible sunshine hours, expressed in °C Day hours.

$$\text{PTU (°C day hours)} = \sum_i^j \text{HU x maximum bright sunshine hours}$$

(ii)

Cumulative helio-thermal unit were (HTU) determined by multiplying the HU to the actual bright sunshine hours, expressed in ºC day hours.

$$\text{HTU (°C day hours)} = \sum_i^j \text{HU x actual bright sunshine hours}$$

(iii)

RESULTS AND DISCUSSION

The agrometeorological indices were derived from Agromet observatory recorded meteorological variables. These indices can be used as a tool for prediction of crop phenology, yield, and biomass production in crops.

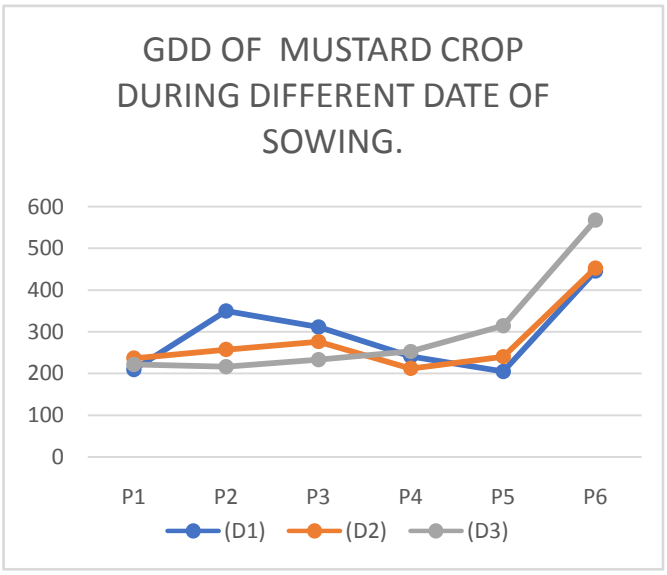
Heat Unit

The Heat Unit (HU) is a measurement used to track the accumulation of heat during different stages of crop growth. The HU values were observed in different treatments and crop seasons. HU varied depending on the growing conditions and the specific stages of crop growth. The HU accumulated for the occurrence of different phenophase among the treatments during two crop seasons are presented in Figure 1. Figure 1 revealed that growing environments varied for accumulated HU over different phenophases. Accumulation of HU to attain crop maturity was higher under the 17th Nov. sown crop as compared to the other sowing dates and the respective values for three sowing dates were 1806.4, 1669.3, and 1645.4 °C Day in 17th Nov., 03rd Nov. and 17th Oct. In the seasons the accumulated HU increase with successive delay in sowing and the findings are in conformity with those reported by Roy *et al.,* (2005) and Neogi *et al.,* (2005). The late sowncrop accumulated fewer HU during early phenophase than early sown crop due to prevalence of comparatively lower temperature (Srivastava *et al.*, 2011; Renganayaki and Krishnasamy, 2013). Different varieties had a marked influence on the Thermal unit/Heat unit/growing degree days of Indian mustard at all the phenophase. Maximum Thermal unit/G.D. D/heat unit requirement from sowing to maturity 1500.5°C days were obtained in Jhalak variety. while minimum thermal unit was obtained in Ratna Variety (1201.2°C days) from sowing to maturity of different date of sowing and verities.

Treatment	Phenophase							
	Germination	Stem elongation	Inflorences	flowering	Fruit development	Ripening	Senescence	Total
17/10/2022	209.4	349.9	311.5	241.3	204.8	240.6	87.9	1886.2
03/11/2022	236.9	257.6	276.6	212.4	240.6	314.9	130.3	1392.7
17/11/22	222.1	216.6	233.4	253.1	314.9	419	659.9	2319
Varieties								
Jhalak	189.3	332.1	282.2	216.6	177.9	225.9	75.5	1500.5
Kala sona	169.4	313.8	269.9	201.6	185.9	198.5	63.1	1401.9
Shri ram	149.2	276.8	253.3	155.7	191.7	168.1	50.5	1245.3
Ratna	128.7	256.8	223.6	171.7	170.7	212.1	37.6	1201.2

Table No 1 Effect of microclimate on GDD different varieties and different dates of

sowing of mustard crop under Prayagraj conditions.



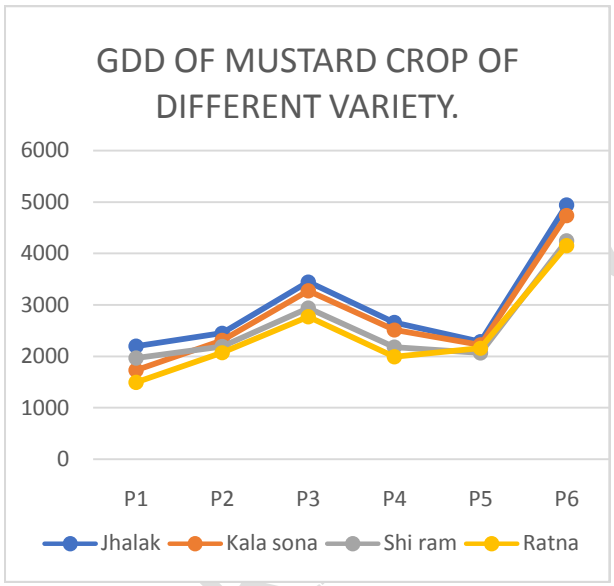


Fig.no.1 A **Fig.no.1B**

Fig. No1.a&b Effect of microclimate on GDD different varieties and different dates of sowing of mustard crop under Prayagraj conditions.

3.2 Helio-Thermal Unit (HTU)

Helio thermal units consumed for the completion of different phenological stage mustard varieties under different growing environments were worked out and are present in Table 2 The cumulative Helio thermal unit different phenophase requirement were maximum in D3 18787.92 day was observed. And the minimum Helio thermal unit in D2 17013.52 ^{o}C day was observed. Different varieties had a marked influence on the Helio thermal unit of Indian mustard at all the phenophase. Maximum heliothermal unit requirements from sowing to maturity 19146.11^{o}C days were obtained in the Jhalak variety. while the minimum thermal unit was obtained in Ratna Variety (12864.56 ^{o}C days) from sowing to a different date of sowing and variety. These findings are in line with those reported earlier by Kumar *et al.*, (2010); Kingra and Kaur (2012), and Neogi *et al.*, (2005). HTU accumulation was higher at all growth phases during 2012-13 as compared to 2013-14 due to the availability of higher mean numbers of sunshine hours in this year.

Table No.2 Effect on HTU of different varieties and different dates of sowing of mustard crop under Prayagraj conditions.

Phenophase						
DATES	P1	P2	P3	P4	P5	P6
D1	2429.04	2564.49	3613.4	2798.08	2375.68	3750.6

D2	2748.04	2818.8	3208.56	2463.84	2790.96	5164.32
D3	2576.36	2512.56	2707.56	2935.96	3652.84	6569.08
Varieties						
Jhalak	2195.88	2448.79	3444.04	2657.56	2282.8	4940.36
Kala sona	1730.72	2311.54	3273.52	2512.56	2223.7	4736.26
Shi ram	1965.04	2190.64	2938.28	2179.64	2063.6	4243.24
Ratna	1492.92	2068.44	2768.96	1991.72	2156.4	4148.12

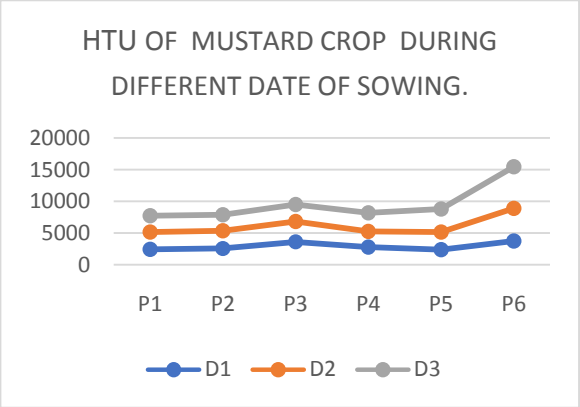


Fig.no.2 A

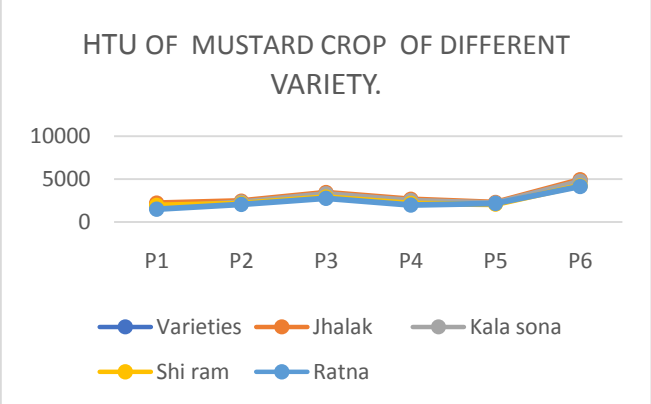


Fig.no.2B

Fig. No 2. a&b Effect of microclimate on GDD different varieties and different dates of sowing of mustard crop under Prayagraj conditions.

3.3 Photothermal units (PTU)

The photothermal units (PTU) (a product of HU and maximum possible sunshine) accumulation by mustard crop to attain different phenophase. Photothermal units consumed for the completion of different phenological stage mustard varieties under different dates of sowing and variety were worked out and are present in Table 3. The cumulative photo thermal unit different phenophase requirements were maximum in D3 11747.87 ^{o}C day was observed. And the minimum photo thermal unit in D1 8017.86 ^{o}C day was observed. Different varieties had a marked influence on the photothermal unit of Indian mustard at all the phenophase. The maximum photothermal unit requirement from sowing to maturity 10873.99^{o}C days was obtained in the Jhalak variety. while the minimum thermal unit was obtained in Kalasona Variety (5984.76 ^{o}C days) from sowing to maturity of Indian mustard. The PTU accumulation increased from emergence to physiological maturity and the highest values were recorded at physiological maturity in all treatments. Similar findings have also been reported by Srivastava *et al.*, (2011).

Table 3. Effect of PTU on different varieties and different dates of sowing of mustard crop under Prayagraj conditions.

Treatment	Phenophase						
	Germination	Stem elongation	Inflorescences	flowering	Fruit development	Ripening	Total
17-10-2022	1649.52	4058.84	1883.3	1439.1	833.63	1806.47	8017.86
03-11-2022	1800.44	1772.82	1632.82	875.64	1170.67	3830.63	11083.02
17-11-2022	1519.3	1246.44	1095.89	1238.77	2643.05	4004.42	11747.87
Verities							
Jhalak	1478.67	3852.36	1777.34	1343.94	808.03	1613.65	10873.99
Kala sona	1156.03	3640.08	1873.59	1246.44	804.97	539.65	5984.76
Shi ram	1307.53	3424.32	1669.84	996.62	746.01	1252.01	9396.33
Ratna	987.93	3206.24	1659.62	909.14	774.81	1039.37	8577.11

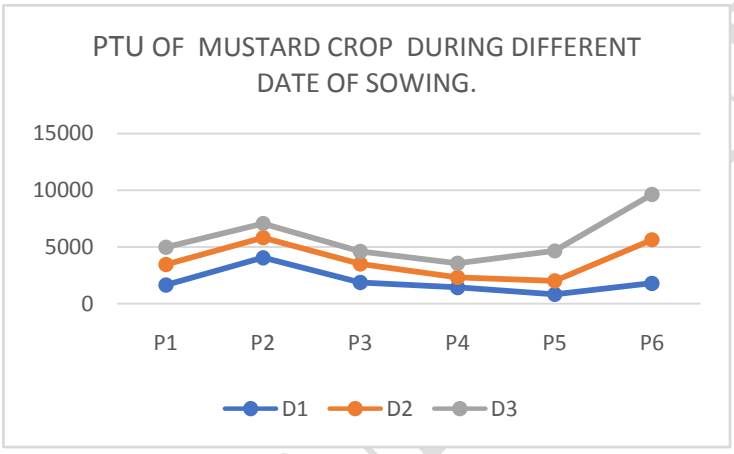


Fig.no. 3A

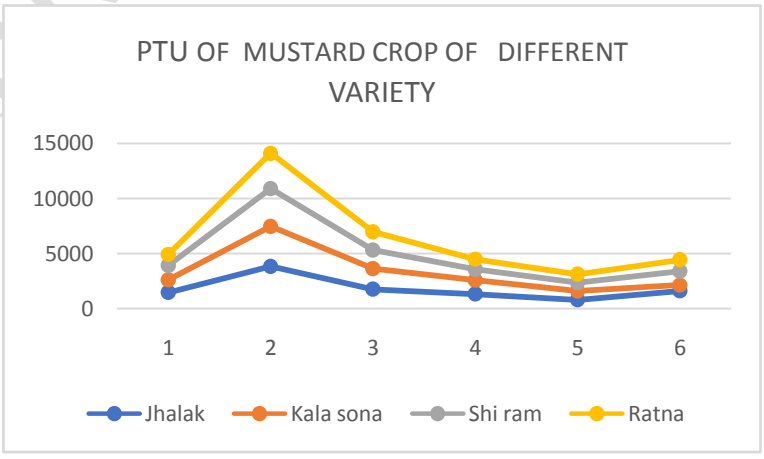


Fig. no.3B

Fig.No. 3 A&B Effect of PTU on different varieties and different dates of sowing of mustard crop under Prayagraj conditions.

Conclusion

Based on the findings of the present research work it can be concluded that the 1st (17 Oct 2022) and 2nd (03 Nov 2022) date of sowing was the most suitable time for the mustard crop because at that time sown crop are consume optimum heat units and change timely phenological stages. Heat units (GDD, HTU, PTU) play the most important role in plant growth and production. 3rd date of sowing (1st Oct. 2022) was found most suitable period for sowing mustard which resulted in maximum growth and yield attributes. & In case of variety md rani super gold is the most suitable variety for the Prayagraj region. Based on this study we can recommend farmers around Prayagraj prefer the use of the Ratna variety and sowing of mustard on the 1st (17 Oct 2022) and 2nd (03 Nov 2022) for better results and yield.

REFERENCES

Kumar, A.: Rapeseed-mustard in India: current status and future prospects. In: Winter School on Advances in Rapeseed-Mustard Research Technology for Sustainable Production of Oilseeds, National Centre on Rapeseed-Mustard, Sewar, Bharatpur, December 15 to January 04, 2005, pp. 278–288 2005.

Roy, S., R. L. Meena, S. C. Sharma, K. Vinod, C. Chattopadhyay, S. A. Khan, and N. V. K. Chakravarthy, Thermal requirement of oilseed *Brassica* cultivars at different phonological stages under varying environmental conditions. *Ind. J. Agril. Sci*., 75(11):17-21 2005.

Neogi, P., N. V. K. Chakravarty, A. K. Srivastava, B. Goutom, R. K. Katiyar, and H. B. Singh: Thermal time and its relationship with seed yield and oil productivity in *Brassica* cultivars. *Int. J.Brassica*, 7(1 & 2): 63-70 2005

Srivastava A. K., N. V. K. Chakravarty, T. Adak: Quantification of growth and yield of oilseed *Brassica* using thermal indices under semi-arid environment. *J. Agromet*., 13(2): 135-140 2011.

Renganayaki, P. R. and V. Krishnasamy: Correlation equation for synchronizedflowering in sunflower (*Helianthus annuus* L.) hybrid KBSH-1 parental for seed yield and component traits under two environments in Indian mustard. *J. Oilse. Bra*., 4(1), 43–48 2013.

Kumar, G., N. V. K. Chakravarty, R. S. Kurothe, D. R. Sena, K. P. Tripathi, T. Adak, D. Haldar, and Anuranjan: Effect of projected climate change on mustard (*Brassica juncea*). *J. Agromet*., 12(2):168-173 2010.

Kingra, P. K. and P. Kaur: Effect of Dates of Sowing on Thermal Utilisation andHeat Use Efficiency of Groundnut Cultivars in Central Punjab. *J. Agril. Phy*., 12(1): 54-62 2012

Srivastava A. K., N. V. K. Chakravarty, T. Adak: Quantification of growth and yield of oilseed *Brassica* using thermal indices under semi-arid environment. *J. Agromet*., 13(2): 135-140 2011.

Mustard seeds output to rise 29% to 109.5 lakh tonnes in 2021-22: COOIT: https://m.economictimes.com/news/economy/agriculture/mustard-seeds-output-to-rise-29-to-109-5-lakh-tonnes-in-2021-22-cooit/articleshow/90265190.cms

India to harvest record mustard crop in 2022-23, finds SEA's crop survey: https://economictimes.indiatimes.com/news/economy/agriculture/india-to-harvest-record-mustard-crop-in-2022-23-finds-seas-crop-survey/articleshow/98805081.cms