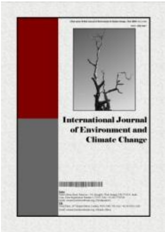

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Studies on the Thermal Unit and Heat Use Efficiency Requirement of the Mustard Crop (*Brassica juncea* L.) under Different Ambient Temperatures and Cultivars

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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

A field experiment was directed during the rabi period of 2020-21 in the sandy topsoil of A.N.D. University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.). The investigation was directed in Split Plot Design (S.P.D.), comprising of three growing environments/ambient temperature *viz.* 31st October (22.6°C), 10th November(21.2°C), 20th November(19.4°C) and three cultivars *i.e.* NDR-8501 (V1), Kranti (V2) and Varuna (V3). The experiment was replicated four times. Results revealed that the highest thermal unit (1667.2 days) and thermal use efficiency (0.61 g/m²/ºdays) was recorded at developing climate/encompassing temperature of 31st October (T1) (22.6°C)while least gathered hotness units from planting to development (1468.9ºC days) was seen under the developing climate/surrounding temperature of twentieth November. The late-planted mustard crop recorded the least GDD prerequisite at every one of the stages. The least Thermal use proficiency from planting to development 0.435g/m²/ºdays was seen under developing climate/encompassing temperature (tenth November)(21.2°C). Late planted cultivars recorded the least warm use effectiveness necessity at all stages.

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Keywords: Ambient temperature; thermal unit; thermal use efficiency and climate

1. INTRODUCTION

In India, Rapeseed and mustard is the major Rabi season oilseed crop and stand next to groundnut in the oilseed economy. Among the different oilseed crops, it is one of the signs as a result of its possible utilities in the bio-fills enterprises [1]. It occupies a prominent place among the leading oilseed crop being next to groundnut both in area and production which accounts for nearly 30% of the total oilseeds produced in India, meeting the fat requirement of about 50% population in the state of Uttar Pradesh, Punjab, Rajasthan and Assam. The mustard cultivated in India is known as Indian mustard or Rai {*Brassica juncea* L. (Czern and Coss)}.

The mustard seeds are small and spherical approximately about 1-2 mm in diameter and they are a crucial spice in lots of areas in the country and the world. The oil content in mustard varies from 38% to 46% and the average oil recovery is around 38% to 39%. Mustard is a self-pollinated crop and is mainly pollinated by honey bees.

In India, Rapeseed and mustard are grown in diverse agro-climatic regions. It is discovered that the mustard crop can tolerate annual precipitation of 450 to 1150 mm, the annual temperature of 5 to 27^{o}C and a pH of 6.5 to 8.5. Mustard is a C_3 crop *i.e.* it follows the C_3 pathway for Carbon assimilation. So, it has an economic photosynthetic response at the temperature range of 15-20^{o}C. Rapeseed and mustard need well-drained, sandy loam soil and have a moderate water demand (240-400 mm). This is appropriate for the rain-fed cropping systems. The seed yield of rapeseed and mustard is mainly affected by the ambient temperature especially at the time of flowering and seed set. It is important to choose an appropriate time for sowing. Early varieties produce less number of siliqua^{-1} plant, which was sown late while early sown late varieties give leafier growth and produce siliqua very late. The optimum date of sowing for rapeseed mustard varies according to cultivar and climatic conditions. Information suggested in the literature is not suitable for every situation. Higher temperature is the primary limitation at the hour of germination as well as at the hour of the grain filling stage. Blossoming and grain filling stages are the most delicate stages for temperature stress twisted because of the weakness during dust and grain improvement, anthesis and treatment prompting decline in the harvest yield. The higher temperature in rapeseed and mustard improves the plant advancement and causes blossom suspension and helpless grain loading up with critical misfortune in yield. An ascent of 3oC in the greatest everyday temperature (21-24oC) during blossoming and grain filling stages causes a downturn of around 430 kg/ha in mustard yield. Along these lines, it is important to assess the impact of various planting dates on plant development, seed yield and quality. The mustard plants react to high-temperature stress through formative, physiological and biochemical changes and the sort of noticed reaction relies upon a few factors like pressure power (SI), stress period and genotype [2]. Mustard is significantly delicate to climate boundaries as proof from the variable reaction to variable dates of planting[3]. As per Boomiraj et al. [4] temperature rise would be generally destructive for the yield in the eastern area of India, trailed by focal India, where winter season temperature is similarly higher than the northern district. Kaur et al., [5] saw that deferred planting of the harvest extraordinarily stifled different development and yield parts including plant tallness, quantities of blossoms and siliquae and the number of seeds per siliqua. One month delay in planting from mid of October resulted in the loss of 40.6% in seed yield [6]. Among the different agronomic practices, optimum sowing time is very important for mustard production [7,8]. Hence the study was conducted to find out the suitable ambient temperature/growing environment of the mustard crop.

2. MATERIALS AND METHODS

The test was spread out at Agrometeorological Research Farm of Acharya Narendra Deva University of Agriculture and Technology, Narendra Nagar, Kumarganj, Ayodhya (U.P.) during Rabi season 2020-21. The exploratory site lies at scope 26° 47'North longitude 82° 12' East and height of 113 meters from mean ocean level in the Indo - hereditary alluvium of Eastern Uttar Pradesh.

Different meteorological parameters *viz.* most extreme and least temperatures, precipitation, greatest and least relative mugginess, soil temperature at various depths, wind speed, wind direction, cloud cover and sunshine hour recorded during the crop growing period have been recorded from the Agrometeorological observatory of the University**.** The normal week by week greatest and least temperatures during the yield development period went from 25.64 to 10.16°C, soil temperature ranged between 5 cm 12.6°C to 26.2°C, at 10 cm 12.6°C to 26.1°C and 20 cm 12.8°C to 26.1°C and bright sunshine between 1.9 to 8.3 hours.

The experiment was conducted in Split Plot design with nine treatment combinations consisting of three ambient temperatures/growing environments.*e.*31st October (22.6°C), 10th November(21.2°C), 20th November(19.4°C) and three cultivars *i.e.* NDR-8501 (V1), Kranti (V2) and Varuna (V3) and replicated four times.

2.1 Growing Degree Days

Growing degree days (GDD) at various phenological stages were determined by utilizing the following equation:

$$Heatunit = \sum_{i=1}^{n} GDD$$

Where,

1, 2, 3… n is number of days and
The base temperature for the mustard (Rabi) crop is 5.0°C.

$$\mathrm{GDD} = \frac{\mathrm{Tmax} + \mathrm{Tmin}}{2} - \mathrm{baseTemperature}$$

2.2 Heat Use Efficiency (g/m^2/^{0}day)

Heat use efficiency (HUE) is the dry matter creation per unit of hotness unit by the harvest. Heat use efficiency (HUE) might be determined from the heating unit acquired above as follows –

$$\mathrm{HUE} = \frac{\mathrm{Totaldrymatter}\ (\frac{\mathrm{g}}{\mathrm{m2}})}{\mathrm{Heatunit}\ (°\mathrm{days})}$$

3. RESULTS AND DISCUSSION

1. **Growing degree days/ Thermal unit (Heat unit):**

Information relating to aggregated Heat Unit necessity of mustard crop at various pheno-stages as affected because of various developing conditions/surrounding temperature and cultivars have been referenced in Table 1 and portrayed in Figs. 1, 2 and 3. The greatest hotness Unit (GDD) prerequisites from planting to development were recorded (1667.2ºC days) under the developing climate/surrounding temperature of 31st October. While least amassed heat units from planting to development (1468.9 ºC days) were seen under the developing climate/encompassing temperature of twentieth November. The late-planted mustard crop recorded the least GDD prerequisite at all the stages. Similarity has been found with the investigation of Srivastava et al. [9]; Singh et al*.* [10,11] and Singh et al*.* [12].

Table 1.Growing degree days/ Thermal unit (Heat unit) at different phenophases (˚C days) of mustard as influenced by Ambient temperature/Growing environments (T) and cultivars (V)

Growing environment/ambient temperature	Phenophases					
	Emergence	Four Leaf Stage	Flower Initiation	Siliqua Initiation	Pod Development	Maturity
NDR-8501						
31st Oct. (T1) (22.6 °C)	101.75	181	648.75	799	998.25	1667.2
10th Nov. (T2) (21.2 °C)	101.5	192	625.5	788	889.45	1593.2
20th Nov. (T3) (19.4 °C)	89	179.5	615	726.45	938.95	1468.9
Kranti						
31st Oct. (T1) (22.6 °C)	101.75	181	659.75	799	1007.5	1568.45
10th Nov. (T2) (21.2 °C)	116.25	192	625.5	796.75	926.45	1593.2
20th Nov. (T3) (19.4 °C)	63.75	179.5	619.5	730.95	925.2	1490.7
Varuna						
31st Oct. (T1) (22.6 °C)	117.5	197.5	659.75	806.5	998.25	1667.2
10th Nov. (T2) (21.2 °C)	116.2	203.25	641.25	788	889.45	1593.2
20th Nov. (T3) (19.4 °C)	102.7	192.75	609.5	726.45	925.2	1468.9

Table 2. Thermal use efficiency (g/m²/°days) of mustard as affected by Ambient temperature/Growing environments (T) and cultivars (V)

Growing environment/ambient temperature	Heat/Thermal use efficiency (g/m²/°days)			
	30 DAS	60 DAS	90 DAS	At Harvest
NDR-8501				
31st Oct. (T1) (22.6°C)	0.13	0.27	0.82	0.58
10th Nov. (T2) (21.2°C)	0.13	0.28	0.87	0.57
20th Nov. (T3) (19.4°C)	0.14	0.27	0.73	0.54
Kranti				
31st Oct. (T1) (22.6°C)	0.12	0.22	0.654	0.46
10th Nov. (T2) (21.2°C)	0.13	0.219	0.65	0.45
20th Nov. (T3) (19.4°C)	0.14	0.217	0.59	0.44
Varuna				
31st Oct. (T1) (22.6°C)	0.134	0.29	0.81	0.61
10th Nov. (T2) (21.2°C)	0.13	0.26	0.81	0.60
20th Nov. (T3) (19.4°C)	0.15	0.28	0.81	0.55

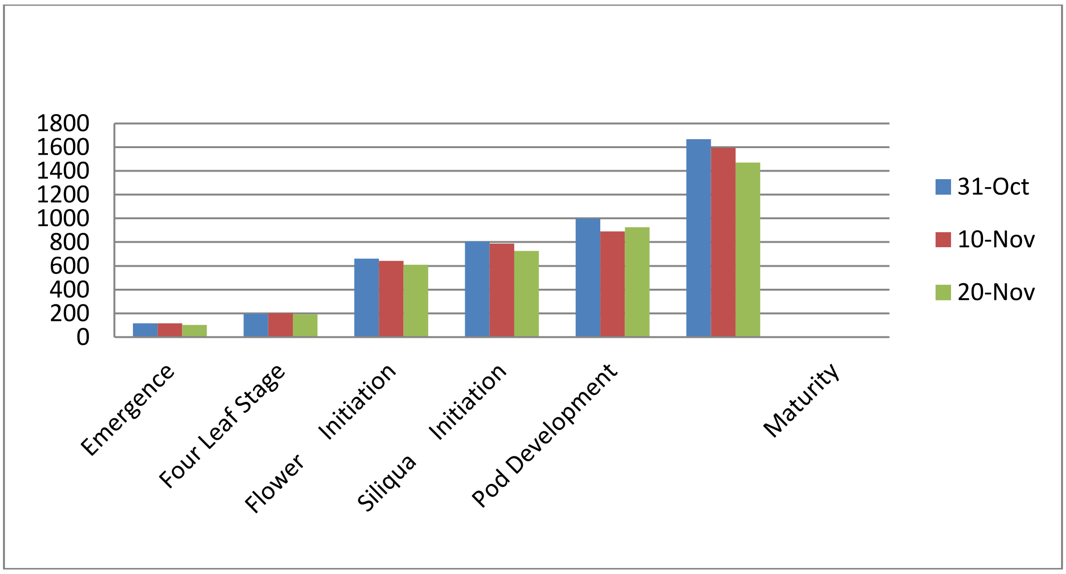

Fig. 1. Growing degree days at different phenophases (˚C days) of mustard as influenced by Ambient temperature/Growing environments (T) and cultivar NDR-8501

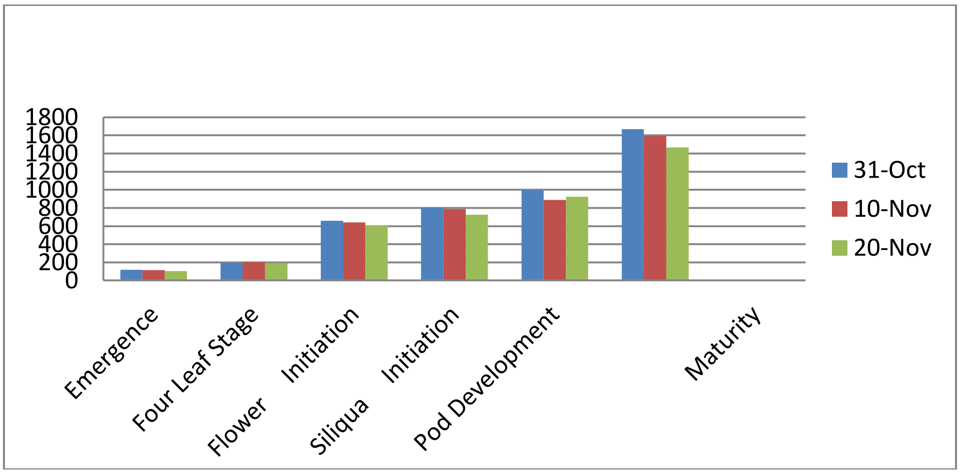

Fig. 2. Growing degree days at different phenophases (˚C days) of mustard as influenced by Ambient temperature/Growing environments (T) and cultivar Kranti

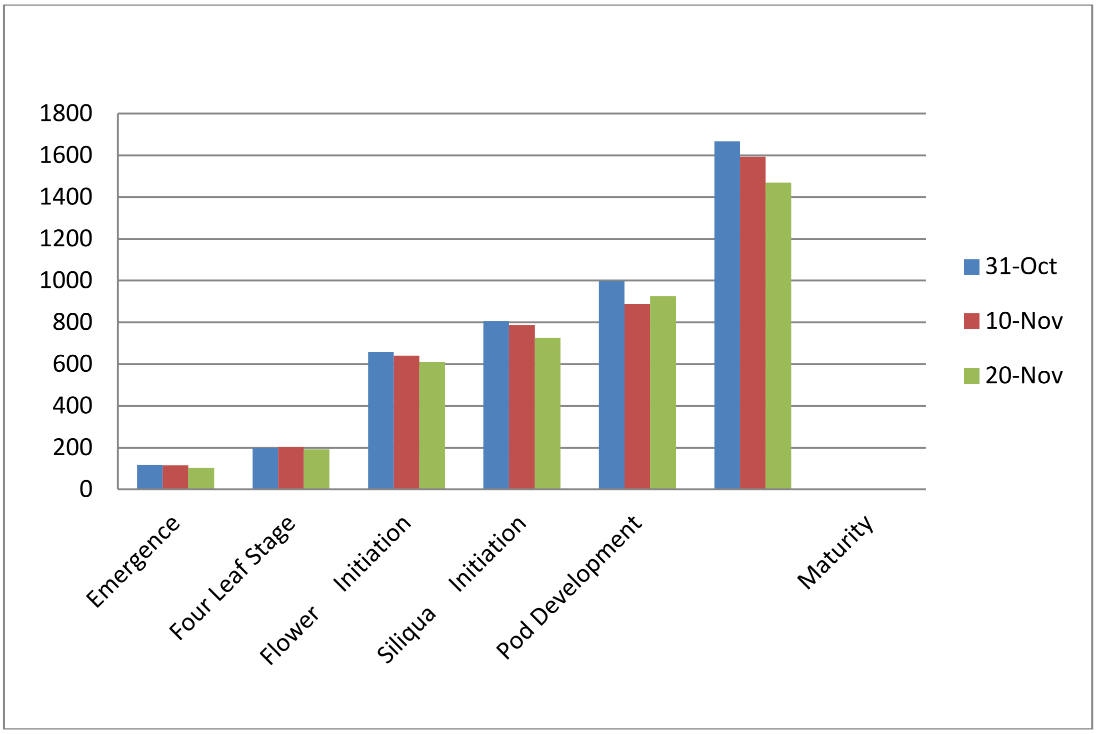

Fig. 3. Growing degree days at different phenophases (˚C days) of mustard as influenced by Ambient temperature/Growing environments (T) and cultivar Kranti

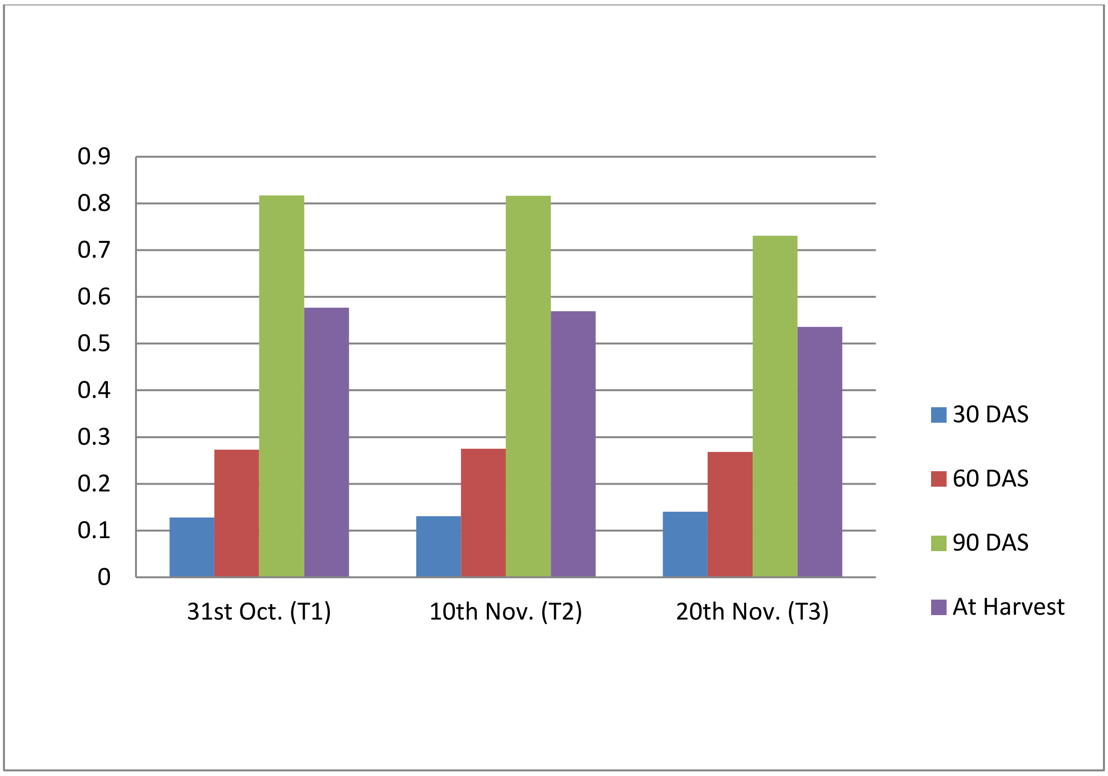

Fig. 4. Thermal use efficiency (g/m²/ºdays) of NDR-8501 affected by different Ambient temperature

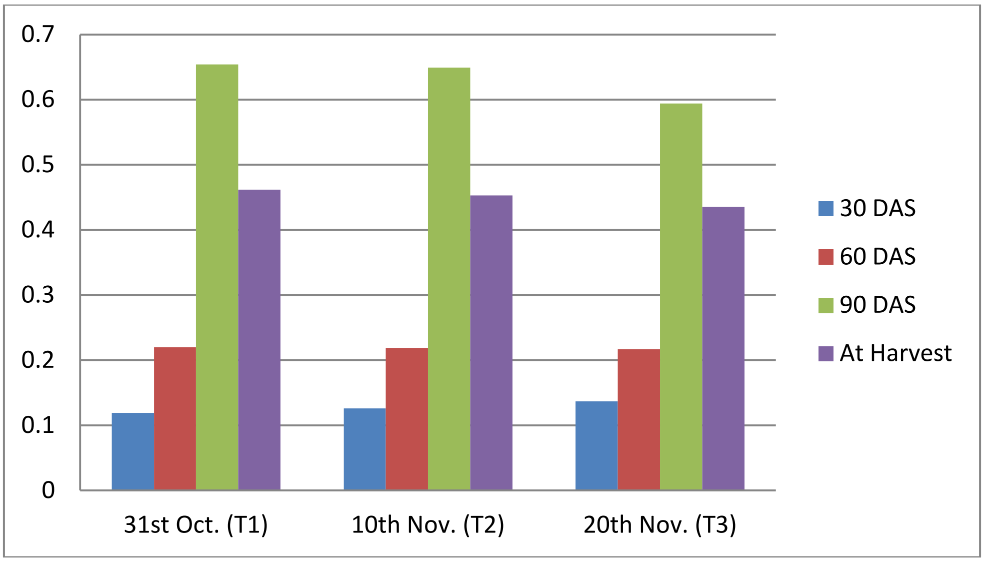

Fig. 5. Thermal use efficiency (g/m²/ºdays) of Kranti as affected by different Ambient temperature

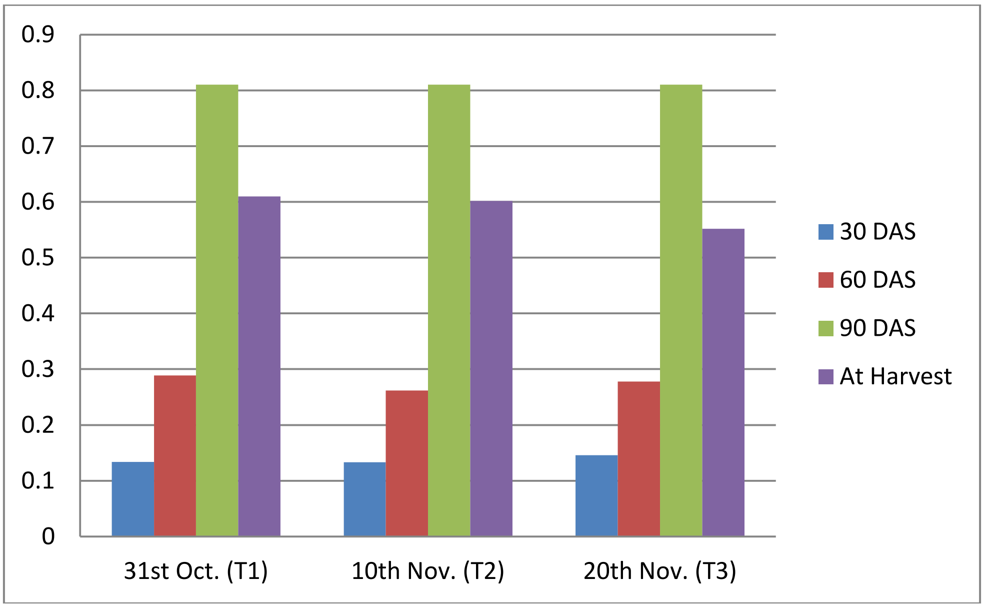

Fig. 6. Thermal use efficiency (g/m²/ºdays) of Varuna as affected by different Ambient temperature

2. Heat/Thermal use efficiency (g/m²/days):

Information relating to Thermal/heat use effectiveness prerequisite of the mustard crop at various pheno-stages as impacted because of various developing conditions/surrounding temperature and cultivars have been introduced in Table 2 and portrayed in Figs. 4, 5 and 6. The most extreme Thermal/heat use proficiency prerequisite from planting to development was recorded 0.61 under the developing climate/encompassing temperature of twentieth November (19.4°C) while least Thermal use effectiveness from planting to development 0.44g/m²/ºdays was seen under developing climate/surrounding temperature (tenth November) (21.2°C). Late planted cultivars recorded the least warm use effectiveness prerequisite at all stages. These results are additionally in similarity with the discoveries of Singh et al*.* [12].

4. CONCLUSION

Results showed that the 31st October sown mustard crop gives better yield followed 10th November and 20th November. The most extreme Heat unit necessity from planting to development was (1667.2days) obtained on 1st date of sowing (31st October), while minimum heat unit was obtained (1468.9º days) on 3rd date of sowing (20th November) from planting to development of mustard. The greatest Thermal/heat use proficiency necessity from planting to development was recorded 0.61 under the growing environment/ambient temperature of 20th November (19.4°C) while least Thermal use proficiency from planting to development 0.44g/m²/ºdays was seen under developing climate/encompassing temperature (tenth November) (21.2°C). Late planted cultivars recorded the least warm use productivity prerequisite at all stages.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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