Original Research Article

Studies on the thermal unit and heat use efficiency requirement of mustard crop (*Brassica juncea* L.) under different ambient temperature and cultivars.

Abstract

A field experiment was conducted during rabi season of 2020-21 in the sandy loam soil of A.N.D. University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.). The experiment was conducted 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/°days) was recorded at growing environment/ambient temperature of 31st October (T1) (22.6 °C).

Introduction

In India, Rapeseed and mustard is the major Rabi season oilseed crop and stand next to groundnut in the oilseed economy. Among the various oilseed crops, it is one of the important because of its potential utilities in the bio-fuels industries **(Dubie *et al.*, 2013).** It occupies a prominent place among the leading oilseed crop being next to groundnut both in area and production which accounts nearly 30% of the total oilseeds produced in India, meeting fat requirement of about 50% population in 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 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 an annual precipitation of 450 to 1150 mm, 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 C_3 pathway for Carbon assimilation. So, it has economic photosynthetic response at the temperature range of 15-20^{o}C. Rapeseed and mustard needs well drained, sandy loam soil and has the 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 setting. It is important to choose an appropriate time of sowing. Early varieties produces less number of siliqua^{-1} plant, which was sown late while early sown late varieties give leafier growth and produces 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 main constraint not only at the time of germination but also at the time of grain filling stage. Flowering and grain filling stages are the most sensitive stages for temperature stress wound due to the vulnerability during pollen and grain development, anthesis and fertilization leading to decrease in the crop yield. Higher temperature in rapeseed and mustard improve the plant development and causes flower cessation and poor grain filling with significant loss in yield. A rise of 3^{o}C in maximum daily temperature (21-24^{o}C) during flowering and grain filling stages causes a recession of about 430 kg/ha in mustard yield. Thus, it is necessary to evaluate the effect of different sowing dates on the plant growth, seed yield and quality. The mustard plants respond to high temperature stress through developmental, physiological and biochemical changes and the type of the observed response depends on several factors such as stress intensity (SI), stress period and genotype (Moradshahi *et al.,* 2004). Mustard is substantially sensitive to weather parameters as evidence from the variable response to variable dates of sowing. (Kar and Chakravarty, 2000). According to Boomiraj *et al.* (2010) temperature rise would be most harmful for the crop in eastern region of India, followed by central India, where winter season temperature is comparatively higher than northern region. Kaur *et al.,* (2006) observed that delayed sowing of the crop greatly suppressed various growth and yield components including plant height, numbers of flowers and siliquae and the number of seeds per siliqua. One month delay in sowing from mid of October resulted loss of 40.6% in seed yield (Lallu *et. al.,* 2010*).* Among the different agronomic practices, optimum sowing time is very important for mustard production (Mondal and Islam, 1993; Mondal *et al.,* 1999). Hence the study was conducted to find out the suitable ambient temperature/growing environment of the mustard crop.

Materials and Methods

The experiment was laid out at Agro-meteorological Research Farm of Acharya Narendra Deva University of Agriculture & Technology, Narendra Nagar, Kumarganj, Ayodhya (U.P.) during Rabi season 2020-21. The experimental site lies at latitude 26° 47'North longitude 82° 12' East and altitude of 113 meter from mean sea level in the Indo - genetic alluvium of Eastern Uttar Pradesh.

Different meteorological parameters *viz.* maximum and minimum temperatures, rainfall, maximum and minimum relative humidity, 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 average weekly maximum and minimum temperatures during the crop growth period ranged from 25.64 to 10.16^{o}C, soil temperature ranged between at 5 cm 12.6^{o}C to 26.2^{o}C, at 10 cm 12.6^{o}C to 26.1^{o}C and at 20 cm 12.8^{o}C to 26.1^{o}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 *i.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.

Growing degree days

Growing degree days (GDD) at different phenological stages were calculated by using following formula:

$$Heat\ unit = \sum_{i=1}^{n} GDD$$

Where,

1, 2, 3… n is number of days and

The base temperature for mustard (*Rabi*) crop is 5.0°C.

$$GDD = \frac{Tmax + Tmin}{2} - base\ Temperature$$

Heat use efficiency (g/m^2/^{0}day):

Heat use efficiency (HUE) is the dry matter production per unit of heat unit by the crop. Heat efficiency (HUE) may be calculated from heat unit obtained above as following –

$$HUE = \frac{Total\ dry\ matter\ (\frac{g}{m2})}{Heat\ unit\ \ (°days)}$$

Result and discussion:

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

Data pertaining to accumulated Heat Unit requirement of mustard crop at different pheno-phases as influenced due to different growing environments/ambient temperature and cultivars have been mentioned in Table 1 and depicted in fig. 1.1, 1.2 and 1.3. The maximum heat Unit (GDD) requirements from sowing to maturity were recorded (1667.2ºC days) under the growing environment/ambient temperature of 31st October. While minimum accumulated heat units from sowing to maturity (1490.7 ºC days) was observed under the growing environment/ambient temperature of 20th November. Late sown mustard crop recorded minimum GDD requirement at all the stages. Similarity has been found with the study of **Srivastava *et al.* (2011); Singh *et al.* (2014) and Singh *et al.* (2019).**

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

Data pertaining to Thermal/heat use efficiency requirement of mustard crop at different pheno-phases as influenced due to different growing environments/ambient temperature and cultivars have been presented in Table 2 and depicted in fig. 2.1, 2.2 and 2.3. The maximum Thermal/heat use efficiency requirement from sowing to maturity was recorded 0.61 under the growing environment/ambient temperature of 20th November (19.4 °C) while minimum Thermal use efficiency from sowing to maturity 0.435 g/m²/ºdays was observed under growing environment/ambient temperature (10th November) (21.2 °C). Late sown cultivars recorded minimum thermal use efficiency requirement at the all stages. These results are also in conformity with the findings of **Singh *et al.* (2019).**

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/m^2/ºdays) of mustard as affected by Ambient temperature/Growing environments (T) and cultivars (V)

Growing environment/ambient temperature	Heat/Thermal use efficiency (g/m^2/ºdays)			
	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. 1.1 Growing degree days at different phenophases (˚C days) of mustard as influenced by Ambient temperature/Growing environments (T) and cultivar NDR-8501

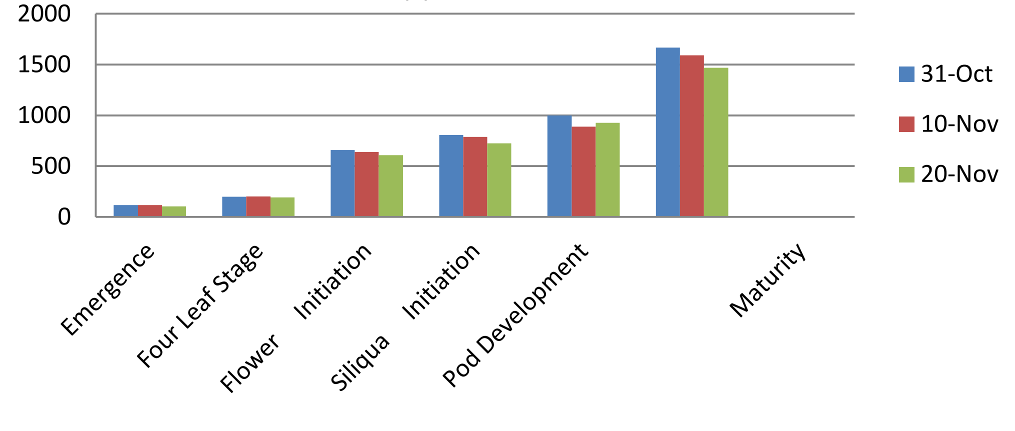


Fig. 1.2 Growing degree days at different phenophases (˚C days) of mustard as influenced by Ambient temperature/Growing environments (T) and cultivar Kranti

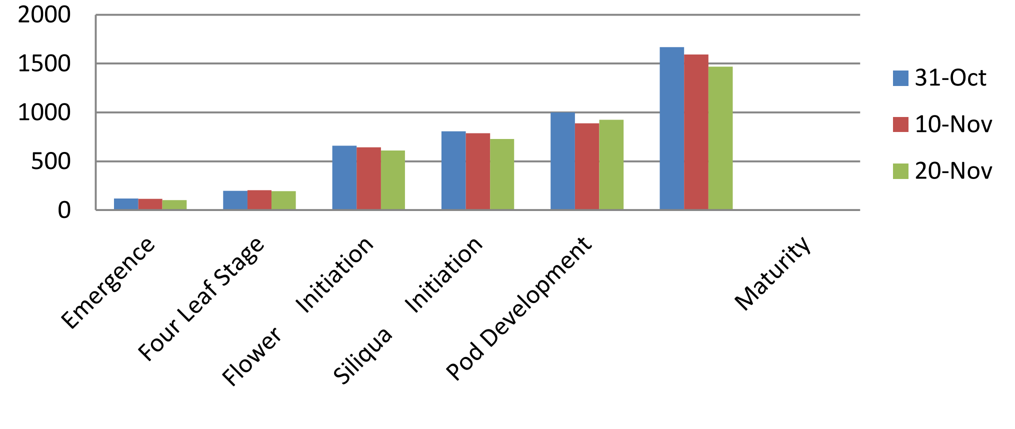


Fig. 1.3 Growing degree days at different phenophases (˚C days) of mustard as influenced by Ambient temperature/Growing environments (T) and cultivar Kranti

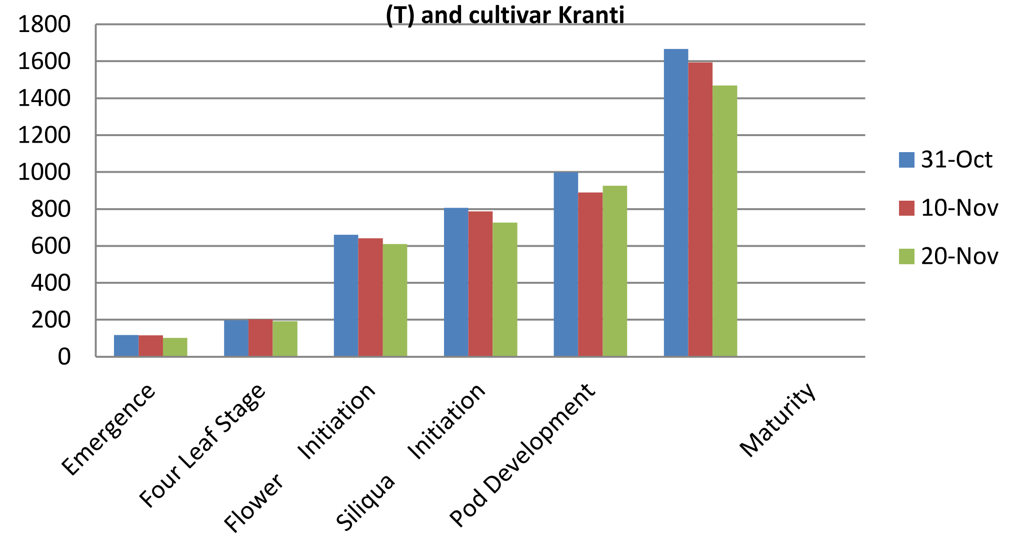


fig.2.1 Thermal use efficiency (g/m²/ºdays) of NDR-8501 affected by different Ambient temperature

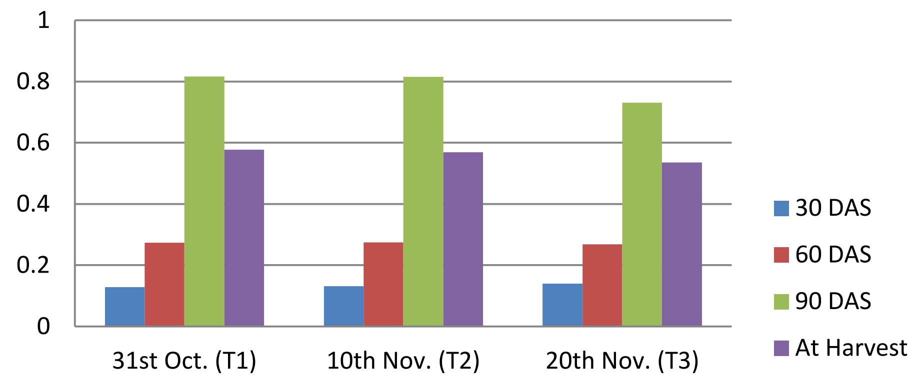


fig.2.2 Thermal use efficiency (g/m²/ºdays) of Kranti as affected by different Ambient temperature

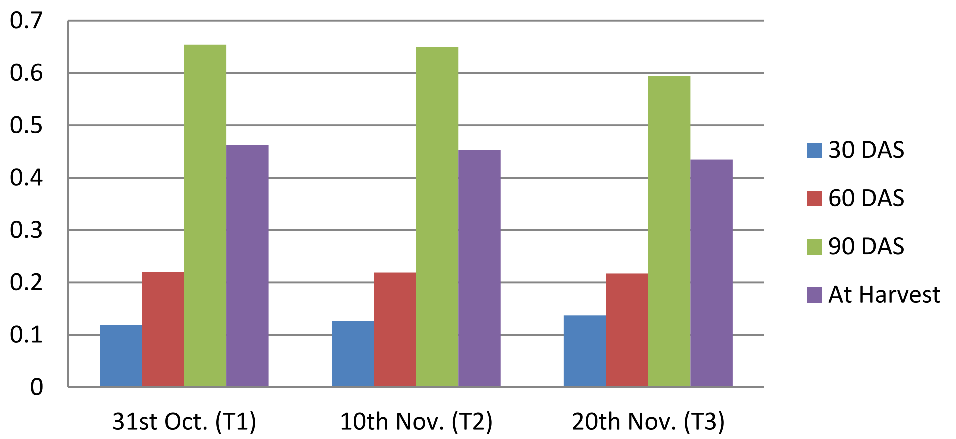
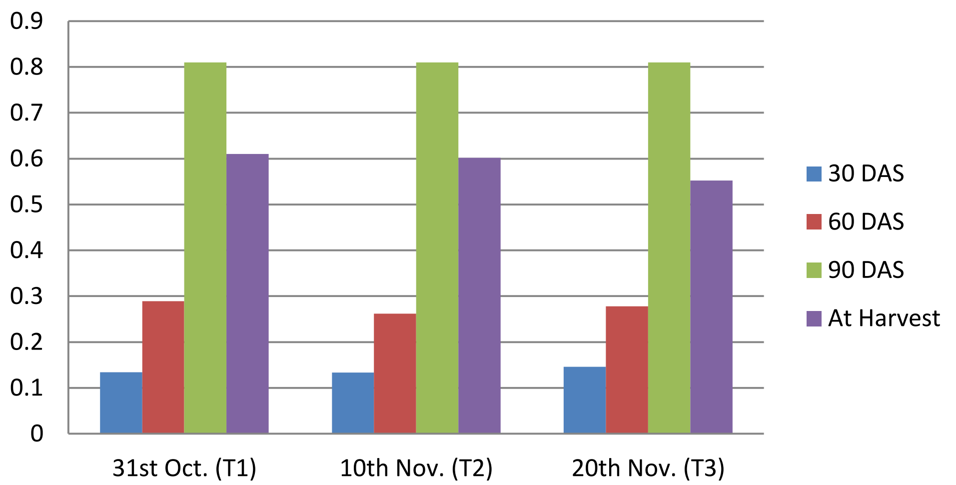


fig.2.3 Thermal use efficiency (g/m²/ºdays) of Varuna as affected by different Ambient temperature



Conclusion

Results showed that 31^{st} October sown mustard crop gives better yield followed 10^{th} November and 20^{th} November. Maximum Heat unit requirement from sowing to maturity was (1667.2 ^{o}days) obtained on 1^{st} date of sowing (31^{st} October), while minimum heat unit was obtained (1490.7º days) on 3^{rd} date of sowing (20^{th} November) from sowing to maturity of mustard. Maximum Heat unit requirement from sowing to maturity was (1667.2 ^{o}days) obtained on 1^{st} date of sowing (31^{st} October), while minimum heat unit was obtained (1490.7º days) on 3^{rd} date of sowing (20^{th} November) from sowing to maturity of mustard.

References:

Boomiraj, K., Chakrabarti, B., Aggarwal, P.K., Choudhary, R. and Chander, S. (2010). Assessing the vulnerability of Indian mustard to climate change. *Agri. Eco sys. Enviro.* 138: 265–73.

Dubie, J., Stancik, A., Morra. and Nindo, C. (2013). Antioxidant extraction from mustard (*Brassica juncea*) seed meal using high-intensity ultrasound. *J Food Sci.* 78(4): 542-548.

Kar, G. and Chakravarty, N.V.K. (2000). Phenological stages and growth dynamics of *Brassica* as influenced by weather. *J. of agrometeorology*. 2(1): 39-46.

Kaur K, Setia N, Setia R.C. (2006). Influence of delayed sowing and kinetin on growth and yield components of Indian mustard (*Brassica juncea*). *Environment and Ecology*; 24S (Special 3A):872-875

Lallu, Baghel, R. S. and Srivastava, S. B. L., (2010). Assessment of mustard genotypes for thermo tolerance at seeddevelopment stage, *Indian J. Plant Physiology* 15(1):36-43.

Mondal, M.R.I. and Islam, M.A. (1993). Effect of seed rate and date of sowing on yield and yield components of rapeseed. *Bangladesh J Agric. Sci*. 20(1):29-33.

Mondal, R.I., Biswas, M., HydarAli, M.K. and Akbar, M.A. (1999). Response of rapeseed genotype dhali to seed rate and seeding date. *Bangladesh J Agric. Res*. 24(1):83-90.

Moradshahi, A., Eskandari, B.S. and Kholdebarin, B. (2004). Some physiological responses of canola (*Brassica napus* L.). *Iranian J.l of Sci. Tech. Trans. A- Sci.* 28:43–50

Singh, M. P. and Singh, N. B. 2014. Effect of energy requirement parameter such as GDD, PTU, PTI, HTU, HUE on growth and development of Indian mustard at different Phenological stages under late sown condition. *Indian Journal of Plant Physiology.* 19 (3):238243

Singh, S.P., Sharma, P., Jena, A.K., Bhuyan, T., Deuri, R. and Nyori, T. (2019). Heat unit requirement of mustard (*Brassica Juncea* L.) under different thermal regimes and irrigated conditions of Namsai region of Arunachal Pradesh. *International Journal of Chemical Studies*. 7(3):1038-1041

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