Journal of Agrometeorology 19 (2) : 164-166 (June 2017)

Short Communication

Thermal requirements and heat use efficiency of Indian mustard varieties under different environment

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Indian mustard *(Brassica juncea* L.*)* is a winter season crop and grown in diverse agro-climatic conditions ranging from northern hills to down south under irrigated and rainfed, timely and late-sown, saline soils and mixed cropping. Its sowing gets delayed by mid to end November due to late harvesting of *kharif* crops. Optimum sowing time plays an important role to fully exploit the genetic potentiality of the crop. In general, it was observed that the mustard crop sown after October 30th resulted in lower yields (Panda *et al*., 2004). Heat stress during the post anthesis/ seed filling negatively influences the movement of photosynthates to the developing sinks and inhibits the synthetic processes, thus causes lower seed weight, seed yield and may alter seed quality (Kumari *et al*., 2004). Decline in physiological traits along with the seed yield under high temperature stress has recently been reported in *B. juncea* by Sharma *et al* (2013). Heat unit concept has been applied to correlate phenological development in crops to predict sowing and maturity dates (Nuttonson, 1955). The quantification of heat use efficiency (HUE) is useful for the assessment of yield potential of different crops in different environments (Kumari, *et al*., 2009 and Tyagi, 2014). Information on heat unit requirement and temperature response on mustard for Bundelkhand region of Madhya Pradesh is lacking.

The field experiment was conducted at Research Farm, J.N.K.V.V., College of Agriculture, Tikamgarh (24° 43' N latitude, 78° 49' E longitude at an altitude of 358 m above mean sea level), Madhya Pradesh, India during two consecutive *rabi* seasons of 2012-13 and 2013-14. The experiment was conducted in split-plot design with three replications and comprised of three sowing dates *viz*., October 20, November 4 and November 19 as main plot treatments and five varieties*viz*., Pusa Bold, Pusa Agrani, Pusa Jai Kisan, Kranti and Varuna as sub-plot treatments. The weather data required for the study were collected from the Agrometeorological Observatory, College of Agriculture, Tikamgarh. The fertilization, irrigation and management practices as recommended in the packages and practices for mustard crop in the Tikamgarh region were strictly applied. Total dry matter accumulation (g m^{-2}) was recorded at various growth stages *viz*., fifth true leaf exposed, first flower opened, lowest pod more than 2 cm long, most seeds green and physiological maturity. The cumulative thermal units (°C) at various phenological stages were determined by summing the daily mean temperatures above the base temperature (Tb= 5 °C) by using the formula as per Nuttonson (1955). Heat use efficiency (HUE), which is a measure of amount of dry matter production per unit of thermal unit, was worked as per procedures reported by Sahu *et al*. (2007).

Thermal units

The results show that fifteen-day successive delay in sowing from October 20 to November 4 and November 19 reduced the crop duration by 4 and 10 days, respectively and accumulated thermal units by 142 and 203 °C, respectively.The total accumulated thermal unit during the entire growth period of the crop decreased from 1648 °C under October 20 sowing to 1506 °C and 1445 °C under late sowings on November 4 and November 19, respectively (Table 1). October 20 sown crop accumulated higher thermal units for all the growth stages except emergence followed by November 4 and November 19 sowings. Khushu *et al*. (2008) and Kumari and Rao (2005) reported that higher temperatures during the reproductive phase reduced the duration of the late- sown *Brassica* crop. Among varieties, varuna had higher thermal unit requirement (1645 °C) due to comparatively longer duration of maturity (132 days) followed by *cvs*. Kranti, Pusa Bold, Pusa Jai Kisan and Pusa Agrani. The varietal differences in mustard for phasic duration and thermal units were also reported by Goswami *et al*., (2003), Khushu *et al*. (2008) and Tharranum *et al*. (2016).

Heat use efficiency

October 20 sown crop produced significantly higher total dry matter all the growth stages followed by November 4 and November 19(Table 1). Fifteen-day successive delay

Table 1: Days taken to maturity, accumulated heat unit, dry matter and heat use efficiency mustard as affected by various treatments (Pooled data over two years 2012-13 and 2013-14).

Treatments	Days to maturity (days)	Accumulated heat unit (^{0}C days)	Dry Matter at maturity (g m^{-2})	Heat use efficiency (kg ha^{-1}^{0}C days)
Sowing dates				
Oct 20	132.0	1648	1061.4	6.441
Nov 04	128.0	1506	961.9	6.387
Nov 19	122.0	1445	874.5	6.052
S.Em±	1.48	—	9.78	—
CD at 5%	4.22	—	28.1	—
Varieties				
Pusa Bold	130.0	1561	980.4	6.281
Pusa Agrani	122.0	1430	861.6	6.025
Pusa Jai Kisan	124.0	1462	1061.9	7.263
Kranti	131.0	1568	988.9	6.307
Varuna	132.0	1645	936.8	5.695
S.Em±	0.64	—	9.74	—
CD at 5%	1.92	—	28.9	—

in sowing from October 20 to November 4 and November 19 decreased the total dry matter accumulation by 9.37% and 17.6%, respectively at maturity. Reduction in total dry matter accumulation in mustard cultivars under delayed sowing beyond October 20 was also reported by Roy and Chakravarty (2007).Total dry matter accumulation also differed significantly among cultivars and Pusa Jai Kisan produced significantly higher total dry matter accumulation at all the growth stages followed by Kranti, Pusa Bold, Varuna and Pusa Agrani.

The heat use efficiency (HUE) was higher for October 20 sown crop followed by November 4 and November 19 at all growth stages. At maturity, HUE was the maximum for October 20 (6.441 kg ha^{-1} °C day) followed by November 4 (6.387 kg ha^{-1} °C day) and the minimum in November 19 (6.052 kg ha^{-1} °C day) sown crops. This was because of less dry matter production and less accumulated thermal units in delayed sown crop (Khushu *et al*., 2008). Irrespective of growing environments, the increase in HUE was the maximum during reproductive phase from first flower opened to physiological maturity. Varietal difference for HUE was also found at all growth stages of crop growth. Pusa Jai Kisan recorded higher value of HUE at all growth stages followed by Kranti, Pusa Bold, Varuna and Pusa Agrani. Similar results in mustard were also reported by Jat (2014).

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Received : September 2016; Accepted: April 2017