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Short communication

Thermal time indices for some mustard genotypes in the Jammu region

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Prevailing weather conditions during the whole crop growing season have direct bearing upon the phenological events of the crop which ultimately affect the crop yield. The effect of temperature, determining the phenological behavior of the crop, can be assessed by accumulated heat units. The duration of each growth phase is a result of crop response to external environmental factors. The concept of heat units has been applied to correlate the phenological development of different crops to predict grain yield and physiological maturity (Swan *et al.*, 1989) of the crop. Thermal time effect has been described as the independent variable to delineate plant growth and development (Dwyer and Stewart, 1986.) Temperature based agrometeorological indices such as growing degree days (GDD), heliothermal units (HTU) and photothermal units (PTU) are based on the concept that real time to attain the phenological stage is linearly related to temperature in the range between base temperature and optimum temperature (Monteith, 1981).

Mustard is an important oil seed crop grown in Jammu. Information on heat unit requirements is helpful to crop modeler for calibration and sensitivity analysis of several crop growth simulation models. Therefore, the present investigation was carried out to study the phenological development of two mustard genotypes in relation to growing environment under field conditions.

Field experiment was conducted during *rabi* 2004 on the research farm under the All India Coordinated Research Project on Agrometeorology at Chatha, Jammu (32° 40' N, 74° 58' E, 332 meters above mean sea level). The main plot treatments consisted of three dates of sowing, *viz.*, October 06 (D_1), October 21 (D_2) and November 05 (D_3) and subplot treatments included two genotypes *viz.*, Varuna (V_1) and Pusa Bahar (V_2), were sown in randomized block design with four replications. The soil was sandy loam in texture. The crop was raised following the recommended package of practices of the Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu. The above ground biomass observations were taken at ten days interval. Five plants were randomly selected from each plot and separated into leaves, shoot and reproductive parts which were sundried for two days and then oven dried at 60 °C for 24 hours. The dry weight was taken with the help of electronic balance.

Daily weather data were recorded from the Agrometeorological Observatory situated at about 100 meters away from the experimental site. Observations on different phenophases (Table 1) were recorded at an interval of 3-4 days. Growing degree days (GDD) were calculated for each phenophase using a base temperature of 5°C (Nuttonson, 1955). Heliothermal units (HTU) are the product of GDD and corresponding actual sunshine hours for that day. Photothermal units (PTU) are the product of GDD and corresponding daylength for that day (Nuttonson, 1948). GDD, HTU and PTU were accumulated from the date of sowing to each phenophase.

Heat use efficiency (HUE) was computed to compare the relative performance of the mustard crop under different treatments using the formula:

$$\underset{(\text{kg ha}^{-1}\text{per C}^{\circ}\text{day})}{\text{HUE}} = \frac{\text{Total dry matter (kg ha}^{-1})}{\text{Accumulated heat units (C}^{\circ}\text{day)}}$$

The investigations on crop development were examined by considering different phenophases and the number of days taken for completing each phenophase. The duration (days taken) for different phenological

Table 1: Effect of sowing dates on duration and growth environment of mustard genotypes

Phenophase	DOS	Mustard geno			
		Varuna (V_1)			
		DAS	∑GDD	∑HTU	∑PTU
	D_1	5	118	510	1342
P_0 to P_1	D_2	4	80	717	872
	D_3	6	92	758	962
	D_1	8	164	726	1855
P_0 to P_2	D_2	6	110	841	1189
	D_3	10	142	1090	1478
	D_1	11	213	1148	2398
P_0 to P_3	D_2	11	176	1377	1896
	D_3	14	193	1447	1996
	D_1	22	389	963	4316
P_0 to P_4	D_2	21	308	2476	3278
	D_3	30	379	2225	3856
	D_1	43	662	3063	7157
P_0 to P_5	D_2	41	555	3722	5785
	D_3	45	525	3163	5302
	D_1	49	741	5087	7962
P_0 to P_6	D_2	51	652	4379	6744
	D_3	49	549	3249	5538
	D_1	55	810	5262	8650
P_0 to P_7	D_2	53	672	4475	6940
	D_3	52	568	3277	5721
	D_1	86	1085	6707	11371
P_0 to P_8	D_2	85	896	5391	9155
	D_3	83	754	4065	7590
	D_1	141	1424	8090	14910
P_0 to P_9	D_2	135	1274	6889	13233
	D_3	103	1209	5945	12679

P_0 = sowing, P_1 = emergence, P_2 =cotyledon above ground, P_3 = both cotyledon unfolded and green, P_4 =fifth true leaf exposed, P_5 = flower bud visible from above, P_6 = first flower open, P_7 = lowest pod more than 2 cm long, P_8 = most seeds green, P_9 = most seeds brown) and P_{10} = fully ripened.
DOS = Date of sowing and DAS = Days after sowing

events i.e. P_1 to P_{10} under different treatments (Table 1) revealed that the crop had maturity periods ranging from 139 to 146 and 136 to 143 days in Varuna (V_1) and Pusa Bahar (V_2) respectively. The duration of each phenophase as well as days to maturity in general were shortened as the sowing was delayed from D_1 to D_2 and D_3. Similar results were also reported by Mallick *et al*., (2006) in wheat crop.

It was observed that for different sowing dates GDD for sowing to maturity varied between 1269 to 1476 °C days (Table 1). GDD was higher in October 06 sowing in both the genotypes. This was due to the availability of longer growth period for early sown crop. For the genotype Varuna, GDD required for attaining maturity was more due to its longer duration (Goswami *et al.*, 2003).

Table 2: Heat use efficiency (HUE) of mustard under different treatments (*rabi* 2004-05)

Treatments	AGDD	Total dry matter (kg ha^{-1})	Grain yield (kg ha^{-1})	HUE (kg ha^{-1} $^{o}C^{-1}$)
D_1	1460	7419.6	1533.2	5.08
D_2	1350	4738.0	1014.8	3.51
D_3	1287	2971.3	593.9	2.31
V_1	1381	5150.4	1093.1	3.73
V_2	1350	4935.5	1001.5	3.66

The accumulated heliothermal units ranged between 6103 and 8298 ^{o}C days. The cumulative heliothermal units were higher in October 06 followed by October 21 and November 05 sown crop respectively. The photothermal units ranged between 13395 and 15488 ^{o}C day hours. The maximum PTU was accumulated in October 06 sowing followed by October 21 and November 05 sowings respectively. The accumulated photothermal units in genotypes also differed significantly.

Total dry matter accumulation, grain yield and HUE

Accumulated GDD, total dry matter accumulated at the time of physiological maturity, grain yield and HUE of mustard for different treatments are given in Table 2. It was observed that grain and biomass yield was more in October 06 sown crop followed by October 21 and November 05 sown crops which may be attributed to the more radiation absorbed by October 06 sown crop. Similar results were reported by Mani *et al.,* (2007). Among the two cultivars the highest grain and biomass yield of 1093 and 5150 kg ha^{-1} respectively was recorded in Varuna.

Heat use efficiency (HUE) was computed to determine the biomass yield per unit of growing degree day for mustard cultivars. Highest HUE was recorded in October 06 sown crop followed by October 21 and November 05 sown crops. This was because of less biomass production and less accumulated thermal time in delayed sown crop. Similar results were obtained by Singh (2001) in wheat crop.

Predictive models

Regression models were developed for grain yield (kg ha^{-1}) and total dry matter (kg ha^{-1})**.** The linear regression relationships obtained between grain yield (GY) and GDD; total dry matter (TDM) and GDD are shown below.

$$GY = 5.28(GDD) - 6160.22, \quad (R^2 = 0.98)$$

$$TDM = 25.01(GDD) - 29106.58, \quad (R^2 = 0.98)$$

The study shows that growing degree days explained the 98% variation in grain yield and total dry matter of mustard genotypes under varied thermal regimes. Similar works on developing Agroclimatic models based on temperature, photoperiod and day length for mustard (Hundal *et al.,* 2003) and for wheat (Hundal *et al.,* 1997) have been reported under Punjab conditions.

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