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DOES GEOMETRY OF CROP AFFECT THERMAL REQUIREMENT OF MUSTARD CROP: AN ANALYSIS OF INDIAN MUSTARD

1. Rapeseed-mustard (*Brassica* spp.) is a major group of oilseed crops of the world being grown in 53 countries across the six continents with India being the third largest cultivator and producer after Canada and China (DRMR, 2014). Crop yield is influenced by several factors like weather, soil type and its nutrient status, management practices and other inputs available. Out of these, weather is the only environmental factor which influences the growth in every phenophase of the crop cycle. Phenological development of the crop and the efficient conversion of biomass into economic yield depends on optimum sowing time and selection of improved cultivars. Delay in sowing causes early maturity resulting in drastic reduction in yield as compared to the timely sowing which has a longer growth duration that consequently provides an opportunity to accumulate more biomass. The primary focus for estimating phenology has been the approach of growing degree-days (Nuttonson, 1955). This concept assumes that there is a direct and linear relationship between growth of plants and temperature with every plant having its own threshold or base temperature below which the growth does not take place, which has been applied by scientist in past to correlate the phenological development of different crops to predict maturity days.

2. A field experiment was conducted in silty clay loam soil at Norman E. Borlaug Crop Research Centre (CRC) of the Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, (Uttarakhand) during the rabi season of the year 2014-15. Geographically this centre is situated at 29° N latitude and 79.3° E longitude with an elevation of 243.83 m from the mean sea level. This region comes under sub-humid and sub-tropical climate with four distinct seasons. Meteorological data used for the study (*i.e.*, minimum and maximum temperature, bright sunshine hours) were taken from Agrometeorological observatory of the University and are depicted in Table 1. The experiment was laid out in Split Plot Design having three planting dates, *viz*., 22nd October, 1st November and 11th November, as main plot treatment and five planting geometries, *viz*., 30 × 10 cm, 30 × 20 cm, 30 × 30 cm, 45 × 15 cm and 45 × 30 cm as sub-plot treatment with three replications. An Indian mustard (*Brassica juncea*) variety namely, RGN-73 was selected for the experiment which is a medium maturing variety and takes 120-151 days to mature with an

TABLE 1

Average meteorological data recorded at Pantnagar during mustard growing season from 2013-14

Std week	Tmax (°C)	Tmin (°C)	Relative humidity max (%)	Relative humidity min (%)	Rainfall (mm)	Sun shine (Hrs)	Wind velocity (km/hr)	Pan Evaporation (mm)
43	30.9	16.6	85	55	0	1.7	5.3	2.5
44	28.5	13.1	91	46	0	1.8	4.3	2.6
45	29.2	12.8	91	46	0	2.7	8.2	2.5
46	27.9	9.5	94	34	0	2.7	7.7	2.9
47	26.3	8.6	92	38	0	2	8	2.4
48	26.2	8.7	92	41	0	2.3	7.9	2.3
49	24.3	9.9	94	49	0	2	4.9	1.8
50	20.8	8.2	91	57	5.7	5.3	4.3	2.1
51	16.8	7.4	96	78	0	3.9	4.1	1.2
52	18.5	4.9	95	57	0	3.4	5.2	1.1
1	19.1	11.5	93	77	3.1	6	2.8	1.4
2	15.7	8.4	95	75	0	3.5	3	0.8
3	15.8	8.1	95	71	0	3.4	2.5	1.2
4	18.4	8.6	95	75	1.6	4.8	3.6	1.2
5	18.4	8.1	88	62	0	6	4	1.5
6	22.4	7.4	94	54	0	3.9	7	2.1
7	23.2	9.7	88	51	0	3.9	5.7	2
8	27.1	13.4	90	55	0	3.3	5.5	2.1
9	23.3	13	92	61	9.7	6.3	4.4	2.8
10	25.2	10.2	89	45	0	5.8	8.8	2.9
11	26.9	12.7	90	51	0.2	5	6.6	2.9
12	29.3	13.7	88	45	0	4.6	9.5	3.5
13	31.3	17.7	85	46	3.7	5.1	7.7	4.3
14	29.2	15.8	90	48	2.7	5	6.4	3.7

average yield of 20 q/ha under normal conditions (Yadava and Shekhawat, 2007). The number of days taken to attain various phenophases of mustard was determined visually by daily field inspection. For determination of thermal indices, daily maximum and minimum temperature and bright sunshine hours during crop growth period were used and growing degree days (GDD), photo-thermal unit (PTU), helios thermal unit (HTU), photo-thermal index (PTI) and heat use efficiency (HUE) were worked out following Neog *et al.* (2013). Base temperature at different phenological stages of mustard was taken as 5 °C.

3. Duration of growth phases of a plant life is of prime importance in deciding the amount of the final produce. Date of sowing had a pronounced effect on days taken to attain a particular stage as shown in Table 2. The crop planted on October 22 took significantly more number of days to reach all the phonological stages as compared to the crop planted on November 1 and November 11. For the first date of sowing, the weather conditions were favorable as per the crop requirement and deteriorated thereafter. As a resultant the first sown crop attained a good vigor and growth characters as compared to that of the other two dates of sowing. Mustard sown on November 1 and November 11 clearly showed the effect of forced maturity as the temperature increased by the time it matured, which was responsible for its early maturity as compared to the first date of sowing.

TABLE 2

Days taken to attain various phenophases from sowing, Accumulated growing degree days, Photo-thermal unit, Helios-thermal unit and Pheno-thermal index requirement of Indian mustard var. RGN-73

Treatment		Days taken			AGDD (°C days)			PTU (°C days hr)			HTU (°C days hr)			PTI (°C days day^{-1})		
		Ger	50% F	Mature	Ger	50%F	Mature	Ger	50% F	Mature	Ger	50% F	Mature	Ger	50% F	Mature
Date of Sowing	D1	12	74.6	140.2	215	919	1593	2350	9632	17026	929	5566	9113	17.6	12.3	11.4
	D2	11	71.3	138.7	177	792	1534	1887	8207	16574	1715	6932	12975	15.6	11.1	11.1
	D3	7.7	60.1	136.9	107	627	1522	1125	6441	16494	841	3743	9408	13.8	10.4	11.2
	SEm±	0.1	0.5	0.3	2.1	3.6	4.4	22.5	36.7	53.4	13.8	10.9	44.5	0.03	0.03	0.007
	CD	0.5	1.8	1	7.3	12.3	15.3	77.7	126.8	184.7	47.7	37.5	153.6	0.12	0.11	0.03
Planting geometry	G1	9.4	67	137.1	152	766	1526	1639	7962	16409	1053	5387	10260	15.8	11.4	11.1
	G2	10	67.7	137.9	165	771	1539	1773	8005	16569	1147	5387	10408	15.6	11.3	11.2
	G3	11	69.1	139.2	170	783	1560	1822	8131	16816	1186	5410	10585	15.6	11.3	11.2
	G4	10	68.5	138.3	166	778	1545	1789	8083	16640	1160	5403	10451	15.6	11.3	11.2
	G5	11	71.1	140.3	177	798	1579	1905	8287	17056	1265	5482	10789	15.6	11.2	11.3
	SEm±	0.2	0.49	0.5	2.8	3.5	8.5	29.1	35.9	103	26	13.5	88.9	0.03	0.03	0.02
	CD	0.6	74.6	1.5	8.1	10.2	24.9	85	104.9	300.7	75.7	39.4	259.5	0.08	0.09	0.06

where, D1- October 22, D2- November 01, D3- November 11; G1- 30 × 10 cm, G2- 30 × 20 cm, G3- 30 × 30 cm, G4- 45 × 15 cm, G5- 45 × 30 cm; Ger- Germination, 50% F- 50% Flowering, Mature-Physiological maturity; CD at 5% level.

The crop sown on October 22 accumulated significantly highest GDD from sowing to maturity (1593 °C days) as compared to the crop sown on November 1 (1534 °C days) and November 11 (1522 °C days). Magnitude of the GDD accumulation showed a decreasing trend with advancement of sowing date. Widely spaced plants accumulated more GDD as compared to the closely spaced plants with the maximum value of 1579 °C days for 45 × 30 cm geometry and the minimum value of 1526 °C days for 30 × 10 cm geometry. For all the three growth stages the crop sown on 22nd October accumulated more number of PTU which is dependent on day length of a location. The maximum value of 17026 °C days hr was observed for 22nd October and the minimum value of 16494 °C days hr for 11th November. Among the five planting geometries, the wider one, *i.e.*, 45 × 30 cm accumulated the highest value of PTU for all the three phenological stages ranging from 1905 to 17056 °C days hr. This higher value of PTU towards the wider geometry was an outcome of more area availability for the plant on both the axis resulting into broader leaf growth and a more stronger interaction between plant leaves and solar radiation. Trend of HTU accumulation for the three dates of sowing was quite different throughout the crop duration as compared to the GDD and PTU accumulation. In this case, the highest value of HTU was recorded by the 1st November sown crop (6932 °C days hr) followed by 22nd October and 11th November sown crops at 50% flowering, which was due to more number of bright sunshine hours during the period in case of November 1 sown crop; and the bright sunshine hours are deciding factor for HTU calculation. PTI accumulation showed similar trend as in the case of GDD and PTU but the values were not on a par resulting in a very low value of CD and SEm, *i.e.*, below 1 for both the factors; the date of sowing and the planting geometries. PTI accumulation decreased from germination to maturity ranging from 17.6 to 11.1 °C days day^{-1}. Neog *et al.* (2013) reported similar results showing a reduction in PTI with advancement of the crop growth from vegetative to reproductive stages and with delay in sowing.

The seed yield decreased significantly with delay in sowing time from 22nd of October to the 11th of November, showing the highest yield of 1665.3 kg/ha for 22nd October and the lowest (1265.8 kg/ha) for the 11th of November sowing. It also represents 1-3 q/ha yield reduction with delay in sowing dates. Among the planting geometries, 30 × 20 cm produced the highest seed yield being significantly superior over the two geometries of 45 × 15 cm and 45 × 30 cm. The effect of sowing dates was also found significant on the biological yield. The crop sown on 22nd of October produced the highest biological yield of 6946.4 kg/ha being significantly superior over that of the 1st and 11th of

TABLE 3

Seed yield, biological yield, harvest index and heat use efficiency of Indian mustard

	Treatment	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	HUE (kg ha^{-1}°C days)	
					Seed yield	Biological yield
Date of Sowing	D1 (October 22)	1665.3	6946.4	24	1.1	4.4
	D2 (November 1)	1512.7	5631.4	26.8	1	3.7
	D3 (November 11)	1265.8	4817.7	26.2	0.8	3.2
	SEm±	39.8	187.9	0.6	0.03	0.13
	CD (P = 0.05)	137.4	649.4	2	0.09	0.44
Planting geometry	G1 (30 × 10 cm)	1635.2	5906.5	28.2	1.1	3.9
	G2 (30 × 20 cm)	1650.3	6018.3	27.9	1.1	3.9
	G3 (30 × 30 cm)	1611.7	5977.4	27	1	3.8
	G4 (45 × 15 cm)	1357.9	5630.8	24.2	0.9	3.6
	G5 (45 × 30 cm)	1140.6	5460	21	0.7	3.4
	SEm±	41.7	167.3	0.8	0.03	0.11
	CD (P = 0.05)	121.8	NS	2.4	0.08	0.33

November. There was nearly 13-28 q/ha reduction in biological yield with the delay in crop sowing. Though the effect of planting geometry was non-significant in terms of biological yield but 30 × 20 cm produced the highest biological yield of 6018.3 kg/ha followed by 30 × 30 cm and 30 × 20 cm planting geometries. Table 3 shows that the date of sowing as well as planting geometry had a significant effect on the harvest index. The second date of sowing *i.e*. 1st of November resulted in the highest harvest index of 26.8 % which was significantly superior over the first date of sowing. The third date of sowing however did not differ significantly. The geometry of 30 × 20 cm resulted in a high harvest index of 27.9% which was significantly superior over the geometries of 45 × 15 cm and 45 × 30 cm. The lowest harvest index of 21.0% was reported in 45 × 30 cm geometry. Reduction in harvest index with delayed sowing and wider geometries have also been reported by Kumari *et al*. (2011). HUE for seed and biological yields is reported in Table 3, showing a reduction with delay in sowing from 22nd October to 11th of November. This reduction in HUE with late sowing of Brassica species has also been reported by Neog *et al*. (2013). Value of HUE to produce unit grain ranged from 0.8 to 1.1 kg ha^{-1} °C days; and 3.2 to 4.4 kg ha^{-1} °C days to produce unit dry matter. Sowing on 22nd October resulted in a higher value for both the cases. The closer geometries of 30 × 10 cm and 30 × 20 cm resulted in similar values in both the cases (1.1 kg ha^{-1} °C days and 3.9 kg ha^{-1} °C days) followed by 30 × 30 cm while, the wider geometries resulted in the least value of HUE (0.7 kg ha^{-1} °C days). These trends are in conformity with the seed yield and biological yield obtained from the crop, therefore, HUE could be used as a measure to optimize the time of sowing and the planting geometry.

4. The results revealed that the mustard var. RGN-73 requires almost 1520-1590 °C days GDD units and 120-140 days to reach maturity. The crop sown on 22nd October stood out superior in terms of accumulation of most of the thermal indices and resulted in higher yields as compared to the 1st and 11th November sown crops. The closer planting geometries (30 × 10 cm and 30 × 20 cm) produced better results in terms of grain and biological yields. HUE, which decides the productivity level of the crop, also emphasized on timely sowing of the crop. Therefore, it could be concluded that one should opt for closer geometries and timely sowing of the mustard crop for getting beneficial results by optimizing the resources.

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