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Research Article

Agroclimatic Indices and Yield of Mustard under Different Thermal Regimes

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ABSTRACT

A field experiment was conducted to study the effect of growing environment on degree day accumulation and crop yield. Mustard was cultivated with three dates of sowing (10th October, 5th November, 1st December) and two mustard cultivars (RLC-3 and PBR-357) replicated thrice during *rabi* 2017-18. Numbers of days taken for completion of various phenological stages starting from emergence to maturity were higher in 10th October sown crop (154 days) followed by 5th November (134 days) and 1st December (112 days) sown crops. The cultivar PBR-357 took more number of days (156 days) to reach maturity than RLC-3 (154 days) in all the dates of sowing. Early sown crop accumulated more number of heat units followed by normal and late sown crop. This was due to the reason that the early sown crop took more number of days to attain physiological maturity. Mustard yield attributing characters viz. number of siliqua/plant, number of seeds per siliqua, 1000 seed weight, biomass and seed yield were significantly higher in early sowing followed by normal and late sowing. The mustard seed yield was observed to be significantly higher in early sowing (15.97 q/ha) followed by normal and late sowing (14.74 and 13.11 q/ha) respectively. Grain yield was significantly higher (15.08 q/ha) in PBR-357 as compared to RLC-3 (14.13 q/ha). Relationship between agroclimatic indices and grain yield gave significant coefficient of determination (R^2=0.66).

Key words: Accumulated growing degree days (AGDD), Accumulated heliothermal units (AHTU), Accumulated photothermal units (APTU), Phenological stages, Seed yield

Introduction

Weather affects all the crop growth stages starting from sowing till harvesting and storage. Temperature and radiation are key factors affecting crop production. Crop growth and development are function of solar energy received and thermal energy changes during the growing season (Neog and Chakravarty, 2005). Oilseed crops occupy 13 per cent of the country's gross crop area and contribute around 5 per cent to the gross national product. Rapeseed-mustard is one of the important oilseed crop. Mustard is cultivated mostly under temperate climates. It is also grown in certain tropical and subtropical regions as a cold weather crop. Indian mustard is reported to tolerate annual precipitation of 500 to 1200 mm, annual temperature of 6 to 27 °C. Therefore, it has efficient photosynthetic response at 15 to 20 °C temperature. At this temperature the plant achieve maximum CO_2 exchange range which declines thereafter. Mustard requires well drained sandy loam soil. Rapeseed- mustard has a low water requirement (240-400 mm) which fits well in the rain fed cropping system (Shekhawat *et al*., 2012). During early stages of mustard crop

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establishment high temperature affects crop and during flowering to pod formation stage cold, fog and winter rains affect the crop adversely and cause yield losses. The IPCC has projected rise in 0.5-1.2°C temperature by 2020 for India (IPCC, 2007). It is projected that heat waves and heavy rainfall events will become more frequent. Overall effect of climate change is projected as increase in *rabi* temperature and more erratic rainfall. If in winter season temperature rises by 1°C from the normal it may reduce mustard yield by 450 kg/ha and shortened the crop duration (Anonymous, 2010). Kalra *et al.,* (2008) studied that in Haryana with every 1°C rise in temperature mustard yield is reduced to the tune of 2.01 q/ha.

Growing degree days (GDD), photo-thermal unit (PTU) and heliothermal unit (HTU) have frequently been used as a weather based parameters for assessing crop phenology. Therefore, all growth and development stages of crop may be estimated more accurately on the basis of GDD rather than calendar method (Warthington and Hatchinson 2005). Mustard crop require different amount of GDD, PTU, HTU, PTI and HUE for growth and development stages. The GDD is used to quantify the effect of temperature and describe the timing of different biological processes (Qiao-yan *et al* 2012). Phenological development of mustard cultivars are known to be significantly influenced by temperature and photoperiod. Every crop requires a specific amount of degree days to attain different phenological stages. Solanki and Mundra (2015) studied the effect of thermal regimes on phenology and productivity of mustard *(Brassica juncea)* variety Bio-902. They observed that with the successive delay in sowing number of days for reproductive phase, growing degree days (GDD) and heliothermal unit (HTU) were decreased significantly.

Grain yield is directly influenced by variations in all the yield contributing characteristics in mustard. Shargi *et al.,* (2011) demonstrated that one month delay in sowing can decrease seed yield from about 10 to 50 per cent in different canola cultivars. Therefore, higher productivity of mustard is dependent on the adjustment of sowing dates with optimum thermal and radiation environment. Agroclimatic indices based on temperature can be utilized by relating with crop growth parameters like phenology, seed yield etc. So, in the present study, an experiment was conducted to investigate the effect of date of sowing on crop phenology, different agroclimatic indices, seed yield etc.

Material and Methods

The experiment was carried out during *rabi* season of 2017-18 at the Research Farm, Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana (30°54′N latitude and 75°48′E longitude and at an altitude of 247 meter above mean sea level). The experiment on mustard crop was conducted with three dates of sowing (10th October, 5th November, 1st December) and two mustard cultivars (RLC-3 and PBR-357) with 3 replications under split plot design. Agroclimatic indices viz. growing degree days, heliothermal units and photo thermal units were calculated by using following formulae:

Growing Degree Day (GDD): Growing degree days were calculated by using the following formula:

$$\text{GDD} = \sum_{i=1}^{n} \frac{T_{\max} + T_{\min}}{2} - T_b$$

Where,

GDD = Growing degree days (°C days).

T_{max} = Maximum temperature (°C) of the day.

T_{min} = Minimum temperature (°C) of the day.

T_b = Base temperature, For *Brassica*, the base temperature was taken as 5.0°C (Slafer and Savin 1991).

Helio–Thermal Units (HTU): The sum of HTU for particular phenophase of interest was determined according to the equation:

$$\text{HTU} = \sum_{i=1}^{n} \text{GDD} \times \text{Bright sun shine hours}$$

Where,

HTU = Helio–thermal units (°C day hour)

i = 1 to n [Time interval (days)], between two phenophasic events

Photo-Thermal Units (PTU): The sum of PTU for particular phenophase of interest was determined according to the equation:

$$PTU = \sum_{i=1}^{n} GDD \times DL$$

Where,

PTU = Photo–thermal units (°C day hour)

DL = Day length of a particular day.

i = 1 to n [Time interval (days)], between two phenophasic events

Yield attributing characteristics viz. number of siliqua per plant, number of seed per siliqua, 1000-seed weight, biomass yield and seed yield were recorded at the time of harvesting of crop.

Results and Discussion

Crop phenology

Phenological development of mustard cultivars is known to be significantly influenced by temperature and photoperiod. The number of days taken by crop for various phenological stages i.e. emergence, flower initiation, siliqua initiation, filling and maturity under different growing environments were visually observed (Fig. 1). The number of days taken for maturity were different for different treatments and it was observed that the cultivars PBR-357 and RLC-3 sown on 10th October took more number of days (156 & 154 days) followed by 5th November (136 &134 days) and 1st December (114 & 112 days) sown crops to attain maturity. Gupta *et al.,* (2017) also reported that with delay in sowing days taken from planting to physiological maturity of both of cultivars (RL-1359 and RSPR-01) was decreased. The early, normal and late sown crop matured in 155, 151 and 148 days respectively under sub-tropical conditions of Jammu. Similar findings were reported by Hokmalipour *et al.,* (2011) that early sown crop reached to maturity later as compared to delayed sowing dates.

Agroclimatic indices

Every crop requires a specific amount of degree days to attain different phenological stages. Different agro climatic indices viz. growing degree days (GDD), heliothermal units

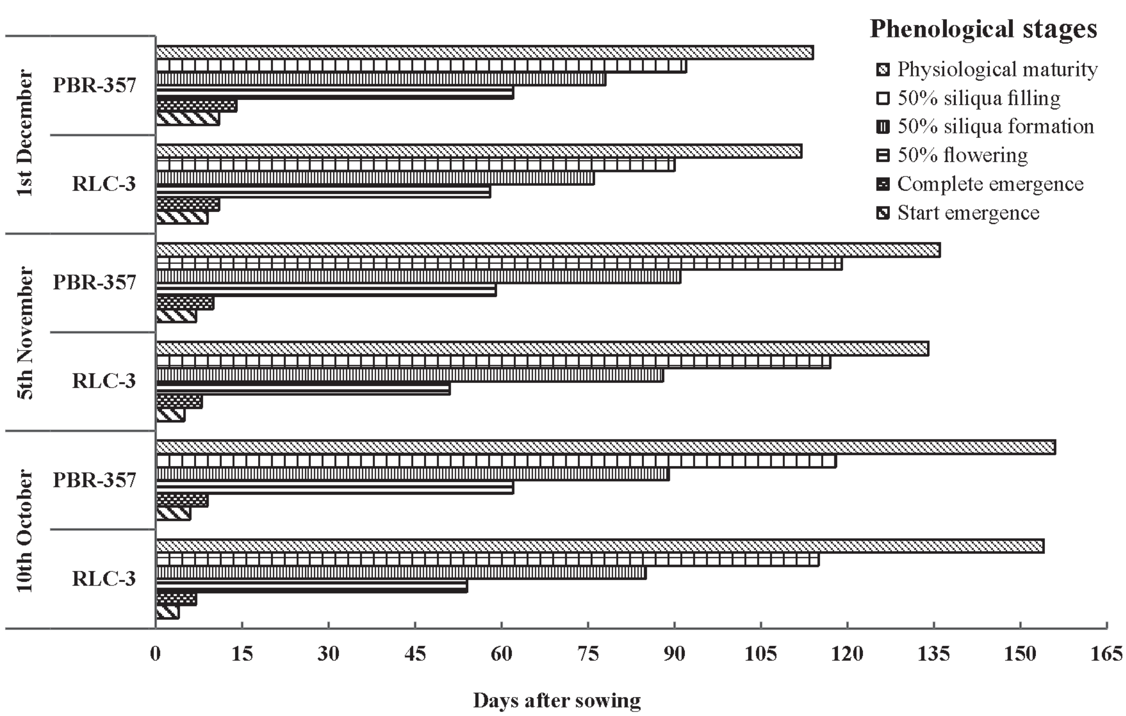

Fig. 1. Phenological stages of mustard cultivars under different dates of sowing

Table 1. Accumulated growing-degree days (AGDD) (°C day) for various phenological stages under different dates of sowing and mustard cultivars in *rabi* season 2017-18

Phenological stages	10th October		5th November		1st December	
	RLC-3	PBR-357	RLC-3	PBR-357	RLC-3	PBR-357
Start emergence	93	139	78	110	98	119
Complete emergence	161	203	124	152	119	145
50% flowering	884	970	589	656	515	549
50% siliqua formation	1175	1199	889	921	683	704
50% siliqua filling	1421	1450	1225	1257	870	903
Physiological maturity	1914	1954	1500	1536	1227	1262

(HTU) and photothermal units (PTU) were calculated for different treatments. The number of days taken to complete different phenological stages were more in early sown crop as compared to timely and late sown crop. From the results, it was observed that the early sown crop accumulated more GDD, HTU and PTU as compared to timely and late sown crop. Solanki and Mundra (2015) also revealed that with the successive delay in sowing number of days for reproductive phase, growing degree days (GDD) and heliothermal unit (HTU) were decreased significantly. The AGDD for mustard cultivar RLC-3 and PBR-357 during early sowing were higher (1914 and 1954 °C day) than normal (1500 and 1536 °C day) and late (1227 and 1262 °C day) sowing (Table 1). The early sown crop accumulated more number of GDD at all the phenological stages as compared to normal and late sown crop. This clearly exhibits the effect of

Table 2. Accumulated helio-thermal units (°C day hour) for various phenological stages under different dates of sowing and mustard cultivars in *rabi* season 2017-18

Phenological stages	10th October		5th November		1st December	
	RLC-3	PBR-357	RLC-3	PBR-357	RLC-3	PBR-357
Start emergence	659	1064	134	191	632	722
Complete emergence	1253	1577	231	235	722	773
50% flowering	4301	4850	2906	3134	3021	3204
50% siliqua formation	5875	5939	4590	4882	4238	4402
50% siliqua filling	7429	7709	7212	7329	5715	5942
Physiological maturity	11433	11844	9743	10031	8776	9116

Table 3. Accumulated photo-thermal units (APTU) (°C day hour) for various phenological stages under different dates of sowing and mustard cultivars in *rabi* season 2017-18

Phenological stages	10th October		5th November		1st December	
	RLC-3	PBR-357	RLC-3	PBR-357	RLC-3	PBR-357
Start emergence	1055	1568	821	1145	992	1209
Complete emergence	1816	2288	1293	1584	1209	1389
50% flowering	9579	10442	5960	6638	5163	5513
50% siliqua formation	12452	12688	9032	9366	6942	7174
50% siliqua filling	14969	15276	12721	13078	9039	9409
Physiological maturity	20472	20933	15898	16337	13188	13611

temperature on various phenological stages of mustard crop. The thermal units consumed by the crop reduced progressively in case of delayed sowing. These findings are in corroboration with results of Pandey *et al.,* (2010) who reported that the requirement of heat units (GDD) decreased for different phenological stages with delay in sowing.

The mustard cultivars RLC-3 and PBR-357 accumulated higher heliothermal units from sowing to maturity under early sowing (11433 and 11844 °C day hours) followed by normal (9743 and 10031 °C day hours) and late (8776 and 9116 °C day hours) sown crop respectively as shown in Table 3. The findings are in confirmation with findings of Singh *et al.* (2010), who revealed that genotypes are known to show differential response with respect to GDD, HTU and PTU. The mustard cultivar RLC-3 and PBR-357 accumulated higher photo thermal units when mustard was sown early (20473 and 20934°C day hours) followed by normal (15899 and 16337°C day hours) and late (13188 and 13611 °C day hours) sown crop as presented in Table 3. The variation for accumulation of GDD, HTU and PTU to complete different phenophases has also been reported by Bhat *et al.* (2015) and Ram *et al.* (2012). Kingra and Kaur (2013) also reported that the growing degree days (GDD), photo-thermal units (PTU) and heliothermal units (HTU) were highest in early sown crop followed by timely and late sown crops in mustard.

Yield attributing characteristics and yield

Seed yield is the major factor determining the commercial success of grain crop. Date of sowing influenced the yield and yield attributes of *Brassica* cultivars. Higher seed yield, biomass yield, and yield attributes (number of siliqua/plant, number of seeds per siliqua and 1000-seed weight) were observed under early sowing (10^{th} October) followed by normal and late sowing (Table 4). Delayed planting of *sarson* results in a significant decline in the yield contributing components *i.e.*, number of siliqua/plant, number of seeds per siliqua and 1000 seed weight as reported by Akhter *et al.,* (2015).

The maximum number of siliqua/plant was recorded under early sowing (10^{th} October) followed by normal (5^{th} November) and late sowing (1^{st} December). Among the cultivars the highest number of siliqua/plant was recorded in PBR-357 than RLC-3. Singh (2016) indicated that highest number of siliqua/plant was recorded in early sowing followed by normal and late sowing.

The number of seed per siliqua were maximum in early sowing followed by normal and late sowing respectively. This was due to more temperature at siliqua filling stage in late sown conditions. Panwar *et al.,* (2000) also revealed that with delay in sowing from early to end October the number of seed per siliqua were reduced significantly.

Table 4. Yield and yield attributes of *Brassica* cultivars under different treatments during *rabi* season 2017-18

Treatments	No. of siliqua/ plant	No. of seed per siliqua	1000seed weight (g)	Biomass yield (q/ha)	Seed yield (q/ha)
Date of sowing					
10^{th} Oct	300.20	12.98	6.82	98.19	15.97
5^{th} Nov	273.95	11.35	6.25	86.92	14.74
1^{st} Dec	204.0	10.55	5.34	75.49	13.11
CD (p=0.05)	24.19	0.16	0.39	3.38	1.25
Cultivars					
RLC-3	233.11	11.65	5.53	83.64	14.13
PBR-357	234.99	11.61	6.74	89.09	15.08
CD (p=0.05)	10.59	0.40	0.13	0.54	0.88

The early sown crop recorded significantly higher test weight (1000 grain weight) than normal (5th November) and late (1st December) sown crop. The highest grain weight in early sown crop was due to favourable weather conditions at siliqua filling stage over late sown conditions at which higher temperature prevailed at siliqua filling stage. Among the cultivars, the highest test weight was recorded in PBR-357 than RLC-3 in all the dates of sowing. Singh (2016) indicated that among the dates of sowing 7th October sown crop recorded highest test weight (1000 grain weight) as compared to 17th October sown crop and 27th October sown crop. The highest grain weight in early sown crop was due to favourable weather conditions at pod filling stage over late sown conditions at which higher temperature was observed at pod filling stage.

The highest biomass yield was recorded in 10th October (early) sown crop which was significantly higher than timely (5th November) and late (1st December) sown crop. With delay in sowing *i.e.* 1st December the lowest biomass yield was obtained due to lower temperature in early sown conditions. With delay in sowing biological yield was significantly reduced due to less time availability to utilize the available resources as observed by Walton *et al.,* (2011). Among the mustard cultivars, PBR-357 produced significantly higher biological yield than RLC-3.

The seed yield was significantly higher under early sowing followed by normal and late sowing. Among the cultivars, PBR-357 produced significantly higher yield than RLC-3. Maximum seed yield was obtained with early sowing because in early sowing crop got longer time period for resource utilization (light, nutrient and moisture etc.) as reported by Shargi *et al.,* (2011), Begna and Angadi (2016). Similar results were also observed by Gupta *et al.,* (2017), they observed that maximum seed and biological yield was obtained from early sown (D_1) mustard crop as compared to normal (D_2) and late sown (D_3) crop respectively.

Relationship between agroclimatic indices and grain yield

The polynomial regression equations were developed between the thermal indices and seed yield to find out the extent of variability in seed yield due to different agroclimatic indices. It was observed that the thermal indices (GDD, HTU and PTU) were able to explain the variability of seed yield by about 66, 61 and 63 per cent respectively (Figs. 2, 3 & 4). Srivastava *et al.,* (2011) also conducted an experiment on widely used thermal indices viz. growing degree days (GDD), heliothermal units (HTU) and photothermal units (PTU). They observed that GDD was able to explain variation in biomass, seed yield and oil content to the tune of 75, 66 and 78 per cent while PTU could explain 73, 66 and 77 per cent variations respectively.

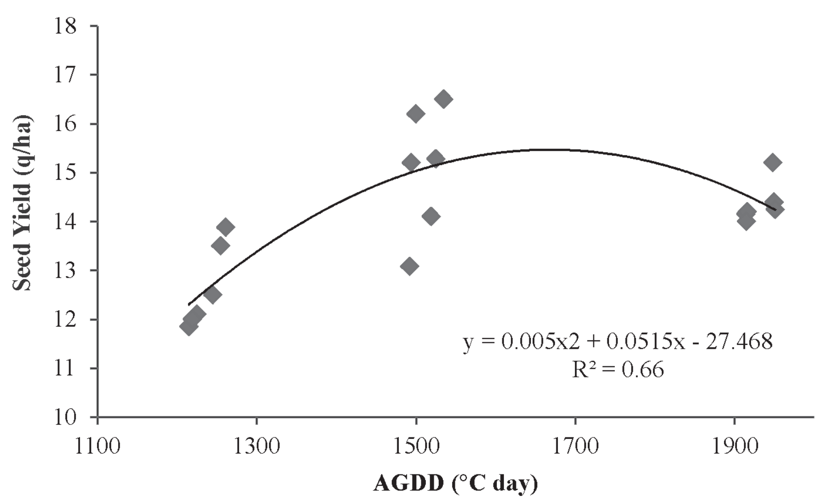

Fig. 2. Relationship between seed yield and AGDD

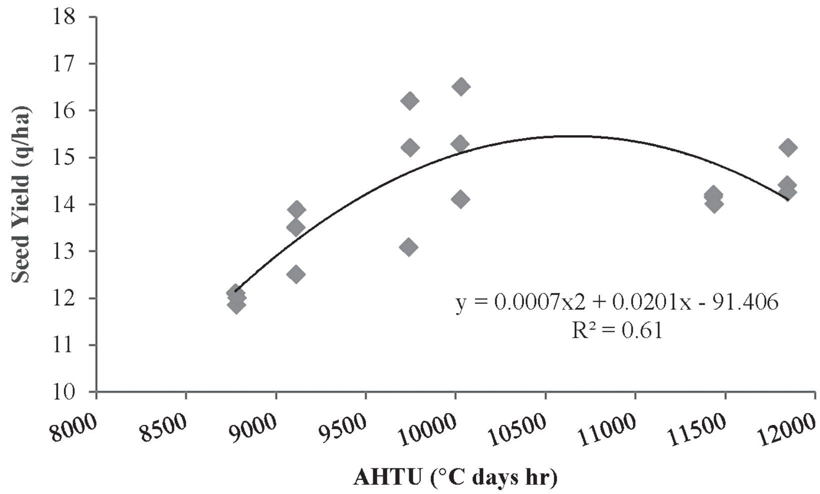

Fig. 3. Relationship between seed yield and AHTU

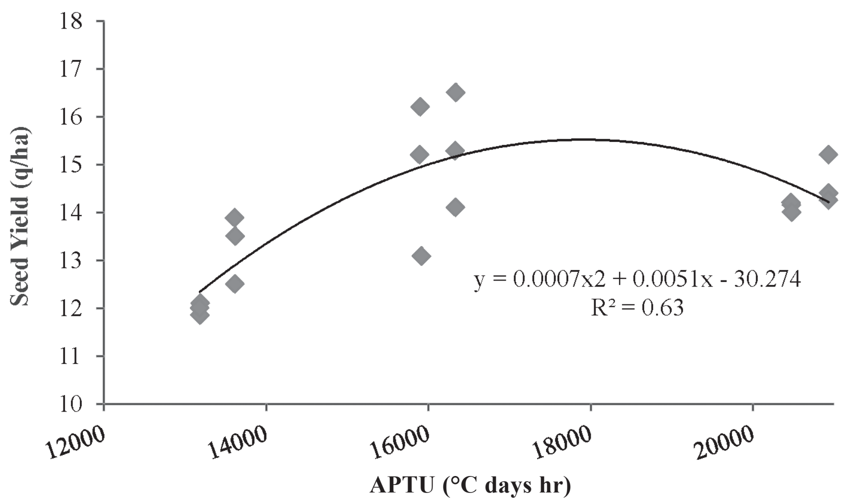

Fig. 4. Relationship between seed yield and APTU

Conclusion

The early sown mustard took more days to mature and thus acquired more heat throughout its growing period. But delay in sowing reduced the GDD, HTU and PTU values as the crop duration reduced with delay in sowing. The timely sown wheat crop performed better in terms of accumulation and utilization of heat units and hence resulted in higher seed yield.

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