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Relation of Growing Degree-days with Plant Growth and Yield in Mustard Varieties Grown under a Semi-arid Environment

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ABSTRACT

To assess the impact of temperature as expressed in heat units (Growing Degree Days) on leaf area index (LAI) and biomass production in mustard, field experiments were carried out on the sandy loam soils of IARI Research Farm with two widely grown *Brassica* cultivars (*Pusa Jaikisan* and *Varuna*) sown at weekly intervals starting the 1st October to 3rd December during two *rabi* seasons 2003-04 and 2004-05. The Growing Degree Days (GDD) were computed up to maximum LAI and maximum biomass production in both the seasons. It was observed that GDD at weekly intervals were significantly correlated with both LAI and biomass production. Further, 82 per cent variation in biomass and 87 per cent variation in LAI in varuna cultivar could be explained through GDD while in case of *Pusa Jaikisan*, the corresponding values were 91 and 80 per cent, respectively. The yields of these two cultivars were highly influenced by the dates of sowing and it was concluded that by and large the seed yields decreased as the dates of sowing were advanced (barring the first two early sowings), because of the prevailing low temperature conditions through out the crop season. The highest yield date was influenced by rainfall amount and its distribution during the early vegetative growth period.

Key words: Biomass, growing degree days, leaf area index, mustard crop and yield.

Introduction

Brassica is a winter season crop and its physiological as well as morphological developments are markedly influenced by temperature conditions during different phenelogical stages. Phenological development in *Brassica* is considered to be altered primarily by photoperiod, with a general shortening of phases as day length increases (Kumari *et al.* 1994). In semi arid environment of North-West Indian conditions, mustard sowing usually starts from mid-October but in some parts of this region, sowing is delayed due to the late harvest of transplanted rice.

The average yield of mustard is only 999 kg/ha in India, which is very low compared to other mustard growing countries of the world (Anonymous, 2002-2003). Farm level survey identified some problems on production of mustard, which included delayed sowing, imbalance use of fertilizers, lack of irrigation water and lack of insect and diseases control. Other agronomic practices such as weed control, insect and disease control can also increase its yield. Lack of any one of the above factors may reduce yield and can contribute to yield gaps between the actual and the potential yield. Cognizant of the above facts, a series of on-field trials have been conducted at IARI research farm areas to evaluate the LAI, biomass and seed yields of mustard, in relation to growing degree days (Kar and Chakravarty, 2000; Neog *et al.* 2005). The specific objectives of these trials were to find out the relationship of the GDD with LAI and biomass under different thermal environments provided by different sowing dates. However, these studies were confined to two or three dates of sowing that too within the optimum sowing window. Hence the present study was taken up to find out the impact of heat units (growing degree days, GDD), the most important single weather parameter, which has influenced the productivity and profitability of mustard under different weather conditions through wide change in sowing dates during *rabi* seasons.

Materials and Methods

Two cultivars of mustard viz., Varuna and Pusa Jaikisan were sown at weekly intervals starting from 1st October to 3rd December during the year 2003-04 and 2004-2005 with recommended package of practices at IARI research farm. The size of the each plot was 5 m x 5 m with a row-to-row spacing of 30 cm and plant-to plant spacing of 10 cm. Thinning was done manually at 25 days after sowing to maintain plant population of 30/m^2. The soil texture is sandy loam and belongs to Holmbi series. The number of days taken to reach first flower appearance, 50 % flowering and maturity were recorded. The thermal time was expressed in terms of GDD with a base temperature of 5°C following Kar and Chakravarty (2000). For leaf area measurement, above ground plants were cut from 30 cm row length of each plot at weekly interval. The green leaf portions were separated and the area of the leaves was measured using leaf area meter (LI-3100) and the mean values of LAI are estimated for the analysis. The samples collected for estimating leaf area index were utilized for assessing biomass production and these samples were oven dried at 70°C for more than 48 hours to get the constant weight. Daily weather data were collected from the nearby Agromet Observatory and their weekly values were calculated for the analysis.

The GDD were calculated on daily basis and cumulated values were taken up to maximum LAI and biomass. The relationship between the GDD, LAI and Biomass were found out and the regression equation were developed taking GDD as a depend variable.

Results and Discussion

Weather conditions during the crop period

The maximum temperatures during crop season of 2003-04 varied from 12 to 38.2°C while during 2004-05, varied from 14 to 37.5°C while the minimum temperature varied from 2.3 to 21.5°C during 2003-04 and 2.5 to 25.0°C during 2004-05 crop season. The temperature conditions are almost similar in both the crop seasons except a lower maximum temperature prevailed during the maturity period during 2004-05 (Fig. 1a). The relative humidity (RH) varied from 38 to 89 per cent in the first season while the second crop season was relatively more humid, with RH ranging from 38 to 95 per cent. During the first crop season, the total rainfall was 35.4 mm while in the second crop season the crop received much higher (95.6 mm) rainfall. The crop was exposed to lower sunshine hours (990 hours) as compared a total of 1031 hours during second season and moreover the bright sunshine hours is lower during grain filling stage in the second crop season as compared to the first crop season (Fig. 1b). The weekly distributions of rainfall and relative humidity during the crop periods are sown in Fig. 1c.

Relationship between GDD, LAI and biomass

The heat requirement for a particular cultivar is linearly related to its crop growth and development and expressed by GDD (Chakravarty, 1980). To find the thermal response of LAI and biomass in different sowings, the cumulative values of GDD were computed from sowing to maximum LAI and up to maximum biomass for the two cultivars during both the crop season and are shown in the Fig. 2 and 3. It was observed that the correlation of the GDD with both the leaf area index and biomass to be highly significant (at 5 per cent). The correlation coefficient between GDD and LAI was found to be marginally higher in case of Pusa Jaikisan (0.88) than Varuna (0.84). Similarly the values of the correlation coefficient between GDD and biomass were 0.88 and 0.89 in case of Pusa Jaikisan and Varuna, respectively. The best-fit polynomial second order regression equations between the thermal units accumulation with LAI and biomass production were worked out for both cultivars as well as for the pooled data, which are given below:

	Max LAI	Max. biomass
Varuna	$y_1 = -8E-06x^2 + 0.02x - 7.07$ $R^2 = 0.87$	$y_2 = -0.001x^2 + 3.03x - 1155$ $R^2 = 0.82$
Pusa Jaikisan	$y_1 = -2E-06x^2 + 0.007x - 1.09$ $R^2 = 0.80$	$y_2 = -0.001x^2 + 3.85x - 1444$ $R^2 = 0.91$

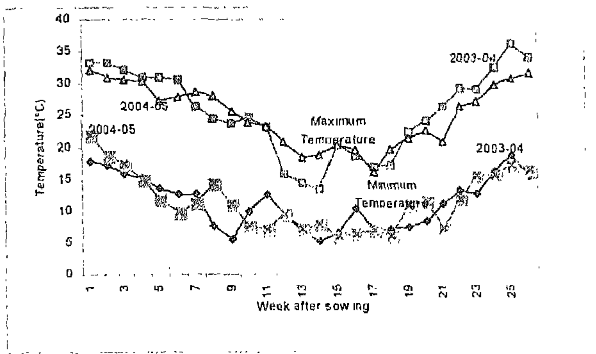

Fig. 1a. Weekly temperatures during crop period of 2003-04 and 2004-05 at IARI farm

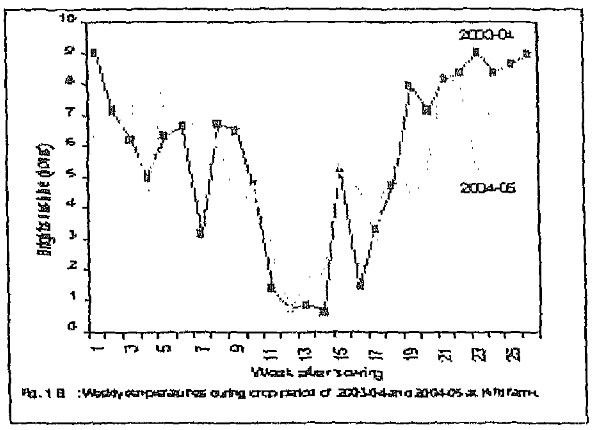

Fig. 1b. Weekly bright sun shine lines during crop period of 2003-04 and 2004-05 at IARI farm

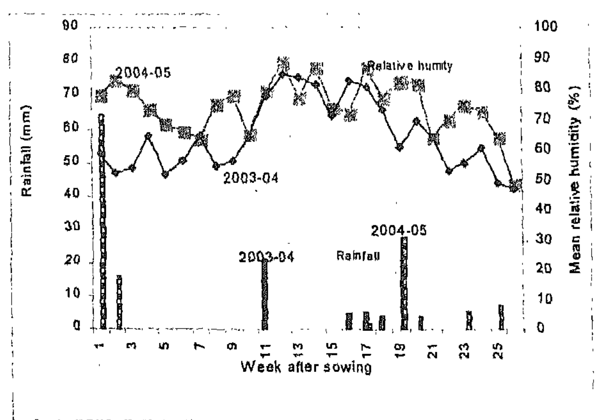

Fig. 1c. Weekly rainfall and mean relative humidity during crop period of 2003-04 and 2004-05 at IARI farm

Pooled data	$y_1 = -4E - 06\ x^2 + 0.012\ x - 3.39$	$y_2 = -0.001\ x^2 + 3.25\ x - 1178$
	$R^2 = 0.79$	$R^2 = 0.81$

Where

y_1 = Leaf area index

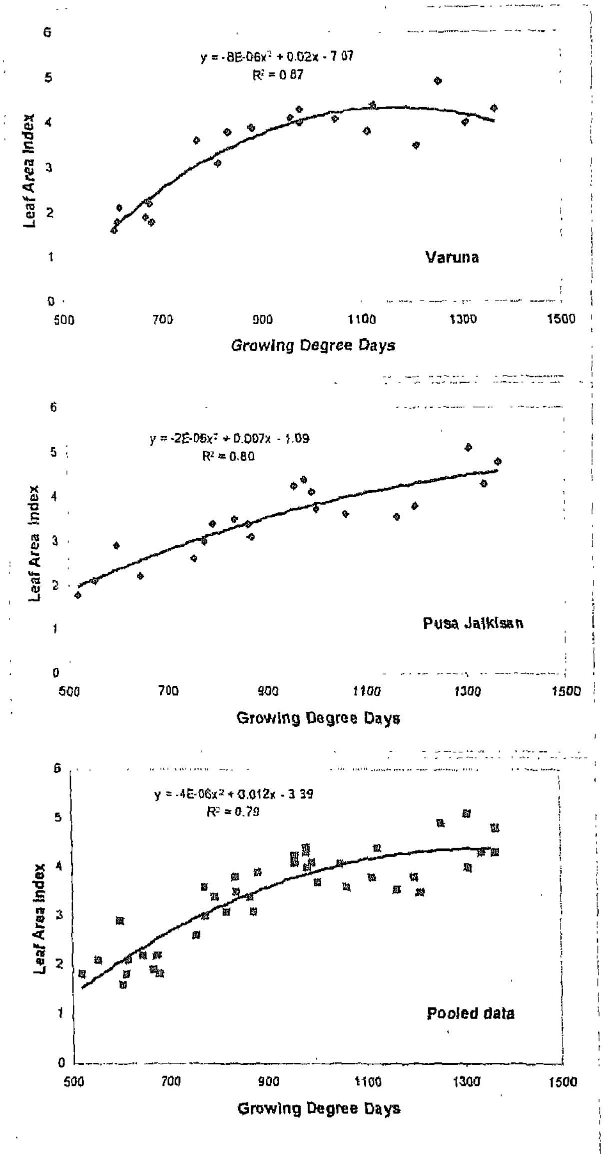

Fig. 2. Thermal response curves for LAI in Varuna, Pusa Jaikisan and pooled data at IARI farm

y_2 = above ground biomass production (g/m²)

x = Growing degree days accumulation from sowing to maximum values (°D)

The response curves explain the non-linear relationship of the thermal accumulation with LAI and biomass in both the mustard cultivars. Since the heat unit accumulation explains the variability of LAI and biomass to a great extent, the maximum LAI and biomass values may be replaced by GDD for modeling purposes.

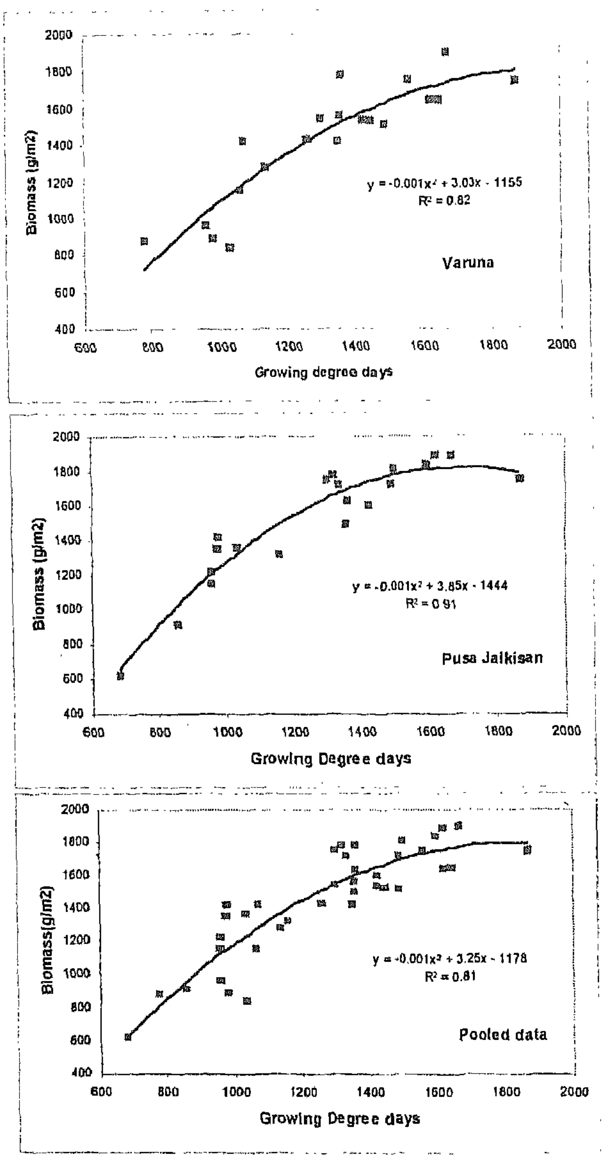

Fig. 3. Thermal response curves for biomass in Varuna, Pusa Jaikisan and pooled data at IARI farm

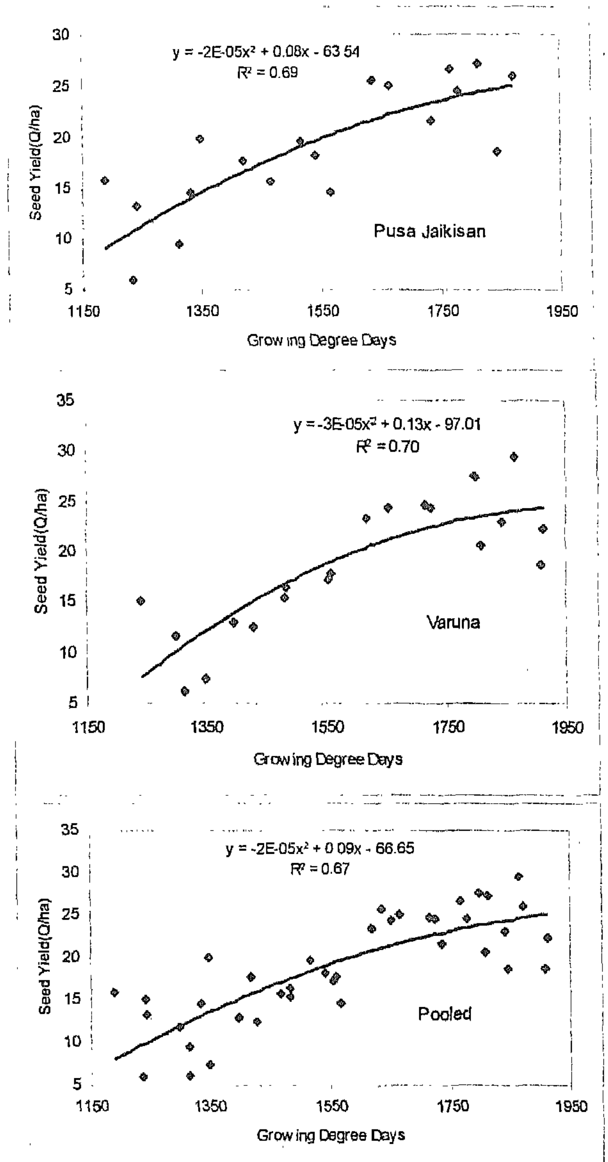

Fig. 4. Thermal response curves for seed yield in Pusa Jaikisan, Varuna and Pooled data at IARI Farm

Relationship between growing degree-days and seed yield

The growing degree-days were found to have been significantly correlated with the seed yield with R^2 values of 0.69 and 0.70 in case of Pusa Jaikisan and Varuna, respectively. Irrespective of the variety, if one wants to assess the relation between the two parameters, the pooled data would give a fairly good idea about the significant level ($R^2 = 0.67$). Thermal response curves depicting the relationship between the growing degree-days and the seed yield are shown in Fig. 4. Similar to biomass production, these curves explain the non-linear relationship between the GDD accumulation and seed yield in both the mustard cultivars. Seed yield in both the cultivars increased as the GDD accumulation increased from 1200 to 1850^{0}D and the maximum yield was observed within the range of 1700-1850^{0}D range. It is likely that with further increase in GDD accumulation the seed yield may decline (Neog *et al.* 2005).

The response curve regression equation are given below :

Varuna : $y = -3E - 05\ x^2 + .13\ x - 97.01$ $(R^2 = 0.70)$

Pusa Jaikisan : $y = -2E - 05\ x^2 + 0.08\ x - 63.54$ $(R^2 = 0.69)$

Pooled data $y = -2E - 05\ x^2 + 0.09\ x - 66.65$ $(R^2 = 0.67)$

where, y = seed yield (q/ha) and x = GDD accumulation from sowing to maturity (^{0}D).

The above equations explain 70 per cent variation in seed yield, which may be used to assess the seed yield in semi-arid regions.

Weather and seed yield

Time of sowing is the most important non-monetary input for higher crop productivity for, ambient temperatures as well as soil temperatures mostly govern it. In rainfed conditions, soil moisture is the major constraint for seed germination as well as for plant establishment and plays a key role, besides temperature. Vast area of mustard in the north-west and central parts of India is generally rainfed, with or without a life saving/ pre-sowing irrigation and hence, early as well as delayed sowing decreases the seed yield to a great extent. Delayed planting besides restricting vegetative growth and pod bearing branches, also leads to forced maturity due to high temperature, which results in lower yield.

Several workers (Neog *et al.* 2005, Chakravarty and Gautam, 2002 etc.) reported 15th October to 31st October to be the optimum sowing window for mustard crop in semi-arid environment and sowing during this window gives the maximum mean seed yield (1.91 t/ha). The seed yield during 2004-05 was highest during early sowing dates (before 15th October), though in both the years the package of practice adopted were same (Table 1). The temperature conditions in both the years are almost similar with minor differences. The bright sunshine hours were also lower in the second season than the first season. The early rainfall during the first week of October in the second crop season recharged the soil moisture and provided suitable macro environmental conditions for good growth. The maximum temperature during February and March was also near optimal conditions. The good growth (higher biomass) combined with near optimal maximum temperature (longer partioning period) facilitated the higher seed yields in addition to the earlier defined optimum-sowing window.

Table 1. Seed yield (q/ha) of mustard varieties sown on different dates during 03-04 (I) and 04-05 (II) *rabi* seasons

Date of sowing	Varuna		Pusa Jaikisan	
	I	II	I	II
1st October	18.6	22.7	18.7	26.0
8th "	23.0	29.5	24.5	27.4
15th "	20.6	27.5	21.6	26.6
22nd "	24.7	24.4	25.6	25.0
29th "	24.3	23.3	14.6	18.2
5th November	17.1	17.7	15.7	19.6
12th "	15.3	16.4	19.9	17.7
19th "	12.5	13.0	9.5	14.6
26th "	7.4	11.8	6.0	13.3
3rd December	6.2	15.1	4.8	15.8
Mean	17	20.1	16	20.4
C.D. (5%)	1.43	1.1	0.82	0.50

Conclusions

The cumulated GDD were significantly correlated with the LAI and biomass accumulation up to maximum values. It is recommended that the growing degree-days might be used to estimate the leaf area index and the maximum biomass production. These correlations assume a greater importance in modeling the phenological events as well as prediction of seed yield of mustard crop in various agro-ecological zones.

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