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Effect of growing degree days on biological growth indices of wheat and mustard

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ABSTRACT

Temperature is an important weather parameter affecting the growth and development of the crop. The growing degree days (GDD) indicate the thermal index required for the onset of phenophases in crop. A two- year (2008-09 and 2009-10) field experiment was conducted at the B.C.K.V Instructional Farm to investigate the effect of GDD on leaf growth rate (LGR), crop growth rate (CGR) and leaf area indices (LAI) of wheat and mustard grown under sole (T_1 and T_2) and intercrop situations, [2 wheat: 6 mustard (T_3), 4 wheat: 4 mustard (T_4) and 6 wheat: 2 mustard (T_5)]. The experiment was laid out in a RBD design with 6 replications having a plot size of 50 m^2. The experimental soil has pH of 6.92, organic carbon 0.63 %, total N 0.06 %, available P_2O_5 18.47 kg/ha and available K_2O 127.22 kg/ha. The experimental site is under tropical humid climate. From the results, leaf growth rate, crop growth rate and leaf area index were found to be polynomial function of GDD. The results also suggested that the effect of GDD on different growth indices of wheat and mustard were strongly expressed in 4 wheat: 4 mustard row ratios which might be adopted in the Gangetic Plains of New Alluvial zone of West Bengal.

Key words: Crop growth rate (CGR), growing degree days (GDD), intercropping, leaf area index (LAI), leaf growth rate (LGR)

The growth of crop depends on weather parameters in a remarkable way. Among the weather parameters, temperature plays the most important role in determining the rate of growth in any crop. The winter crops are mostly affected by the variation in ambient temperature. Variation in maximum and minimum temperature largely alters the growth pattern of the crop by affecting the duration as well as onset of different phenophases. To quantify the effect of temperature on crop, the concept of GDD has been introduced. The GDD, which is the mean ambient temperature minus the threshold temperature required for crop's survival, has been utilized to quantify the thermal requirement for the onset of different phenophases of crops (Chakraborty *et al.*, 1994; Nath *et al.*, 1999; Srivastava *et al.*, 2003; Dhaliwal *et al.*, 2007). Biological responses to thermal changes are altered under intercropping, where two or more crops of different growth habits are grown together, because of complementary competition which is bestowed upon the crops. However, no systematic study is observed in the arena of study. With this background information, a two- year study has been carried out to quantify the thermal requirement for leaf growth rate (LGR), crop growth rate (CGR) and leaf area index (LAI) in wheat and mustard under wheat-mustard intercropping.

MATERIALS AND METHODS

A field experiment was conducted at the Instructional Farm, B.C.K.V, Jaguli during the rabi seasons of 2008 and 2009. The farm is located at $22^0 56'$ N latitude and $88^0 32'$ E longitude and at an altitude of 9.75 m above mean sea level. Soil is sandy loam having pH of 6.92, organic carbon 0.63 % total N 0.06 %, available P_2O_5 18.47 kg ha^{-1} and K_2O 127.22 kg ha^{-1}.

The experimental site belongs to tropical humid climate having the average rainfall of 1457 mm, most of the amount falls in between June to September. Temperature ranges from 10^0 to 37 ^{0}C. The minimum temperature reaches 10.2^{0}C in the month of January and the maximum 37.7 ^{0}C in the month of May. The experimental site experiences short and mild winter season, spans from November to February.

The experiment comprised of 5 treatments *viz.* sole wheat (T_1), sole mustard (T_2), two rows of wheat with six rows of mustard (2: 6; T_3), four rows of wheat with four rows of mustard (4:4, T_4) and six rows of wheat with two rows of mustard (6: 2; T_5); all the treatment combinations were replicated six times in a RBD layout having a plot size of 10m ×5m.

The experimental field was cultivated thrice with cultivators followed by power tiller and leveler, so that a leveled and good tilthed field was achieved. Nitrogen, phosphorus and potassium were applied @120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} through urea, single super phosphate and muriate of Potash. Half nitrogen was applied as basal along with P_2O_5 and K_2O, and the rest half was applied after weeding and thinning operation (25 DAS).

Dry matter from 1 m^2 area was collected at an interval of 15 days starting from 35 DAS. Leaf area index was estimated by area-weight relationship method as described by Radford (1967), crop growth rate (CGR) was computed and the leaf growth rate (LGR) was calculated with the following formula: $LGR = (l_2-l_1)/t$

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Where, 't' is the duration between two sampling

l_1 = weight of leaf at earlier date of sampling

l_2 = weight of leaf at later date of sampling

The growing degree day was computed following Vittum *et al.* (1965) and Chakraborty *et al.* (1994).

$$GDD = \sum_{I=1}^{n} [\{(T_{max} + T_{min})/2\} - T_b]$$

Where, T_{max}, T_{min} and T_b are maximum, minimum and base temperatures respectively. T_b is considered as 5 ^{0}C for winter crops of this zone (Chakraborty *et al.*, 1994).

Regression analysis was carried out keeping biological growth parameters as dependant variable and GDD as independent variable (Gomez and Gomez, 1984). For brevity two year mean values were used.

RESULTS AND DISCUSSION

Leaf growth rate and growing degree days (GDD)

Leaf growth rate in wheat during 0-35 DAS was found to be non significant having the maximum value observed in sole wheat. Among the intercrop treatments, highest leaf growth rates were observed in T_4 and T_5 treatments (Table 1).

Table 1: Leaf growth rate (g m^{-2} day^{-1}) in wheat (W) and mustard (M) (Pooled mean of two years)

	0 – 35 DAS		35 - 50 DAS		50 - 65 DAS		65 - 80 DAS	
	W	M	W	M	W	M	W	M
T_1(Sole W)	0.22	--	1.77	--	1.79	--	6.02	--
T_2(Sole M)	--	0.65	--	3.99	--	4.84	--	-6.22
T_3(2W:6M)	0.16	0.53	1.41	4.23	1.73	4.35	6.08	-5.74
T_4(4W:4M)	0.19	0.69	1.52	3.80	1.86	4.69	6.40	-5.86
T_5 (6W:2M)	0.19	0.87	1.30	3.35	1.80	4.86	6.30	-5.87
SEm (±)	**0.01**	**0.06**	**0.1**	**0.11**	**0.05**	**0.08**	**0.2**	**0.12**
LSD (0.05)	**NS**	**0.18**	**0.3**	**0.33**	**0.15**	**0.27**	**NS**	**0.36**

In case of mustard, highest LGR was observed in T_5 which was significantly higher than all other treatment combinations. The LGR in sole wheat remained higher upto 65 DAS, than the intercropped wheat but LGR was found to be greater in intercropping situation than the sole wheat during 65-80 DAS. From 35 DAS onwards LGR was found to be highest in 4:4 ratios among intercropping treatments. Leaf growth rate in mustard during 35-50 DAS, was found to be maximum in T_3 followed by sole mustard, however during 50-65 DAS, no significant variation was observed among sole, T_4 and T_5 treatments. During 65-80 DAS leaf growth rate was found to be negative because of senescence and leaf fall in mustard. The LGR in wheat remained low upto 50-65 DAS because of severe competition offered by fast-growing mustard which reduced the light penetration into low height canopy (Jena *et al.*, 2009, Jena *et al.*, 2010). Leaf growth rate in mustard during 65-80 DAS became negative, and the degree of negativity was maximum in sole stand indicating a low rate of leaf fall under intercropping system. This might be due to low leaf and canopy temperature under intercropping system (Jena *et al.*, 2009).

The LGR in wheat recorded a quadratic increment with the increase in GDD (Fig.1a). The initial accumulation of GDD from 800-1000 unit did not affect the LGR in sole wheat stand. Beyond 1000 GDD units, LGR increased following a quadratic pattern with high values of coefficient of determination (R^2) ranging from 0.94 to 0.97, indicating a strong association between GDD and LGR. The sole wheat recorded a better LGR than intercropped wheat initially but with the progress of time, LGR of wheat under intercropping system (T_4 and T_5) was found to be better than sole stand. The LGR in mustard, (Fig.1b) increased linearly with the accumulation of GDD up to 1200 units irrespective of treatments and then followed a declining trend due to leaf senescence and leaf fall.

Under sole stand, GDD significantly and linearly affected the mustard leaf growth rate upto 1200 units and thereafter showed an exponential behavior. This relationship remains logarithmic as observed by many workers (Nath *et al.*, 1999; Kiran and Bains, 2007).

Crop growth rate and GDD

The variation in CGR in wheat and mustard has been presented in Table 2. The CGR in wheat did not vary significantly during 0-35 DAS, ranging from 0.22 to 0.26 g/m^2/day, having the highest CGR in sole wheat.

Table 2: Crop growth rate (g m^{-2} day^{-1}) in wheat and mustard **(Pooled mean of two years)**

	0 – 35 DAS		35 - 50 DAS		50 - 65 DAS		65 - 80 DAS	
	W	M	W	M	W	M	W	M
T_1(Sole W)	0.26	--	2.70	--	4.64	--	13.27	--
T_2(Sole M)	--	1.16	--	10.16	--	11.50	--	9.74
T_3(2W:6M)	0.22	0.95	2.19	11.1	4.50	11.50	10.30	5.93
T_4(4W:4M)	0.24	1.35	2.24	11.24	4.47	12.62	11.67	7.74
T_5(6W:2M)	0.25	1.45	2.36	11.28	4.38	11.79	11.76	7.12
SEm (±)	**0.013**	**0.09**	**0.16**	**0.35**	**0.27**	**0.62**	**0.83**	**0.81**
LSD (0.05)	**NS**	**0.28**	**0.49**	**1.07**	**NS**	**1.9**	**2.56**	**2.49**

However, the CGR of wheat increased with the progress of time, reaching the peak during 65-80 DAS; on all occasions, sole wheat recorded the maximum CGR but wheat under different intercrop treatments did not have any significant differences. However maximum intercropped wheat rows, *i.e*, T_5 treatment recorded the highest CGR.

In case of mustard, CGR increased when it was intercropped with wheat when compared with sole mustard. During 0-35 DAS, the CGR did not vary significantly between T_4 and T_5 and the trend did not show any change throughout the growth period (except 50-65 DAS). During 50 to 80 DAS, the CGR was highest in T_4 treatment, where 4 rows of mustard were grown with 4 rows of wheat, however during early stage (0-50 DAS), the T_5 treatment recorded the highest CGR. In general, CGR increased with the reduction in the number of mustard rows growing with wheat under intercropping system. Under intercropping, when the population of companion crop increased, it offered escalating competition to low population of the companion crop. This might be the probable reason of this type of result observed in this experiment.Thermal unit plays a vital role. The CGR of wheat depicted a quadratic relationship with accumulated GDD (Fig.2a), the sole wheat recorded a higher GDD than the intercropped wheat upto 1200 GDD units. Among the intercrop treatments, the T_4 (4 wheat: 4 mustard) and T_5 (6 wheat : 2 mustard) maintained a linear increase in CGR with GDD; the T_4 treatment recorded the strongest association indicating the role of GDD in CGR. In case of mustard, there was a linear increase in CGR with the increase in GDD upto 1300 units (Fig.2b). beyond 1300 GDD units, CGR did not show any increase, rather a decline was observed. It indicated that the increase in maximum and minimum temperature during the later part of growth did not favour the growth of mustard crop either under sole or intercrop situation. The growth of winter crop is hampered due to escalated minimum temperature (Parya, 2009).

GDD and Leaf area index (LAI)

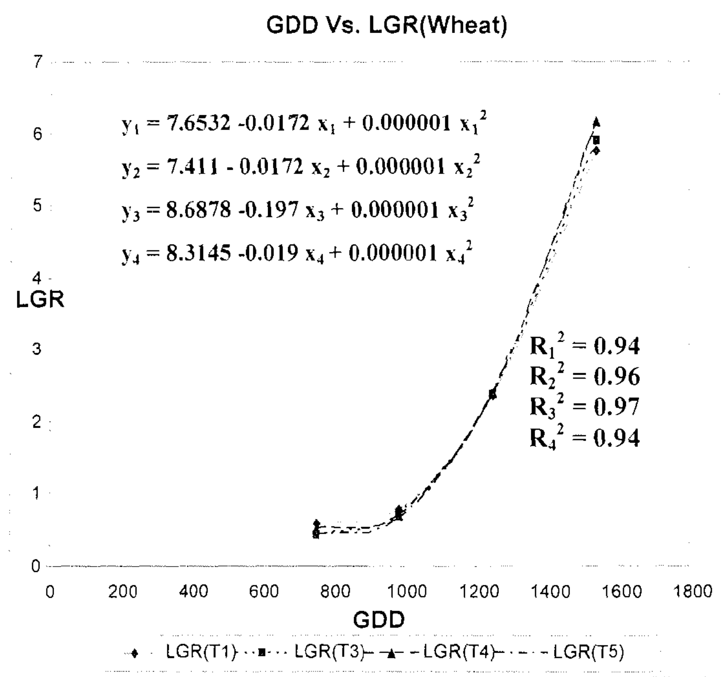
The LAI of wheat and mustard has been shown in Table3. The results showed that the sole wheat recorded maximum LAI however, the T_4 treatment recorded the highest LAI under inter-cropping, although the intercropping treatments did not show any significant variation among themselves. In case of mustard, intercrop treatments recorded higher LAI than the sole mustard almost on all occasions and the T_4 treatment recorded higher LAI (except on 50 DAS) indicating its suitability for adoption. There was strong association between GDD and LAI of both the wheat and mustard crops. The LAI in wheat increased linearly with the increment of GDD upto 1500 units; however the increment in LAI in mustard was found to be linear with the increase in GDD upto 1200 units (Fig.3a and Fig.3b).The association between GDD and LAI in wheat was found to be stronger than mustard which indicated that the effect of temperature was more positive in wheat than in mustard.

Results of this experiment showed that 4:4 or 6:2 wheat: mustard ratios were better under the thermal range prevailing in the Gangetic plains of the new alluvial zone of West Bengal.

Table 3: Leaf area indices of wheat and mustard **(Pooled mean of two years)**

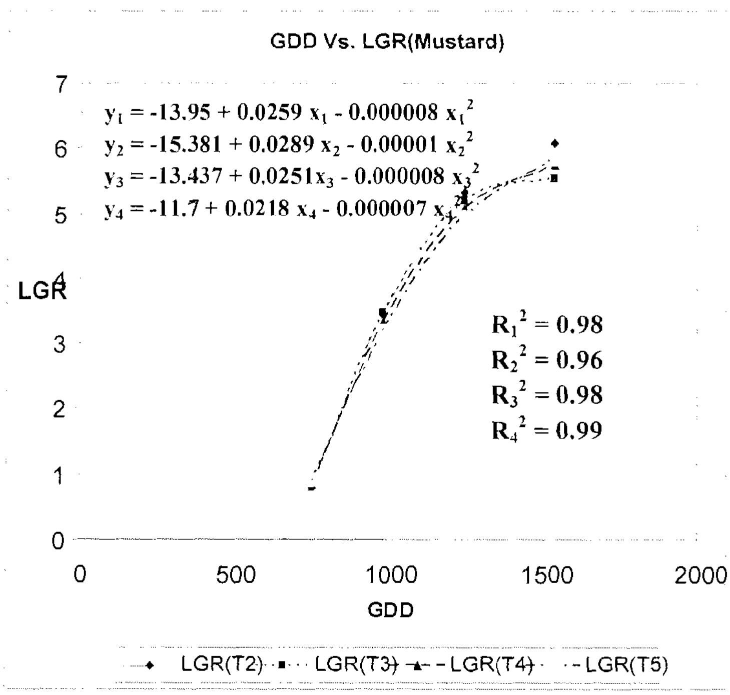
	Leaf area index							
	0 – 35 DAS		35 - 50 DAS		50 - 65 DAS		65 - 80 DAS	
	W	M	W	M	W	M	W	M
T_1(Sole W)	0.31	--	0.90	--	1.79	--	4.50	--
T_2(Sole M)	--	0.85	--	2.29	--	5.52	--	2.50
T_3(2W:6M)	0.19	0.70	0.77	2.60	1.57	6.40	4.40	2.21
T_4(4W:4M)	0.20	1.09	0.85	2.80	1.60	6.60	4.43	2.60
T_5(6W:2M)	0.18	1.50	0.73	2.95	1.62	6.23	4.40	2.50
SEm(±)	**0.06**	**0.05**	**0.03**	**0.07**	**0.03**	**0.18**	**0.07**	**0.1**
LSD (0.05)	**NS**	**0.15**	**0.1**	**0.23**	**0.08**	**0.57**	**NS**	**0.3**

Fig. 1a: Growing degree days and leaf growth rate in wheat under different treatments



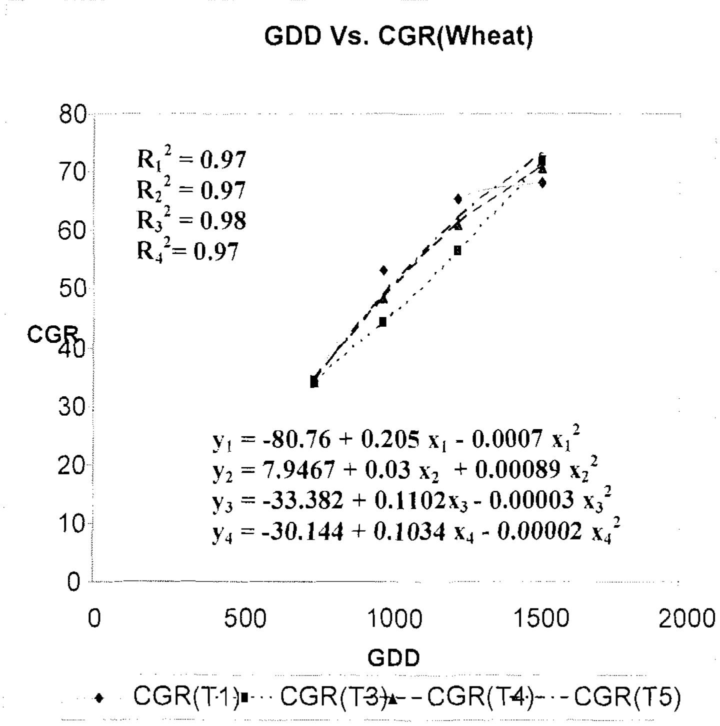
Here,
y_1= LGR of wheat in T_1
y_2= LGR of wheat in T_3
y_3= LGR of wheat in T_4
y_4= LGR of wheat in T_5
and
x_1 = GDD requirement of wheat in T_1
x_2 = GDD requirement of wheat in T_3
x_3 = GDD requirement of wheat in T_4
x_4 = GDD requirement of wheat in T_5

Fig. 1b: Growing degree days and LGR in mustard under different treatments



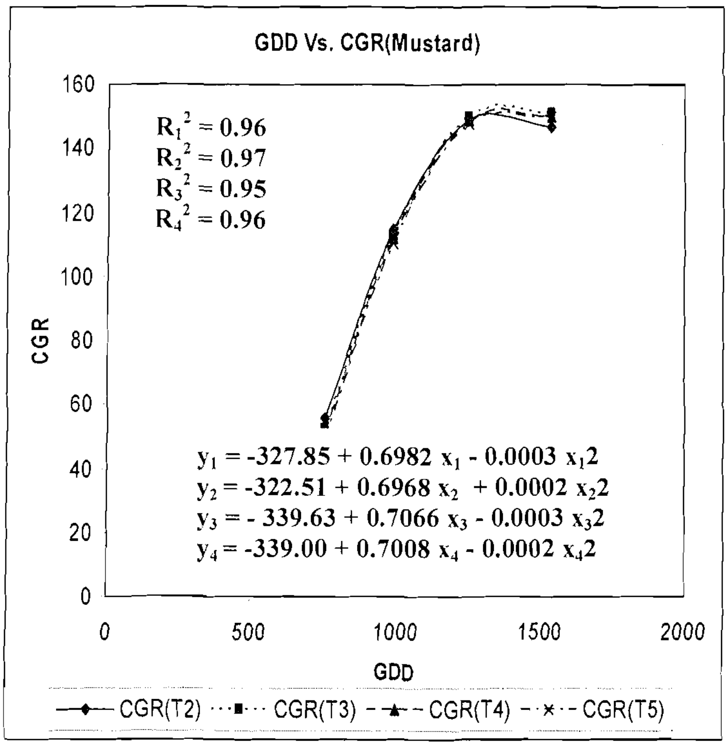
Here,
y_1 = LGR of mustard in T_2
y_2 = LGR of mustard in T_3
y_3 = LGR of mustard in T_4
y_4 = LGR of mustard in T_5
and
x_1 = GDD requirement of mustard in T_2
x_2 = GDD requirement of mustard in T_3
x_3 = GDD requirement of mustard in T_4
x_4 = GDD requirement of mustard in T_5

Fig. 2a: **Growing degree days and CGR in wheat under different treatments**



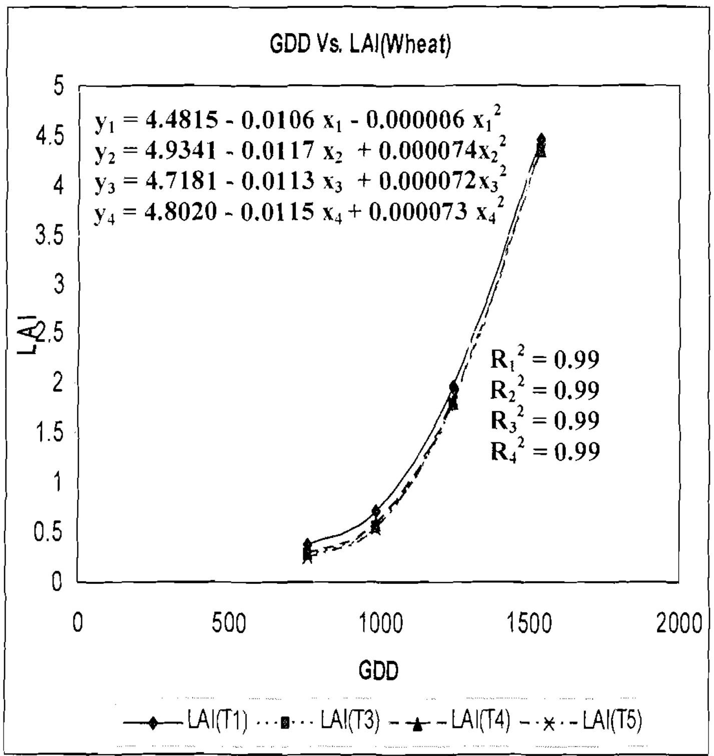
Here,
y_1 = CGR of wheat in T_1
y_2 = CGR of wheat in T_3
y_3 = CGR of wheat in T_4
y_4 = CGR of wheat in T_5
and
x_1 = GDD requirement of wheat in T_1
x_2 = GDD requirement of wheat in T_3
x_3 = GDD requirement of wheat in T_4
x_4 = GDD requirement of wheat in T_5

Fig. 2b: **Growing degree days and CGR in mustard under different treatments**



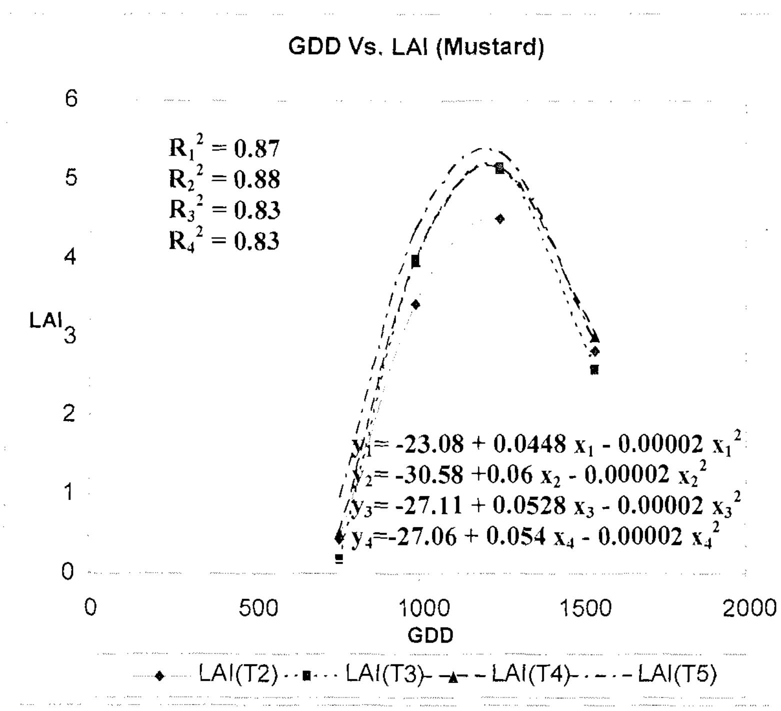
Here,
y_1 = CGR of mustard in T_2
y_2 = CGR of mustard in T_3
y_3 = CGR of mustard in T_4
y_4 = CGR of mustard in T_5
and
x_1 = GDD requirement of mustard in T_2
x_2 = GDD requirement of mustard in T_3
x_3 = GDD requirement of mustard in T_4
x_4 = GDD requirement of mustard in T_5

Fig. 3a: Growing degree days and CGR in wheat under different treatments



Here,
y_1 = LAI of wheat in T_1
y_2 = LAI of wheat in T_3
y_3 = LAI of wheat in T_4
y_4 = LAI of wheat in T_5
and
x_1 = GDD requirement of wheat in T_1
x_2 = GDD requirement of wheat in T_3
x_3 = GDD requirement of wheat in T_4
x_4 = GDD requirement of wheat in T_5

Fig. 3b: Growing degree days and CGR in mustard under different treatments



Here,
y_1 = LAI of mustard in T_2
y_2 = LAI of mustard in T_3
y_3 = LAI of mustard in T_4
y_4 = LAI of mustard in T_5
and
x_1 = GDD requirement of mustard in T_2
x_2 = GDD requirement of mustard in T_3
x_3 = GDD requirement of mustard in T_4
x_4 = GDD requirement of mustard in T_5

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