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Effect of growing degree day on different growth processes of wheat (*Triticum aestivum* L.)

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ABSTRACT

The sensitivity of wheat to the changes in temperature is well known but is not quantified properly in the Indo-Gangetic plain zone. Phenophases of wheat are altered due to temperature sensitivity. The GDD requirement for different phenophases may assess the impact of temperature sensitivity. With this background, a *three year experiment (2005-06, 2006-07 and 2007-08) was conducted on five wheat varieties (V_1-PBW-343, V_2-HD-2733, V_3-HW-2045, V_4-PBW-533 and V_5 – K9107) sown on three different dates (18th November, 3rd December and 18th December) to assess the impact of growing degree day (GDD) on different growth processes in wheat. Results showed that the GDD significantly predicted the stem weight during sowing to CRI, CRI to tillering and flowering to milking. Leaf weights during sowing to CRI and CRI to tillering were significantly affected by the GDD requirement. GDD requirement during sowing to CRI and flowering to milking acted as significant predictor of ear weight of wheat at flowering and milking. Number of tillers at tillering, flowering and milking was significantly affected by the GDD requirement at the different phenophases. About 44% variation in tiller number at tillering could be ascribed to the variation in GDD requirement at the different phenophases. The tiller number at flowering was highly significant when the variation in GDD requirement during tillering to flowering and CRI to tillering was considered.*

Key words**:** Ear weight, GDD, leaf weight, PCR, phenophases, stem weight, wheat

The growing degree day (GDD) is a simple tool to find out the relationship between plant growth, maturity and mean air temperature. A degree day or a heat unit is the departure from the mean daily temperature above the minimum threshold temperature. This minimum threshold temperature is considered as 5^{0}C (Nuttonson, 1955; Mishra *et al.,* 2007). The GDD indicates the thermal environment of a particular crop (Nath *et al.,* 1999). Onset of different phenophases is initiated when a specific temperature regime is available (Chakraborty *et al.,* 1994). The sensitivity of wheat crop to the change in temperature is specially remarkable as the crop switches to reproductive stage when a sudden rise in temperature is observed. Under the changing climatic scenario, wheat will be the most affected cereal in West Bengal. Therefore, it is an urgent need to investigate the impact of temperature, particularly of GDD on different growth processes in wheat. In the present experiment, the GDD was computed for sowing to CRI (crown root initiation), CRI to tillering, tillering to flowering, flowering to milking and milking to harvesting phases for different dates of sowing. The aim of this experiment is to quantify the GDD requirement under different dates of sowing.

MATERIALS AND METHODS

The experiment was carried out during the winter season of 2005-06, 2006-07 and 2007-08 at the Students' Instructional Farm, BCKV, Nadia, West Bengal, India (22^{0}56'N latitude and 88^{0}32'E longitude, 9.75 m above mean sea level). The experimental site falls under tropical humid climate having a short and mild winter, spanning from November to February with an annual rainfall of 1457 m, 85% of which is received during June to September. The average monthly temperature ranged from 10-37^{0}C. The winter wheat growing season is marked by low temperature (occasionally the mercury reach below 10^{0}C), low humidity and little rainfall. The soil is sandy loam in texture and neutral in reaction (pH-6.90) having 0.077% total nitrogen, available P-57.25 kg ha^{-1}, available K-221.51 kg ha^{-1} and organic carbon 0.78%.The experiment was laid out in split plot design where the three dates of sowing (18th November, 3rd December and 18th December) were kept in the main plots and five varieties (V_1- PBW-343, V_2- HD-2733, V_3- HW-2045, V_4- PBW-533 and V_5- K-9107) were allotted in the sub plots. The average duration of all these varieties ranges in between 120-125 days. Each treatment was replicated thrice in the net plot size of 5m×3m. The experimental plot was cultivated by cultivator followed by power-tiller to have a good tilth. The recommended dose of NPK (150 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1}) was applied to plot. The nitrogen was applied in split doses, 1/3rd N was given as basal, 1/3rd during 20-25 days after sowing but before 1st irrigation, the rest 1/3rd was given before 2nd irrigation, *i.e.* 45 days after sowing.

Seeds were sown in rows maintaining a row to row distance of 22.5 cm.

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The GDD is computed as: $GDD = \frac{Tmax + Tmin}{2} - Tb$

Where Tmax, Tmin and Tb are the maximum, minimum and base temperature respectively, the Tb is 5°C for wheat. The impact of growing degree day (GDD) on different growth processes of wheat has been presented. The principal component regression analysis can be used to overcome disturbance of the multicollinearity. The simplified, speeded up and accurate statistical effect is reached through the principal component regression analysis (Jolliffe, 1982). In statistics, principal component regression (PCR) is a regression analysis that uses principal component analysis when estimating regression co-efficients. It is a procedure used to overcome problems which arise when the exploratory variables are close to being collinear. In PCR, instead of regressing the dependent variable on the independent variables directly, the principal components of the independent variables are used. One typically only uses a subset of the principal components in the regression, making a kind of regularized estimation. In present investigation repeated measurement of variables are collinear and the largest variance explained by the first principal component only used to make regression simplified and free from multicollinearity hazards. The loading of first component further help to diagnose the contribution of specific period (s) of repeated observations for larger contribution towards variability explanation of dependent variable.

RESULTS AND DISCUSSION

GDD requirement for sowing to CRI

The GDD requirement from sowing to CRI differed due to variation in dates of sowing (Table1). When the crop was sown on D_1 the GDD requirement was highest in 2005-2006 and 2006-2007. All the varieties had similar GDD requirement. The GDD requirement sharply declined when the crop was sown on D_2 in 2005-2006 and 2006-2007. In 2007-2008, the GDD requirement was maximum under D_2 sowing. Under D_3 sowing, GDD requirement increased in 2005-2006 and 2006-2007 whereas it was sharply reduced in 2007-2008. The results indicated the variation in temperature prevailed under different dates of sowing. In general, the GDD requirement should be reduced with delay in sowing, however, the increase in GDD requirement in 2005-2006 and 2006-2007 might be the resultant effect of rainfall received during the period. Alam *et al.* (2004), Rajput *et al.*(1987), Tripathi *et al.* (2004) and Mishra *et al.* (2007) also pointed out to the increased GDD requirement with increasing frequency in irrigation. During sowing to CRI all the varieties under particular date of sowing recorded similar GDD requirement.

Table 1: GDD requirement of wheat for the onset of different phenophases under varying sowing dates and varieties

Treatment	2005-2006					2006-2007					2007-2008				
	S_1	S_2	S_3	S_4	S_5	S_1	S_2	S_3	S_4	S_5	S_1	S_2	S_3	S_4	S_5
D_1 (18th November)															
PBW343	337.95	426.35	582.70	319.60	306.20	467.15	302.55	473.25	130.60	367.10	424.80	269.10	376.25	345.90	350.15
HD2733	337.95	426.35	582.70	319.60	285.50	467.15	302.55	373.70	116.55	613.80	424.80	269.10	376.25	345.90	350.15
HW2045	337.95	426.35	154.90	171.45	732.85	467.15	302.55	373.70	116.55	372.15	424.80	269.10	376.25	345.90	182.65
PBW533	337.95	426.35	309.85	287.50	605.60	467.15	302.55	373.70	116.55	484.40	424.80	269.10	376.25	345.90	350.15
K9107	337.95	426.35	309.85	287.50	563.55	467.15	302.55	373.70	116.55	484.40	424.80	269.10	376.25	345.90	308.15
D_2 (3rd December)															
PBW343	284.15	402.20	444.30	319.60	427.20	412.85	260.30	428.55	115.50	483.35	481.75	376.25	218.95	144.50	420.50
HD2733	284.15	402.20	444.30	319.60	470.45	412.85	260.30	428.55	115.50	483.35	481.75	376.25	218.95	144.50	443.90
HW2045	284.15	402.20	171.45	287.50	584.90	412.85	260.30	216.40	116.55	452.20	481.75	226.05	162.70	144.50	350.15
PBW533	284.15	402.20	444.30	319.60	381.85	412.85	260.30	428.55	115.50	395.50	481.75	376.25	218.95	144.50	350.15
K9107	284.15	402.20	444.30	319.60	427.20	412.85	260.30	428.55	115.50	395.50	481.75	376.25	218.95	144.50	350.15
D_3 (18th December)															
PBW343	331.30	309.85	586.45	448.00	283.15	319.80	373.70	229.15	115.50	577.35	291.55	376.25	218.95	144.50	596.80
HD2733	331.30	309.85	586.45	448.00	257.60	319.80	373.70	229.15	115.50	577.35	291.55	376.25	218.95	144.50	596.80
HW2045	331.30	309.85	287.50	319.60	542.10	319.80	373.70	229.15	115.50	336.20	291.55	376.25	218.95	144.50	549.40
PBW533	331.30	309.85	586.45	448.00	231.90	319.80	373.70	229.15	115.50	444.80	291.55	376.25	218.95	144.50	596.80
K9107	331.30	309.85	586.45	448.00	183.70	319.80	373.70	229.15	115.50	444.80	291.55	376.25	218.95	144.50	596.80

Note: S_1:Sowing - CRI S_2:CRI-Tillering S_3:Tillering - Flowering S_4: Flowering- Milking S_5: Milking - Harvesting

CRI to tillering

The GDD requirement for CRI to tillering gradually declined with the delay in sowing in 2005-2006; all the varieties recorded similar values under specific dates of sowing. In 2006-2007 the GDD requirement declined from D_1 to D_2 sowing and then increased on D_3 sowing. The discrepancy observed in this case was due to the rainfall received under D_3 dates of sowing in 2006-2007. In 2007-2008 the GDD requirement during CRI to tillering was minimum under D_1 sowing, increased on D_2 sowing and remained similar on D_3 sowing. All the varieties under a particular date of sowing (except HW2045 under D_2 sowing) recorded similar values of GDD. In 2007-2008, the GDD requirement increased in late sown crop because of rainfall during this period.

Tillering to flowering

The GDD requirement for tillering to flowering varied in different years. In general it was gradually decreased from 2005-2006 to 2007-2008. This might be due to increasing trend of temperature during this period. In 2005-2006, under D_1 sowing GDD requirement was maximum in case of PBW343 and HD2733, and minimum in case of HW2045. In 2006-2007 all the varieties had same GDD values (except PBW343), whereas in 2007-2008 no variation in GDD requirement was observed due to variation in the varieties during tillering to flowering. GDD requirement decreased under D_2 sowing in 2007-2008, however, no such definite trend was observed in 2005-2006 and 2006-2007.

Flowering to milking and milking to harvesting

The GDD requirement from flowering to milking decreased from D_1 to D_2 and remained same for D_3 in 2007-2008. In 2006-2007, the GDD requirement remained almost similar except a few aberrations. Varietal difference was also observed in some of the cases. The GDD requirement from milking to harvesting did not have any trend for dates of sowing and the varieties. Both the maximum and minimum temperature varied widely in this three different years of investigation. This led to the variation in GDD requirement in different years under different dates of sowing. Rainfall received during the later part, increased the moisture availability and consequent increase in duration of different phenophases which ultimately increased the GDD requirement. Nath *et al.* (1999) also observed that no definite trend in GDD requirement could be found in sesamum under different dates of sowing in this zone because of the variability of rainfall and temperature. The difference in GDD values obtained in different years might be attributed to the differences in the maximum and minimum temperature observed in these years. The range of maximum temperature during flowering to milking was minimum in 2006-07 as compared to other two years of study when the crop was sown on 18th November and 3rd December (Table 2). Moreover, the maximum and minimum temperature scenario altered the duration of this phenophase which initiated a large difference in GDD values obtained in different years of the study (Table 2).

Table 2: Duration, maximum and minimum temperature during flowering to milking phase of wheat sown under different dates.

Variety	Flowering - Milking								
	Duration (days)			Temperature range (^{0}C)					
	2005-06	2006-07	2007-08	2005-06		2006-07		2007-08	
				Max.	Min.	Max.	Min.	Max.	Min.
D_1 (18th November)									
PBW 343	15	8	23	30-38	18	28	>15	28-30	8-20
HD 2733	15	7	23	30-38	18	27.5-30	14-20	28-30	8-20
HW 2045	13	7	23	30	7.5-15	27.5-30	14-20	28-30	8-20
PBW 533	17	7	23	28-32	<15-20	27.5-30	14-20	28-30	8-20
K 9107	17	7	23	28-32	18	≥ 30	14-20	28-30	8-20
D_2 (3rd December)									
PBW 343	15	8	9	39	18	20-25	12.5	24-30	15-20
HD 2733	15	8	9	39	18	20-25	12.5	24-30	15-20
HW 2045	17	7	23	39	<15	27.5-30	12.5	20-30	9-20
PBW 533	15	8	9	39	18	20-25	12.5	24-30	15-20
K 9107	15	8	9	39	18	20-25	12.5	24-30	15-20
D_3 (18th December)									
PBW 343	21	8	9	25-38	20	24-26.5	12.5-15	22-30	11-20
HD 2733	21	8	9	25-38	20	24-26.5	12.5-15	22-30	11-20
HW 2045	15	8	9	38	18	24-26.5	12.5-15	22-30	11-20
PBW 533	21	8	9	25-38	20	24-26.5	12.5-15	22-30	15-20
K 9107	21	8	9	25-38	20	24-26.5	12.5-15	22-30	15-20

GDD and crop growth process

The growing degree day (GDD) affected the stem weight at milking significantly (Table 3). GDD during sowing to CRI, CRI to tillering and flowering to milking acted as a significant predictor of the stem weight at the milking, however, GDD during tillering to flowering did not affect significantly the stem weight at milking. Only about 25% variation in stem weight at the milking could be explained through the GDD requirement at different phenophases. Leaf weight during sowing to CRI was significantly affected by the GDD requirement. Leaf weight at tillering was also significantly affected by the GDD requirement during sowing to CRI and CRI to tillering (Table 3).

Table 3: Principal component regression analysis (PCRA) results keeping principal component score of GDD as predictor stem, leaf and ear weight at different phenophases as dependent variables

Variables	Constant	Standardized Coefficient	R^2	S.E. (est)	Dependent variable
	-186.17				
GDD PC-1 (Sowing CRI)		0.51	0.25*	54.93	Stem weight at milking
GDD PC-1 (CRI-tillering)		0.38			
GDD PC-1 (tillering-flowering)		0.24			
GDD PC-1 (flowering-milking)		0.45			
GDD PC-1 (milking-harvesting)		0.40			
	0.88				
GDD PC-1 (Sowing CRI)		0.41	0.16	2.19	Leaf weight at CRI
	11.45		0.25*	9.26	Leaf weight at tillering
GDD PC-1 (sowing-CRI)		0.46			
GDD PC-1 (CRI-tillering)		0.49			
GDD PC-1 (tillering-flowering)		0.35			
	99.21	-	-	-	Ear weight at flowering
GDD PC-1 (Sowing CRI)		0.31	0.09	30.91	
	221.44	-	-	-	
GDD PC-1 (flowering-milking)		0.46	0.21*	67.80	Ear weight at milking

*Note: *, ** significant at 5% and 1% level, respectively*

Table 4: Principal component regression analysis (PCRA) results (stepwise) keeping principal component score of GDD as predictor and tiller number at different phenophases as dependent variables

Variables	Constant	Standardized coefficient β	R^2	S.E (est)	Dependent variables
	-340.63				
GDD PC-I (sowing-CRI)		0.78	0.44**	67.34	Tiller number at tillering
GDD PC-I (sowing-CRI)		0.54			
GDD PC-I (sowing-CRI)		0.28			
	343.16				
GDD PC-I (tillering-flowering)		0.43	0.22**	49.15	Tiller number at flowering
GDD PC-I (CRI-tillering)		0.33			
	343.88				
GDD PC-I (tillering-flowering)		0.42	0.21*	50.53	Tiller number at milking
GDD PC-I (CRI-tillering)		0.33			

*Note: *, ** significant at 5% and 1% level, respectively*

About 25% variation in leaf weight could be ascribed to the variation in GDD requirement during sowing to CRI and flowering to milking acted as significant predictor of ear weight of wheat at flowering and milking (Table 3). Number of tillers at tillering, flowering and milking was significantly affected by the GDD requirement at the different phenophases (Table 4). The results showed that GDD requirement during sowing to CRI and CRI to tillering significantly affected the number of tiller at the tillering. About 44% variation in tiller number at tillering could be ascribed to the variation in GDD requirement at the different phenophases. The tiller number at flowering was highly significant when the variation in GDD requirement during tillering to flowering and CRI to tillering was considered. Only 22% variation in the number of tiller could be ascribed to the GDD requirement during the phenophases mentioned. The value of coefficient of determination (adjusted R^2) further declined to 21%

when the effect of GDD requirement on tiller number at the milking stage was considered; however, the relationship was found to be significant.

The results showed that the GDD during different phenological phases of wheat crop significantly affected the growth processes viz. dry matter accumulation in different plant parts as well as the tiller number in case of wheat. Wheat is a very temperature sensitive crop. Changes in maximum and minimum temperature significantly affects the duration of different phenophases (Parya *et al*., 2010). Change in temperature with the radiation input influence the crop growth in general (Dutta *et al*., 2011), wheat in particular. As GDD behaves as a good predictor of growth processes in wheat, it may be used for modelling the growth processes in wheat. Among the three years of study, the 18th November sown crop recorded the highest GDD during sowing to flowering, but the lowest GDD during the reproductive phase irrespective of varieties. The late sown crop had to tolerate higher minimum temperature during the reproductive phase. Among the varieties, K 9107 recorded the minimum GDD values during vegetative and reproductive phases. Under West Bengal situation, this variety may be recommended for better productivity.

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