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Influence of Different Sowing Dates on the Phenology and Accumulated Heat Units in Wheat

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Abstract: A field investigation was carried out to study the influence of sowing dates on phenology and accumulated heat units of four cultivars of bread wheat (***Triticum aestivum*** L.) at different phenological stages over two growing seasons. There were two sowing dates: early and late. The late sown plants had significantly shorter phenological stages and lower growing day degree than the early sown plants in all the four cultivars. Cultivars Akbar was found to be early and C 306 was found to be late maturing. Akbar had the lowest and C 306 had the highest growing degree days during all the phenological stages under each irrigation regimes. Heliothermal units also showed more or less the same trends. The phenothermal indices and heat use efficiency were found to be higher in the early sown plants than the late sown plants.

Key words: Wheat, phenology, growing degree days, heliothermal units

Introduction

Temperature plays a vital role in almost all biological processes of crop plants. It is one of the most important climatic events affecting the growth, phenology, development and yield of wheat (Adam ***et al.***, 1994) as well as the third world food security. Seeding of wheat is done in early November in the medium highland areas of Bangladesh after the harvest of 'Aus' paddy or jute, but in the lowland areas, sowing is delayed even up to late December because the land is occupied by the transplanted 'Aman' paddy or the land remained excessively moist after the removal of flood water. So, wheat seedlings pass through severe cold in January as well as extremely high temperature in March-April during the grain filling stage resulting in reduced yield. Sowing at an appropriate time is necessary to ensure maximum yield. Influence of late sowing as well as temperature on phenology and yield of crop plants can be studied under field conditions through the accumulated heat units system (Chakravarty and Sastry, 1983; Rajput ***et al.***, 1987; Bishnoi ***et al.***, 1995). Crop model may be developed for large areas to forecast the phenology and crop production attributes (Doraiswamy and Thopmson, 1982). The accuracy of prediction depends on the assessment of plant development rate at each growth stage during the growing season. The influence of high temperature stress on the heat unit requirement of crops should be assessed in a large area as the temperature of farms in a zone varies considerably. The relationship of phenological development of wheat with thermal units under different sowing dates was studied in the present investigation.

Materials and Methods

The experiment was conducted in the research field of Rajshahi University Botany Department with four bread wheat (***Triticum aestivum*** L.) genotypes, raised from four regular wheat cultivars grown in Bangladesh, viz., Akbar, Opata, Protiva and C 306. The experimental field was prepared after repeated ploughing and harrowing. A basal dose of urea (80 kg ha^{-1}), TSP (60 kg ha^{-1}) and MP (30 kg ha^{-1}) were added to the soil before sowing. The soil of the experimental field was silty loam having a pH 7.5, low in organic carbon (0.44%) and total N (82 ppm). The average field capacity of the soil within a depth of 0.5 m was 34% for the first and 39% for the second year, respectively. The experiment was arranged in a split plot design having three replications with sowing dates as main plots and cultivars as sub plots. The seeds were sown on 25th November (S_1) and 15th December (S_2). The dates of occurrences of different phenological events viz., crown root initiation, booting, panicle initiation, anthesis, grain filling and physiological maturity were recorded when 50% of the plants in each replication reached the respective stages. The daily meteorological data from the regional meteorological office, situated at about 1 km away from the experimental field, were used. Various measurement were calculated according to the formulae of Rajput (1980):

I. Growing degree days (GDD) = $\sum (T_{max} + T_{min})/2 - T_b$
ii. Heliothermal unit (HTU) = GDD X Duration of sunshine hour
iii. Phenothermal index (PTI) = GDD ÷ Growth days
iv. Heat use efficiency (HUE) = Grain yield ha^{-1} ÷ GDD

Here,
T_{max} = Maximum temperature
T_{min} = Minimum temperature
T_b = Base temperature = 10°C

Results and Discussion

Only the data of 1998-1999 growing season have been reported in the present report because both the data of 1998-1999 and 1999-2000 showed similar trends in the above-mentioned parameters.

Phenology

The number of days required to attain different phenological stages decreased with delay in sowing (Table 1). This result is in agreement with Chakravarty and Sastry (1983) and Rajput ***et al.*** (1987). The highest days taken to attain different phenological stages was found in cultivar C 306 under every sowing date and C 306 was followed by Opata, Protiva and Akbar, respectively. The delay was less sharp in early phenological stages but significant decrease was noticed in the late phenological stages in all the four cultivars.

Table 1: Time (days) taken for different phenological stages of four wheat cultivars as influenced by different sowing dates

	Crown Root Initiation			Booting		
Cultivar	S_1	S_2	Mean	S_1	S_2	Mean
Akbar	16.8c	15.8c	16.5	44.5d	38.5d	41.9
Opata	18.2b	17.0b	17.5	61.8b	57.8b	60.1
Protiva	17.3c	16.2c	16.8	48.3c	45.2c	46.8
C 306	18.8a	17.7a	18.2	66.2a	60.0a	63.5
Mean	17.8	16.7		55.2	50.4	
LSD at 5%	0.61			0.4		
	Panicle Initiation			Anthesis		
Cultivar	S_1	S_2	Mean	S_1	S_2	Mean
Akbar	52.5d	49.3c	51.1	58.8d	53.5d	56.6
Opata	75.2b	66.3a	71.2	83.7b	74.2b	79.3
Protiva	59.3c	55.2b	57.8	67.3c	62.0c	65.1
C 306	77.8a	67.3a	73.7	86.6a	77.2a	82.9
Mean	66.2	59.5		74.1	66.7	
*LSD at 5%	0.28			0.65		
	Grain Filling			Physiological Maturity		
Cultivar	S_1	S_2	Mean	S_1	S_2	Mean
Akbar	72.3d	68.8d	70.8	88.3d	83.2d	85.9
Opata	96.3b	87.7b	92.9	109.3b	101.7b	106.2
Protiva	81.2c	75.2c	78.4	99.3c	92.3c	96.1
C 306	100.8a	93.8a	97.8	117.2a	106.8a	113.4
Mean	87.7	81.4		103.5	96.0	
*LSD at 5%	0.62			0.62		

*Difference within variety between treatments

In a column, means followed by a common letter are not significantly different at the 5% level by Duncan's Multiple Range Test

Growing degree days (GDD)

The requirement of GDD decreased with delayed sowing irrespective of phenological stages and cultivars (Table 2). Heat unit requirement in C 306 was always found to be the highest and this trend was maintained up to the physiological maturity. For anthesis, C 306 required the highest GDD of 902.0 and 757.2 units in the S_1 and S_2 conditions, respectively. The lowest GDD was noticed in the cultivar Akbar in both the sowing conditions (531.2 and 476.8 units). The second highest values were found in Opata and it was followed by Protiva in both the sowing conditions. Decrease in GDD due to late sowing was also reported by Rajput ***et al.*** (1987), Singh ***et al.*** (1984), Saini and Dadhwal (1986) and Bishnoi ***et al.*** (1995) in wheat.

Table 2: Growing degree days (GDD) of four wheat cultivars as influenced by different sowing dates at different phenological stages

	Crown Root Initiation			Booting		
Cultivar	S_1	S_2	Mean	S_1	S_2	Mean
Akbar	170.2d	160.3c	167.0	395.5d	339.3d	376.6
Opata	183.0b	172.3b	176.9	564.2b	523.2b	546.4
Protiva	175.3c	164.0c	170.4	423.7c	401.2c	412.6
C 306	188.7a	178.3a	182.8	612.0a	547.8a	584.3
Mean	179.3	168.8		498.8	455.4	480.0
*LSD at 5%	5.56			4.05		
	Panicle Initiation			Anthesis		
Cultivar	S_1	S_2	Mean	S_1	S_2	Mean
Akbar	465.3d	433.3c	450.8	531.2d	476.8d	508.4
Opata	730.2b	614.2a	678.7	855.0b	717.2b	790.6
Protiva	539.5c	496.5b	523.8	625.7c	566.0c	600.2
C 306	766.8a	627.8a	711.3	902.0a	757.2a	843.9
Mean	625.5	543.0		728.5	629.3	
*LSD at 5%	4.41			8.66		
	Grain Filling			Physiological Maturity		
Cultivar	S_1	S_2	Mean	S_1	S_2	Mean
Akbar	694.2d	647.0d	674.0	924.8d	848.3d	889.3
Opata	1050.2b	914.3b	994.6	1288.8b	1147.0b	1231.6
Protiva	818.7c	730.2c	776.6	1105.7c	982.8c	1046.8
C 306	1129.0a	1005.3a	1076.3	1436.2a	1242.3a	1366.9
Mean	923.0	824.2		1188.9	1055.1	
*LSD at 5%	11.79			11.52		

*Difference within variety between treatments

In a column, means followed by a common letter are not significantly different at the 5% level by Duncan's Multiple Range Test

Heliothermal unit (HTU)

HTU of a definite phenology is the product of the length of sunshine hour of a day and the required days of the phenology accumulated heat units by plants. The HTU for different phenological stages are presented in Table 3. HTU also decreased with delay in sowing in all the four cultivars. Among the cultivars, C 306 had the highest and Akbar had the lowest HTU for almost all the phenological stages in both the sowing dates. HTU decreased with delay in sowing as the late sown plants suffered from high temperature later in the growing season. Late sowing compelled the plants to complete their life cycle with a short period of time resulting in decreased HTU. Decreased HTU for different phenological stages due to delay in sowing was also reported by Masoni ***et al.*** (1990), Rajput ***et al.*** (1987) and Sastry and Chakravarty (1982) in wheat and Rajput and Sastry (1985) in soybean.

Table 3: Helio-thermal units (HTU) of four wheat cultivars as influenced by different sowing dates at different phenological stages

	Crown Root Initiation			Booting		
Cultivar	S_1	S_2	Mean	S_1	S_2	Mean
Akbar	1429.0c	1369.0b	1412.6	3265.0d	2851.0d	3083.6
Opata	1527.0a	1474.0a	1494.9	4849.0b	4438.0b	4671.6
Protiva	1482.0b	1401.0b	1442.9	3520.0c	3320.0c	3423.7
C 306	1560.0a	1484.0a	1518.4	5324.0a	4683.0a	5048.6
Mean	1500.0	1432.3		4239.9	3823.7	
*LSD at 5%	41.5			40.1		
	Panicle Initiation			Anthesis		
Cultivar	S_1	S_2	Mean	S_1	S_2	Mean
Akbar	3891.0d	3614.0c	3768.5	4517.0d	3993.0d	4298.2
Opata	6412.0b	5339.0a	5925.8	7651.0b	5947.0b	6901.8
Protiva	4599.0c	4186.0b	4449.4	5441.0c	4865.0c	5196.1
C 306	6780.0a	5452.0a	6245.1	8092.0a	6677.0a	7532.2
Mean	5421.0	4648		6425.6	5371.3	
*LSD at 5%	42.8			120.7		
	Grain Filling			Physiological Maturity		
Cultivar	S_1	S_2	Mean	S_1	S_2	Mean
Akbar	6049.0d	5611.0d	5860.9	8313.0d	7587.0d	7991.4
Opata	9551.0b	8208.0b	9008.7	11902.0b	10448.0b	11314.9
Protiva	7300.0c	6412.0c	6877.1	10083.0c	8913.0c	9530.0
C 306	10316.0a	9128.0a	9813.1	13232.0a	11421.0a	12591.2
Mean	8304.3	7340.1		10883.0	9592.7	
*LSD at 5%	105.2			108.4		

*Difference within variety between treatments

In a column, means followed by a common letter are not significantly different at the 5% level by Duncan's Multiple Range Test

Phenothermal index (PTI)

The heat units accumulated per growth day between two phenological stages were computed with a view to express the complex relationships of the duration between phenological stages to the prevailing ambient temperature and their compensatory adjustment under field conditions in a single parameter. The parameter is expressed as degree days/growth day. In the present findings, the requirement of PTIs during different phenological durations were in the order of $S_1>S_2$ in almost all cases except sowing to crown root initiation where the order was $S_2>S_1$ (Table 4). This indicates that with delay in sowing, the accumulation of degree days per growth day between these phenological stages was decreased but during sowing to crown root initiation, the effect of sowing date was not pronounced for PTI.

Table 4: Phenothermal index (PTI) of four wheat cultivars as influenced by different sowing dates at different phenological stages

	Sowing to Crown Root Initiation			Crown Root Initiation to Booting		
Cultivar	S_1	S_2	Mean	S_1	S_2	Mean
Akbar	9.10a	10.06a	10.09	8.86a	8.18b	8.12
Opata	9.05ab	10.07a	10.06	8.80a	8.54a	8.70
Protiva	9.07ab	10.11a	10.10	8.89a	8.02b	7.97
C 306	9.03b	10.10a	10.07	9.01a	8.72a	8.88
Mean	10.06	10.08		8.44	8.36	
*LSD at 5%	0.042			0.046		
	Booting to Panicle Initiation			Panicle initiation to Anthesis		
Cultivar	S_1	S_2	Mean	S_1	S_2	Mean
Akbar	8.73d	7.77c	8.12	10.97c	10.41b	10.86
Opata	12.43b	10.75a	11.78	14.82ab	13.18a	13.94
Protiva	10.40c	9.53b	9.98	10.98c	10.31b	10.76
C 306	13.20a	11.02a	12.31	15.01a	13.16a	14.28
Mean	11.19	9.77		12.94	11.76	
*LSD at 5%	0.177			0.221		
	Anthesis to Grain Filling			Grain Filling to Maturity		
Cultivar	S_1	S_2	Mean	S_1	S_2	Mean
Akbar	11.80d	11.14d	11.49	14.41c	14.01c	14.24
Opata	15.33b	14.55b	14.95	18.45a	16.62b	17.84
Protiva	13.86c	12.44c	13.16	15.84b	14.74c	15.31
C 306	16.35a	15.02a	15.78	18.58a	18.16a	18.42
Mean	14.33	13.29		16.82	15.88	
*LSD at 5%	0.177			0.083		

*Difference within variety between treatments

In a column, means followed by a common letter are not significantly different at the 5% level by Duncan's Multiple Range Test

Table 5: Heat use efficiency (HUE) of four wheat cultivars as influenced by different sowing dates

Cultivar	S_1	S_2	Mean
Akbar	7.00a	4.60a	6.08
Opata	4.89c	3.25b	4.16
Protiva	5.66b	4.03a	4.94
C 306	4.99bc	4.71a	4.75
Mean	5.63	4.07	
*LSD at 5%	0.38		

*Difference within variety between treatments

In a column, means followed by a common letter are not significantly different at the 5% level by Duncan's Multiple Range Test

Heat use efficiency (HUE)

The HUE values (grain yield per degree day) were calculated and are shown in Table 5. The early sowing (S_1) has shown the highest HUE (7.00 for Akbar, 4.89 for Opata, 5.66 for Protiva and

4.99 for C 306) and the corresponding values for the cultivars were 4.60, 3.25, 4.03 and 4.71 for S_2, respectively. Higher HUE in the early sown plants could be attributed to the highest grain yield obtained under S_1 condition. As the temperature was optimum throughout the S_1 growing periods, it accumulated heat more efficiently and increased biological activities that confirmed higher grain yield. Similar results were reported by Rajput ***et al.*** (1987) and Paul and Sarker (2000). Cooler temperature and shorter day length resulted in higher grain yield via optimum metabolic activities and thereby the early sown plants of all the cultivars had higher HUE. In contrast, high temperature and water deficiency hampered normal metabolic activities resulting in lower grain yield as well as lower HUE in the late sown plants. Due to its lowest GDD, Akbar had the highest HUE although the highest grain yield was not obtained by Akbar. On the other hand, Opata had the poorest grain yield as well as higher GDD which resulted in the lowest HUE. Although C 306 had the greatest grain yield, it did not show the highest HUE like the other heat units due to its highest GDD and late maturing nature.

The result of the present investigation indicates that changes in the ambient temperature for a short period are reflected in the phenothermal index during the individual growth stages. Thus, the index seems to be effective in taking into account and expressing the effect of varying ambient temperature on the duration between the phenological events for comparing the crop response to the ambient temperature between different phenological stages. The differences in phenothermal indices for different growth stages indicate that the accumulated temperature could be utilized for studying biomass accumulation pattern at different phenological stages which ultimately influence the crop productivity.

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