academicJournals

Vol. 8(49), pp. 6366 -6374, 19 December, 2013
DOI: 10.5897/AJAR2013.8019
ISSN 1991-637X ©2013 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Phenology growth and yield of wheat in relation to agrometeorological indices under different sowing dates

Taruna Amrawat[1], N. S. Solanki[1], S. K. Sharma[1], D. K. Jajoria[1] and M. L. Dotaniya [2]*

[1]Directorate of Research, Maharana Pratap University of Agriculture and Technology, Udaipur – 313 001, India.
[2]Directorate of Research, Indian Institute of Soil Science, Nabi Bagh, Berasia Road, Bhopal- 462 038, India.

Accepted 4 December, 2013

A field experiment was conducted during *rabi* season of 2011 to 2012 at Maharana Pratap University of Agriculture and Technology, Udaipur to study the phenology, accumulated growing degree days, photo thermal unit, helio-thermal unit, heat use efficiency and performance of wheat varieties grown under different sowing dates. The crop was sown on 5th November took maximum calendar days, growing degree days, photo thermal unit, helio-thermal unit to attend different phonological stages till maturity which reduced significantly with subsequent delay in sowing time. The grain yield recorded in 5th November was statistically at par with 20th November. The significant reduction in grain yield of timely sown varieties was recorded when sowing was delayed beyond 20th November. Among the varieties highest grain yield of 62.81 q ha^{-1} was recorded in varieties Raj 4037, which was significantly superior over HI-1544 (58.75 q ha^{-1}) and MP-1203 (50.32 q ha^{-1}). Among the varieties MP-1203 took highest calendar days growing degree days, photo thermal unit, helio-thermal unit to reach the maturity. The variety Raj 4037 recorded the highest grain yield at 5th November sowing as compared to all other sowing dates.

Key words: Grain yield, growing degree day, photo-thermal units, temperature.

INTRODUCTION

Wheat is second most important cereal crop in the world after rice, with acreage of 45 M ha and production of 80.85 M tones (Agriculture Statistics, 2012). The optimum sowing time and selection of improved cultivars play a remarkable role in exploiting the yield potential of the crop under particular agro climatic condition. It governs the crop phonological development and the efficient conversion of biomass into economic yield. Delay in sowing caused early maturity resulting drastic reduction in yield as compare to normal sowing which has a longer growth duration which consequently provides an opportunity to accumulate more biomass. Growing of suitable varieties at an appropriate time is an essential for ensuring optimum crop productivity. Being a thermo-sensitive crop, choice of suitable variety for different seeding time further gets prime importance. Temperature is an important environmental factor influencing the growth and development of crop plants. It influences the crop phenology and yield of crop (Bishnoi et al., 1995). Plants have a definite temperature requirement to attain phenological stages. Hence, it becomes imperative to have knowledge of the exact duration of phonological stages in a particular crop-growing environment and their impact on yield of crop. Therefore, an experiment was conducted to determine the phenology and heat unit requirement of promising wheat varieties under different

*Corresponding author. E-mail: mohan30682@gmail.com.

Table 1. Effect of date of sowing, nitrogen and varieties on yields and harvest index of wheat.

Treatments	Grain yield (q ha^{-1})	Straw yield(q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
Date of sowing				
5^{th} November	64.86	108.84	173.70	37.30
20^{th} November	64.25	108.36	172.61	37.25
5^{th} December	58.04	103.53	161.57	35.84
20^{th} December	42.03	85.99	127.02	33.09
SEm±	0.29	0.44	0.52	0.16
CD (P=0.05)	0.90	1.35	1.58	0.49
Nitrogen levels				
90 kg ha^{-1}	55.76	98.59	154.35	35.84
120 kg ha^{-1}	58.83	104.27	163.10	35.79
SEm±	0.14	0.22	0.26	0.08
CD (P=0.05)	0.45	0.67	0.79	NS
Varieties				
HI- 1544	58.75	101.34	160.09	36.50
MP- 1203	50.32	98.69	149.01	33.46
Raj- 4037	62.81	104.25	167.17	37.50
SEm±	0.16	0.16	0.24	0.08
CD (P=0.05)	0.46	0.46	0.66	0.22

crop growing environment.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* 2011 to 2012 at the Agronomy Research farm, Rajasthan college of Agriculture, Udaipur, India is situated at an altitude of 582.17 m above mean sea level, 24° 34' N latitude and 73°42' E longitude. The soil of experimental site was clay loam having pH (1:2 soil water ratio)7.9, EC (dS m^{-1}) 0.40, organic carbon (%) 0.72, 250.4 kg ha^{-1} available nitrogen, 22.5 kg ha^{-1} available P, 296.8 kg ha^{-1} available K. The experiment was laid out in split plot design with three replication and 24 treatments combinations consist of 4 dates of sowing, 2 nitrogen levels and 3 genotypes. The main plot receives 4 dates of sowing v*iz*., 5 November, 20^{th} November, 5^{th} December and 20^{th} December, two nitrogen levels v*iz.,* 90 and 120 kg N ha^{-1} , while 3 varieties that is, HI-1544, MP-1203, Raj-4037 were imposed in sub plots. Seeds were sown manually at 23 cm (R x R) spacing in the well prepared field. Six irrigation was applied at all critical growth stages. In regards to fertilizer application full dose of phosphorus (40 kg ha^{-1}) and 50% of nitrogen at sowing and remaining 25% at first irrigation and 25% at second irrigation were applied. Meteorological data *viz,* rainfall, relative humidity, maximum and minimum temperature, bright sun shine hrs and day length were recorded from Agro-meteorological observatory of Maharana Pratap University of Agriculture and Technology, Udaipur, India.

The Agro-meteorological indices growing degree days (GDD), photothermal units (PTU), heliothermal units (HTU), heat use efficiency (HUE) were calculated using following formula:

$$GDD = \frac{(\text{Max.temperature} + \text{Min.temperature})}{2} - \text{Threshold temperature}$$

Threshold temperature of 5°C was considered for wheat crop (Nuttonson, 1955).

PTU = GDD × maximum sunshine hours (Rajput, 1980; Pandey et al., 2010)

$$HUE\ [(kg/ha)/\ °C\ day] = \frac{\text{Grain or biological yield (kg/ha)}}{\text{Accumulated GDD (°C day)}}$$

HTU (0C day hours) =(GDD × Sun shine hours.)

RESULTS AND DISCUSSION

Grain yield

The crop sown on 5^{th} November recorded the highest grain (64.86 q ha^{-1}) and straw (108.84 q ha^{-1}) yield which was statistically on par with 20^{th} November sowing, but significantly higher than recorded in late sowing dates (Table 1). It might be due to higher GDD, PTU, day taken to attain physiological maturity stage in these sowing dates (Tables 2 to 4). The detrimental effect of heat at a later stage of crop development and earing in delayed sowing had an adverse effect on grain yield. Wardlaw and Wringley (1994) reported 3 to 4% decrease in grain yield for each 1°C rise in ambient temperature above 15°C during grain filling. The grain yield is the sum total of different yield contributing factors controlled both genetically and environmentally (Shirpurkar et al., 2008). Since wheat yield formation is a complex process and interaction governed by the complimentary interaction between source (photosynthesis and availability of assimilates) and sink component (storage organs). In this

Table 2. Temperatures (°C) during vegetative and reproductive phase of wheat (2011 to 2012).

Sowing date	Vegetative phase			Reproductive phase		
HI-1544	**Max T**	**Min T**	**Mean**	**Max T**	**Min T**	**Mean**
5th November	28.2	11.8	20.0	25.7	8.3	17.0
20th November	25.7	8.6	17.2	28.6	10.4	19.5
5th December	24.8	7.8	16.3	32.0	13.0	22.5
20th December	25.1	7.7	16.4	34.0	15.2	24.6
MP-1203						
5th November	27.8	11.2	19.4	27.1	9.3	18.2
20th November	26.0	8.8	17.5	30.1	10.8	20.4
5th December	26.0	8.5	17.2	33.5	14.1	23.8
20th December	25.2	7.8	16.5	34.8	16.5	25.7
Raj-4037						
5th November	28.2	11.8	20.0	25.9	8.0	17.0
20th November	25.9	8.9	17.5	28.5	10.2	19.3
5th December	24.8	7.8	16.3	32.2	13.5	22.8
20th December	25.1	7.6	16.3	34.2	15.8	25.0

Table 3. Temperatures (°C) during different phenophases of wheat sown under different environment (2011 to 2012).

Sowing date	Tillering to heading (P_1)			Heading to milking stage (P_2)			Milking to dough (P_3)			Milking to maturity (P_4)			Heading to maturity stage (P_5)		
HI-1544	**Max T**	**Min T**	**Mean T**	**Max T**	**Min T**	**Mean T**	**Max T**	**Min T**	**Mean T**	**Max T**	**Min T**	**Mean T**	**Max T**	**Min T**	**Mean T**
5th November	24.4	7.7	16.0	23.2	6.7	15.0	29.0	11.0	20.0	28.3	9.9	19.1	25.7	8.3	17.0
20th November	22.7	6.2	14.5	24.6	7.7	16.1	29.7	10.8	20.3	32.6	13.1	22.9	28.6	10.4	19.5
5th December	25.2	7.9	16.5	29.2	10.5	19.8	32.9	12.5	22.7	34.8	15.6	25.2	32.0	13.0	22.5
20th December	27.8	9.8	18.8	30.5	11.6	21.0	36.8	17.0	26.9	37.6	18.8	28.2	34.0	15.2	24.6
MP-1203															
5th November	23.2	6.5	14.9	24.1	7.6	15.9	29.2	10.5	19.8	30.2	11.1	20.6	27.1	9.3	18.2
20th November	23.7	7.2	15.5	27.6	10.1	18.9	30.8	11.2	21.0	32.5	11.5	22.0	30.1	10.8	20.4
5th December	27.3	9.1	18.1	29.8	10.9	20.3	35.4	15.5	25.4	37.2	17.3	27.3	33.5	14.1	23.8
20th December	27.7	10.0	18.8	31.5	12.2	21.8	38.2	20.3	29.3	38.2	20.9	29.6	34.8	16.5	25.7
Raj-4037															
5th November	23.7	6.8	15.4	22.6	5.7	14.2	30.2	11.4	20.8	29.3	10.4	19.8	25.9	8.0	17.0
20th November	23.3	6.9	15.1	25.2	7.9	16.6	29.6	11.1	20.3	31.8	12.5	22.1	28.5	10.2	19.3
5th December	25.2	7.9	16.5	29.1	10.5	19.7	34.3	13.6	24.0	35.3	16.6	26.0	32.2	13.5	22.8
20th December	28.1	10.4	19.3	30.9	12.6	21.8	37.0	17.5	27.3	37.5	18.9	28.3	34.2	15.8	25.0

Table 4. Effect of date of sowing, nitrogen and varieties on heat unit efficiency (HUE) of wheat.

Treatments	HUE (kg/ha/°Cday)	
	On grain yield basis	On biological yield basis
Date of sowing		
5th November	3.78	10.11
20th November	4.09	10.96
5th December	3.72	10.34
20th December	2.80	8.47
SEm±	0.02	0.03
CD (P=0.05)	0.06	0.10
Nitrogen levels		
90 kg ha^{-1}	3.50	9.69
120 kg ha^{-1}	3.70	10.25
SEm±	0.01	0.02
CD (P=0.05)	0.03	0.06
Varieties		
HI- 1544	3.76	10.24
MP- 1203	3.05	9.08
Raj- 4037	3.98	10.60
SEm±	0.02	0.02
CD (P=0.05)	0.04	0.07

experiment, the grain yield was significantly influenced by different varieties and all varieties were noticed significant difference to each other (Table 1). The highest grain yield was produced by Raj-4037 (62.81 q ha^{-1}) followed by HI-1544 (58.75 q ha^{-1}) and MP-1203 (50.32 q ha^{-1}). High yield of Raj-4037 may be attributed to its higher biomass accumulation and due to genetic potential difference. Delayed sowing hastened the crop phonological development, thereby causing significant reduction in wheat yields (Singh and Paul, 2003). Kaur et al. (2010) and Pandey et al. (2010) also reported the similar observation under delayed sowing.

Effect of temperature

Temperatures during vegetative and reproductive stage are presented in (Table 2). Data shows that wheat crop sown under different sowing dates had exposed to various thermal regimes during vegetative and reproductive phase of the crop. It was noted that 5th November sown crop experienced higher mean temperature during vegetative phase in all three varieties. However, during reproductive phase, later sowing dates that is, 5th December and 20th December experienced higher maximum, minimum and mean temperatures as compared to early sowing dates (5th November and 20th November) in all varieties.

Vegetative phase v/s mean temperature

It was observed that vegetative phase of wheat that is, the period from sowing to heading has a negative relationship with mean temperature during that period (Figure 1). An increase in mean temperature by 1°C resulted in reduction of vegetative period by about 3 days. The regression equation (Y= -2.896 X + 123.6, R^2=0. 265) to predict the vegetative phase of the experiment.

Reproductive phase v/s mean temperature

The relationship between reproductive is presented in Figure 2 which show that reproductive period that is, the period between heading and physiological maturity of the crop have negative relationship with mean temperature during that period. An increase in mean temperature during reproductive period by 1°C reduces the reproductive period by about 4 days. The grain yield of wheat varieties was reduced with increasing in temperatures during reproductive phase.

Temperature during critical growth period

Temperature data at different phonological stages of

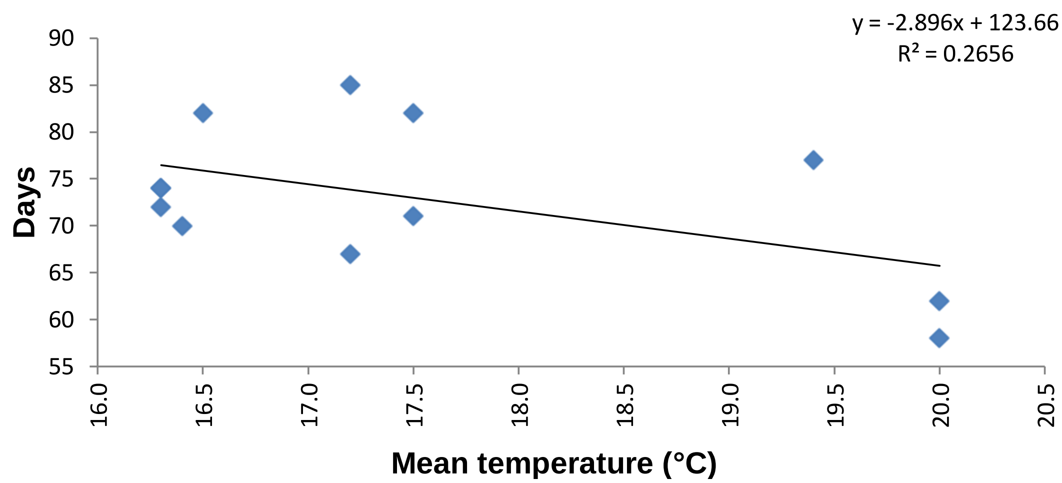

Figure 1. Vegetative phase of wheat as influenced by mean temperature.

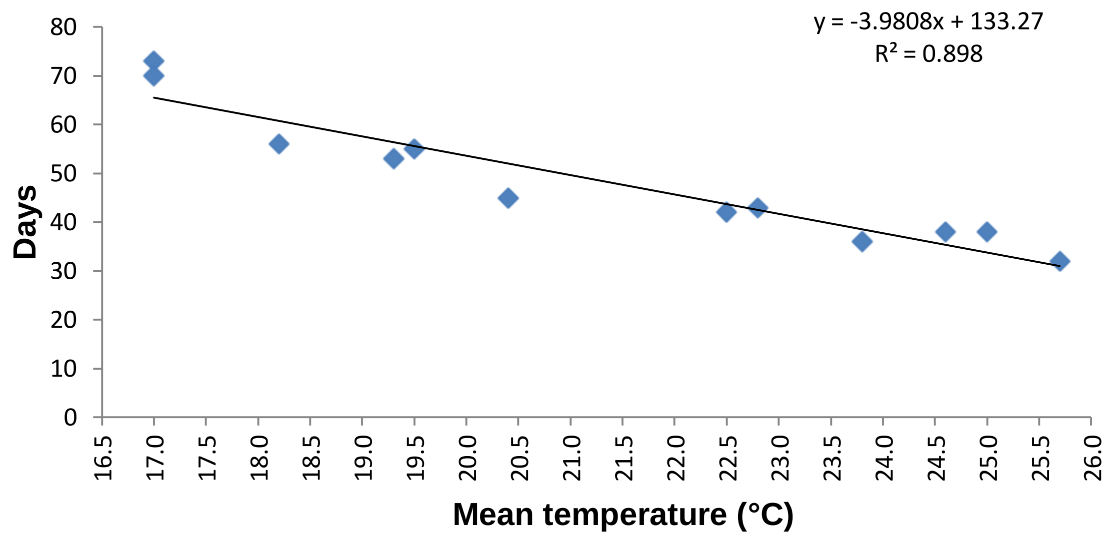

Figure 2. Reproductive phase of wheat as influenced by mean temperature.

wheat are presented in (Table 2 and Figure 3). Data shows that highest mean temperature of 18.8°C during tillering to heading was observed under 20th December sown crop followed by 16.5°C in 5th December sown crop. However, larger variation in mean temperature during heading to milking stage and milking to dough stage was recorded in different sowing dates. It was noted that the early sown crop (5th November and 20th November) experienced lower mean temperature as compared to delayed sowing that is, 5th December and 20th December in all varieties. Similarly, first two dates of sowing also experienced lower mean temperature during milking to dough stage as compared to later sowing dates.

The mean temperature of during heading to milking stage and during milking to dough stage found conducive for getting a higher grain yield of wheat. Hence, the period between headings to dough stage is more sensitive to higher mean temperature which resulted in a reduction in grain yield in delayed sowing crops. On the basis of data (2011 to 2012), it was observed that higher grain yield of 64.86 q ha^{-1} (variety Raj-4037) was obtained when the mean temperature of 17.4 to 19.5°C experienced during the reproductive phase of the crop (Figure 3). The increase in the temperature above this limit during reproductive phase caused a drastic reduction in grain yield by 15.3 to 34.7% (Figure 4).

Heat use efficiency

Data in Table 4 show that the highest HUE for total dry

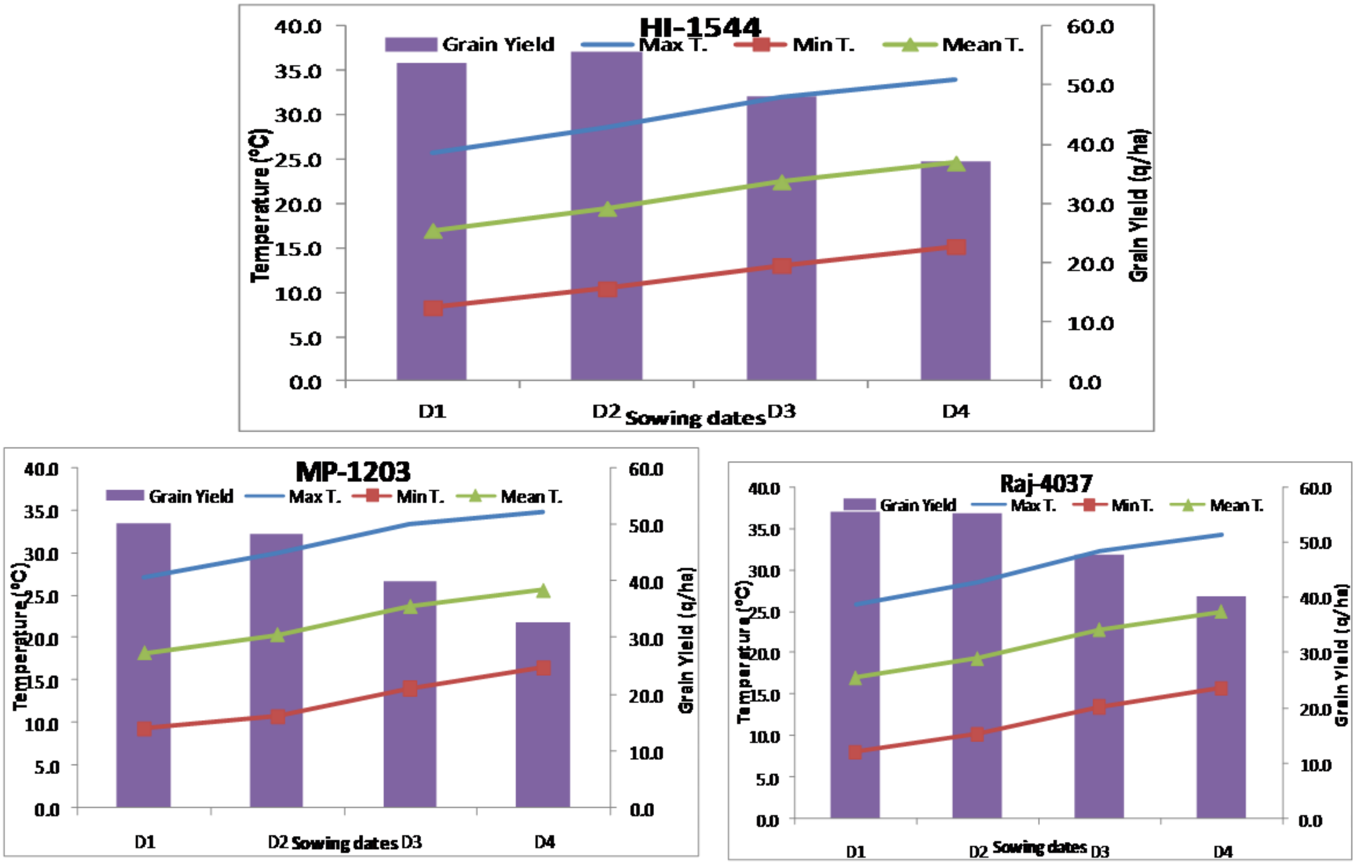

Figure 3. Effect of temperature at reproductive stage on grain yield wheat varieties (2011 to 2012).

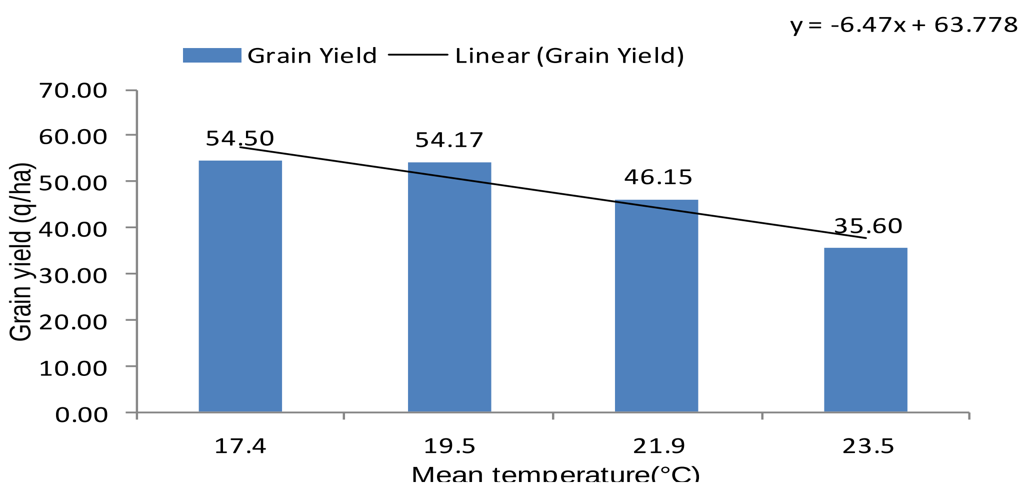

Figure 4. Effect of mean temperature on grain yield of wheat variety Raj 4037(2007-08 to 2011 to 2012).

matter (10.2 kg/ha/°C days) as well as grain yield (3.4 kg/ha/°C days) was recorded under 20th November sown crop. With respect to varieties, it was noted that MP-1203 registered maximum accumulated GDD (1637°C day) followed by Raj 4037 (1569°C day) and HI-1544 (1539°C day). However, maximum HUE for grain yield was recorded in variety HI-1544 and Raj-4037 and lowest HUE was recorded in variety MP-1203. The higher HUE

Table 5. Effect of date of sowing, nitrogen and varieties on accumulated growing degree days (°C days) of wheat.

Treatment	Phenological stages							
	Emergence	CRI	Tillering	Flag leaf	Heading	Milking	Dough	Maturity
				Date of sowing				
5th November	89.4	307.0	478.0	869.0	923.0	1280.9	1525.1	1724.5
20th November	64.5	261.0	350.0	765.0	870.3	1181.0	1479.9	1580.7
5th December	65.5	220.0	316.0	735.6	848.6	1168.3	1430.3	1565.2
20th December	78.2	213.9	311.9	718.5	818.6	1168.6	1421.8	1504.5
SEm±	0.2	0.7	1.1	2.5	2.8	3.8	4.7	5.1
CD (P=0.05)	0.8	2.3	3.5	7.6	8.5	11.8	14.3	15.4
				Nitrogen levels				
90 kg ha^{-1}	74.9	250.5	364.0	772.1	865.1	1200.1	1464.3	1593.7
120 kg ha^{-1}	73.8	250.5	363.9	772.1	865.1	1199.4	1464.3	1593.7
S. Em±	0.1	0.3	0.5	1.2	1.4	1.9	2.3	2.5
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
				Varieties				
HI- 1544	75.5	250.5	363.9	711.9	806.7	1141.3	1409.0	1562.5
MP- 1203	74.6	250.5	364.0	875.5	975.9	1279.2	1532.9	1641.8
Raj- 4037	73.0	250.5	364.0	728.7	812.7	1178.7	1450.9	1576.8
SEm±	0.2	0.5	0.8	1.6	1.8	2.5	3.1	3.1
CD (P=0.05)	NS	NS	NS	4.5	5.0	7.0	8.6	8.8

in 20th November sown crop could be ascribed by proportionate increasing dry matter per each heat unit absorbed. The lower HUE in delayed sowing can be expected due to accumulation of comparable GDD to that of early sowing at later crop growth stages. Since both maximum and minimum temperature remained higher during reproductive phase causing detrimental effect on dry matter accumulation. The results are in close agreement with those of Pandey et al. (2010). Application of 120 kg N ha^{-1} registered significant increase in heat use efficiency over 90 kg N ha^{-1} (Table 4). This could be ascribed to the fact that significantly higher grain and biological yields under 120 kg N ha^{-1} over 90 kg N ha^{-1} but the heat unit required to achieve yields were more or less similar under both the levels of nitrogen.

Growing degree days (GDD)

Growing degree days were found to be significant both at earing and maturity of different dates of sowing. The heat unit or GDD was proposed to explain the relationship between growth duration and temperature. This concept assumes a direct and linear relationship between growth and temperature (Nuttonson, 1955). It required for different phenophase varied with date of sowing (Table 5). The GDD was decreased with the successive delay in sowing. The early sown crop had accumulated maximum GDD at all phonological stages as compared to the rest. This describes clearly the effect of temperature on phenological stage. Every crop needs a specific amount of GDD to enter its reproductive phase from vegetative phase. Early sowing resulted in absorbing sufficient GDD in relatively more time. While late sown crop experienced higher temperature during later stage in less time. Pandey et al. (2010) also reported lower consumption of heat units under delayed sowing. MP-1203 took longer time to attain the various phenological phases and growing degree days. The differential behaviors to heat unit requirements and days required to reach the various phenological phases could be ascribed solely to their genetic makeup.

Effect on maturity

Date of sowing and different varieties had significant difference in days taken to earing and maturity (Table 6). The phenologial studies revealed that 5th November sown varieties took maximum number of days to attain maturity and constantly decreased with subsequent sowing (Table 6). With delay in sowing, the crop duration was drastically reduced on account of shorter vegetative and reproductive phase. In late sown varieties the duration of crop growth decreased because of forced maturity due to higher mean temperature coupled with low relative humidity. It is an established fact that crop phenology are largely dependent on genetic and environmental factors *Viz* temperature, relative humidity, sun shine hours, rainfall etc (Venkataraman and Krishnan, 1992).

Table 6. Effect of date of sowing, nitrogen and varieties on days required to attain different phenological stages of wheat.

Treatment	Emergence	CRI	Tillering	Flag leaf	Heading	Milking	Dough	Maturity
				Date of sowing				
5th November	5.1	16.0	30.1	67.2	72.7	101.1	118.5	130.2
20th November	5.0	15.9	30.1	68.0	76.1	98.7	116.4	121.8
5th December	6.0	17.0	31.0	66.3	73.8	95.7	109.7	116.7
20th December	7.0	18.0	32.0	60.7	68.3	89.1	101.8	105.3
SEm±	0.01	0.007	0.01	0.06	0.05	0.11	0.41	0.10
CD (P=0.05)	0.04	0.021	0.04	0.19	0.17	0.33	1.26	0.21
				Nitrogen levels				
90 kg ha^{-1}	5.8	16.7	30.8	65.6	72.6	96.1	110.7	118.1
120 kg ha^{-1}	5.7	16.7	30.7	65.4	72.8	96.1	112.4	118.8
SEm±	0.07	0.004	0.08	0.03	0.02	0.05	0.02	0.01
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
				Varieties				
HI- 1544	5.8	16.8	30.8	60.4	68.1	92.4	108.6	116.8
MP- 1203	5.8	16.7	30.9	73.8	81.4	101.5	115.0	120.8
Raj- 4037	5.7	16.8	30.8	62.4	68.7	94.5	111.2	117.8
SEm±	0.01	0.005	0.01	0.03	0.03	0.08	0.21	0.04
CD (P=0.05)	NS	NS	NS	0.10	0.09	0.24	0.58	0.11

Table 7. Effect of date of sowing, nitrogen and varieties on accumulated photo thermal units (°C day-hour) at different phenological stages of wheat.

Treatment	Phenological stages							
	Emergence	CRI	Tillering	Flag leaf	Heading	Milking	Dough	Maturity
				Date of sowing				
5th November	975.7	3888.7	5224.4	9396.8	11076.0	14719.5	18299.7	20688.0
20th November	707.6	2808.3	3758.3	8348.7	9398.8	12989.3	16562.4	17772.4
5th December	693.7	2327.1	3358.6	7969.5	9266.1	13024.1	16170.3	17786.9
20th December	828.8	2288.1	3340.6	7916.3	9113.4	13441.5	16563.1	17627.1
S. Em±	2.6	8.8	12.5	26.6	35.1	126.8	133.7	133.6
CD (P=0.05)	7.9	26.7	38.0	80.9	106.6	NS	NS	405.2
				Nitrogen levels				
90 kg ha^{-1}	801.8	2827.9	3920.5	8407.9	9713.5	13543.5	16898.5	18468.8
120 kg ha^{-1}	801.8	2827.9	3920.5	8407.7	9713.5	13543.6	16899.3	18468.7
SEm±	1.3	4.4	6.2	13.3	17.5	63.4	66.8	66.8
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
				Varieties				
HI-1544	801.4	2827.9	3920.8	7711.8	7577.7	12865.4	16235.0	18077.9
MP-1203	801.5	2827.9	3920.5	9625.3	11713.7	14465.5	17725.6	19072.9
Raj-4037	801.5	2827.9	3920.5	7886.8	9849.3	13300	16736.1	18255.0
SEm±	1.6	6.0	8.6	17.6	23.7	86.2	91.1	84.2
CD (P=0.05)	NS	NS	NS	48.8	65.6	238.9	NS	NS

Significant differences were observed in respect of days taken by the varieties to reach at the various phenological phases and among the varieties MP-1203 took longer time to attain the various phonological phases.

Effect on photo-thermal unit (PTU)

The variation in PTU in different treatments at earing and maturity has been presented in (Table 7). The varieties

Table 8. Helio Thermal Units required to attain different phenophases of wheat (2011 to 2012).

Variety	Treatment	Emergence	CRI	Tillering	Flag leaf	Heading	50% heading	Milking	Dough	Maturity
HI-1544	5th November	583	3113	4161	6421	6757	7267	10232	13178	14098
	20th November	544	2603	3424	5731	6204	6950	9459	12066	12799
	5th December	817	2173	2725	5372	6344	7358	9418	11785	12544
	20th December	536	1593	2307	5033	6183	6910	9636	11633	12185
MP-1203	5th November	583	3113	4161	7330	8210	9055	11833	13707	14440
	20th November	544	2603	3424	6753	7447	8328	10804	12927	13571
	5th December	817	2173	2725	6344	7820	8384	10476	12943	13506
	20th December	536	1593	2307	6465	7447	7622	10323	11988	13449
Raj-4037	5th November	583	3113	4161	6572	7092	7662	10702	13273	14264
	20th November	544	2603	3424	5892	6537	7255	9738	12066	13060
	5th December	817	2173	2725	5548	6344	7258	9810	12171	12739
	20th December	536	1593	2307	5349	6456	7086	9636	12000	12582

sown on 5th November required maximum PTU till maturity which was superior over 20th November, 5th and 20th December sown crop at all stages. MP-1203 requires maximum PTU at flag leaf, heading and milking stage which was significantly superior over HI-1544 and Raj 4037. The higher PTU value in early sown crop may be due to fact that crop took longer duration to reach phenological stages.

Effect on helio thermal units (HTU)

Accumulated Helio thermal units required to attain different phenological stages of wheat varieties are presented in (Table 8). Data shows that the highest Helio thermal unit 14440°C day hours were required for maturity in MP-1203 when sown on 5th November. Variety HI-1544 and Raj-4037 also required more helio thermal units for attaining maturity under 5th November sown crop as compared to delay sowing. This might be due to delayed maturity in early sown as compare to late sown wheat crop. It was reported that HTU for different phenological stages decreased with delay in sowing as reported by Masoni et al. (1990).

Conclusions

The crop sown on 5th November took a maximum calendar day, GDD, PTU for maturity which got reduced significantly with subsequent delay in sowing time and recorded lowest value on the 20th December sown crop. The 5th November recorded the highest grain yield which was statistically at par with 20th November. Highest mean temperature during vegetative and reproductive phase was also under 5th November sown crop. Among the varieties, variety MP-1203 took highest calendar days, GDD, PTU for maturity. The highest grain yield was recorded in variety Raj 4037 as compared to HI-1544 and MP-1203.

REFERENCES

Agriculture Statistics (2012). Progress report. All India coordinated Wheat and Barley Improvement Project. Directorate of Wheat Researh, Karnal.

Bishnoi OP, Singh S, Niwas R (1995). Effect of temperature on phonological development of wheat (*Triticum aestivum* L.) crop in different row orientation. Indian J. Agric. Sci. 65:211-214.

Kaur A, Pannu RK, Buttar GS (2010). Impact of nitrogen application on the performance of wheat and nitrogen use efficiency under different dates of sowing. Indian J. Agron. 55:40-45.

Masoni A, Ercoli L, Maassantini F (1990). Relationship between number of days, growing degree days and photothermal units and growth in wheat according to seeding time. Agric. Mediterrancea. 120: 41-51.

Nuttonson MY (1955). Wheat climate relationship and the use of phenology in ascerting the thermal and photo thermal requirement of wheat. American Institute of crop ecology.Washington DC, USA. P. 388.

Pandey IB, Pandey RK, Dwivedi DK, Singh RS (2010). Phenology, heat unit requirement and yield of wheat varieties under different crop-growing environment. Indian J. Agric. Sci. 80:136-140.

Rajput RP (1980). Response of soybean crop to climate and soil environments. Ph.D. Dissertation, IARI, New Delhi.

Shirpurkar GN, Wagh MP, Patil DT (2008). Comparative performance of wheat genotypes under different sowing dates. Agric. Sci. Dig. 28:231-232.

Singh S, Paul M (2003). Growth, yield and penological responses of wheat cultivars to delayed sowing . Indian J. Plant Physiol. 8:277-286.

Venkataraman S, Krishnan A (1992). Crops and Weather. Publication and Information division of ICAR, New Delhi, India.

Wardlaw IF, Wringly CW (1994). Heat tolerance in temperate cereals. An Overview. Australian J. Plant Physiol. 21:695-703.