Journal of Agrometeorology 21 (3) : 282-287 (September 2019)

Heat unit requirement and yield of wheat (*Triticum aestivum* L.) varieties under different growing environment in mid hill conditions of Himachal Pradesh

RANU PATHANIA[1], RAJENDRA PRASAD[2], RANBIR SINGH RANA[2] and S. K. MISHRA[3]

[1] *Department of Agriculture, Himachal Pradesh*

[2] *Department of Agronomy, Forages and Grassland Management, CSKHPKV, Palampur, Himachal Pradesh*

[3] Punjab Agricultural University, Regional Research Station, Faridkot, Punjab

**** Corresponding author:*** *ranu44raone@gmail.com*

ABSTRACT

A field experiment was conducted during *rabi* seasons of 2015-16 and 2016-17 to study the accumulated growing degree days (GDD), helio-thermal unit (HTU), photo-thermal unit (PTU), heat use efficiencies (HUE) at different phenological stages and performance of wheat (*Triticum aestivum* L.) varieties grown under different sowing dates. Results of present study revealed that the crop sown on 20th October required maximum calendar days, growing degree days, photo-thermal unit and helio-thermal unit for tillering, flowering, earing and maturity which was significantly reduced with subsequent delay in sowing time. The grain yield recorded in 20th November (4065 kgha^{-1}) was statistically at par with 5th November yield (3863 kgha^{-1}). The significant reduction in grain yield on varieties was recorded when sowing was delayed beyond 20th November. Among the varieties 'VL-907' produced highest grain yield (3771 kgha^{-1}) which was statistically on par with 'VL-829' (3726 kgha^{-1}). The early and timely sown wheat variety like VL-829 and VL-907 took highest calendar days, GDD, HTU and PTU for earing and maturity. The variety 'VL-907' recorded the highest grain yield (4196 and 4168 kgha^{-1}) at 5th and 20th November sowing as compared to all other sowing dates.

Key words: Wheat, GDD, PTU, HTU, PTI, Grain yield

Wheat (*Triticum aestivum* L.) an important, widely adapted *rabi* crop grown from temperate irrigated to dry and high rainfall areas ranging from warm humid to dry cold environments of India. It occupies approximately 30.6 million hectares area with 98.5 million tonnes wheat production in India (FAO 2017). Cool weather during vegetative period and warm weather during maturity are ideal for wheat. Changes in seasonal temperature affect the productivity through the changes in phenological development of the crop. Date of sowing is most important factors that govern the phenological development of the crop and also influence the conversion of biomass into economic yield. Being a temperature sensitive crop, late sown wheat crop is sometimes exposed to low temperature at the time of establishment and often to high temperature during reproductive phase that accelerate the maturity predominantly in North Indian conditions. This not only inhibits the crop growth, but also affects the yield and yield components of wheat. Therefore, the optimization of sowing time is an important parameter to attain maximum yield and efficient conversion of biological yield into economic yield. Generally, normal sowing has longer growth duration which consequently supports high biomass accumulation as compared to late sowing and henceforth manifested in higher grain and biological yield (Singh and Pal, 2003). Influence of temperature on phenology and yield of crop plants can be studied under field condition through accumulated heat units system (Bishnoi *et al.* 1996). Though accumulation of degree-days for each development stage is relatively constant and independent on sowing date, but it considerably vary among the varieties. Under North Indian condition, the maturity of wheat hastened due to gradual rise in ambient temperature under delayed planting (Hari Ram *et al.* 2012; Bist *et al.* 2019). Hence, it becomes imperative to have knowledge of exact duration of phenological stages in a particular crop-growing environment and their impact on yield of crop. Growing of suitable variety at an appropriate time is essential for ensuring optimum productivity. Being a thermo-sensitive crop, choice of suitable variety for different sowing windows further gets prime importance. Therefore, an experiment was planned to determine the phenology and heat unit requirement of promising wheat varieties under different growing environments in mid hill conditions of Himachal Pradesh

MATERIALS AND METHODS

A field investigation was conducted at the experimental farm of CSK HP University, Palampur during the *rabi* seasons of 2014-15 and 2015-16. The experiment was conducted in split plot design with five dates of sowing (20th October, 5th November, 20th November, 5th December and 20th December) in main plots and four varieties of wheat (viz., HS-490, VL-829, VL-892 and VL-907) in sub-plots with three replications. Wheat crop was sown with the row spacing of 22.5 cm as per treatments. Two irrigations (50 mm water in each irrigation) were applied at two critical phenological stages. The crop was fertilized with 120 kg N, 60 kg P_2O_5 and 40 kg K_2O. Out of which, 1/3rd N and full dose of P_2O_5 and K_2O were applied as basal dose at the time of sowing by broadcasting method. The remaining 2/3rd dose of N were given in two equal splits at CRI and late tillering stages. Meteorological data viz., rainfall (mm), maximum and minimum relative humidity (%), maximum and minimum temperature (°C), duration of bright sunshine (hours), wind speed (kmh^{-1}) etc. were recorded from Agrometeorological observatory, CSK HPKV, Palampur. Following agro-meteorological indices were computed using the daily meteorological data.

GDD (°C day) = $\sum$ (Tmax+ Tmin) /2 - 4.5 (base temperature)

PTU (°C day hour) = $\sum$ (GDD × day length)

HTU (°C day hour) = $\sum$ (GDD × actual bright sun shine hours)

RESULTS AND DISCUSSION

Yield attributes

The growth and yield attributes were significantly influenced by sowing dates and varieties (Table 1). The significantly highest effective tillers m^{-2} were recorded in crop sown on 20th November (285) which was statistically on par with 5th November (275) sown crop and were significantly better than other dates of sowing. Among different varieties, the effective tillers m^{-2} recorded in 'VL-907' and 'VL-829' were significantly more than 'VL-892' and 'HS-490'. Similarly, numbers of grains spike^{-1} was significantly more in 'VL-907' (43) and VL-829 (39). Maximum 1000-grain weight (46.4 g) was recorded on 20th November sown crop and among varieties VL-907 (45.2 g). The straw yield was also higher under 5th and 20th November (6397 and 6104 kgha^{-1}, respectively) sowing environments. The wheat variety 'VL-907' produced highest straw yield (6396 kgha^{-1}). The higher yield and yield attributing parameters under early over delayed sowing could be attributed to availability of optimum environmental conditions for growth and development of crop which might have enhanced accumulation of photosynthates from source towards sink.

Table 1: Effect of sowing dates and varieties on yield and yield attributes of wheat (Pooled 2015-16 and 2016-17)

Treatments	Grain yield (kgha^{-1})	Straw yield (kgha^{-1})	No. of grains spike^{-1}	No. of effective tillers m^{-2}	1000-grain weight (g)	Length of spike (cm)	Harvest index
Sowing dates							
20th Oct.	3449	5384	38	263	41.6	10.6	0.40
05th Nov.	3863	6104	40	275	42.6	10.9	0.40
20th Nov.	4065	6397	43	285	46.4	11.6	0.39
05th Dec.	3276	5040	37	261	40.8	10.5	0.39
20th Dec.	3187	5054	35	257	38.6	10.2	0.38
LSD (P=0.05)	130	313	2	6	1.8	0.3	NS
Varieties							
HS- 490	3519	5026	34	264	40.9	10.5	0.41
VL- 829	3726	6054	39	272	42.1	10.8	0.38
VL- 892	3255	4908	37	259	39.7	10.5	0.40
VL- 907	3771	6396	43	278	45.2	11.1	0.37
LSD (P=0.05)	284	417	3	10	2.8	0.4	0.02

Table 2: Interaction effect of treatments on grain yield (kg ha^{-1})

Varieties	Dates of sowing				
	20th Oct.	5th Nov.	20th Nov.	5th Dec.	20th Dec.
HS-490	3029	4046	4102	3277	3143
VL- 829	3877	3957	3876	3623	3299
VL- 892	3066	3254	4112	2957	2884
VL- 907	3822	4196	4168	3249	3421
CD (P=0.05)					
For comparison of varieties at same date		130.1			
For comparison of dates at same or different varieties		283.9			

Grain yield

A perusal of data in Table 1 revealed that yield under 20th November sowing (4065 kgha^{-1}), was closely followed by 5th November sowing (3863 kgha^{-1}) during both the years. The highest yield recorded with 20th November was due to significantly higher effective tillers (285), grains per spike (43) as well as 1000-grain weight (46.4g) while lowest yield (3187 kgha^{-1}) was recorded from last sowing (20th December). Prevailing high temperature during reproductive phase of the crop growth under delayed sowing caused forced maturity of the crop and resulted in lower test weight, less number of filled grains spike^{-1} and ultimately the lower grain yield. Reduced effective tillers, grains spike^{-1} and 1000-grain weight etc. under delayed sowing are responsible for lesser grain yield. The detrimental effect of heat at later stage of crop development in delayed sowing had adverse effect on grain yield (Mishra *et al.* 2015).

Among the varieties, VL-907 and VL-829 gave significantly highest grain yield (3771 and 3726 kg ha^{-1}) though it was at par with VL-892 (3519 kgha^{-1}). Both years, VL-892 produced lowest grain yield as compared to other varieties. The interaction effect between dates of sowing and wheat varieties was also found to be significant (Table 2). Under timely sowing, VL-907 produced maximum yield (4196 and 4168 kgha^{-1}). The greater reduction in yield of long season wheat varieties under delayed sowing was because of shorter growing season length. Delayed sowing hasten the crop phenological development, hence the reduced wheat yields (Singh and Pal, 2003).

Growing degree days (GDD)

The GDD was calculated from complete emergence to physiological maturity. The GDD decreased with delay in sowing during both the years in all growth stages except during physiological maturity. Sowing date strongly influenced the GDD requirement for a particular developmental stage. Analysis of the data (Table 3) confirmed that postponement of sowing date resulted in reduction of GDD requirement. The cumulative GDD (1512.1°C day^{-1}) was highest in 20th October. There was a progressive decrease in GDD as the sowing date was delayed from 20th October to 20th December at the rate of 0.6 to 7.7 per cent, respectively. The emergence of wheat cultivars was completed approximately at 121-137 degree days. For maturity accumulated GDD was 1512.1°C day^{-1} in 20th October, 1502.7°C day^{-1} in 5th November and 1394.6°C day^{-1} in 20th December both years. The decrease in thermal requirements with delay in sowing may possibly be due to low temperature in late sown crop. The reduction in GDD accumulation was due to reduction in number of days taken to attain any phenological stages under water stress conditions, as was also reported by Bist *et al.* (2019).

Helio thermal unit (HTU)

Analysis of the data presented in Table (3), revealed that postponement of sowing date decreased the HTU consumption. With delay in sowing HTU decreased at the rate of 1.9 to 6.06 per cent from 20th October to 20th December. VL-829 accumulated maximum HTU followed by VL-907, both years. HTU varied from 4182 to 5953 for ear emergence and 9387 to 12189 for physiological maturity of the crop (Table 1). Hundal *et al.* (1997) also observed that cumulative helio thermal units (HTU) were reduced with delay in sowing after November due to reduction in actual sunshine hours. Conversely, higher HTU accumulation by the earlier sowing dates was due to extended phenophases.

Photo thermal unit (PTU)

Analysis of the data described that postponement of sowing date resulted in reduction in PTU requirement (Table

Table 3: Effect of sowing dates and varieties on Agro meteorological indices at different growth stages of wheat (Pooled data 2015-16 and 2016-17)

Treatments	Complete emergence	Tillering	Flag leaf	Ear emergence	Physiological maturity
			Growing degree day (°C days)		
Sowing dates					
20th Oct.	148	601	858	879	1512
05th Nov.	140	491	752	787	1503
20th Nov.	143	404	631	722	1458
05th Dec.	107	305	593	640	1372
20th Dec.	105	288	588	622	1395
Varieties					
HS- 490	126	416	597	616	1355
VL- 829	137	434	768	886	1702
VL- 892	121	400	675	698	1279
VL- 907	130	420	699	719	1455
			Helio thermal units (°C day hour)		
Sowing dates					
20th Oct.	1232	4521	6229	6338	10627
05th Nov.	1021	3526	5088	5358	10421
20th Nov.	998	2782	4166	4723	10071
05th Dec.	705	2035	3830	4156	9624
20th Dec.	790	1775	3840	4078	9982
Varieties					
HS- 490	930	2930	4034	4182	9387
VL- 829	1013	3018	5163	5953	12190
VL- 892	895	2808	4596	4742	8789
VL- 907	958	2954	4730	4846	10215
			Photo thermal units (°C day hour)		
Sowing dates					
20th Oct.	1544	6130	8806	9048	17099
05th Nov.	1420	4975	7779	8207	17671
20th Nov.	1441	4109	6623	7719	17666
05th Dec.	1091	3138	6486	7073	17056
20th Dec.	1077	3046	6729	7167	17793
Varieties					
HS- 490	1290	4263	6217	6456	16173
VL- 829	1398	4459	8331	9788	20985
VL- 892	1238	4091	7150	7457	15116
VL- 907	1331	4304	7441	7670	17554

3). The trends of PTU were similar as HTU and GDD for all varieties and sowing environments. A gradual decrease in PTU was noticed with delay in sowing of wheat from 20th October to 20th December. The maximum PTU accumulation (°C day hour) for attaining maturity was 17793 in 20th December at par 5th November (17671) and 20th November (17666) least in 5th December (17056). VL-829 being a long duration variety accumulateshighest PTU among the varieties.

Heat use efficiency (HUE)

Heat use efficiency (HUE), heliothermal use efficiency (HTUE) and photothermal use efficiency (PTUE) determine the ability of a plant to convert per unit available energy into the economic product. The data presented in Table 4 revealed that HUE, HTUE and PTU were higher in 20th November followed by 5th November sowing. HUE values varied from 2.31 to 2.86 during sowing windows from 20th October to 20th

Table 4: Effect of treatments on heat use efficiencies, helio thermal use efficiency and photo thermal use efficiency (Pooled 2015-16 and 2016-17)

Treatments	HUE	HTUE	PTUE
Sowing dates			
20th Oct.	2.31	0.33	0.21
05th Nov.	2.62	0.38	0.22
20th Nov.	2.86	0.42	0.24
05th Dec.	2.41	0.35	0.19
20th Dec.	2.31	0.32	0.18
LSD (P=0.05)	0.15	0.02	0.01
Varieties			
HS- 490	2.63	0.38	0.22
VL- 829	2.20	0.31	0.18
VL- 892	2.55	0.37	0.22
VL- 907	2.62	0.38	0.22
LSD (P=0.05)	0.22	0.04	0.02

December. Both years, the maximum HUE (2.86 kg/°C days), HTUE (0.42kg/°C day hour) and PTUE (0.24 kg/°C day hour) were found in 20th November (Table 4). Whereas, minimum HUE and HTUE, PTUE were recorded in 20th December (2.31, 0.32 and 0.18, respectively). The efficiencies were higher in November sowing dates due to higher yield during November sowing as compared to the delayed sowings. Sattar *et al.* (2015) also reported higher heat use efficiency, while as Girijesh *et al.* (2011) reported higher helio thermal use efficiency within optimum sowing window.

CONCLUSION

The crop sown on 20th October could took maximum calendar days hence, higher growing degree days, photo-thermal units and helio-thermal units for all the stages which were considerably reduced with subsequent delay in sowing. Thus, wheat crop sown on 20th November recorded the highest grain yield closely followed by 5th November sown crop. Among the varieties the timely sown wheat varieties 'VL-829' acquired maximum thermal units and produced maximum yield because of longer duration. HS-490 and VL-907 have potential to efficiently convert the heat units into the economic yield and biomass.

REFERENCES

Bishnoi, O.P., Singh, S. and Niwas, R. (1996). Testing and validation of CERES-wheat model in different environments. *Agricultural Science Digest,* Karnal, 16 (2): 101-104.

Bist, H., Singh, D.K., Shaloo, Mishra, A.K., Sarangi, A., Prajapati, V.K., Singh, M. and Krishnan, P. (2019). Heat unit requirement of wheat under different thermal and moisture regimes. *J. Agrometeorol.,* 21(1):36-41.

FAO. (2017). Food and Agriculture Organization of the United Nations. http://FAOSTAT.fao.org [18th Feb, 2019]

Girijesh, G.K., Kumara, A.S., Sridhara, S., Kumar, D.M., Vageesh, T.S. and Nataraju, S.P. (2011). Heat use efficiency and helio-thermal units for maize varieties as influenced by dates of sowing under southern transitional zone of Karnataka state. *International J. Sci. Nature,* 2:529-33.

Hari Ram, Singh, G., Mavi, G.S. and Sahu, V.S. (2012). Accumulated heat unit requirement and yield of irrigated wheat wheat (*Tritium aestivum* L.) varieties under different crop growing environment in central Punjab. *J. Agrometeorol.,* 14(2): 147-153.

Hundal, S.S., Singh, R. and Dhaliwal, L.K. (1997). Agro-climatic indices for predicting phenology of wheat (*Triticum aestivum*) in Punjab. *Indian J. Agric. Sci.,* 67(6): 265-268

Mishra, S.K., Shekh, A.M., V. Pandey, Yadav, S.B. and Patel, H.R. (2015). Sensitivity analysis of four wheat cultivars to varying photoperiod and temperature at different phonological stages using WOFOST model. J. Agrometeorol., 17(1): 74-79.

Sattar, A., Iqbal, M.M., Areeb, A., Ahmed, Z., Irfan, M., Shabbir, R.N., Aisha, G. and Hussian, S. (2015). Variety variation in wheat for phenology and accumulative heat unit under different sowing times. *J. Environ. Agric. Sci.,* 2:1-8.

Singh, S. and Pal, M. (2003). Growth, yield and phonological response of wheat cultivars to delayed sowing. Indian Journal of Plant Physiology, 8: 277-286.

Wardlaw, I.F. and Wringley, C.W. (1994). Heat tolerance in temperate cereals. An Overview. Australian Journal of Plant Physiology, 21: 695-703.

Received : April 2019 : Accepted : August 2019