Plant Archives Vol. 17 No. 2, 2017 pp. 1439-1443 ***ISSN 0972-5210***

AGRO METEOROLOGICAL INDICES INFLUENCED BY VARYING SOWING ENVIRONMENT AND VARIETIES OF WHEAT UNDER SUB-TEMPERATE CLIMATE OF HIMACHAL PRADESH, INDIA

Karan Verma*, Ranbir Singh Rana and Pankaj Chopra

Department of Agronomy, Forages and Grassland Management, C.S.K. Himachal Pradesh Krishi Vishvavidyalaya, Palampur - 176 062 (Himachal Pradesh), India.

Abstract

A field experiment was conducted during *Rabi* 2011-12 and 2012-13 at department of Agronomy, CSK HPKV, Palampur (H.P.), India. The experiment comprising of four dates of sowing *viz.* October 20, November 10, November 30 and December 20 and three genotypes *viz*. HPW-249, HPW-155 and HPW-42 laid out in Randomized Block Design. The agrometeorological indices indicated more values for October 20 to November 30 sown crops and lowest values in late sown crop. Days to physiology maturity, vegetative stage, days to complete emergence and days to heading matched closely with observed values for all sowing environments. Revealed that variety HPW-249 gave significantly highest grain yield (41.3 q ha^{-1} during 2011-12 and 44.2 q ha^{-1} during 2012-13) as compared to HPW-155 and HPW-42 during both the years. Amongst dates of sowing, 20^{th} October sown crop significantly out yielded the subsequent dates of sowing (43.0 q ha^{-1} during 2011-12 and 45.6 q ha^{-1} during 2012-13) during both the years.

Key words : Wheat, GDD, HTU, PTU, PTI, HUE, sowing dates, verities, growth stages and yield.

Introduction

Wheat (*Triticum aestivum* L.) is world's second important cereal crop after rice. India is second largest producer of wheat in the world after China. Area under this crop in India is 33.23 million hectare with a production of 96.53 million tonnes of production and 3.98 t/ha productivity (Anonymous, 2016). In Himachal Pradesh, this crop is presently being cultivated on 0.358 million hectare with a production of 690 thousand tones and productivity of 1.18t/ha^{-1} (Anonymous, 2015).

In general, there is paucity of information on impact of weather parameters on growth and development of different varieties of wheat except a large number of modeling studies where in variable temperatures are used at different phenophases and yields are predicted. In general, the response of weather parameters to different varieties at different growth stages is different.

Wheat (*Triticum aestivum* L.) is basically a long day crop of the temperate region and requires relatively low temperature for satisfactory growth. Among the climatic factors, temperature plays a key role in determining the sowing time and consequently the duration of different phenophases, which affect the crop productivity (Tewari and Singh, 1993).

Wheat (*Triticum aestivum* L.) is world's second important cereal crop after rice. India is second largest producer of wheat in the world after China with about 12 per cent share in total world wheat production.

Prabhakar *et al*. (2007) November to December and and four varieties (DWR-162, DWR-195, DWR-185 and DWR-1013) on phenological development, growth and productivity of wheat under Raichur (Karnataka, India) conditions. Maximum GDD (1989) and PTU (14760) were recorded in DWR-1013 followed by DWR-185, DWR-162 and DWR-195. It was concluded that GDD and PTU could also be used as tools for recommending the optimum sowing period for wheat genotypes.

Kumari *et al*. (2009) reported that the maximum differences of 7.5^0C in temperature were observed at the milking stage between very late (19^{th} December) and normal sown (19^{th} November) conditions and exhibited

***Author for correspondence :** E-mail: karanverma2123@gmail.com

maximum heat use efficiency of 2.23 kg grain/ha degree day in timely sown wheat in agro climatic condition of Jharkhand.

Solanki (2010) advocated that the normal sowing of wheat crop around 7th November to 20th November coincided with the mean temperature regimes of 16.8 to 20.0°C, 14.5 to 18.9°C and 18.4 to 21.7°C at tillering to heading, heading to milking and milking to dough stages, respectively. The increase in 6.0°C mean temperature during 90 to 105 days after sowing caused reduction in number of effective tillers m^{-1} row at 105 days after sowing by 15 per cent. The highest grain yield was obtained under 20th November sown crop followed by 7th November sown crop under the agro-climatic conditions of Udaipur (Rajasthan), India. Similarly, Khan *et al*. (2010) revealed from their study that the highest thermal and radiation regimes of 2095°C day for GDD, 15515°C day ha^{-1} for HTU, 31880°C day h for PTU and 2140 mmol m^{-2} for PAR were associated with maximum yield from crop sown on 20th November. Grant *et al*. (2011) reported that climate warming may raise wheat (*Triticum aestivum* L.) yields in cooler climates and lower them in warmer climates.

Singh and Khushu (2012) conducted field experiments under irrigated as well as rainfed conditions and observed that the variety PBW 343 took higher thermal time (1602 degrees C days) as compared to Raj 3765 (1576 degrees C days) and RSP81 (1574 degrees C days) for attaining physiological maturity. Maximum heat use efficiency (HUE) by variety PBW343 (5.87 kg ha^{-1} degrees ^{0}C days) was found under irrigated situation as compared to other cultivars. GDD was found best indices for prediction of phenology followed by PTU, HTU.

Materials and Methods

The field experiments was conducted during the *Rabi* season of 2011-12 and 2012-13 in randomized block design (RBD) with the combination of four dates of sowing *viz*. 20th October, 10th November, 30th November, 20th December and three varieties *viz*. HPW- 249, HPW-155 and HPW- 42 replicated three times. The soil of experimental area was silty clay loam in texture, acidic in reaction, medium in available nitrogen, medium in available phosphorus, medium in organic carbon and high in available potassium.

Geographically, the experimental site is situated at 32°6' N latitude and 76°3' E longitude at an elevation of about 1290.8 m above mean sea level in North-Western Himalaya. Agro climatically the experimental area falls in sub-temperate and sub-humid zone, characterized by high rainfall with mild summers (19.0-31°C) and severe winters (3.5 13.4°C). The average rainfall of the place is 2500 mm, of which 78 percent is received during June to September. In general, the monsoon sets in during June. Winter rains usually occurs during December to February rendering October, November, April and May as dry months. Weather data recorded at the Meteorological Observatory of department of Agronomy Forages and Grassland Management during the crop season 2011-12 and 2012-13. During crop growing season from October to May in 2011-12, the weekly maximum and minimum temperature ranged between 9.8 to 35.6°C and 2.4 to 21.6°C, respectively during the entire crop growing period. The crop experienced well distributed rainfall of 509.2 mm during the crop season. The highest weekly rainfall of 76.2 mm was received during Meteorological week 7. The sunshine duration ranged 6.8 hours/day duration respectively during the season. Similarly during October to May 2012-13, the weekly maximum and minimum temperature ranged between 14.5 to 37.3°C and 2.3 to 22.6°C, respectively during ontogeny of crop. The crop experienced well distributed rainfall of 475.5 mm during the crop season. The highest weekly rainfall of 109.2 mm was received during Meteorological week 7. The sunshine duration ranged 6.2 hours/day, respectively during the season.

In general, there is paucity of information on impact of weather parameters on growth and development of different varieties of wheat except a large number of modeling studies where in variable temperatures are used at different phenophases and yields are predicted. In general, the response of weather parameters to different varieties at different growth stages is different.

Agro meteorological indices

Growing degree days (GDD)

The GDD were computed using Nuttonson (1955) method given as under:

$$GDD = (T_{max} + T_{min})/2]-T_t$$

Where,

T_{max} = Maximum temperature (°C) of the day

T_{min} = Minimum temperature (°C) of the day

T_t = Threshold temperature (4.5°C, Hundal *et al*., 1997)

GDD is expressed as degree C day, day degrees or heat units.

Photo thermal units (PTU)

The product of the growing degree days and the length of the day in hours over a given period were expressed as photo thermal units (Dhaliwal *et al*., 2007).

$$PTU = GDD \times \text{day length}$$

Helio thermal units (HTU)

Helio thermal units (HTU) were computed following methods given by Chakarvarty and Sastry (1985). In this method, the actual bright sunshine hours were used in place of total day length in PTU to arrive at heat summations. Thus, the product of day degrees and corresponding actual bright sunshine hours has been termed as helio thermal units and accumulated for the period of crop growth.

HTU =GDD × actual sunshine hours

Pheno thermal index (PTI)

The heat units accumulated per day between two phonological stages were computed to obtain phenol-thermal index (PTI), which is expressed as degree-days per growth day; following Nuttonson (1948), Chakravarty and Sastry (1983).

$$\text{PTI} = \frac{\text{Degree days consumed between two phonological stages}}{\text{Number of days between two phonological stages}}$$

Heat use efficiency (HUE)

With the view to compare the relative performance of two different genotype and treatments with respect to utilization of heat in term growing degree days during the crop growth period, heat use efficiency HUE was computed by the methods suggested by Sastry et al. 1985. It is given by the expression.

$$\text{HUE (kg ha}^{-1}\text{day}^{-1}) = \frac{\text{Accumulated dry matter (kg ha}^{-1})}{\text{Accumulated heat units (degree day }^{o}\text{C)}}$$

Grain yield (q ha^{-1})

The produce from each net plot was harvested and threshed after sun drying. The grains were cleaned and weighed after threshing. The weight of grains recorded on each plot was converted into (q ha^{-1}).

Results and Discussion

Agro meteorological indices

Growing degree days (GDD)

The data on GDD revealed that to attain complete emergence 140-164 degree days averaged over two years were accumulated in all the varieties when crop sown on 20th October. The GDD decreased with delay in sowing during both the years. However, GDD varied between 123 to 158 degree days in sowing windows from 10th November to 20th December. The lowest GDD values were observed on 20th December sown crop during both the years. Similar trends of GDD were observed in vegetative, heading and physiological maturity stages of the crop during both the years. The magnitudes of the values were highest in early sown crop of 20th October during both the years. Pooled of two years data revealed that varieties HPW-249, HPW-155 and HPW-42 accumulated 1661, 1641 and 1586 degree days in October sown crop and GDD decreased with delay in sowing windows. The GDD values varied between 1428 to 1547 degree days in all varieties in sowing windows from 10th November to 20th December. Similarly, GDD values varied between 376 to 591 degree days to attain vegetative and 851 to 853 degree days to heading stage of the crop (table 1). The possible reasons for decrease in thermal requirements with delay in sowing may be due to low temperature in late sown crop. These findings are in conformity with *Ram et al*. (2012).

Helio thermal unit (HTU)

The data on helio thermal unit (HTU) revealed that to attain complete emergence HTU accumulated in all the varieties ranged from 1657-1850 and highest values were observed in all varieties when sown on 20th October during both the years. The HTU decreased with delayed in sowing. However, HTU varied from 1409 to 1780 in sowing windows from 10th November to 20th December during both years. The lowest HTU values were observed in 20th December sown crop. Similar trends of HTU were followed in vegetative, heading stage and physiological maturity stages of the crop. The magnitudes of the values were highest in early sown crop 20th October. Data revealed that varieties HPW-249, HPW-155 and HPW-42 accumulated HTUs to the tune of 11310, 11786 and 10169 respectively average over two years in October sown crop. The HTU value varied between 8894 to 10695 HTU for all varieties in sowing windows from 10th November to 20th December. Similarly, HTU values varied between 4652 to 5649 HTU to attain vegetative and 4685 to 9538 HTU for heading stage of the crop (Table 2). Hundal *et al.,* (1997) also observed that cumulative helio thermal units (HTU) were reduced with delay in sowing after October and this is might be due to reduction in actual sunshine hours also.

Photo thermal unit (PTU)

The data on photo thermal unit (PTU) presented in (table 3) revealed similar results and trends as observed in HTUs and GDD for all varieties and sowing environments. The studies conducted by Sharma (1993) and Ram (2012) also observed that accumulated photo thermal units (PTU) were reduced with delayed in sowing after October and this might be due to reduction in day length for late sown crop.

Pheno thermal index (PTI)

The data averaged over two years on pheno thermal index (PTI) revealed that PTI values were 11.0-13.8 in all the varieties to attain complete emergence. The highest

Table 1 : Effect of sowing dates and varieties on growing degree days (GDD) at different growth stages of wheat during 2011-12 and 2012-13 averaged over two years (pooled data).

Growth stages	HPW-249				HPW-155				HPW-42			
	20 Oct	10 Nov	30 Nov	20 Dec	20 Oct	10 Nov	30 Nov	20 Dec	20 Oct	10 Nov	30 Nov	20 Dec
Days to complete emergence	164	157	150	141	162	154	150	142	161	150	151	140
Days to vegetative stage	553	506	469	452	529	499	485	510	529	475	462	401
Days to heading	827	821	808	735	833	772	754	723	821	799	785	767
Days to physiological maturity	1662	1552	1531	1480	1642	1571	1521	1451	1587	1534	1481	1452

Table 2 : Effect of sowing dates and varieties on Helio Thermal Unit (HTU) at different growth stages of wheat during 2011-12 and 2012- 13 averaged over two years (pooled data).

Growth stages	HPW-249				HPW-155				HPW-42			
	20 Oct	10 Nov	30 Nov	20 Dec	20 Oct	10 Nov	30 Nov	20 Dec	20 Oct	10 Nov	30 Nov	20 Dec
Days to complete emergence	1694	1629	1554	1443	1769	1688	1585	1489	1719	1584	1495	1458
Days to vegetative stage	5434	5062	4954	4851	5542	5442	5331	4997	5442	5089	4979	4903
Days to heading	8134	7694	7056	6947	8120	7912	7831	7650	7177	6666	6571	6514
Days to physiological maturity	11310	10276	9286	9059	11787	10764	9938	9672	10170	10074	9568	8740

Table 3 : Effect of sowing dates and varieties on Photo Thermal Unit (PTU) at different growth stages of wheat during 2011-12 and 2012-13 averaged over two years (pooled data).

Growth stages	HPW-249				HPW-155				HPW-42			
	20 Oct	10 Nov	30 Nov	20 Dec	20 Oct	10 Nov	30 Nov	20 Dec	20 Oct	10 Nov	30 Nov	20 Dec
Days to complete emergence	1774	1625	1511	1445	1733	1654	1569	1495	1746	1596	1529	1470
Days to vegetative stage	6540	6285	6163	5547	5609	5600	5512	5385	5372	5205	4998	4853
Days to heading	9378	8669	8520	8398	9321	9107	8574	8331	8986	8420	8124	7845
Days to physiological maturity	16080	15533	13217	11185	15915	15332	14355	13976	16373	15071	13861	13296

PTI values were observed in crop sown on 20th October for all varieties. Likewise, GDD the PTI values decreased when sowing was delayed. However, PTI varied from 6.9 to 12.8 in sowing windows from 10th November to 20th December. The lowest PTI values were observed in 20th December sown crop. Amongst dates and different stages of crop, the lowest values were obtained during vegetative stages of crop. The values were highest in early sown crop on 20th October. The varieties *viz*. HPW-249, HPW-155 and HPW-42 observed 10.4, 17.7 and 17.2 PTI values averaged over two years, respectively in October sown crop. Similarly, PTI values varied between 6.7 to 9.8 to attain vegetative and 13.9 to 15.4 for heading stage of the crop (table 4). Similar results were reported by Kumari *et al*. (2009) under Jharkhand conditions.

Heat use efficiency (HUE)

The data presented in (table 5) revealed that heat use efficiency (HUE) values averaged over two years to attain complete emergence were 0.07-0.09 in sowing windows from 20 October to 20th December irrespective of all varieties. The HUE decreased with delayed in sowing. However, HUE values varied from 0.04 to 0.09 during sowing windows from 10th November to 20th December. The lowest HUE values were observed in 20th December sown crop. Similar trends of HUE were followed in vegetative, heading stage and physiological maturity stages of the crop. However, the HUE values varied between 0.3 to 1.4 during heading and 3.4 to 8.5 in physiological maturity stages of the crop. The magnitudes of the values were highest in early sown crop 20th October. The results indicated that varieties *viz*. HPW-249, HPW-155 and HPW-42 showed 4.6, 5.3 and 4.2 HUEs values, respectively in October sown crop and it decreased with delay in sowing windows. Amongst dates of sowing, the values of HUE were different for the different dates of sowing and did not follow deceasing trend with delay in sowing. The results reported by Solanki (2010) under Udaipur, Rajasthan conditions revealed inconsistent trends within different genotypes and sowing environments of wheat crop. Bhosale (2009) also reported similar findings in mustard crop grown during *Rabi* season under similar agro-climatic conditions.

Grain yield (q ha^{-1})

The data presented in (table 6) revealed that variety HPW-249 gave significantly highest grain yield (41.3 q ha^{-1} during 2011-12 and 44.2 q ha^{-1} during 2012-13) as

Table 4 : Effect of sowing dates and varieties on Pheno Thermal Index (PTI) at different growth stages of wheat during 2011-12 and 2012-13 averaged over two years (pooled data).

Growth stages	HPW-249				HPW-155				HPW-42			
	20 Oct	10 Nov	30 Nov	20 Dec	20 Oct	10 Nov	30 Nov	20 Dec	20 Oct	10 Nov	30 Nov	20 Dec
Days to complete emergence	13	12	11	10	12	11	11	8	12	11	10	10
Days to vegetative stage	9	8	8	10	8	9	8	9	7	9	9	8
Days to heading	15	15	15	14	14	14	15	14	15	15	15	15
Days to physiological maturity	17	18	18	17	18	18	18	18	17	18	17	17

Table 5 : Effect of sowing dates and varieties on Heat Use Efficiency (HUE) at different growth stages of wheat during 2011-12 and 2012-13 averaged over two years (pooled data).

Growth stages	HPW-249				HPW-155				HPW-42			
	20 Oct	10 Nov	30 Nov	20 Dec	20 Oct	10 Nov	30 Nov	20 Dec	20 Oct	10 Nov	30 Nov	20 Dec
Days to complete emergence	0.09	0.07	0.07	0.04	0.08	0.08	0.07	0.07	0.08	0.08	0.08	0.08
Days to vegetative stage	0.6	0.7	0.6	1.5	0.7	0.8	0.6	1.5	0.7	0.7	0.8	1.1
Days to heading	7.9	8.2	7.4	7.9	4.8	3.4	3.5	6.2	6.1	3.6	5.8	5.7
Days to physiological maturity	5.3	5.7	4.9	5.1	5.0	4.4	4.6	5.7	3.9	5.0	5.2	5.3

Table 6 : Effect of sowing dates and varieties on yield of wheat during 2011-12 and 2012-13.

	Grain yield (q ha^{-1})	
	2011-12	**2012-13**
Variety HPW-155	38.7	41.3
HPW-249	41.3	44.2
HPW-42	37.6	39.8
CD (5%)	2.2	1.8
Dates of sowing		
20 Oct	43.0	45.6
10 Nov	41.5	44.4
30 Nov	37.8	40.4
20 Dec	34.5	36.6
CD (5%)	2.5	2.1

compared to HPW-155 and HPW-42 during both the years. Amongst dates of sowing, 20th October sown crop significantly out yielded the subsequent dates of sowing (43.0 q ha^{-1} during 2011-12 and 45.6 q ha^{-1} during 2012-13) during both the years.

References

Anonymous (2015). *Economic survey of Himachal Pradesh*. pp 43-47.

Anonymous (2016). Food and Agriculture Organization of the United Nations. *http://FAOSTAT.fao.org*

Grant, R. F., B. A. Kimball, M. M. Conley, J. W. White, G. W. Wall and M. J. Ottman (2011). Controlled warming effects on wheat growth and yield : field measurements and modeling. *Agronomy Journal*, **103** : 1742-1754.

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

Khan, S. A., A. Marak, A. Gupta and K. Sarmah (2010). Effects of dates of on phenology, thermal and radiation regimes, and yield of wheat. *Journal of Agrometeorology*, **12** : 53-57.

Kumari, P., A. Wadood, R. S. Singh and R. Kumar (2009). Response of wheat crop to different thermal regimes under the agro-climatic conditions of Jharkhand. *Journal of Agrometeorology*, **11** : 85-88.

Kumari, P., A. Wadood, R. S. Singh and R. Kumar (2009). Response of wheat crop to different thermal regimes under the agro-climatic conditions of Jharkhand. *Journal of Agrometeorology*, **11** : 85-88.

Prabhakar, B. N., A. S. Halepyati, B. K. Desai and B. T. Pujari (2007). Growing degree days and photo thermal units accumulation of wheat (*Triticum aestivum* L. and *T. durum* Desf.) genotypes as influenced by dates of sowing. *Journal of Agricultural Sciences*, **20** : 594-595.

Solanki, N. S. (2010). Response of wheat (*Triticum aestivum* L.) under varying weather environment. Impact of Climate Change on Agriculture in Workshop Proceedings 58-61.

Sharma, V. (1993). Comparative performance of late sown rainfed *Rabi* crops under different moisture conservation practices. *Ph.D. Thesis*, Himachal Pradesh Krishi Vishvavidyalaya, Palampur.

Ram, H., G. Singh, G. S. Mavi and V. S. Sohu (2012). Accumulated heat unit requirement and yield of irrigated wheat (*Triticum aestivum* L.) varieties under different crop growing environment in central Punjab. *Journal of Agrometeorology*, **14(2)** : 147-153.

Singh, M. K. and M. S. Khushu (2012). Growth and yield prediction of wheat in relation to agro climatic indices under irrigated and rainfed condition. *Journal of Agrometeorology*, **14** : 63-66.

Tewari, S. K. and M. Singh (1993). Yielding ability of wheat at different dates of sowing : a temperature development performance. *Indian Journal of Agronomy*, **38** : 204-209.