Effect of sowing dates and wheat cultivars on agro meteorological indices of wheat under conditions of North-Western Himalayas

Abstract

A field investigation was conducted in *rabi* season of 2016-17 at Research farm, Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur to evaluate the influence of sowing dates and wheat cultivars on agro-meteorological indices such as growing degree days, photothermal units, Helio thermal units and phenothermal index of wheat crop. The field investigation involved five sowing dates (15thOctober, 30th October, 15th November, 30th November and 15th December) and wheat cultivars (HPW-349 and HPW-155) which were studied in a factorial randomized block design with three replications. The results of the investigation revealed that timely sown crop i.e., on 15th October recorded the highest values for agro-meteorological indices for both the wheat cultivars such as growing degree days, Helio thermal units, photothermal units and phenothermal index across various wheat development stages such as complete emergence, crown root initiation, tillering, ear emergence and physiological maturity. Therefore, timely sowing of wheat by 15th October was concluded to be the best for optimized agro-meteorological indices such as growing degree days, photothermal units, Helio thermal units and phenothermal index under conditions of North-Western Himalayas.

Introduction

Wheat being a staple food for the global population supplies 20% of global protein and dietary supply (Kettlewell*et al.*, 2023). Globally, wheat cultivation covers an acreage of 219 million hectares producing around 808.4 million tons of wheat (FAOSTAT, 2024). Among various countries, China is the global leader in wheat production whereas India has been the second significant producer of wheat with production of around 107.7 million tons from an area of 30.4 million hectares. In North-western Himalayas of India, a mountainous state Himachal Pradesh produces a considerable amount of wheat i.e., 609.31 thousand tones from an area of 319.476 thousand hectares(Department of Agriculture, 2022-23).

Rising temperatures are one of the malign effects of changing climate leading to several issues over wheat production in India as well as globally. Impact of elevated temperature can be seen especially during the reproductive stages of wheat with considerably alterations in wheat phenology as well as reduced wheat grain yield (Zhu *et al.,* 2018; Sattar and Srivastava, 2021). Along with higher temperature, dry western winds when occurs at flowering to milking stage of wheat, leads to reduction in period of grain filling and shrinkage of wheat grains (Vashisth*et al.*, 2020). To study the response of crops to differential temperature regimes, varying of sowing dates can be a great option. Sowing crop at different times or dates, expose the crop at various phenological phases to prevailing weather conditions specifically temperature and atmospheric winds. Several agrometeorological indices such as growing degree days (GDD), photo-thermal units (PTU), Helio-thermal units (HTU) and photothermal index can be studied to investigate the response of crop to temperature and have critical insights into wheat productivity at differential temperature regimes (Sattar *et al.*, 2023).

Considering the issues of rising temperature-based heat stress and variability in annual wheat yield, and availability of limited scientific investigation-based information on effect of variable sowing dates and wheat cultivars over agro-meteorological indices especially growing degree days, photo-thermal units, Helio-thermal units and photothermal index especially under the limited irrigation conditions, we planned to carry out a field investigation under the conditions of North-western Himalayas. The present investigation was based on hypothesis that optimized sowing dates and wheat cultivars can offset the negative impacts of temperature-based heat stress.

Material and Methods

The present field study was conducted at Research Farm of Department of Agronomy, CSKHPKV, Palampur located in the mid hills sub-humid zone of Indian North-western state of Himachal Pradesh. The region can be characterized for mild summers, cool winters, annual rainfall ranging from 1500-2500 mm and mean elevation above sea level of 1290.8 m. During the cropping season, the maximum temperature ranged from 10-34^{0}C whereas the minimum temperature ranged from 0.5 to 25.5^{0}C. Higher values for maximum temperature was recorded in the 19th meteorological week (34^{0}C) whereas for minimum temperature highest values were recorded in the 16th meteorological week (25.5^{0}C). The maximum temperature remained above 25^{0}C for the crop growing period from 13th to 19th meteorological week. The lowest values for the maximum (10^{0}C) and minimum temperature (0.5^{0}C) were recorded in the 2nd

meteorological week. The crop received a well distributed rainfall of 370.8 mm with average weekly rainfall of 78.6 mm. The relative humidity was recorded to be the highest for the 3rd meteorological week (89%) whereas the lowest values for relative humidity was recorded for the 19th meteorological week (49%).

Experimental field

A composite soil sample (0-15 cm) was collected from the experimental field using stainless steel auger to determine the initial physicochemical properties i.e., before initiation of the field experiment. The soil at the experimental field can be characterized for silty clay loam texture, acidic soil reaction, medium available nitrogen, phosphorus, organic carbon and high available potassium.

Experimental details

The present field study was conducted in a factorial randomized block design with ten treatments based on five sowing dates i.e., 15th October, 30th October, 15th November, 30th November and 15th December and two wheat cultivars i.e., HPW-349 and HPW-155 which were replicated thrice. The experiment consisted of plots with gross and net plot size of 16.8 and 13 m^2. The fields were prepared before sowing thoroughly using twoploughings and a levelling practice. The seed rate was 100 kg/ha. The row spacing was kept at 22 cm. The recommended fertilizers were applied at the rate of 120, 60 and 30 kg/ha for nitrogen, phosphorus, and potassium, respectively. The fertilizer application schedule was based on application of half of the recommended nitrogen, full of phosphorus and potassium as basal whereas rest of nitrogen was applied as top dressing at crown root initiation stage. Weeds were managed using isoproturon at the rate of 1.25 kg/ha followed by a single hand weeding. The harvesting as well as threshing was carried out manually(Rana *et al.,* 2014).

Agrometeorological observations

The agro-meteorological indices were derived using the below given equations (Kumari *et al.,* 2009; Deep *et al.,* 2022):

1. $Growing\ degree\ days\ (GDD) = \Sigma[(Tmax + Tmin)/2 - Tb]$

(T_b = Base temperature= 4.5^{0}C)

2. $Helio - thermal\ unit\ (HTU) = GDD \times Duration\ of\ sunshine\ hour$

3.$Phenothermal\ index\ (PTI) = GDD \div Growth\ days$

4. $Photothermal\ unit\ (PTU) = GDD \times Day\ length$

Data analysis

The data presented underwent analysis using procedures for factorial randomized block design (FRBD) (Gomez and Gomez, 1984). The treatment mean variation was assessed at 5% level of significance using critical difference.

Results and discussion

Growing degree days (GDD)

The perusal of the data presented din the Table 1. revealed that growing degree days varied significantly for the wheat sowing dates during the present field investigation. For the wheat cultivar HPW-349 sown on 15th October, crop accumulated around 131.3, 375.9-, 757.1-, 1216.1- and 1601.5-degree days for complete emergence, crown root initiation, tillering, ear emergence and physiological maturity whereas the crop sown on 15th December accumulated around 116.2, 201.0-, 385.6-, 1095.7- and 1474.0-degree days for complete emergence, crown root initiation, tillering, ear emergence and physiological maturity, respectively.

In case of wheat cultivar, HPW-155, the crop sown 15th October recorded around 131.3, 364.2, 746.1, 1195.7 and 1564.9 for complete emergence, crown root initiation, tillering, ear emergence and physiological maturity, respectively whereas for the 15th December sown crop accumulated around 116.2, 208.8-, 393.6-, 1078.2- and 1464.3-degree days for complete emergence, crown root initiation, tillering, ear emergence and physiological maturity, respectively.

A consistent reduction in growing degree days was observed with delay in crop sowing at various crop development stages. The highest growing degree days were accumulated for the 15th October sown crop whereas the least for 15th December sown crop. The variance in growing degree days can be attributed considerably to the atmospheric temperature to which the crop is exposed during various sowing dates across different development stages. The crop sown on 15th December accumulated growing degree days faster than the crop sown on 15th October i.e., in a lesser number of days having considerable influence over crop yield (Aslam *et al.,* 2017). Similarly, a field investigation by Aslam and his co-workers in 2017 based on evaluation of correlation between growing degree days and wheat phenology, it was found that experiencing higher temperatures than optimum accelerates the process to accumulate growing degree days for wheat leading to considerable reduction in grain yield.

Helio thermal units (HTU)

Helio thermal units varied significantly across variable sowing dates for both the wheat cultivars i.e., HPW-349 and HPW-155. The highest heat thermal units were observed for the 15^{th} October sown crop at respective crop development stages such as complete emergence, crown root initiation, tillering, ear emergence, physiological maturity i.e., 1436.2, 4054.1, 7940.2, 12770.5, 17555.6 and 1436.2, 3931.2, 7829.6, 12543.8, $17073.0^{0}C$ day hour for HPW-349 and HPW-155 wheat cultivar, respectively. The heat thermal units were found to be declined with the delay in sowing of wheat from 15^{th} October to 15^{th} November and 15^{th} December consequently. The lowest heat thermal units were observed for the 15^{th} sown December crop for the respective wheat development stages such as complete emergence, crown root initiation, tillering, ear emergence, physiological maturityi.e., 1168.84, 2084.0, 3963.1, 12782.3, 17349.9 and 1168.8, 2112.2, 4050.1, 12545.7, $17124.0^{0}C$ day hour for HPW-349 and HPW-155 wheat cultivar, respectively.

The consumption of higher Helio thermal units for the timely sown crop (15^{th} October) can be attributed to accumulation for considerably higher growing degree days as well as longer phenophases. Similarly, the crop sown delayed (15^{th} December) consumed comparatively lower Helio thermal unit due to substantially lower accumulation of growing degree days as well as reduction in bright sunshine hours in the peak winter months. Deep et al. 2023 also reported considerably higher Helio thermal unit consumption for timely sown crop compared to late sown wheat crop. Similarly, Pathania et al. 2019 reported considerably higher Helio thermal units for the timely sown wheat crop as compared to late sown crop.

Photothermal units (PTU)

Photothermal units varied considerably in response to variable sowing dates of wheat crop for both the cultivars i.e., HPW-349 and HPW-155. For both the wheat cultivars, the highest photothermal units were recorded for the crop sown on 15^{th} October whereas the least photothermal units were reported for the 15^{th} December sown crop. In case of wheat cultivar

HPW-349, the estimated photothermal units for crop sown on 15th October at different crop development stages such as complete emergence, crown root initiation, tillering, ear emergence, physiological maturity were1247.5, 3370.4, 6218.1, 8680.1, 11508.0 whereas for 15th December sown crop were 870.7, 1354.1, 2081.9, 7287.7, 10290.2^{0}C day hour. Similarly for wheat cultivar, the estimated photothermal units for crop sown on 15th October at different crop development stages such as complete emergence, crown root initiation, tillering, ear emergence, physiological maturity was1247.5, 3299.9, 6119.1, 8536.5,11180.0whereas for 15th December sown crop was870.7, 1361.6, 2161.9, 7095.2, 10103.4^{0}C day hour.

The optimal sowing of the wheat crop resulted in the considerably higher number of days to complete growing degree days as well as longer phenophasic duration, whereas the later sowing with reduced number of days to complete growing degree days and shorter phenophasic duration was responsible for comparatively lesser consumption of thermal units at different crop development stages of wheat (Singh *et al.,* 2016). Similarly to the present investigation, Pathania et al. 2019 reported considerably higher consumption of photothermal units for crop sown on 20th October as compared to crop sown in the month of November (5th and 20th November) or December (5th and 20th December). Deep et al. 2023 also reported considerably higher consumption of photothermal units for November sown crop as compared to December sown crop.

Phenothermal Index (PTI)

The phenothermal index was significantly influenced for wheat cultivars under the influence of sowing dates. The phenothermal index was found to be significantly higher for 15th October sowing date for both the cultivars at crop development stages such as complete emergence, crown root initiation, tillering, ear emergence and physiological maturity. However, a decline in phenothermal index was observed with delay in sowing of wheat for subsequent delayed sowing dates i.e., comparatively from 15th October to 15thNovember or 15th December. The lowest phenothermal index was recorded for the crop sown on 15th December. Among various crop development stages for the two wheat cultivars (HPW-349, HPW-155), PTI values decreased continuously from complete emergence till ear emergence followed by a considerable increase till physiological maturity. The shorter duration of crop development stages especially in reproductive phase i.e., accelerated maturity due to rising atmospheric temperature for delayed sown crop was the major reason for lower values of phenothermal index for late sown crop. However, contrary to this, optimum duration between phenological stages lead to comparatively higher values of photothermal index for timely sown crop (Ram *et al.,* 2017). A decline in values of phenothermal index with delayed sowing of wheat was also observed by Kumari et al. 2009. The researchers further reiterated that there was a decline in PTI values till reproductive stages which increased again till maturity of the wheat crop.

Conclusion

The outcomes of the present investigation concluded sowing of wheat on 15th October as the optimized sowing date for the wheat cultivars (HPW-349 and HPW-155) for considerably better values of agro-meteorological indices such as growing degree days, photothermal units, Helio-thermal units and photothermal index of wheat at various crop development stages such as complete emergence, crown root initiation, tillering, ear emergence and physiological maturity under conditions of North-Western Himalayas.

References

Aslam MA, Ahmed M, Stöckle CO, Higgins SS, Hassan FU and Hayat R. 2017. Can growing degree days and photoperiod predict spring wheat phenology?. *Frontiers in Environmental Science* 5: 57.

Deep P, Khichar ML, Niwas R and Singh M. 2023. Effects of sowing dates on phenology, radiation interception and yield of wheat. *MAUSAM* 74(3): 807-814.

Department of Agriculture. 2022-23. Statement showing crop-wise area, production and productivity of principal crops in Himachal Pradesh. Himachal Pradesh. https://agriculture.hp.gov.in/en/production-2/

FAOSTAT. 2024. Food and Agriculture Organization. Rome, Italy. https://www.fao.org/faostat/en/#data

Gomez KA and Gomez AA. 1984. Statistical Procedure for Agricultural Research. 2nd edition. Wiley Inter Science, New York, USA. p 680

Kettlewell P, Byrne R and Jeffery S. 2023. Wheat area expansion into northern higher latitudes and global food security. *Agriculture, Ecosystems & Environment* 351: 108499.

Kumari P, Wadood A, Singh RS and Kumar R. 2009. Response of wheat crop to different thermal regimes under the agroclimatic conditions of Jharkhand. *Journal of Agrometeorology* 11(1): 85-88.

Pathania R, Prasad R, Rana RS and Mishra SK. 2019. Heat unit requirement and yield of wheat (Triticum aestivum L.) varieties under different growing environment in mid hill conditions of Himachal Pradesh. *Journal of Agrometeorology* 21(3): 282-287.

Ram H, Gupta N, Mavi GS, Sarlach RS and Singh G. 2017. Phenology, photo-thermal units requirement and productivity of wheat varieties as influenced by sowing dates under irrigated conditions in Punjab. *Journal of Crop and Weed* 13(3): 73-77.

Rana KS, Choudhary AK, Sepat S, Bana RS and Dass A. 2014. Methodological and analytical agronomy. New Delhi: ICAR-IARI.

Sattar A and Srivastava RC. 2021. Modelling climate smart rice-wheat production system in the middle Gangetic Plains of India. *Theoretical and Applied Climatology* 144: 77–91. doi: 10.1007/s00704-020-03497-6.

Sattar A, Nanda G, Singh G, Jha RK and Bal SK. 2023. Responses of phenology, yield attributes, and yield of wheat varieties under different sowing times in Indo-Gangetic Plains. *Frontiers in Plant Science* 14: 1224334.

Sattar A, Gulab S, Singh Shruti V, Mahesh K, Vijaya Kumar P and Bal SK. 2020. Evaluating temperature thresholds and optimizing sowing dates of wheat in Bihar. Journal of Agrometeorology 22: 158–164. doi: 10.54386/jam.v22i2.156.

Singh S, Kingra PK and Singh SP. 2016. Heat unit requirement and its utilisation efficiency in wheat under different hydrothermal environments. *Annals of Agricultural Research 37*(2): 130-140.

Vashisth A, Goyal A and Krishnan P. 2020. Effect of weather variability on growth and yield of wheat crop under semi-arid region of India. *Journal of Agrometeorology* 22(2): 124–131. doi: 10.54386/jam.v22i2.152.

Zhu P, Jin Z, Zhuang Q, Ciais P, Bernacchi C, Wang X,Makowski D andLobell D. 2018. The important but weakening maize yield benefit of grain filling prolongation in the US Midwest. *Global Change Biology* 24: 4718–4730. doi: 10.1111/gcb.14356.

Table 1.Effect of varieties and sowing dates on GDD at different growth stages of wheat

Sowing window	Growth stages									
	HPW-349					HPW-155				
	Days to complete Emergence	Days to CRI	Days to Tillering	Days to Ear Emergence	Days to Physio-logical maturity	Days to complete Emergence	Days to CRI	Days to Tillering	Days to Ear Emergence	Days to Physio-logical maturity
15th October	131.3	375.9	757.1	1216.1	1601.5	131.3	364.2	746.1	1195.7	1564.9
30th October	107.2	311.6	665.0	1112.3	1583.3	107.2	298.3	656.0	1105.1	1548.8
15th November	125.4	301.5	510.3	1019.9	1543.1	125.4	294.0	502.5	1008.2	1519.3
30th November	114.5	263.7	443.5	1060.7	1501.4	114.5	256.7	428.8	1023.9	1467.4
15th December	116.2	201.0	385.6	1095.7	1474.0	116.2	208.8	393.6	1078.2	1464.3

Table 2. Effect of varieties and sowing dates on HTU at different growth stages of wheat

Sowing window	Growth stages									
	HPW-349					**HPW-155**				
	Days to complete Emergence	Days to CRI	Days to Tillering	Days to Ear Emergence	Days to Physio-logical maturity	Days to complete Emergence	Days to CRI	Days to Tillering	Days to Ear Emergence	Days to Physio-logical maturity
15th October	1436.2	4054.1	7940.2	12770.5	17555.6	1436.2	3931.2	7829.6	12543.8	17073.0
30th October	1155.1	3278.9	6849.9	11677.8	17842.3	1155.1	3143.0	6758.2	11594.8	17376.1
15th November	1296.4	3077.4	5189.6	10868.3	17850.6	1296.4	3002.1	5110.0	10715.2	17523.7
30th November	1157.33	2657.8	4503.6	11851.3	17845.7	1157.3	2587.1	4350.6	11364.5	17373.4
15th December	1168.84	2084.0	3963.1	12782.3	17349.9	1168.8	2112.2	4050.1	12545.7	17124.0

Table 3.Effect of varieties and sowing dates on PTU at different growth stages of wheat

Sowing window	Growth stages									
	HPW-349					HPW-155				
	Days to complete Emergence	Days to CRI	Days to Tillering	Days to Ear Emergence	Days to Physio-logical maturity	Days to complete Emergence	Days to CRI	Days to Tillering	Days to Ear Emergence	Days to Physio-logical maturity
15th October	1247.5	3370.4	6218.1	8680.1	11508.0	1247.5	3299.9	6119.1	8536.5	11180.0
30th October	914.5	2471.1	5045.3	7484.4	11098.1	914.5	2384.9	4973.3	7484.4	10718.6
15th November	909.6	2248.9	3617.4	6492.7	11087.0	909.6	2188.9	3603.1	6375.2	10825.8
30th November	899.2	2001.5	2789.9	6925.0	10815.0	899.2	1945.5	2752.9	6630.2	10507.5
15th December	870.7	1354.1	2081.9	7287.7	10290.2	870.7	1361.6	2161.9	7095.2	10103.4

Table 4. Effect of varieties and sowing dates on PTI at different growth stages of wheat

Sowing window	Growth stages									
	HPW-349					HPW-155				
	Days to complete Emergence	Days to CRI	Days to Tillering	Days to Ear Emergence	Days to Physio-logical maturity	Days to complete Emergence	Days to CRI	Days to Tillering	Days to Ear Emergence	Days to Physio-logical maturity
15th October	14.5	12.9	11.1	9.2	9.5	14.5	13.0	11.1	9.2	9.4
30th October	11.9	11.1	9.7	8.6	9.5	11.9	11.0	9.7	8.6	9.4
15th November	10.4	10.1	8.1	8.0	9.8	10.4	10.1	8.2	8.0	9.7
30th November	9.5	8.7	7.1	8.6	10.0	9.5	8.8	7.1	8.4	9.9
15th December	8.3	6.4	6.6	9.1	10.3	8.3	6.3	6.6	9.1	10.3