

Pentad wise variability in heat use efficiency (HUE) of wheat (*Triticum aestivum* L.) during different sowing windows under Punjab conditions

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Wheat is an important staple crop of the world and is a major constituent of Indian agriculture. It covers more than 30 million hectares in India and 35 lakh hectares in Punjab (Anonymous, 2019). Being a thermo-sensitive crop, it is highly affected by the temperature conditions that prevail during the growing season (Nagarajan *et al.* 2008). As this crop requires cold weather during early growth period followed by warm weather at maturity, so any deviation from the normal temperature significantly affects its growth and yield. Several studies reported that temperature above 25 °C or below 10 °C than optimum (12-25 °C) has deleterious effect on phenology and lowers wheat yield (Hakim *et al.* 2012).

Climate is the main deciding factor of agricultural production and plays an important role in Indian economy. Intergovernmental Panel on Climate Change in its fourth assessment report pinpointed that Earth's mean temperature has increased by 0.6°C in the 20th century and it may increase up to 0.4-2.6°C by 2046-2065 and 0.3-4.8°C during 2081-2100 with respect to base period of 1986-2005 (IPCC, 2014). And this increasing temperature is considered a major challenge for high wheat productivity. High temperature during early phase of the crop results in scanty vegetative growth, sparse tillering and early heading while, at grain development stage results in premature ripening and shriveled grains, ultimately lowering the final yield (Reddy 2006). Rao *et*

al. (2015) reported that mean wheat yield reduced by 7 % under Indo-Gangetic conditions during 1980-2011 with 1°C increase in minimum temperature.

Growing degree days (GDD) is the atmospheric energy that a plant utilizes to grow over the phenological stages up to the harvesting stage. GDD values are calculated from phenological dates during the growth period and daily mean temperature of observations. Under field conditions, accumulated heat unit method can be used to identify the effect of temperature on phenology and crop yield (Gouri *et al.* 2005). Heat use efficiency (HUE) which is measured in terms of grain yield produced per unit of growing degree days was calculated for different time series and its variation was studied.

A field experiment was conducted at research farm of Punjab Agricultural University (PAU), Ludhiana (30°90'N latitude, 75°81'E longitude and altitude of 247 m from mean sea level) during *rabi* season (2019-2020). Wheat variety Unnat PBW 343 was sown on five different dates (D₁-25th October, D₂-5th November, D₃-15th November, D₄-25th November and D₅-5th December) in randomized block design. Phenological observations of crop were recorded from seedling emergence to physiological maturity for different sowing dates. And accordingly growing degree days (GDD) were calculated from the data of maximum and minimum temperature.



Calculation of GDD

$$GDD = \sum_{i=1}^n \frac{T_{\max} + T_{\min}}{2} - T_b$$

Where,

T_{max} - Maximum daily Temperature (°C),

T_{min} - Minimum daily Temperature (°C) and

T_b - Base Temperature (5°C) (Slafer and Savin, 1991)

Phenological data of the field experiment was used for calculation of accumulated growing degree days of the crop from 1990-2018.

Long term data from 1990-2018 with respect to maximum and minimum temperature was collected from the Department of Climate Change and Agricultural Meteorology, PAU Ludhiana and Indian Meteorological Department Chandigarh. District wise data on wheat productivity was collected from statistical abstracts of Punjab. However, data of Barnala, Fazilka, Pathankot, SAS Nagar and Tarn Taran Sahib was not available. Average value of wheat yield for entire district was used under all sowing windows and heat use efficiency (HUE) was calculated.

Calculation of HUE

$$HUE \text{ (kg/ha/°C day)} = \frac{\text{Yield (kg/ha)}}{\text{Accumulated GDD (°C day)}}$$

Pentad wise analysis of historical data (except P₆ - Average of 4 years) was done for the following time series:

Table 1: Time series of data for historical analysis

Time series	Range of the data for analysis
P ₁	1990-1994
P ₂	1995-1999
P ₃	2000-2004

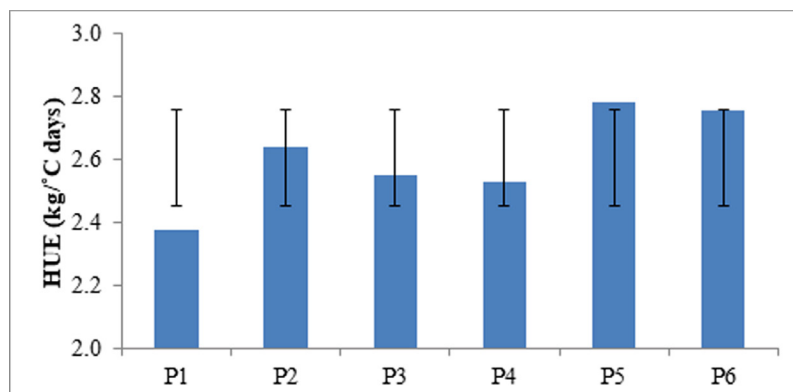


Fig 1: Variation of HUE during different Pentads under sowing window I

P ₄	2005-2009
P ₅	2010-2014
P ₆ *	2015-2018

Average value of heat use efficiency of all districts was used during different pentads to generate bar graphs and variability was studied under different sowing windows.

Effect of date of sowing on phenological behavior of wheat crop

From the field experiment, it was found that the maximum number of calendar days to reach physiological maturity was recorded for 5th November crop (156) followed by 25th October (152), 15th November (146), 25th November (137) and 5th December crop (130), respectively.

Variation of heat use efficiency (HUE) during different Pentads under different Sowing windows

Under all sowing windows, maximum variability in heat use efficiency was observed during P5 (2010-2014) and minimum during P1 (1990-1994).

Under sowing window I, the average value of HUE was 2.8 kg/ha/°C day during P5 and 2.4 kg/ha/°C day during P1 (Fig.1). However under sowing window II, HUE was 2.7 kg/ha/°C day during P5 and 2.3 kg/ha/°C day during P1 (Fig.2). Under sowing window III, value of HUE in P5 was 2.9 kg/ha/°C day and P1 was 2.5 kg/ha/°C day (Fig.3). And under sowing window IV during P5, HUE was 3.1 kg/ha/°C day and during P1 was 2.7 kg/ha/°C day (Fig.4). While under sowing window V, HUE of 3.2 kg/ha/°C day was observed during P5 and 2.8 kg/ha/°C day during P1(Fig.5). Among different sowing windows, highest value of HUE (3.2 kg/ha/°C day) was noticed under sowing window V during P5 and lowest (2.3 kg/ha/°C day) under sowing window II during P1.



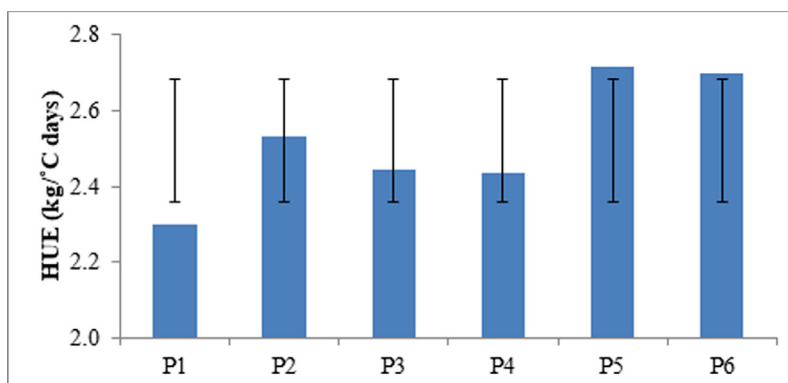


Fig 1.2: Variation of HUE during different Pentads under sowing window II

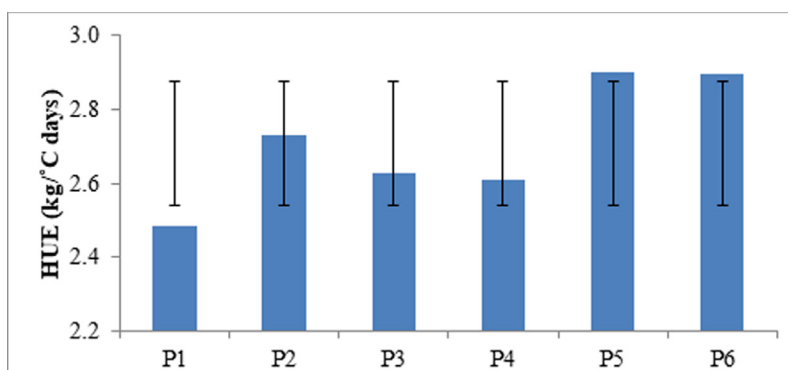


Fig 1.3: Variation of HUE during different Pentads under sowing window III

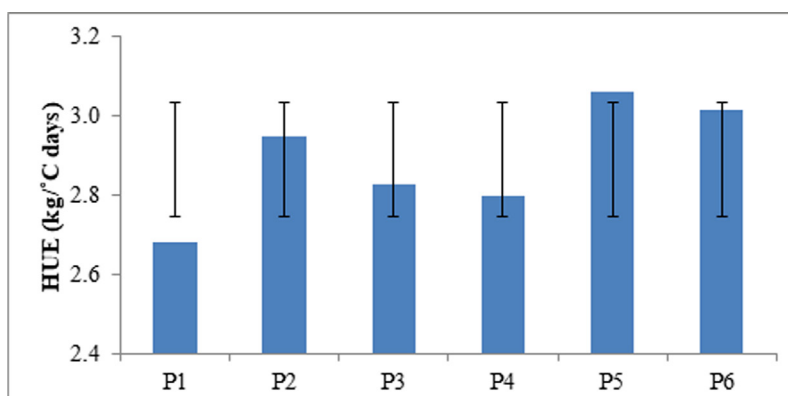


Fig. 4.4: Variation of HUE during different Pentads under sowing window IV

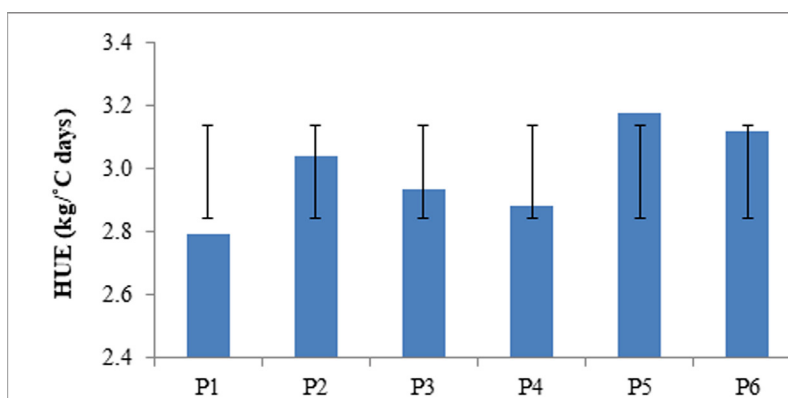


Fig. 4.5: Variation of HUE during different Pentads under sowing window V



Conclusion

Heat use efficiency derived from long term temperature and yield data was used to investigate its variability during different pentads and under different sowing windows in Punjab. Pentad wise analysis revealed that under all sowing windows, maximum variability in heat use efficiency was observed during P5 (2010-2014) and minimum during P1 (1990-1994). This might be attributed to higher temperature during P5 as compared to other pentads. And among different sowing windows, highest value of HUE (3.2 kg/ha/°C day) was noticed under sowing window V, during P5 and lowest (2.3 kg/ha/°C day) under sowing window II, during P1. Lowest heat use efficiency under sowing window II was due to accumulation of more growing degree days as compared to sowing window V that took minimum calendar days to reach maturity and accumulated less GDD, while considering an average yield value under all sowing windows.

Kingra *et al.* (2016) also reported that maximum calendar days and accumulated growing degree days were recorded for the crop sown on 29th October (157days, 1759.9°C day) followed by 12th November (151days, 1756.2°C day) and 28th November (142days, 1623.3°C day), respectively. Increasing variability of HUE warns about more warming scenarios in future and thus, creating a strong need to develop climate smart adaptation strategies for sustaining crop productivity in future.

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Conflict of Interest

Authors declare that they have no conflict of interests.

Author Contribution

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Ethical Compliance Statement

NA

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