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Heat unit requirement of wheat (*Triticum aestivum* L.) varieties under different sowing dates and irrigation levels in *Tarai* region of Uttarakhand

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ABSTRACT: A field study was conducted at the N.E. Borlaug Crop Research Center of G.B. Pant University of Agriculture and Technology, Pantnagar, to investigate the heat unit (GDD) requirements of wheat varieties under different dates of sowing and various irrigation levels in *Tarai* region of Uttarakhand. The experiment was laid out in Split Split Plot Design, with two dates of sowing *viz*., D1 (1st December) and D2 (15th December), three irrigation levels I1 (IW/CPE ratio 1.0), I2 (IW/CPE ratio 0.8) and I3 (IW/CPE ratio 0.6) and two varieties V1 (UP 2855) and V2 (PBW 502). Studies showed that GDD needed to reach different phenological stages varies between the two sowing dates. Late-sown crops required more GDD for the booting (623.47) and milking stages (1065.08), while early-sown crops needed more GDD overall (1434.18). Irrigation levels affected GDD, with the lowest at emergence and the highest at maturity under irrigation level I1. Variety V1 (UP 2855) outperformed variety V2 (PBW 502) in GDD requirements across most stages.

Key words: Heat unit, IW/CPE ratio, phenological stage, wheat, yield

A staple diet for most people, wheat (*Triticum aestivum* L.) is the most significant cereal crop. It's a winter crop that's grown all over the world in a variety of agroecological conditions and cropping techniques (Kamboj *et al.*, 2022). India accounts for 13.3% of global wheat output. Often referred to as the "King of cereals, " wheat can self-pollinate, it is the nation's second-most significant grain supply, behind rice (Kumar *et al.*, 2024). After China, India is the world's second-largest wheat producer. There is no other cereal that is grown more widely than wheat followed by rice. The yield of wheat in India was increased drastically in 1967 and 1968 by dwarf Mexican wheat (Ahmad and Kumar, 2015; Pal *et al.*, 2023).

To sustain the growth of irrigated agriculture, water is the primary production input (Abate, 1994; Tewabe *et al.*, 2022). Since irrigated agriculture contributes significantly to economic growth, poverty alleviation and food security, efficient irrigation system management is crucial (Zewdie, 1994). To enhance water management and get rid of the related issues, comprehensive irrigation water management techniques are necessary (Tewabe *et al.*, 2020; Tewabe *et al.*, 2022).

Maximum and minimum temperatures in the range of 18-22°C and 5-10°C during the vegetative stage, 17-20°C and 4- 9°C during the anthesis stage and 20-25°C and 5-9°C during the grain filling and reproductive stage of the wheat crop can all result in higher wheat yields (Bala and Kaur, 2013). Wheat thrives in temperatures between 3.5 and 35°C. One of the most important factors influencing wheat productivity is temperature (Lenka, 2006).

A specific temperature is necessary for plants to reach specific phenological phases. A common occurrence in every region of India is an abrupt increase in temperature during grain filling before maturity, which significantly lowers yield (Mehta and Dhaliwal, 2020). Wheat output is predicted to decrease by 6% for every one degree Celsius if the temperature rises above average (Akter and Islam, 2017). Based on the environmental circumstances, the wheat crop should be seeded at the optimal time to enhance crop development and yield.

The accumulated heat unit approach is used in the field to investigate the effects of temperature on agricultural production and phenology. The crop's life cycle, which dictates its lifespan, growth and

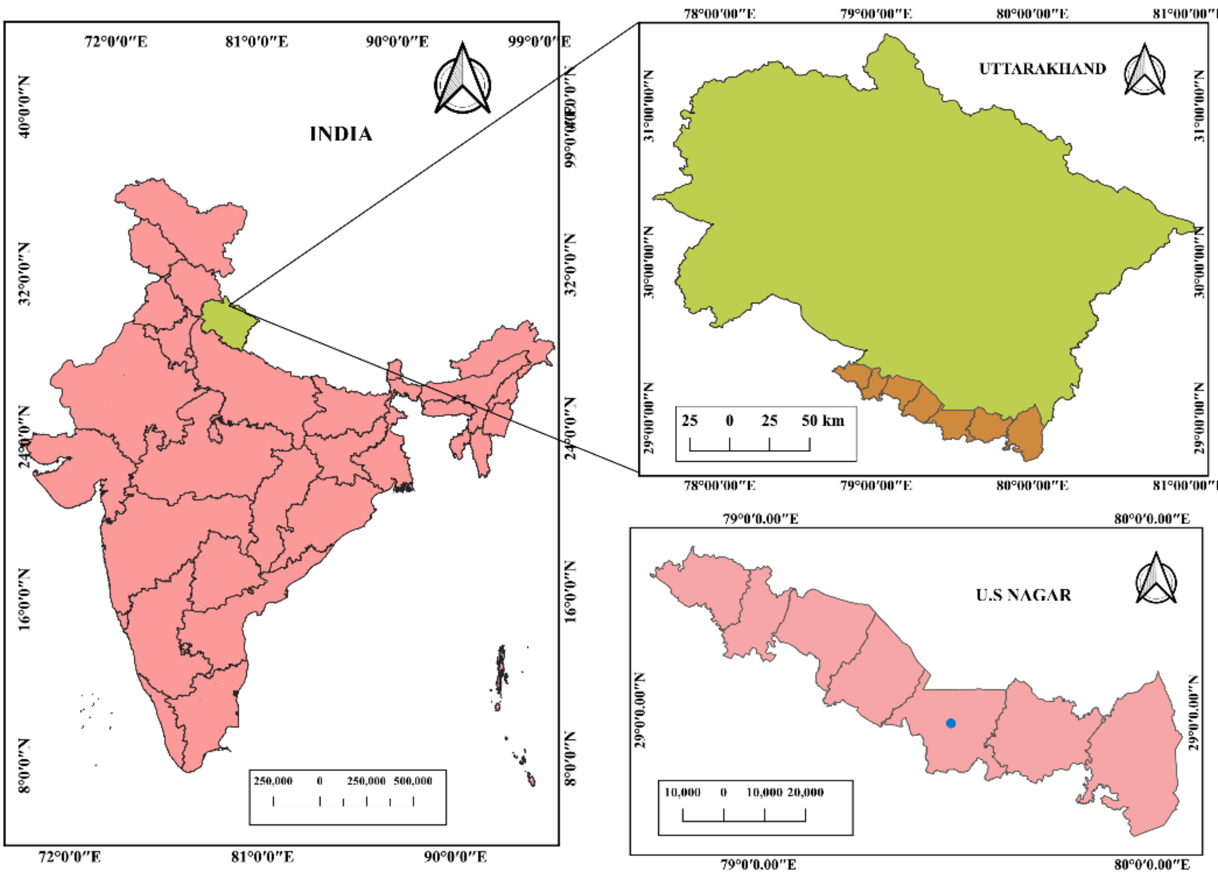

Fig.1: Study area map

production, is influenced by temperature and photoperiod. For any crop to grow, develop and produce at its best, specific environmental conditions are required. The efficiency of heat utilization, or the ability to convert heat into dry matter, is influenced by factors such as the type of crop, the timing of sowing and genetic traits. (Mehta and Dhaliwal, 2020). According to Rajbongshi *et al.* (2016), heat use efficiency (HUE) is a valuable tool for predicting the growth and production of various crops. To predict grain yield and physiological maturity, the idea of heat units has been used to link the phenological development of various crops. In light of all of this, the trials were designed to investigate the GDD, heat use efficiency and wheat yield as impacted by various irrigation methods, planting dates and varieties in the *Tarai* region of Uttarakhand.

MATERIALS AND METHODS

Study site

The study was carried out at the plot C6, N.E. Borlaug Crop Research Center of G.B. Pant University of Agriculture and Technology, Pantnagar (Fig. 1), which is located in the Kumaon division of the *Tarai* belt at the foothills of the Shivalik range of the Himalayas at an average elevation of 243 m above mean sea level.

The experiment was laid out in Split Split Plot Design. The treatments comprised two dates of sowing viz., D1 (1st December) and D2 (15th December) as the main plot and three irrigation levels (IW/CPE: 1.0, 0.8 and 0.6) under two varieties i.e., V1 (UP 2855) and V2 (PBW 502), replicated three times. A recommended package of practices for the wheat for the region was adopted during the experiment.

IW/CPE ratio

The IW/CPE ratio is a metric used to determine the appropriate timing for irrigation based on the relationship between the amount of irrigation water (IW) and cumulative pan evaporation (CPE). This ratio indicates how much water should be applied when the cumulative pan evaporation reaches a specified level. For instance, with an IW/CPE ratio of 1, if the irrigation water depth is 5 cm, irrigation is triggered when the cumulative pan evaporation reaches 5 cm, ensuring that the water applied matches the evaporative demand.

The statistical analysis was performed using Opstat software (Sheoran *et al.*, 1998), the study area map was created using QGIS.

Meteorological data were recorded from the Agro-meteorological Observatory in the N.E. Borlaug Crop Research Center. Growing degree days (GDD) were computed by adopting a procedure by McMaster and Wilhelm, 1997. From emergence to maturity/harvesting, heat unit (GDD) was computed daily using the following formula, with 5°C serving as the base temperature.

Growing Degree Days (GDD)

The sum of the daily mean temperature above the base temperature (5° C) for a comparable time from emergence to maturity was used to calculate growing degree days for various phonological phases.

$$GDD = \sum_{i=1}^{n} \frac{\text{Tmax} + \text{Tmin}}{2} - Tb$$

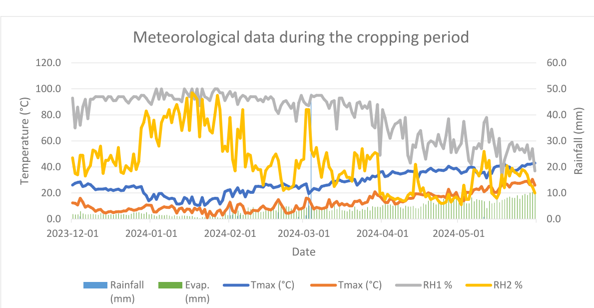

Fig. 2: Meteorological data during the cropping period

Where, Tmax = Daily maximum temperature (°C); Tmin = Daily minimum temperature (°C); Tb = Minimum threshold/base temperature taken as 5° C for wheat crop

RESULTS AND DISCUSSION

Crop phenology

The research findings (fig.3) revealed that early-sown crops generally mature faster than later-sown crops due to more favorable temperatures, reduced heat stress and better resource utilization. However, the specific relationship between sowing date and crop duration can vary depending on the crop, cultivar and environmental conditions. By maturing earlier, these crops are less exposed to heat stress, which can negatively impact their growth, development and ultimately, their yield (Devi *et al.*, 2019). Furthermore, the ability to mature before the onset of elevated temperatures can lead to a more

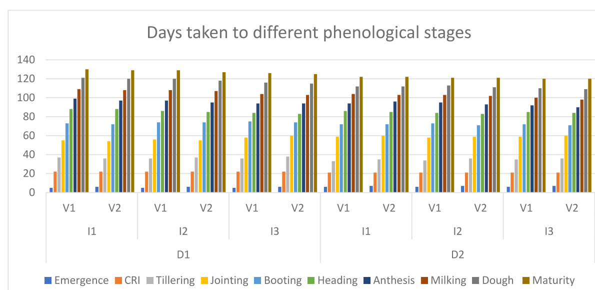

Fig. 3: Number of days taken to attain different phenophages

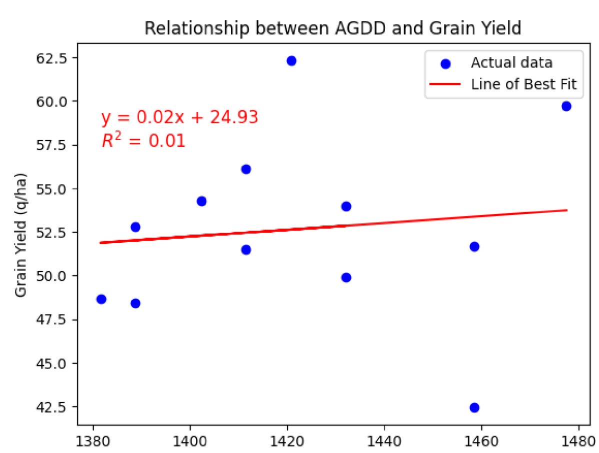

Fig.4: Relationship between Accumulated Growing Degree days and grain yield

Table 1: Accumulated GDD of different varieties under different sowing dates and irrigation levels

Treatment	Emergence	CRI	Tillering	Jointing	Booting	Heading	Anthesis	Milking	Dough	Maturity
Date of sowing										
D1	80.98	245.35	385.36	490.39	618.08	787.95	909.73	1, 055.82	1, 250.56	1, 434.18
D2	59.00	203.50	274.95	475.08	623.47	785.80	884.36	1, 065.08	1, 232.56	1, 412.15
SEm±	0.07	0.05	0.29	0.28	8.18	0.04	0.23	0.50	0.98	0.54
CD (p=0.05)	0.42	0.32	1.83	1.72	NS	0.24	1.40	3.09	6.03	3.32
Irrigation level										
I1	69.90	224.42	333.58	479.85	624.70	802.81	921.62	1, 092.47	1, 271.35	1, 451.07
I2	69.99	224.34	330.74	476.12	624.16	787.12	903.62	1, 074.18	1, 255.83	1, 426.66
I3	70.07	224.42	326.14	492.23	613.48	770.69	865.89	1, 014.70	1, 197.50	1, 391.76
SEm±	0.06	0.06	0.41	0.89	5.29	0.79	1.26	0.21	0.58	0.81
CD (p=0.05)	NS	NS	1.323	2.92	NS	2.58	4.11	0.68	1.89	2.65
Variety										
V1	64.27	224.42	330.78	479.69	627.88	792.01	906.22	1, 069.40	1, 253.24	1, 429.07
V2	75.70	224.37	329.52	485.78	613.68	781.74	887.86	1, 051.50	1, 229.89	1, 417.26
SEm±	0.06	0.04	0.49	0.45	1.29	0.53	0.88	0.14	0.49	0.63
CD (p=0.05)	0.17	0.12	NS	1.40	3.97	1.63	2.71	0.43	1.51	1.93

favorable environment for seed development, enhancing both the quality and quantity of the harvest.

Growing degree days (GDD)

A perusal of data from Table 1 showed that GDD requirement to attain the different phenological stages significantly varies during the two sowing dates. The lowest GDD requirement was observed at the emergence stage 15th December (59.00 °C days) and the highest GDD requirement was observed at maturity (1434.18 °C days). Plants sown later (December 15th) needed to accumulate more heat (measured in GDD) to reach the booting and milking stages compared to plants sown earlier (December 1st). However, for all other stages of development, the earlier-sown plants generally required more accumulated heat. These results are also in conformity with those obtained by Khichar and Niwas, 2006; Bisht *et al.*, 2019 and Wahid *et al.*, 2017 who studied the effect of two sowing dates on GDD and found that wheat plants sown early needed more GDD than those sown late. As shown in Table 1 irrigation levels differed significantly in all stages except emergence, CRI and booting stages. The lowest GDD was found with irrigation I1 (IW/CPE ratio 1.0) at the emergence stage (69.90 °C days) and also highest (1451 °C days) was found in the maturity stage followed by I2 (IW/CPE ratio 0.8). The amount of heat required for plants to reach different developmental stages varied significantly across different varieties, except for the tillering stage where the heat requirement was relatively consistent. The lowest GDD was found in V1 *i.e.*, UP 2855 (64.27 °C days) at emergence and also found highest at maturity (1429.07 °C days) which is significantly superior over variety V2 *i.e.* PBW 502. Similar results were also reported by Paul and Sarkar, 2000; Wahid *et al.*, 2017.

Relationship between Accumulated GDD and grain yield

There is a positive linear relationship between grain yield and Accumulated GDD of each treatment as shown in Fig. 4. As AGDD increases, grain yield also increases. We can conclude that yield is dependent on the GDD/Heat unit. Comparable findings were also reported by Sidhu and Raj (2018). The maximum yield was found in the treatment comprised of D1 *i.e.* 1st December I2 *i.e.* IW/CPE ratio 0.8 V1 *i.e.* UD 2855 (62.3 q/ha) followed by treatment D1I1V1(59.7 q/ha). Similar results were also reported by Singh *et al.*, 2016 and concluded that the IW/CPE ratio 0.8 gives better yield in wheat than IW/CPE ratio 0.6.

CONCLUSION

The study showed that the growing degree days (GDD) needed to reach different growth stages changed between the two sowing dates, late-sown crops required more GDD for the booting and milking stages, while early-sown crops needed more GDD overall. Irrigation levels affected GDD, with the lowest at emergence and the highest at maturity under irrigation level I1. Variety V1 (UP 2855) outperformed V2 (PBW 502) in GDD requirements across most stages. This suggests that sowing timing is crucial for determining the growth cycle length and plays a significant role in optimizing crop resilience to climatic variations. Thus, selecting the appropriate sowing date is essential for maximizing agricultural productivity and ensuring food security, especially in regions susceptible to temperature fluctuations.

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