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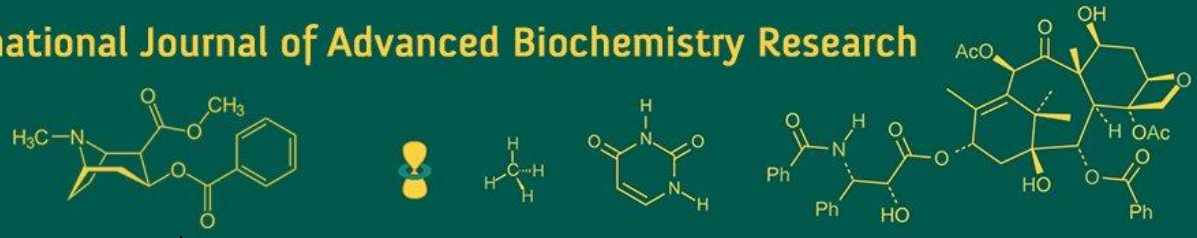

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Agrometeorological indices for different varieties of wheat crop under different growing environment at Raipur district (C.G.), India

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Abstract
The present experiment was carried out during *Rabi* season of 2022-23 at the research and instructional farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, to analyse different agrometeorological indices for different varieties of wheat crop under different growing environment at Raipur District. The experiment was laid out in factorial Randomized Block Design with three replications and two factors. First factor (Sowing dates) *viz*., D_1- 30th Nov, D_2- 10th Dec, D_3- 20th Dec and second factor (3 Varieties) *viz*., V_1 -Kanchan, V_2-HD-2967 and V_3 -CG-1013. The weather data required for the study were collected from the Agromet observatory, Department of Agricultural meteorology, COA, IGKV, Raipur. The results observed in this experiment indicate that highest accumulated GDD, PTU, HTU, HUE and RUE were found in growing environment D_1 (30th Nov.) followed by D_2 (10th Dec.) and D_3 (20th Dec.). Among three varieties, HD-2967 variety showed highest accumulated growing degree day (AGDD), accumulated photo thermal unit (APTU) and accumulated helio thermal unit (AHTU) i.e. 1924.5 to 2064.2 °C days, 22146.0 to 23441.6 °C day hours and 11537.8 to 11733.0 °C day hours, respectively. Kanchan variety reported highest heat use efficiency (HUE) 1.23 to 2.45 g/m^2 deg day and radiation use efficiency (RUE) 3.19 to 6.49 g/m^2 /MJ, respectively.

Keywords: Wheat, GDD, PTU, HTU, HUE and RUE

Introduction
Wheat is the first important and strategic cereal crop for the majority of world's population. Wheat cultivation is the backbone of the whole agricultural system in our country being a major food grain crop next to rice. Wheat ranks first in the world among the cereal in respect to area and second in respect to production. The wheat production has increased from 220 million tons in 1961 to 789.2 million tons in 2023 with total production area of 220 million hectares which showed significant changes across years (Anonymous (a), 2023) [2]. In India, wheat is cultivated on an area of 9.75 million ha, with a production of 6.46 million tones and productivity of 662.56 kg/ha in 1950- 1951 has gradually increased up to 30.46 million ha, with a production of 106.8 million tones and productivity of 3507 kg/ha during 2022-2023 (Anonymous (b), 2023) [3]. In Chhattisgarh, wheat is grown mostly under irrigated conditions in a rice based cropping system. Wheat is a major crop of *Rabi* season next to chickpea in Chhattisgarh state. Its grown in Bemetra, Rajnadgaon, Balrampur, Kabirdham, Durg, Bilaspur, Raipur and other districts of Chhattisgarh. Which covers total area 245.3 thousand hectares with production 317.25 metric tons and productivity 1293 kg/ha during 2022-2023 (Anonymous (c), 2023) [4]. Wheat is the thermo-sensitive, photo-insensitive and long day plant. Temperature ranging between 20 ºC to 25 ºC is ideal for seed sowing and germination of wheat crop. Whereas, the optimum temperature for vegetative growth ranges from 16º to 22 ºC. During the grain development wheat requires a mean maximum temperature of about 25 ºC for at least 4-5 weeks (Singh *et al.*, 2020) [13]. Temperature based agrometeorological indices such as growing degree days (GDD), photo thermal units (PTU), helio thermal units (HTU), radiation use efficiency (RUE) and heat use efficiency (HUE) can be quite useful in predicting growth and yield of crops. Growing degree days are based on the concept that real time to attain a phenological stage is linearly related to temperature in the range between base temperature (Tb) and optimum temperature. Heat use efficiency

(HUE), i.e. efficiency of utilization of heat in terms of dry matter accumulation is an important aspect, which has great practical application. The efficiency of conversion of heat energy into biomass depends upon genetic factors, sowing time and crop type (Rao *et al.*, 1999) [11].

Materials and Methods

The field experiment was carried out during *Rabi* season of 2022-23 at the research and instructional farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh. Raipur is located in south-eastern part of Chhattisgarh belongs to Chhattisgarh plain zone at latitudes, longitudes and altitudes of 210 16' N, 810 36' E and 289.5 m above mean sea level, respectively. The experiment was laid out in factorial Randomized Block Design with three replications and two factors. Sowing dates *viz*., D_1- 30th Nov, D_2- 10th Dec, D_3- 20th Dec and varieties *viz*., V_1-Kanchan, V_2- HD-2967 and V_3- CG-1013 are the factors used in this study. The fertilization, irrigation and management practices as recommended in the packages of practices for wheat crop in the raipur district were strictly applied. The weather data required for the study were collected from the Agromet observatory, Department of Agricultural Meteorology, COA, IGKV, Raipur. Agrometeorological indices *viz*., accumulated growing degree days (AGDD), accumulated photothermal units (APTU), accumulated heliothermal unit (AHTU), heat use efficiency (HUE) and radiation use efficiency (RUE) were calculated to quantify the thermal heat requirements. All these indices were calculated by using the following formula:

1. Accumulated Growing degree days (AGDD):

$$\Sigma GDD = [(Tx + Tn)/2 - T_{Base}]$$

Where, Tx = Daily maximum temperature
Tn = Daily minimum temperature
T_{Base} = Base temperature which is considered 4.5 ºC for *Rabi* crops.

2. Accumulated Photothermal Unit (APTU):

$$PTU = GDD \times N$$

Where, N = maximum possible sunshine hour.
GDD = Growing degree day.

3. Accumulated Heliothermal Unit (AHTU):

$$HTU = GDD \times n$$

Where, n = actual sunshine hour.
GDD = Growing degree day.

4. Heat Use Efficiency (HUE):

$$HUE\ (gm^{-2}/°C) = Biomass\ (g/m^2) / GDD$$

5. Radiation Use Efficiency (RUE):

$$RUE = Biomass\ (g/m^2) / IPAR\ (MJ/m^2/day)$$

Where, IPAR is cumulative intercepted photo synthetically active radiation. The photo synthetic active radiation can be calculated by using the following formula:

$$PAR = Rs \times 0.5$$

Where, Rs = incoming solar radiation
The incoming solar radiation can be calculated by the formula:

$$Rs = Rs_0\ (a + b \times n/N)$$

Where, Rs_0 = Extra terrestrial radiation,
n / N = Percent sunshine hours,
a and b are Angstrom empirical coefficients (a = 0.42, b = 0.30)

Results and Discussion

Accumulated Growing Degree Days (AGDD)

The accumulated growing degree days (AGDD) for different genotypes under different thermal environments varied considerably at physiological maturity stage presented in table 1. Different wheat genotypes responded differently in terms of AGDD. The highest AGDD was observed under D_1 (30th Nov.) followed by D_2 (10th Dec.) and D_3 (20th Dec.) in most of the varieties. It is quite clear from the results revealed that Kanchan variety required accumulated growing degree days 1958.3, 1907.8 and 1832.0 °C days for the completion of growth period in D_1 (30th Nov.), D_2 (10th Dec.) and D_3 (20th Dec.), respectively. In HD-2967, crop sown on D_1 (30th Nov.) reported highest accumulated degree days 2064.2 °C days for physiological maturity followed by 2001.2 °C days in D_2 (10th Dec.) and 1924.5 °C days in D_3 (20th Dec.). Whereas, in CG-1013 the crop sown on D_1 (30th Nov.) exhibited highest degree days 1941.3 °C days for physiological maturity followed by 1907.8 °C days in D_2 (10th Dec.) and 1808.3 °C days in D_3 (20th Dec.), respectively. Similarly decreased heat unit with delay in sowing were reported by Rajput *et al*., (1980) [9] and Agrawal *et al*., (1999) [1].

Accumulated Photo Thermal Units (APTU)

The accumulated Photo Thermal Unit (APTU) for different genotypes under different thermal environments presented in table 1 at physiological maturity stage. Table revealed that the accumulated photo thermal unit (APTU) required 22170.8, 21732.8 and 21008.8 °C day hours to complete the growth period of Kanchan variety in D_1 (30th Nov.), D_2 (10th Dec.) and D_3 (20th Dec.), respectively. Highest accumulation PTU 22170.8 °C day hours was recorded in D_1 (30th Nov.), followed by 21732.8 °C day hours in D_2 (10th Dec.) and 21008.8 °C day hours in D_3 (20th Dec.). In HD-2967, the highest APTU 23441.6 °C day hours was observed to attained physiological maturity under sown crop D_1 (30th Nov.) followed by 22853.0 °C day hours in sown crop D_2 (10th Dec.) and 22146.0 °C day hours in sown crop D_3 (20th Dec.). Similarly, CG-1013 variety sown on D_1 (30th Nov.) tooks the highest Photo thermal unit 21966.8 °C day hours to attained physiological maturity followed by 21732.8 °C day hours in D_2 (10th Dec.) and 20724.4 °C day hours in D_3 (20th Dec.). Prasad *et al*., (2017) [7] reported that crop sown

on 30th November accumulated maximum PTU (16900 °C day hours) as compared to rest of sowing date. Ram *et al*., (2017) [10] reported higher accumulation of PTU under timely sowing wheat crop as compared to late sowing.

Accumulated Helio Thermal Units (AHTU)

Table 1 revealed that the accumulation helio thermal units (AHTU) required 10956.5, 10884.8 and 10800.6 °C day hours to complete the growth period of Kanchan variety in D_1 (30th Nov), D_2 (10th Dec) and D_3 (20th Dec.), respectively. Highest accumulation HTU 10956.5 °C day hours was recorded in D_1 (30th Nov.), followed by 10884.8 °C day hours in D_2 (10th Dec.) and 10800.6 °C day hours in D_3 (20th Dec). In HD-2967, highest HTU 11733.0 °C day hours was observed under sown crop D_1 (30th Nov.) at physiological maturity followed by 11664.4 °C day hours in sown crop D_2 (10th Dec) and 11537.8 °C day hours in sown crop D_3 (20th Dec.). Similarly, CG-1013 variety sown on D_1 (30th Nov.) reported the highest Helio Thermal Units (HTU) 10956.5 °C day hours for physiological maturity followed by 10884.8 °C day hours in D_2 (10th Dec.) and 10589.6 °C day hours in D_3 (20th Dec). Praveen *et al*., (2018) reported that wheat crop sown on 5th November accumulated highest HTU (11952.5 °C day hrs) as compared to 11323.1 °C day hrs in 15th November and 9734 °C day hrs in 25th November sown crops.

Table 1: Accumulated Growing Degree Days, Photo Thermal Units, Helio Thermal Units at physiological maturity stages of different wheat varieties under different growing environments.

Sowing dates	AGDD (°C days)	APTU (°C day hours)	AHTU (°C day hours)
Kanchan (V1)			
30 Nov (D1)	1958.3	22170.8	10956.5
10 Dec (D2)	1907.8	21732.8	10884.8
20 Dec (D3)	1832.0	21008.8	10800.6
HD-2967 (V2)			
30 Nov (D1)	2064.2	23441.6	11733.0
10 Dec (D2)	2001.2	22853.0	11664.4
20 Dec (D3)	1924.5	22146.0	11537.8
CG-1013 (V3)			
30 Nov (D1)	1941.3	21966.8	10897.0
10 Dec (D2)	1907.8	21732.8	10884.8
20 Dec (D3)	1808.3	20724.4	10589.6

Heat use Efficiency (HUE) and Radiation use efficiency (RUE)

Heat use efficiency (HUE) and Radiation use efficiency (RUE) for different varieties under different growing environment were presented at table 2. The results revealed that highest HUE and RUE shows in D_1 (30th Nov.) followed by D_2 (10th Dec.) and D_3 (20th Dec.), respectively.

In Kanchan variety, the highest HUE value of 2.45 g/m^2 degree day was recorded in D_1 (30th Nov.) followed by 1.66 g/m^2 degree day in D_2 (10th Dec.) and 1.23 49 g/m^2 degree day in D_3 (20th Dec.), respectively. Similarly, CG-1013 shows highest value of 2.43 g/m^2 degree day of HUE in D_1 (30th Nov.) followed by 1.60 g/m^2 degree day in D_2 (10th Dec.) and 0.96 g/m^2 degree day in D_3 (20th Dec.), respectively. However, HD-2967 variety reported 2.12, 1.37 and 0.89 g/m^2 degree day values of HUE, when crop was sown on D_1 (30th Nov.), D_2 (10th Dec.) and D_3 (20th Dec.), respectively.

Similarly, In Kanchan variety, D_1 (30th Nov.) shows highest value of RUE (6.49 g/m^2/MJ) followed by 4.36 g/m^2/MJ in D_2 (10th Dec.) and 3.19 g/m^2/MJ value in D_3 (20th Dec.). Whereas, CG-1013 variety shows highest accumulate value 6.43 g/m^2/MJ of RUE in D_1 (30th Nov.) followed by 4.21 g/m^2/MJ in D_2 (10th Dec.) and lowest value 2.50 g/m^2/MJ of RUE in D_3 (20th Dec.). Highest value of RUE for HD-2967 variety was recorded 5.59 g/m^2/MJ in D_1 (30th Nov.) followed by 3.58 g/m^2/MJ in D_2 (10th Dec.) and 2.29 g/m^2/MJ recorded in D_3 (20th Dec.).

Patra and Sahu (2007) also found that the crop accumulated higher amount of heat units in early sown than late sown condition. The RUE and HUEs were also higher for earlier sowings than later sowings. Sharma *et al*., (2003) also found that the delay in sowing from (25th Nov.) to (10th Dec.) significantly reduced the radiation use efficiency.

Table-2: Accumulated Heat Use Efficiency and Radiation Use Efficiency of different wheat varieties under different growing environments.

Varieties	Heat use efficiency (HUE) (g/m^2 deg day)			Radiation use efficiency (RUE) (g/m^2/MJ)		
	D1 (30 Nov.)	D2 (10 Dec.)	D3 (20 Dec.)	D1 (30 Nov.)	D2 (10 Dec.)	D3 (20 Dec.)
Kanchan (V1)	2.45	1.66	1.23	6.49	4.36	3.19
HD-2967 (V2)	2.12	1.37	0.89	5.59	3.58	2.29
CG-1013 (V3)	2.43	1.60	0.96	6.43	4.21	2.50

Conclusion

Highest accumulated GDD, PTU, HTU, HUE and RUE were found in first date of sowing D_1 (30th Nov.) followed by D_2 (10th Dec.) and D_3 (20th Dec.). In varieties, HD-2967 shows highest value of AGDD, APTU and AHTU as compared to Kanchan and CG-1013. Whereas, RUE and HUE were found maximum in Kanchan variety followed by CG-1013 and HD-2967.

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