

Thermal and radiation effect studies of different wheat varieties in Chhattisgarh plains zone under rice-wheat cropping system

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सार – क्रमानुसार यादृच्छिक ब्लॉक डिजाइन में पाँच अलग-अलग बुवाई की तारीखों के तहत बोई गई चार गेहूँ की किस्मों ऋतुजैविकी, संवर्धित डिग्री के दिनों (जी डी डी) के संचयन, हेलियोथर्मल एकको (एच टी यू), फोटोथर्मल एकको (पी टी यू) और गेहूँ के निष्पादन (*Triticum aestivum* L.) की जाँच व अध्ययन करने के लिए इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर के अनुसंधान और अनुदेशात्मक फार्म में 2010-11, 2011-12 और 2012-13 की रबी मौसम के दौरान फील्ड प्रयोग किए गए। इसमें यह देखा गया है कि बुवाई के समय में परवर्ती देरी के साथ जी डी डी में उल्लेखनीय रूप से कमी आई है। इस अध्ययन के लिए और व्यावहारिक रूप से पैकेज के अनुसार 25 नवंबर को D₁ को समय से पहले बुवाई के लिए और 5 दिसंबर को D₂ को समय पर बुवाई की स्थितियों में लिया गया है। अमर और सुजाता नामक गेहूँ की किस्मों ने परिपक्वता के लिए अधिकतम जी डी डी, एच टी यू और पी टी यू प्राप्त किए। माध्य आधार पर कंचन किस्म ने सबसे अधिक अनाज की पैदावार (3147 Kg/ha) उत्पन्न की इसके बाद GW 273 (2947 Kg/ha) ने की। अनाज की पैदावार में उस समय उल्लेखनीय रूप से कमी रिकार्ड की गई जब 5 दिसंबर को D₂ के पार बुवाई देरी से की गई। गेहूँ की किस्मों में कंचन का निष्पादन आर यू ई के अनुसार सबसे बेहतर रहा, इसके बाद GW 273 और सुजाता का रहा। गेहूँ की किस्म कंचन में एच यू ई पाए गए इसके बाद GW-273 और सुजाता में पाए गए। पैदावार की अलग-अलग बढ़ती-बढ़ती की स्थितियों के तहत अधिक पैदावार वाली किस्मों आर यू ई और एच यू ई का पता लगाया गया ताकि छत्तीसगढ़ के मैदानी भागों में गेहूँ की किस्मों की समुचित बुवाई की तारीखों को बताया जा सके। जी डी डी से अनुकूल परिणाम प्राप्त हुए क्योंकि इसकी परिवर्तनशीलता में अलग-अलग किस्मों के लिए सबसे कम भिन्नता 3.4-5.3 प्रतिशत के बीच पाई गई और अतः इस क्षेत्र में गेहूँ पर पर्यावरण संबंधी प्रभावों का अध्ययन करने के लिए यह विश्वसनीय सूचकांक है। सभी किस्मों में 5 जनवरी बुवाई (D₅) के तहत न्यूनतम आर यू ई पाए गए जिससे यह निष्कर्ष निकला है कि बुवाई की तारीखों को अनदेखा किया जाए और उत्पादकता पर पड़ने वाले प्रतिकूल प्रभावों से बचने के लिए 25 दिसंबर तक गेहूँ की फसल की बुवाई को पूरा कर लिया जाए।

ABSTRACT. Field experiment was conducted during *Rabi* seasons of 2010-11, 2011-12 and 2012-13 at Research and Instructional Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur to examine and study the phenology, accumulation of growing degree days (GDD), heliothermal units (HTU), photothermal unit (PTU) and performance of wheat (*Triticum aestivum* L.) of four wheat varieties grown under five different sowing dates in factorial Randomized Block Design. It was observed that GDDs got reduced significantly with subsequent delay in sowing time. For our study purpose and as per package of practices, 25 November D₁ can be taken as early sowing and D₂ - 5 December as timely sowing conditions. The wheat varieties Amar and Sujata took highest GDD, HTU and PTU to maturity. On the mean basis the variety Kanchan produced highest grain yield (3147 kg/ha) followed by GW-273 (2947 kg/ha). The significant reduction in grain yield was recorded when sowing was delayed beyond D₂ - December 05. Among the wheat varieties Kanchan showed better performance in terms of RUE followed by GW-273 and Sujata. Highest HUE was observed in wheat variety Kanchan followed by Sujata and GW-273. Varieties giving higher yield, RUE and HUE are identified under varying growing environments so as to suggest the appropriate sowing dates of wheat varieties in Chhattisgarh plains. GDD is giving consistent results as its variability is least varying between 3.4-5.3 per cent for different varieties and therefore it is reliable index for studying environmental effects on wheat in this region. Lowest RUE was observed under 5 January sowing (D₅) in the all varieties which leads to conclusion that this sowing date must be avoided and wheat crop sowing must be completed latest by 25 December to avoid adverse effects on productivity.

Key words – Growing degree days, Heat use efficiency, Radiation use efficiency, Helio-Thermal units and sowing dates.

1. Introduction

In general higher temperature accelerate the rate of development at all phenological stages of a crop and thereby reduce the length of a phenological stage (Oldemann *et al.*, 1986). Growing degree days were calculated in rice crop for different varieties in Chhattisgarh state for first time and the phenological duration considered was germination to 50 per cent flowering (Chaudhary *et al.*, 1996). Growing degree days also called as heat units, effective heat units or growth units are a simple means of relating plant growth, development and maturity to air temperature (Vittum *et al.*, 1965). This concept assumes that there is direct and linear relationship between growth and temperature and this is called thermal effect on the crop and this concept can be applied for evaluating the suitability of a variety in particular region. Further radiation in crop production provides the necessary energy for all the phenomena concerning biomass production.

Chhattisgarh state popularly known as “Rice Bowl of India” occupies an area around 3610.47 thousand hectares with the production of 5.48 Mt and productivity of 1517 kg ha⁻¹ (Anonymous, 2010), however wheat is major *rabi* crop after rice and this state is the southern limit of wheat growing area of the country. This region is a fragile one as far as wheat cultivation is concerned because of fluctuations of temperature during the cropping season. As such the productivity of wheat fluctuates considerably in this area due to thermal stress. It is therefore necessary to identify the suitable thermally insensitive varieties of wheat for this region as rice-wheat crop rotation is still prominent in this region under Mahanadi and Hasdeo-Bango rivers command area. Chhattisgarh has embarked on a concerted plan to increase double cropped areas and diversify the cropping pattern. Wheat crop is being grown mainly in Chhattisgarh plains, covering northern hill region partly but to limited extent in Bastar Plateau. Chhattisgarh farmers are mainly dependant on climate for wheat cultivation and assured irrigation is the primary requirement of wheat crop. It is estimated that approximately 14.15 lakh hectares can be potentially irrigated covering 30 per cent of the entire cropped area in the state.

This study has been carried out to examine the consistency of PTU, HTU and GDDs as well as the derived parameters like RUE and HUE of different wheat varieties under different dates of sowing under All India Co-ordinated Research Project on Agrometeorology project at IGKV, Raipur during three years 2010-11, 2011-12 and 2012-13 in the *rabi* season. Moreover sowing time is critically important and it is always better to identify the varieties which can perform better in terms of

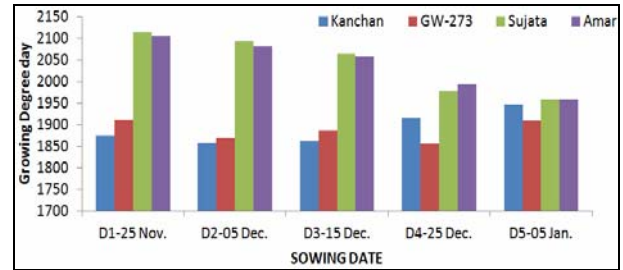


Fig. 1. Average accumulated growing degree days (GDD) at maturity stages of wheat varieties under different thermal environments

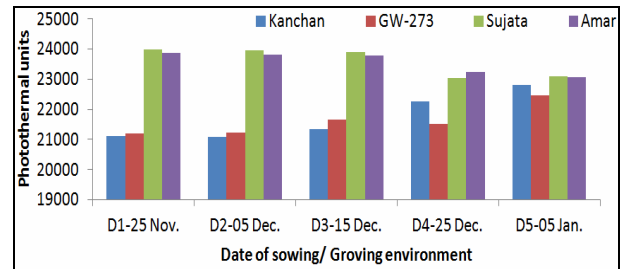


Fig. 2. Average photothermal units at maturity stages of wheat varieties under different thermal environments

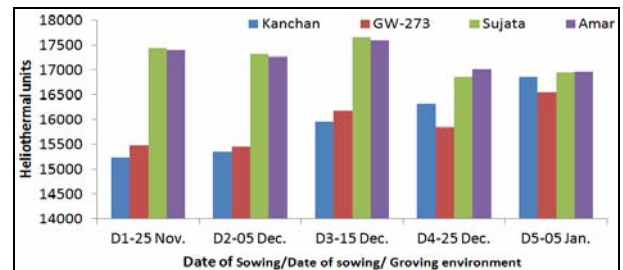
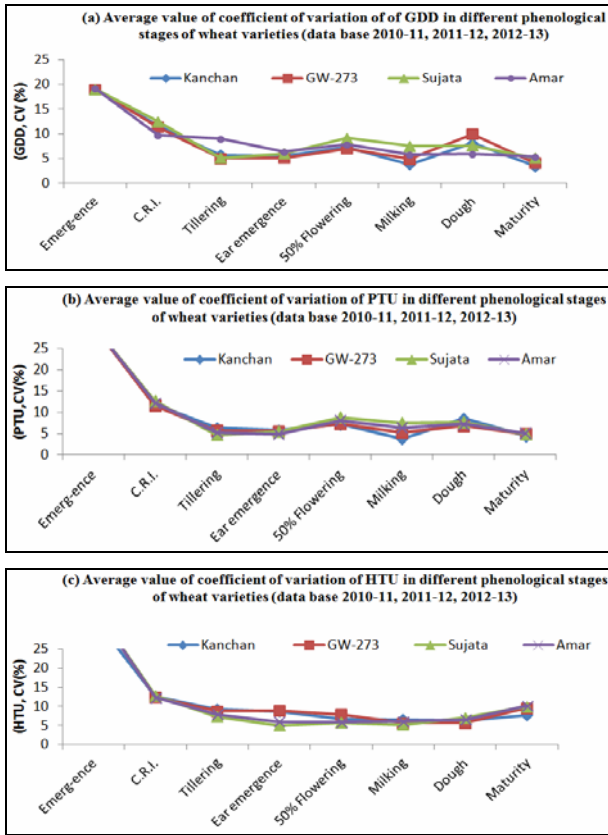


Fig. 3. Average heliothermal units at maturity stages of wheat varieties under different thermal environments

grain yield under different sowing conditions and growing environments. As different units are covering thermal and radiation parameters, it is desirable to examine the units which will be having better consistency.

2. Materials and method

The experiment was conducted at Research and Instructional farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur situated in Eastern Central part of Chhattisgarh at latitude of 21° 16' N, longitude 81° 36' E and altitude 289.5 m above mean sea level. The present experiment was conducted during three consecutive *rabi* seasons of 2010-11, 2011-12 and 2012-13. Four prominent wheat cultivars, *viz.*, Kanchan, GW-273, Sujata and Amar were used and cultivated in a factorial Randomized Block Design (RBD) with five



Figs. 4(a-c). Variation of coefficient of variation of GDD, PTU and HTU

sowing dates 25 November (D₁), 5 December (D₂), 15 December (D₃), 25 December (D₄) and 5 January (D₅). The GDD, PTU, HTU, Intercepted PAR and HUE were computed by using following formula:

2.1. Accumulated Growing Degree Days (GDD)

$$GDD = \sum [(T_x + T_n)/2 - \text{Base temperature}]$$

where,

T_x = Daily maximum temperature and

T_n = Daily minimum temperature

2.2. Heat Use Efficiency (HUE)

Heat Use Efficiency (HUE) for total dry matter was obtained as under

$$HUE \left(\frac{g/m^2}{^\circ\text{day}} \right) = \frac{\text{Biomass} \left(\frac{g}{m^2} \right)}{GDD (^\circ\text{day})}$$

2.3. Radiation Use Efficiency (RUE)

$$RUE (gMJ^{-1} \text{ day}^{-1}) = \frac{\text{Biomass} \left(\frac{g}{m^2} \right)}{\text{Radiation intercepted} \left(\frac{MJ}{m^2/\text{day}} \right)}$$

2.4. Photo Thermal Units (PTU)

Photo Thermal Units (PTU) are calculated by multiplying GDD with maximum possible sunshine hours (N).

$$PTU = GDD \times N$$

where, N = maximum possible sunshine hour.

2.5. Accumulated Heliothermal Unit (HTU)

HTU is calculated by multiplying GDD with actual sunshine hours (n).

$$HTU = GDD \times n$$

where, n = actual sunshine hour.

3. Results and discussion

3.1. Variation of different indices (growing degree days, photothermal units and heliothermal units)

The different derived indices are shown in Figs. 1-3. It can be clearly observed that satisfaction level for two varieties Sujata and Amar are significantly higher as compared to Kanchan and GW-273. Accumulated growing degree days (GDD) for different genotypes under different thermal environments varied considerably from sowing to maturity (Fig. 1). Different wheat varieties responded differently in terms of accumulated GDD at the time of maturity. One interesting result is there that for Sujata and Amar varieties as the date of sowing is delayed, GDD goes on decreasing. However, the least GDD required for physiological maturity are in Kanchan and there is somewhat higher satisfaction higher requirement for GW-273. For Photothermal indices, range of 21000 to 23000 is observed for two wheat varieties Kanchan and GW-273 however the satisfaction level is more for the varieties Sujata and Amar (Fig. 2). Moreover growing environments had varying effect on PTUs. Regarding Heliothermal indices it can be seen from Fig. 3 that HTU are in the lower range when timely sowing (5 December) or early sowing (25 November) could be taken and with delayed sowing, significant more HTU units are required to achieve maturity. However for

TABLE 1

Average values of coefficient of variation in different phenological stages of wheat varieties (Data base 2010-11, 2011-12, 2012-13)

Varieties	Emergence	C.R.I.	Tillering	Ear emergence	50% Flowering	Milking	Dough	Maturity
GDD								
Kanchan	19.0	11.6	5.7	5.5	7.2	3.8	8.1	3.4
GW-273	19.0	11.4	5.0	5.1	7.0	4.9	9.9	4.1
Sujata	19.0	12.5	5.1	6.0	9.1	7.5	7.6	5.1
Amar	19.2	9.7	9.0	6.4	7.9	5.8	5.9	5.3
PTU								
Kanchan	30.5	11.9	6.4	5.7	7.3	3.8	8.5	4.5
GW-273	30.6	11.6	5.6	5.5	7.3	5.2	6.8	4.9
Sujata	30.6	12.7	4.6	5.4	8.8	7.5	7.7	4.9
Amar	30.6	12.2	5.3	4.8	8.0	6.3	7.2	5.0
HTU								
Kanchan	33.2	12.5	9.2	8.7	6.8	6.6	6.3	7.6
GW-273	36.1	12.4	8.8	8.9	7.9	5.7	5.7	9.6
Sujata	36.1	12.7	7.3	4.9	5.7	5.2	7.0	9.9
Amar	36.1	12.3	7.9	6.0	5.9	6.1	6.6	10.1

TABLE 2

Heat use efficiency (HUE) of wheat varieties under different thermal environments

Varieties	Heat use efficiency (g/m ² deg day)					Mean
	D ₁ - 2 5 Nov	D ₂ - 5 Dec	D ₃ - 15 Dec	D ₄ - 25 Dec	D ₅ - 5 Jan	
Kanchan	0.40	0.46	0.43	0.35	0.32	0.39
GW-273	0.37	0.43	0.41	0.35	0.31	0.37
Sujata	0.37	0.37	0.40	0.36	0.34	0.37
Amar	0.37	0.38	0.35	0.36	0.32	0.36
Mean	0.38	0.41	0.40	0.36	0.32	0.37

varieties like Sujata and Amar with delayed sowing, HTU trend is generally declining which leads to interpretation that these varieties may be photo-period sensitive.

3.2. Comparison of coefficient of variation of growth indices in different phenological stages of wheat varieties

Using all the datasets (5 sowing dates over three years) of required GDDs, PTU and HTU for physiological maturity of different wheat varieties under different dates of sowing, Coefficient of Variation (CV) has been calculated during different phenological stages (Table 1).

It can be observed clearly that GDD is giving consistent results as its variability is least varying between 3.4-5.3 per cent for different varieties. For PTU, it is varying between 4.5 to 5.0 per cent and for HTU, it is varying between 7.6 to 10.1 per cent for different varieties. Therefore, GDD seems to be more reliable index in terms of consistency. CV of these three indices has been shown by graphical interpretation in Fig. 4. It can be seen that with the advancement of phenological stages, CV value goes on decreasing for all indices. However, GDD index is most reliable index for studying environmental effects on wheat in this region and moreover its requirement is simple and needing inputs of daily maximum and

TABLE 3
Radiation Use Efficiency (RUE) of wheat varieties under different thermal environments

Varieties	Radiation Use Efficiency (g MJ ⁻¹)					Mean
	D1 - 25 Nov	D2 - 5 Dec	D3 - 15 Dec	D4 - 25 Dec	D5 - 5 Jan	
Kanchan	0.97	1.10	1.03	0.87	0.80	0.95
GW-273	0.90	1.04	0.97	0.86	0.78	0.91
Sujata	0.92	0.93	0.97	0.89	0.85	0.91
Amar	0.92	0.93	0.85	0.90	0.81	0.88
Mean	0.93	1.00	0.96	0.88	0.81	0.91

TABLE 4
Intercepted Photosynthetically Active Radiation (IPAR) of wheat varieties under different thermal environments

Varieties	IPAR (g MJ ⁻¹ day ⁻¹)					Mean
	D1 - 25 Nov	D2 - 5 Dec	D3 - 15 Dec	D4 - 25 Dec	D5 - 5 Jan	
Kanchan	392.38	391.70	403.72	401.85	399.78	397.89
GW-273	393.84	395.36	407.79	391.78	393.86	396.53
Sujata	437.72	433.41	436.26	411.93	402.38	424.34
Amar	436.24	432.22	436.02	414.97	402.54	424.40
Mean	415.04	413.17	420.95	405.14	399.64	410.79

TABLE 5
Grain yield (kg/ha) of wheat varieties under different thermal environments

Varieties	D1	D2	D3	D4	D5	Mean
Kanchan	3207	3532	3396	2884	2859	3176
GW-273	2924	3545	3290	2594	2382	2947
Sujata	2896	3280	3069	2475	2138	2772
Amar	2814	3022	2679	2696	2278	2698
Mean	2960	3345	3109	2662	2414	

minimum temperature only. One interpretation can be that radiation input is also affecting temperature and that's why GDD is proving to be more reliable for environmental impact studies.

3.3. Heat use efficiency (HUE)

Heat Use Efficiency (HUE) for different genotypes under different thermal environments varied considerably (Table 2). Higher HUE was observed in wheat variety

Kanchan followed by Sujata and GW-273. Least HUE on 3 years data can be observed for Amar variety. With respect to the sowing dates maximum HUE was observed under 5 December (D₂) sowing followed by 15 December (D₃) sowing and the minimum HUE was observed under 5 January (D₅) sowing. Highest HUE were observed in wheat varieties Kanchan, GW-273 and Amar when sown on 5 December whereas in Sujata HUE was higher in 15 December. Therefore, heat conversion efficiency levels are better in Kanchan variety in D₂ sowing followed by

GW-273 variety in D₂ and Kanchan variety in D₃. This clearly indicates the potential of Kanchan variety to adjust in different growing environments.

3.4. Radiation Use Efficiency (RUE)

Radiation Use Efficiency (RUE) for different genotypes under different thermal environments varied considerably (Table 3). On the mean basis higher RUE value was observed under D₂ followed by D₃ and D₁ sowing. Among the wheat varieties Kanchan showed promising results in terms of RUE followed by GW-273 and Sujata. In case of Kanchan and GW-273 maximum RUE was observed in D₂. In variety Sujata the highest RUE was observed in D₃. In Amar, the highest RUE was observed in D₂. Lowest RUE was observed under 05 January sowing (D₅) in the all varieties which leads to interpretation that this sowing date must be avoided and wheat crop sowing must be completed latest by 25 December.

3.5. Intercepted Photosynthetically Active Radiation (IPAR)

Intercepted Photosynthetically Active Radiation (IPAR) for different varieties under different thermal environments varied considerably (Table 4). On the mean basis higher IPAR value was observed under D₃ followed by D₁. Among the wheat varieties Amar showed better in terms of IPAR immediately followed by Sujata.

3.6. Grain yield of wheat crop in rice-wheat sequence

Grain yield as influenced by different sowing dates are given in Table 5 on the basis of three years data 2010-11, 2011-12 and 2012-13. Varieties and sowing dates reflecting growing environments showed significant effect on wheat grain yield. On the mean basis the variety Kanchan produced highest average grain yield (3176 kg/ha) followed by GW-273 (2947 kg/ha). However, there are variations among the years and GW-273 variety gave the highest yield in 2010-11 when sown on 5 December (4248.8 kg/ha). However in terms of consistency and average grain yield Kanchan variety performed better. On an average basis, wheat varieties sown on 5 December produced maximum grain yield (3345 kg/ha) followed by sowing on 15 December (3109 kg/ha).

4. Conclusions

Based on the above findings it can be concluded that on the mean basis, the variety Kanchan produced higher grain yield (3176 kg/ha) followed by GW-273 (2947 kg/ha), Sujata (2772 kg/ha) and Amar (2698 kg/ha). On an average wheat varieties sown on 5 December - D₂ produced maximum grain yield followed by sowing 15 December-D₃. Wheat variety Kanchan showed stable yield in almost all the sowing dates and it is performing overall best in terms of utilization of HUE and RUE, hence this variety is recommended under rice based cropping system. The growing degree day, helio- thermal units and photo thermal units for entire crop growing period decreased with subsequent delay in sowing which might have been due to higher radiation and temperature values in later part of growing season coinciding with milking stage of wheat crop hastening the development process. These results are in general agreement with the findings of Hundal *et al.* (2005); Sandhu *et al.* (1999) and Sreenivas *et al.* (2010).

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