MAUSAM, **74**, 3 (July 2023), 807-814

MAUSAM

DOI : https://doi.org/10.54302/mausam.v74i3.6304
Homepage: https://mausamjournal.imd.gov.in/index.php/MAUSAM

UDC No. 633.11 : 631.436.5

Effects of sowing dates on phenology, radiation interception and yield of wheat

PREMDEEP, M. L. KHICHAR, RAM NIWAS and MADHO SINGH

Department of Agricultural Meteorology,

CCS Haryana Agricultural University, Hisar – 125 004, India

(*Received 10 August 2020, Accepted 23 December 2022*)

e mail : badalk2008a37@gmail.com

सार — 2015-16 और 2016-17 की रबी ऋतु के दौरान कृषि मौसम विज्ञान विभाग, चौधरी चरण सिंह हरियाणा कृषि विश्वविद्यालय, हिसार के अनुसंधान फार्म में गेहूं परघटना विज्ञान, बढ़ते डिग्री केदिनों का संचय (GDD), हेलियो-थर्मल यूनिट (HTU), फोटो-थर्मल यूनिट (PTU), हीट यूज एफिशिएंसी (HUE), रेडिएशन यूज एफिशिएंसी (RUE) और थर्मल के प्रभावों और विकिरण व्यवस्थाका आकलन करने के लिए एक प्रयोग किया गया।

तीन प्रतिकृति के विभाजित प्लॉट डिजाइन में सत्ताईस उपचार संयोजनों का परीक्षण किया गया।मुख्य भूखंड उपचार में बुवाई की तीन तारीखें शामिल हैं अर्थात D1- नवंबर का दूसरा पखवाड़ा, D2- दिसंबर का पहला पखवाड़ा, D3- दिसंबर का दूसरा पखवाड़ा तथा सब प्लॉट ट्रीटमेंट में तीन किस्में अर्थात V1- WH 1105, V2- DPW 621-50 और V3- HD 2967 शामिल हैं ।

प्रायोगिक प्लॉट के पास कृषि मौसम वेधशाला में रिकॉर्ड किए गए दैनिक मौसम डेटा का उपयोग कृषि विज्ञान सूचकांकों अर्थात हीट यूनिट (HU), हेलियोथर्मल यूनिट (HTU), फोटो थर्मल यूनिट (PTU), हीट यूज एफिशिएंसी (HUE) और रेडिएशन यूज एफिशिएंसी (RUE) की गणना के लिए किया गया।

नवंबर के दूसरे पखवाड़े में बोई गई फसल में, अधिकतम दिन, ग्रोइंग डिग्री डे, फोटो-थर्मल, हेलियो-थर्मल यूनिट लगे। देर से बोई गई फसलों की तुलना में परिपक्वता के लिए उगाए गए दिनों की संख्या अधिक होने के कारण पहले बोई गई फसल में HU, HTU, PTU और HUE का संचयन अधिक था। एचडी 2967 ने अन्य किस्मों की तुलना में लंबी वृद्धि की अवधि के कारण अधिकतम HU, HTU, PTU और HUE का उपभोग किया। अनाज की उपज ने दोनों वर्षों के दौरान तीन अलग-अलग बुवाई तिथियों के बीच एक महत्वपूर्ण अंतर और नवंबर की बुवाई की तारीख के दूसरे पखवाड़े में अधिकतम अंतर दिखाया। वर्ष 2016-17 की तुलना में विभिन्न बुआई तिथियों में रबी 2015-16 में गेहूँ की औसत उपज अधिक रही। अलग-अलग बुवाई की तारीखों ने दोनों वर्षों में गेहूं की उत्पादकता और बायोमास उपज को महत्वपूर्ण रूप से प्रभावित किया। WH 1105 किस्म के परिणामस्वरूप अन्य किस्मों जैसे DPW 621-50 और HD 2967 की तुलना में अधिक उपज हुई।

ABSTRACT. An experiment was conducted during rabi seasons of 2015-16 and 2016-17 to study the phenology, accumulation of growing degree days (GDD), helio-thermal unit (HTU), photo-thermal unit (PTU), Heat use efficiency (HUE), Radiation use efficiency (RUE)and to assess the effects of thermal and radiation regimes on wheat at research farm of Department of Agricultural Meteorology, Chaudhary Charan Singh Haryana Agricultural University, Hisar during rabi seasons of 2015-16 and 2016-17.

The twenty-seven treatment combinations were tested in split plot design with three replications. The main plot treatments consist of three date of sowing, *i.e*., D1- 2nd fortnight of November, D2- 1st fortnight of December, D3- 2nd fortnight of December and sub plot treatments consist of three varieties, *i.e*., V1- WH 1105, V2- DPW 621-50 and V3- HD 2967.

Daily meteorological data recorded at Agromet observatory near the experimental plot was used for computation of agrometerological indices, *i.e*., heat unit (HU), heliothermal unit (HTU), photothermal unit (PTU), heat use efficiency (HUE) and radiation use efficiency (RUE).

The crop sown on 2nd fortnight of November took maximum no. of days, growing degree days, photo-thermal, helio-thermal unit. The accumulation of HU, HTU, PTU and HUE in early sown crop was higher due to more number of growing days taken for maturity as compared to late sown crops. HD 2967 consumed maximum HU, HTU, PTU and

HUE due to longer growth duration as compared to other varieties. Grain yield showed a significant difference among the three different sowing dates during both the years and highest under 2nd fortnight of November sowing date. Mean grain yield of wheat crop in Rabi 2015-16, under different sowing dates, was more as compared to 2016-17 year. Different sowing dates significantly affected wheat productivity and biomass yield in both the years. WH 1105 variety resulted in higher yield as compared to other varieties, *viz*., DPW 621-50 and HD 2967.

Key words – Growing Degree Days (GDD), Heat Use Efficiency (HUE), Radiation Use Efficiency (RUE), Wheat etc.

1. Introduction

Wheat occupies the prime position among the food crops in the world. In India, it is the second important food crop being next to rice and contributes to the total food grain production of the country to the extent of about 25%. Wheat has played a very vital role in stabilizing the food grain production in the country over the past few years. The meteorological factors play an important role in the development of plant growth and yield of the crop. The most important meteorological variables associated with crop production are air temperature (minimum and maximum), solar radiation and precipitation, relative humidity and wind speed. Solar radiation provides the energy for the process that derive photosynthesis, affecting carbohydrates portioning and biomass growth of the individual plant components. Temperature, humidity and radiation are major agrometeorological parameters which influence all aspects and stages of growth. Temperature is a key component of climate, determining the seedling time and consequently the rate and duration of growth and productivity of the crop (Pal *et al*., 2001). Temperature regulates many of the physical and chemical processes within the plant, which in turn control the rate of growth and development toward maturity. The crop growth and development also depend upon the thermal time. High temperature strongly influences apparent photosynthesis and leaf area index of wheat in semi-arid region (Johnson *et al*., 1981). The growing degree day (GDD), heliothermal unit (HTU) and photothermal unit (PTU) are some simple tools to find out the relationship between plant growth, temperature, bright sunshine hours and day length. Agroclimatic indices, *i.e*., heat unit, photothermal units and heliothermal units are useful in assessing the agroclimatic resources in crop planning and reflecting the impact of agrometeorological variables at different crop growth stages (Bauer *et al.*, 1985).

2. Material & methods

A field experiment was conducted at research farm of Department of Agricultural Meteorology, Chaudhary Charan Singh Haryana Agricultural University, The experiment was laid out in Split-plot design with four replications. The main plot treatments consist of three date of sowing, *i.e*., D_1- 2nd fortnight of November, D_2- 1st fortnight of December, D_3- 2nd fortnight of December and sub plot treatments consist of three *varieties*, *i.e*., V_1- WH 1105, V_2- DPW 621-50 and V_3- HD 2967. The agrometeorological indices, *i.e*., Heat unit, Heliothermal unit, Photothermal unit, Heat use efficiency was computed at important phenophases using agrometeorological data. The determination of following agro metrological indices has carried out by following method and formula-

2.1. *Growing Degree Days (GDD)*

Cumulative growing degree days were determined by summing the daily mean temperature above base temperature, expressed in day °C. This was calculated by using the following formula:

$$\text{GDD (°C)} = \sum_{a}^{b} \left[\frac{(T_{\max} + T_{\min})}{2} - T_b \right]$$

where,

a = Date of start of a phenophase

b = Date of end of the phenophase

$T_{max.}$ = Daily maximum temperature (°C)

$T_{min.}$ = Daily minimum temperature (°C)

T_b = Minimum threshold/base temperature (10°C, WMO, 1996)

2.2. *Heliothermal unit*

Heliothermal units (HTU) for a day represent the product of heat unit and bright sunshine hours for that day and are expressed in °C day hours. The sums of HTU for particular phenophases of interest were determined according to the equation:

$$\text{HTU (°C day hours)} = \sum (\text{HU} \times \text{BSS})$$

where,

BSS = Bright sunshine hours

2.3. *Photothermal unit*

Day and night is one of the basic factors controlling the period of vegetative growth in a photosensitive crop.

TABLE 1

Agrometeorological indices of wheat cultivars under different treatments at various phenophases during the *Rabi* season of 2015-16

Treatments	Emergence			Tillering			Jointing			Anthesis			Milking			Physiological maturity		
	HU	HTU	PTU	HU	HTU	PTU	HU	HTU	PTU	HU	HTU	PTU	HU	HTU	PTU	HU	HTU	PTU
Dates of sowing																		
D_1	100.0	425.7	1080.5	505.4	2824.7	5341.3	734.4	4102.2	7685.9	1059.4	5765.6	11155.1	1348.7	7976.0	14461.2	1683.8	10901.9	18483.3
D_2	93.7	707.7	985.9	390.7	2204.8	4046.2	620.9	3237.4	6425.8	938.7	5268.3	9920.8	1252.4	7723.1	13582.9	1636	10674.8	18036.9
D_3	100.8	449.2	1037.7	369.20	2021.2	3791.8	574.6	2975.6	5984.2	793.6	4570.8	8444.2	1117.6	7063.4	12255.5	1595.4	10609.5	17937.1
Mean	98.1	527.5	1034.7	421.7	2350.3	4393.1	643.3	3438.4	6698.7	930.6	5201.6	9840.1	1239.5	7587.5	13433.2	1638.4	10728.7	18152.4
Varieties																		
V_1	85.8	475.1	907.3	412.2	2257.1	4294	646.8	3431.7	6733.3	978.2	5617.3	10405	1425.3	9030.3	15625.7	1730.1	11495.7	19344.6
V_2	71.3	410.8	754.9	402.9	2211.1	4198.9	639.3	3366.3	6653.7	952.1	5390.7	10105.3	1392	8709.7	15252.6	1670.3	10956.1	18587.6
V_3	99.8	515.7	1054.3	421.2	2313.5	4386.9	654.5	3479.3	6881.4	1030.5	5985.7	11026.8	1464.2	9374.3	16104.6	1811.8	12259.3	20392.7
Mean	85.6	467.2	905.5	412.1	2260.5	4293.2	646.8	3425.7	6756.1	986.9	5664.5	10512.3	1427.1	9038.1	15660.9	1737.4	11570.3	19441.6

Photothermal units (PTU) are cumulative value of heat units multiplied by maximum possible sunshine hours and are expressed in °C day hours. PTU was calculated using the following formula:

$$\text{PTU (°C day hours)} = \sum \left(\text{HU} \times \text{N}\right)$$

where,

N = Maximum possible sunshine hours or day length

2.4. *Heat use efficiency*

Heat use efficiency (HUE) was calculated as the ratio of dry matter (DM) and cumulative thermal time (ΣHU) between any two consecutive phenological stages of the crop.

$$\text{HUE (g/m}^2\text{/°C day)} = \frac{\text{DM}\left(\text{g/m}^2\right)}{\sum \text{HU}\left({}^\circ\text{C day}\right)}$$

2.5. *Radiation use efficiency*

The radiation use efficiency is a ratio of biological or biomass yield and accumulated intercepted radiation and expressed as g MJ^{-1}. RUE is calculated by using the following formula:

$$\text{RUE} = \frac{\text{Biomass yield}\left(\text{gm}^{-2}\right)}{\text{Accumulated intercepted radiation}\left(\text{MJ m}^{-2}\right)}$$

2.6. *Intercepted photosynthetically active radiation (IPAR)*

Daily solar radiation was computed by the expression

Rs = Ra (1-r) (a+b (n/N))

where,

Rs is solar radiation received at the surface of the earth (cal/cm^2), Ra is solar radiation received outside the atmosphere (cal/cm^2) used from Smithsonian tables corresponding to the latitude values of Hisar, r is reflection coefficient (0.25) for green vegetations, a and b are constants, a = 0.256; b = 0.56 for Hisar, (Bishnoi *et al*., 1995).

Daily PAR was calculated by the formula:

PAR = Rs × 0.48 (Oleson *et al*., 2000)

The PAR values were converted into MJ/ m^2. The daily IPAR was calculated using the following expression:

IPAR = PAR ($1-e^{-kf}$) (Rosenthal and Gerik, 1991).

where, k is extinction coefficient = ln (I-Io)/f (Monsi and Saeki, 1953).

F is cumulative leaf area index of foliage layer.

TABLE 2

Agrometeorological indices of wheat cultivars under different treatments at various phenophases during the *Rabi* season of 2016-17

Treatments	Emergence			Tillering			Jointing			Anthesis			Milking			Physiological maturity		
	HU	HTU	PTU	HU	HTU	PTU	HU	HTU	PTU	HU	HTU	PTU	HU	HTU	PTU	HU	HTU	PTU
Dates of sowing																		
D_1	63.9	441.0	662.9	403.4	2438.6	4143.5	622.7	3730.5	6762.6	1073.0	6831.5	11547.6	1463.1	10614.5	16685.7	2076.8	16287.6	25331.4
D_2	54.8	375.8	560.1	308.5	1564.9	3168.3	559.1	3374.7	5878.2	996.9	6566.5	10975.0	1454.5	10414.2	16198.8	1969.2	15207.5	23422.5
D_3	91.1	265.0	934.1	326.3	1298.5	3427.3	621.7	3006.6	6437.7	953.3	6460.1	10727.3	1384.8	10342.6	16163.4	1923.5	14508.5	22234.0
Mean	69.9	360.6	719.0	346.1	1767.3	3579.7	601.2	3370.6	6359.5	1007.7	6619.4	11083.3	1434.1	10457.1	16349.3	1989.8	15334.5	23662.6
Varieties																		
V_1	53.3	293.6	548.1	335.8	1736.5	3469.6	613.8	3461.5	6503.1	1122.7	7641.1	12521.4	1586.8	11850.6	18397.8	1989.9	15314.9	23700.9
V_2	50.8	124.6	519.6	326.4	1681.9	3369.5	591.8	3310.4	6256.9	1020.4	6846.9	11269.1	1491.0	10993.2	17168.4	1885.7	14361.9	22314.6
V_3	63.6	208.2	654.9	364.4	1845.7	3772.2	625.9	3548.5	6638.7	1157.1	7967.3	12945.9	1637.8	12275.9	19057.2	2099.8	16258.7	25170.3
Mean	55.9	208.8	574.2	342.2	1754.7	3537.1	610.5	3440.1	6466.2	1100.1	7485.1	12245.5	1571.9	11706.6	18207.8	1991.8	15311.8	23728.6

Io is radiation energy at the top of the canopy,

I is radiation energy at a level inside the crop canopy.

2.7. *Yield and yield attributes*

The observations on yield and yield attributing characters, *i.e*., grain, straw and biological yield were taken from each plot at the time of harvest.

3. Results and discussion

The results revealed that agrometeorological indices accumulated (HU, HTU, PTU and HUE) at different phenophases were higher in 2nd fortnight of November (D_1) sown crop as compared to 1st fortnight of December (D_2) and 2nd fortnight of December (D_3) at physiological maturity in comparison to the other dates of sowing.

Growing degree days (HU) accumulation was significantly higher under early sown crop at all the phenophases in comparison to the other sowing dates of crops. The cumulated GDD was maximum in the 2nd fortnight of November (D1) sown crop followed by 1st fortnight of December (D2) and 2nd fortnight of December (D3) sown crop at all phenological stages sown crop during 2015-16, respectively. (Table 1) These GDD values at physiological maturity were 1683.8, 1636.0 and 1595.4 °C day for D1, D2 and D3 respectively. Among the wheat varieties, the highest number of GDD were accumulated 1811.8 °C day by HD 2967 (V3) ; the next higher were 1730.1 °C day by WH 1105 (V1) and 1670.3 °C day by DPW 621-50 (V2). Among varieties, HD 2967 (V3) accumulated higher GDD as compared to other varieties.

The cumulative value of *heliothermal units* (HTU) at physiological maturity was higher in the first sown crop as compared to late sown wheat crop. The wheat crop sown on 2nd fortnight of November (D1) consumed higher heliothermal units as compared to 1st fortnight of December (D2) and 2nd fortnight of December (D3) sown crop at all phenological stages and similar trend in crop sown during the season of 2016-17. (Table 2) These values at physiological maturity were 10901.9, 10674.8 and 10609.5 °C day hour for D1, D2 and D3 respectively. Among wheat varieties, V3 -HD 2967 accumulated higher amount of HTU with the value of 12259.3 °C day as compared to V1 -WH 1105 (11495.7 °C day) and V2 -DPW 621-50 (10956.7 °C day). The accumulation of HTU in early sown crop (10901.9 °C day) was higher due to more growing days taken for maturity as compared to late sown crops. HD 2967 consumed maximum HTU (12259.3 °C day) due to more growth duration as compared to other varieties.

TABLE 3

Effect of different treatments on heat use efficiency (g °C day^{-1}) at different phenophases in wheat during *Rabi* 2015-16 and 2016-17

Treatment	Tillering		Jointing		Anthesis		Milking		Physiological maturity	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Date of sowing										
D_1	0.25	0.21	0.47	0.44	0.66	0.53	0.91	0.67	0.81	0.62
D_2	0.23	0.28	0.44	0.41	0.56	0.50	0.84	0.66	0.72	0.60
D_3	0.18	0.27	0.37	0.40	0.49	0.47	0.82	0.62	0.67	0.59
CD at 5%	0.008	0.010	0.016	0.018	0.022	0.024	N/A	0.021	0.028	0.031
Varieties										
V_1	0.23	0.29	0.45	0.44	0.61	0.56	0.91	0.70	0.81	0.69
V_2	0.22	0.23	0.42	0.41	0.58	0.51	0.84	0.59	0.72	0.64
V_3	0.21	0.25	0.41	0.38	0.52	0.43	0.78	0.51	0.66	0.62
CD at 5%	0.012	0.014	0.025	0.028	0.034	0.033	0.051	0.058	0.045	0.032

TABLE 4

Effect of different treatments on cumulative radiation use efficiency (g MJ^{-1}) at different phenophases in wheat during *Rabi* 2015-16 and 2016-17

Treatment	Tillering		Jointing		Anthesis		Milking		Physiological maturity	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Date of sowing										
D_1	0.46	0.43	0.71	0.66	0.85	0.67	1.39	1.11	1.13	0.87
D_2	0.42	0.44	0.72	0.61	0.82	0.65	1.26	1.00	1.08	0.82
D_3	0.26	0.31	0.62	0.48	0.86	0.64	1.22	0.96	1.06	0.81
Mean	0.38	0.4	0.68	0.6	0.84	0.7	1.29	1.0	1.09	0.8
S.D.	0.11	0.1	0.06	0.1	0.02	0.0	0.09	0.1	0.04	0.01
C.V.	28.95	25.00	8.82	16.67	2.38	1.43	6.98	10.00	3.67	1.25
Varieties										
V_1	0.41	0.45	0.70	0.60	0.92	0.67	1.44	1.07	1.15	0.90
V_2	0.41	0.37	0.71	0.58	0.84	0.67	1.24	1.01	0.94	0.80
V_3	0.39	0.37	0.68	0.51	0.71	0.50	1.12	0.92	0.84	0.64
Mean	0.40	0.4	0.70	0.6	0.82	0.6	1.27	1.0	0.98	0.8
S.D.	0.01	0.0	0.02	0.0	0.11	0.1	0.16	0.1	0.16	0.1
C.V.	2.50	2.50	2.86	1.67	13.41	16.67	12.60	10.00	16.33	12.50

Photothermal units were significantly higher in the 2nd fortnight of November (D1) followed by 1st fortnight of December (D2) and 2nd fortnight of December (D^3) sown crop at all phenological stages during the crop season of 2015-16 (Table 1) and similar trend in crop sown during 2016-17 (Table 2). These values at physiological maturity were 18483.3, 18036.9 and 17937.1 °C day hour for D1, D2 and D3 respectively. V3 -HD 2967 accumulated higher PTU (20392.7 °C day hour) as compared to V1 -WH 1105 (19344.6 °C day hour) and V2 -DPW 621-50

(18587.6 °C day hour). Among wheat varieties, WH 1105 consumed highest heat units, heliothermal units and photothermal as compared to DPW 621-50 and HD 2967 under different sowing environments at physiological maturity.

Heat use efficiency (HUE) gradually increased from tillering to milking stage and thereafter decreased toward physiological maturity among all the dates of sowing during both the crop season of 2015-16 and 2016-17 (Table 3). Significantly highest HUE was found in the 2nd fortnight of November (D1) followed by 1st fortnight of December (D2) and 2nd fortnight of December (D3) sown crop, at all phenophases respectively in the year 2015-16 and similar trend was obtained during the crop season of 2016-17. Among varieties, WH 1105 (V1) had significantly higher HUE at physiological maturity followed by DPW 621-50 (V2) and HD 2967 (V3). The decrease in HUE with delay in sowing was due to the fact that delayed sowing of wheat crop led to both early vegetative and reproductive phases, high temperature prevailed in the late sown crop during reproductive phase. The results revealed that during both the years of experimentations, the highest heat use efficiency was under D_1 (2nd fortnight of November) sown crop during the year 2015-16 because of longer bright sunshine (BSS) hours at vegetative stage as compared to other date of sowing. During the second year, *i.e*., 2016-17, *i.e*., 2016-17, highest thermal use efficiency was recorded under first date of sowing as compared to other sowing treatments (Table 3). Among varieties, WH 1105 (V_1) had significantly higher HUE at physiological maturity followed by DPW 621-50 (V_2) and HD 2967 (V_3). This might be due to the decrease in HUE with delay in sowing was due to the fact that delayed sowing of wheat crop led to early reproductive phase due to low temperature and shorter days prevailed in the late sown crop The results are in close agreement with Pandey *et al.* (2010); Jhanji and Gill (2011) and Khavse *et al.* (2015).

Radiation use efficiency (RUE) is outcome of total dry matter and amount of cumulative intercepted photosynthetically active radiation (IPAR) of crop at different phenophases in all the treatments. RUE was computed in all the treatments at foresaid phenophases and presented in Table 4. The RUE increased gradually from tillering to milking stage thereafter decreased up to physiological maturity. RUE attained maximum value at milking stage in all the treatments. Thereafter, it declined till physiological maturity in both the year of experimentation. The maximum RUE (1.39 g MJ^{-1}) at milking stage in the year 2015-16 was observed in D1 crop followed by D2 and D3 respectively. Maximum RUE during 2015-16 at milking was 1.39, 1.26 and 1.22 MJ^{-1} in D1, D2 and D3, respectively. The maximum value of RUE was recorded with D_1 (2nd fortnight of November) and V_1 (WH 1105) and minimum with D_3 (2nd fortnight of December) and V_3 (HD 2967) among various date of sowing and varieties during both crop seasons. This may be due to PAR absorption and force maturity in late sown and poorly nourished crop. The less RUE was obtained in D_3 (2nd fortnight of December) and V_3 (HD 2967) could be attributed to less dry matter accumulation at different growth stages under these treatments. This result was confirmed by Sharma *et al.* (2000) and Khavse *et al.* (2015). The sowing of 2nd fortnight of November wheat crop in *Rabi* season resulted in about two days earlier emergence than 1st fortnight of December and three days earlier than 2nd fortnight of December (Table 4). The seedling emergence in D_1 (2nd fortnight of November) treatment was significantly earlier than all the treatments during both the the crop seasons. This was resulted due to lower temperature experienced by late sowing date. The days taken to attainment of tillering, anthesis and physiological maturity were higher in D_1 (2nd fortnight of November) sown crop as compared to other sowing treatments. This was due to higher temperature experienced in middle and late phases by delayed sowing which caused reduction in duration of reproductive phases. These results are similar with the finding of Murungu and Madanzi (2010), Kaur *et al.* (2010) and Khavse *et al.* (2015).

Grain yield Data pertaining to grain yield as influenced by sowing dates and varieties are presented in Table 5. Grain yield differed significantly under different sowing dates during both the crop seasons. Crop sown on D1 recorded significantly highest grain yield (53.4 & 48.59 q ha^{-1}) over D2, (51.90 & 40.02 q ha^{-1}) and D3 (46.40 & 32.85 q ha^{-1}) sowing during both years of experiments. Among the varieties, WH 1105 (V1) variety recorded significantly highest grain yield (49.50 & 41.34 q ha^{-1}) than rest of the varieties (V2 -DPW 621-50) and (V3-HD 2967) during both the years. Significant lowest grain yield (46.10 & 36.43 q ha^{-1}) was observed in one HD 2967 during the year 2015-16 & 2016-17, respectively.

Straw yield Data related to straw yield as influenced by sowing dates and varieties are presented in Table 5. Straw yield differed significantly under different sowing dates during both the years. Crop sown on D2 recorded significantly highest straw yield (82.73 q ha^{-1}) over D1 (79.20 q ha^{-1}) and D3 (66.80 q ha^{-1}) sowing during the year 2015-16. But during the year 2016-17, Crop sown on D1 (2nd fortnight of December) recorded significantly highest straw yield (82.73 q ha^{-1}) over D2 (1st fortnight of December), (74.32 q ha^{-1}) and D3 (2nd fortnight of December) (76.65 q ha^{-1}). Among the varieties, WH 1105 (V1) variety recorded significantly highest straw yield

TABLE 5

Effect of different treatments on yield of wheat crop during *Rabi* 2015-16 and 2016-17

Treatment	Grain yield (q/ha)		Straw yield (q/ha)		Biological yield (q/ha)		Harvest index	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Date of sowing								
D_1	53.40	48.59	79.20	82.73	132.60	131.32	0.40	0.37
D_2	51.90	40.02	82.50	74.32	134.40	114.34	0.38	0.35
D_3	46.40	32.85	66.80	76.65	113.20	109.50	0.40	0.30
CD at 5%	2.07	1.62	2.90	2.79	4.65	3.94	NS	0.01
Varieties								
V_1	49.50	41.34	77.00	73.49	126.50	114.83	0.39	0.36
V_2	47.70	38.30	67.30	81.38	115.00	119.68	0.41	0.32
V_3	46.10	36.43	67.10	73.96	113.20	110.39	0.41	0.33
CD at 5%	2.87	2.49	4.30	4.62	7.65	7.22	0.024	0.02

(77.00 q ha^{-1}) than rest of the varieties (DPW 621-50 and HD 2967) during the year 2015-16. Significant lowest straw yield (67.10 q ha^{-1}) was observed in HD 2967 variety during the year 2015-16, respectively. But during the year 2016-17, DPW 621-50 (V2) variety recorded highest straw yield (81.38 q ha^{-1}) as compared to rest of the varieties (V1-WH 1105 and (V2- HD 2967).

Biological yield Data related to biological yield as influenced by sowing dates and varieties are presented in Table 5. Biological yield differed significantly under different sowing dates during both the years. Crop sown on D2 recorded significantly highest biological yield (134.40 q ha^{-1}) over D1 (132.60 q ha^{-1}) and D3 (113.20 q ha^{-1}) sowing during the year 2015-16 of experimentation (Table 5). But during the year 2016-17, crop sown on D1 recorded significantly highest biological yield (131.32 q ha^{-1}) over D2 (114.34 q ha^{-1}) and D3 (109.50 q ha^{-1}) Among the varieties, WH 1105 (V1) variety recorded significantly highest biological yield (126.50 q ha^{-1}) than rest of the varieties (DPW 621-50 and HD 2967) during the year 2015-16. Significant lowest biological yield (113.20 q ha^{-1}) was observed in HD 2967 (V3) variety during the year 2015-16, respectively. But during the year 2016-17, (V2- DPW 621-50 variety recorded highest biological yield (119.68 q ha^{-1}) as compared to rest of the varieties (WH 1105 and HD 2967).

Harvest index Data pertaining to harvest index as influenced by sowing dates and varieties are presented in Table 5. Harvest index values were varied significantly under different sowing dates during first year of experimentation. Crop sown on D1 (2^{nd} fortnight of November) recorded significantly higher harvest index (40 %) over D2 and D3 sowings, while during second year of experimentations there was significant difference among all the sowing times. Among the varieties, DPW 621-50 (V2) and HD 2967 (V3) recorded significantly highest harvest index (41 %) than the variety WH 1105 (V1) during the year 2015-16. Significant lowest harvest index (39 %) was observed in WH 1105 variety during the year 2015-16, respectively. But during the year 2016-17, WH 1105 variety recorded highest harvest index (36 %) as compared to rest of the varieties (DPW 621-50 and HD 2967).

The yield attributes such as grain yield, straw yield, biological yield and harvest index showed a significant difference among the three different sowing dates during both the years and highest under D_1 (2^{nd} fortnight of November) sowing date. Mean grain yield of wheat crop in *Rabi* 2015-16, under different sowing dates, was more as compared to 2016-17 year. (Table 5). Different sowing date also significantly affected wheat productivity and biomass yield in both the years. WH 1105 (V_1) variety resulted higher yield as compared to other varieties DPW 621-50 (V_2) and HD 2967 (V_3).

4. Conclusion

The study clearly indicates that different agrometeorological indices (HU, HTU, PTU and HUE) required for the maturity of wheat crop has been influenced by different sowing time. It was found that influenced of agro meteorological indices was highest in wheat sown on D1 and lowest in D3 sown crop. The accumulation of HU, HTU, PTU in early sown crop was higher due to more growing days taken for maturity as compared to late sown crops. HD 2967 consumed maximum HU, HTU, PTU due to more growth duration as compared to other varieties. Grain yield showed a significant difference among the three different sowing dates during both the years and highest under 2^{nd} fortnight of November sowing date. Mean grain yield of wheat crop in *Rabi* 2015-16, under different sowing dates, was more as compared to 2016-17 year. Different sowing date also significantly affected wheat productivity and biomass yield in both the years. WH 1105 variety resulted higher yield as compared to other varieties DPW 621-50 and HD 2967.

Apart from this, further study required for establishment of relationship for growth, development and yield of wheat with other agro meteorological indices after that it is possible to study the effects of dates of sowing on phenology, thermal and radiation regimes, and yield of wheat in future.

Disclaimer : The contents and views expressed in this study are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

Reference

Bauer, A., Frank, A. B. and Black, A. L., 1985, "Estimation of spring wheat grain dry matter assimilation from air temperature", *Agronomy Journal*, **77**, 743-752.

Bishnoi, O. P., Singh, S. and Niwas, R., 1995, "Effect of temperature on phenological development of wheat", *Indian Journal of Agricultural Science*, **63**, 211-214.

Jhanji, S. and Gill, D. S., 2011, "Phenological development and heat unit requirement of wheat under different dates of sowing", *Indian Journal of Agricultural Research*, **45**, 2, 161-166.

Johnson, R. C., Witters, R. E. and Chia, A. J., 1981, "Daily patterns of apparent photosynthesis and evapotranspiration in a developing winter wheat crop", *Agronomy Journal*, **73**, 414-418.

Kaur, M., Singh, K. N., Singh, M., Thakur, N. P. and Kachroo, D., 2010, "Phenophase prediction model for wheat (*Triticumaestivum*) growth using agro meteorological indices sown under different environments in temperate region of Kashmir", *Journal of Agrometeorology*, **12**, 33-36.

Khavse, R., Deshmukh, R., Verma, N. and Kausik, D., 2015, "Phenology growth and yield of wheat in relation to agrometeorolog indices under different sowing dates", *Plant Archives*, **15**, 1, 81-87

Monsi, M. and Saeki, T., 1953, "Uberden Lichtfacktor in denpflanzengeselischaften and seirbeedentungjur die stuft production, *Journal of Japanese botany*, **14**, 22-52.

Murungu, F. S. and Madanzi, T., 2010, "Seed priming, genotype and sowing date effects on emergence, growth and yield of wheat in a tropical low altitude area of Zimbabwe", *African Journal of Agricultural Research*, **5**, 2341-2349.

Oleson, J. E., Jorgenson, L. N. and Mortensen, J. V., 2000, "Irrigation strategy, nitrogen application and fungicide control in winter wheat on a sandy soil. II", Radiation interception and conversion. *Journal of Agricultural Sciences*, Cambridge, **134**, 13-23.

Pal, S. K., Verma, U. N., Singh, M. K., Upsani, R. R. and Thakur, R., 2001, "Growth and yield of late sown wheat under different irrigation schedules", *Indian Journal of Agricultural Science*, **71**, 664-667.

Pandey, I. B., Pandey, R. K., Dwivedi, D. K. and Singh, R. S., 2010, "Phenology, heat unit requirement and yield of wheat varieties under different crop-growing environment", *Indian Journal of Agricultural Sciences*, **80**, 136-140.

Rosenthal, W. D. and Gerik, T. J., 1991, "Radiation use efficiency among cotton cultivars", *Agronomy Journal*, **83**, 655-658.

Sharma, K., Niwas, R. and Singh, M., 2000, "Effect of sowing time on radiation use efficiency of wheat cultivars", *Journal of Agrometeorology*, **2**, 166-169.

World Meteorological Organization, 1996, WMO/ UMAP Workshop on Broad-band UV Radiometers (Garmisch-Partenkirchen, Germany, 22-23 April 1996). Global Atmosphere Watch Report No. 120, WMO/TD-No. 894, Geneva.