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Agrometeorological indices in relation to phenology of wheat

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Abstract
Field experiment was conducted at research farm of Department of Agricultural Meteorology, Chaudhary Charan Singh Haryana Agricultural University, Hisar (long.75^0 46 $^/$ E, lat. 29^{0}10 $^/$ N and alti. 215.2 meters MSL) during *Rabi* season of the year 2015-16., to study the phenology and, heat and radiation use efficiency in wheat. Crop was sown on three different dates *viz.,* D_1- 2nd fortnight of November, D_2- 1st fortnight of December and D_3- 2nd fortnight of December as main plots and three varieties *viz.,* V_1-WH 1105, V_2-DPW 621-50 and V_3-HD 2967 as sub-plots in split plot design and replicated thrice. Results revealed that, during physiological maturity, HD 2967, WH 1105 has accumulated growing degree days (GDD) of 1811.8, 1730.1 and heliothermal units (HTU) of 12259.3, 11495.7 with coefficient of variation (CV) of 4% and 5%, respectively. While DPW 621-50 has accumulated 1670.3 growing degree days and 10956.1 heliothermal units during physiological maturity, respectively. In both the varieties i.e., WH 1105 and DPW 621-50 higher heat use efficiency (0.81 and 0.72) and radiation use efficiency (1.15 and 0.94) were obtained in crop sown on second fortnight of November. In WH 1105, DPW 621-50 and HD 2967 physiological maturity can be predicted using accumulated growing degree days and heat use efficiency.

Keywords: Agrometeorological indices, GDD, Phenology, HUE, RUE

Introduction

Wheat is the major winter cereal crop of Haryana state. It is grown in an area of about 2.50 million ha with production of 11.80 million tones with a second highest productivity (4722 kg ha^{-1}) in the country (Anonymous, 2014). The low productivity of wheat in our country is mainly attributed to the delayed sowing, imbalanced and lower doses of fertilizer, improper selection of varieties, poor irrigation facilities and adverse weather conditions. It depends largely on the prevailing weather conditions during crop growth period. The choice of sowing time and selection of improved varieties is an important management decision to optimize grain yields. Late sown wheat face low temperature in the earlier part and high temperature stress in the later part of the growing season (Alam *et al*., 2013) [1]. Bannayan *et al*., 2013 have reported increased yield with early sowing, however yield decreased when sowing is late. 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) [9]. 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 depends upon the thermal time. High temperature strongly influence apparent photosynthesis and leaf area index of wheat in semi-arid region (Johnson *et al*., 1981). 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) [4].

Material and Methods

The field experiment was conducted at Research Area of Department of Agricultural Meteorology, Chaudhary Charan Singh Haryana Agricultural University, Hisar located at 29°10'N, 75°46'E and altitude of 215.2 m. The experiment was laid in split-plot design with three dates of sowing D_1- 2nd fortnight of November, D_2- 1st fortnight of December and D_3- 2nd fortnight of December as the main plots treatments in combination with three wheat varieties *viz*. V_1- WH 1105, V_2-DPW 621-50 and V_3-HD 2967 as the sub-plots.

The agro meteorological indices i.e Heat unit, Heliothermal unit, Radiation use efficiency, 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-

(a) Heat unit: Cumulative heat units (HU) were determined by summing the daily mean temperature above base temperature and are expressed in ^{0}C day. This was calculated using the following formula:

$$\text{Heat Unit } (^{0}\text{C day}) = \Sigma \left(\frac{b\ (T_{max.} + T_{min.})}{a\ \ 2} - T_b \right)$$

Where

a = Date of start of a phenophase
b = Date of end of the phenophase
$T_{max.}$ = Daily maximum temperature (^{o}C)
$T_{min.}$ = Daily minimum temperature (^{o}C)
T_b = Minimum threshold/base temperature (10^{o}C, WMO, 1996)

(b) 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 ^{o}C day hours. The sums of HTU for particular phenophases of interest were determined according to the equation:
HTU (^{0}C day hours) = Σ (HU x BSS)

Where

BSS = Bright sunshine hours

(c) Radiation use efficiency (RUE)

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:

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

(d) 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.

$$\text{HUE (g/m}^2/^{0}\text{C day)} = \frac{\text{DM (g/m}^2)}{\Sigma\ \text{HU } (^{0}\text{C day})}$$

Results

The results revealed that accumulated GDD were significantly different at emergence among sowing dates during both the crop season because number of days taken to emergence stage was significantly lower in late sowing in D_3 (2nd fortnight of December) followed by D_2 (1st fortnight of December) and D_1 (2nd fortnight of November) (Table 1). These finding were supported by Dubey *et al.* (2008) [5] and Khavse *et al.* (2015) [8]. The Accumulated GDD was less at emergence due to comparatively low temperature (Singh *et al*., 2008). Subsequently heat units accumulation was higher under early sown crop D_1 (2nd fortnight of November) at all the phenophases till milking stage and their after decreased due to low temperature at that time as compare to other date of sowing. This might be due to more days taken by 2nd fortnight of November sown crop to attain the different developmental phenophases as compared to other growing.

Heliothermal units accumulated at all phenophases were also varied in different date of sowing. Heliothermal units calculated during *Rabi* season 2015-16 (Table 2) show that the cumulative value of HTU at physiological maturity was higher in the first sown crop as compared to late sown wheat crop. The HTU values were higher in the D_1 (2nd fortnight of November) sown crop followed by D_2 (1st fortnight of December) and D_3 (2nd fortnight of December) sown crop at all phenological stages. These finding were supported to Khavse *et al.,* (2015) [8].

Radiation use efficiency varied significantly among different treatments and increased with crop growth and its peak values were at maturity in all treatments (Table 3). The reason for radiation use efficiency decline might be due to less IPAR by the crop due to decreased chlorophyll content in the matured leaves in addition to the slower rate of biomass production during this period because of high temperature stress and leaf senescence and only translocation of biomass was happing from source to sink. This result was confirmed by Sharma *et al.* (2000) [11] and Khavse *et al.* (2015) [8]. 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 date of sowing and varieties during both crop season. 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 was also related to higher PAR because of direct effect of increased irrigation on leaf area index in higher irrigation level treatment.

Highest heat use efficiency for yield was under D_1 (2nd fortnight of November) sown crop during the year 2015-16 because of more bright sunshine (BSS) hours was there at vegetative stage as compare to other date of sowing (Table 4).The lowest HUE D_3 (2nd fortnight of December) in delayed sowing can be expected due to accumulation of comparable heat unit (HU) to that of early sowing at later crop growth stages. 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) [10], Jhanji and Gill (2011) [6] and Khavse *et al.* (2015) [8].

Table 1: Effect of different treatments on cumulative heat units (day °C) at different phenophases in wheat during *Rabi* 2015-16

Treatment	Emergence	Tillering	Jointing	Anthesis	Milking	Physiological maturity
Effect of dates of sowing						
D_1	100.0	505.4	734.4	1059.4	1348.7	1683.8
D_2	93.7	390.7	620.9	938.7	1252.4	1636
D_3	100.8	369.20	574.6	793.6	1117.6	1595.4
Mean	98.1	421.7	643.3	930.6	1239.5	1638.4
S.D	3.9	73.2	82.2	133.0	116.0	44.2
C.V	3.98	17.36	12.78	14.29	9.36	2.70
Effect of varieties						
WH 1105	85.8	412.2	646.8	978.2	1425.3	1730.1

DPW 621-50	71.3	402.9	639.3	952.1	1392	1670.3
HD 2967	99.8	421.2	654.5	1030.5	1464.2	1811.8
Mean	85.6	412.1	646.8	986.9	1427.1	1737.4
S.D	14.2	9.1	7.6	39.9	36.1	71.0
C.V	16.59	2.21	1.18	4.04	2.53	4.09

Table 2: Effect of different treatments on cumulative heliothermal units (°C day hours) at different phenophases in wheat during *Rabi* 2015-16

Treatment	Emergence	Tillering	Jointing	Anthesis	Milking	Physiological maturity
Effect of dates of sowing						
D_1	425.7	2824.7	4102.2	5765.6	7976.0	10901.9
D_2	707.7	2204.8	3237.4	5268.3	7723.1	10674.8
D_3	449.2	2021.2	2975.6	4570.8	7063.4	10609.5
Mean	527.5	2350.3	3438.4	5201.6	7587.5	10728.7
S.D	156.4	421.0	589.5	600.2	471.1	153.4
C.V	29.65	17.91	17.14	11.54	6.21	1.43
Effect of varieties						
WH 1105	475.1	2257.1	3431.7	5617.3	9030.3	11495.7
DPW 621-50	410.8	2211.1	3366.3	5390.7	8709.7	10956.1
HD 2967	515.7	2313.5	3479.3	5985.7	9374.3	12259.3
Mean	467.2	2260.5	3425.7	5664.5	9038.1	11570.3
S.D	52.8	51.2	56.7	300.3	332.3	654.80
C.V	11.30	2.26	1.66	5.30	3.68	5.66

Table 3: Effect of different treatments on cumulative radiation use efficiency (g MJ^{-1}) at different phenophases in wheat during *Rabi* 2015-16

Treatment	Tillering	Jointing	Anthesis	Milking	Physiological maturity
Effect of dates of sowing					
D_1	0.46	0.71	0.85	1.39	1.08
D_2	0.42	0.72	0.82	1.26	1.06
D_3	0.26	0.62	0.86	1.22	1.13
Mean	0.38	0.68	0.84	1.29	1.09
S.D.	0.11	0.06	0.02	0.09	0.04
C.V.	28.95	8.82	2.38	6.98	3.67
Effect of varieties					
WH 1105	0.41	0.7	0.92	1.44	1.15
DPW 621-50	0.41	0.71	0.84	1.24	0.94
HD 2967	0.39	0.68	0.71	1.12	0.84
Mean	0.40	0.70	0.82	1.27	0.98
S.D.	0.01	0.02	0.11	0.16	0.16
C.V.	2.50	2.86	13.41	12.60	16.33

Table 4: Effect of different treatments on cumulative heat use efficiency (g ^{0}C day^{-1}) at different phenophases in wheat during *Rabi* 2015-16

Treatment	Tillering	Jointing	Anthesis	Milking	Physiological maturity
Effect of dates of sowing					
D_1	0.25	0.47	0.66	0.91	0.81
D_2	0.23	0.44	0.56	0.84	0.72
D_3	0.18	0.37	0.49	0.82	0.67
CD at 5%	0.008	0.016	0.022	N/A	0.028
Effect of varieties					
WH 1105	0.23	0.45	0.61	0.91	0.81
DPW 621-50	0.22	0.42	0.58	0.84	0.72
HD 2967	0.21	0.41	0.52	0.78	0.66
CD at 5%	0.012	0.025	0.034	0.051	0.045

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