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Agrometeorological Indices Requirement of Wheat Crop at Allahabad Region under Different Sowing Environment

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ABSTRACT

A field experiment was conducted during Rabi season 2016-17 at Farm Research Centre, College of Forestry, SHUATS, Allahabad to calculate agro-meteorological indices of wheat crop under three date of sowing i.e. 5th November, 15th November and 25th November and three variety i.e. HD-2967, PBW-502, PBW-154. Wheat crop sown on 5th November utilised more thermal and heat units as compared to 15th November and 25th November sown crops. The shortening of the duration of the crop sown late was due to forced maturity because of higher temperature during reproductive phase of the crop. Similarly Hygrothermal Unit-I and II was found highest at 5th November followed by 15th November. The heat use efficiency and temperature use efficiency was found highest for HD-2967 variety and lowest for PBW-154 variety.

Introduction

Wheat is a cereal grass of the *Graminae* (*Poaceae*) family, genus *Triticum* and is the world's largest cereal crop. It has been described as the 'King of Cereals' because of the acreage it occupies, high productivity and the prominent position it holds in the international food grain trade. World production of wheat was 757 metric tons which making it the second most-produced cereal after maize (FAO Stat, 2017). Wheat is the important food crop of the world it provides food to 36% of the global population contributing 20% of the food calories for the world people and is a national staple in many countries. India ranks second among wheat producing country in the world. The sowing time is the most important factor determining the yield of wheat. The nutrient content in grain and straw has been reported to be increased with optimum sowing of wheat whereas, uptake of these nutrients decreased as the sowing of wheat gets delayed. Temperature based agro meteorological indices such as growing degree days (GDD), heliothermal units (HTU) and photo thermal units (PTU) are based on the concept that real time to attain the phenological stage is linearly related to temperature in the range between base temperature and optimum temperature. Heat and photoperiodic units are considered as the fundamental units used to examine the phenology of crops over climatic variations (Sreenivas *et al.*, 2010). Heat use efficiency depicted that the heat utilized to produce one unit of plant biomass (Rajbongshi *et al.*, 2016). Every crop has its own definite requirements for particular environmental conditions for its proper growth and yield (Razzaq *et al.*, 1986). By keeping above facts in view an attempt has been made to study the agro-meteorological indices under different sowing dates to obtain higher grain yield of wheat.

Materials and Methods

Field experiment was conducted in the farm research centre, College of Forestry, Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad during rabi season (2016-17). Allahabad is located at 25.57^0 N latitude, 81.51^0 E longitude and 90 meter above the sea level. This region has Sub-tropical climate with extreme of summer and winter. The soil was sandy loam and slightly alkaline. The temperature falls down to as low as $1\text{-}2^0$ C during winter season especially in the month of December and January. The Mercury rise up to 46^0-48^0C during summer. The Allahabad receives the mean annual rainfall ranges 886 mm. More than 70% rains are received during S-W monsoon season, 5–10 % rains are received in winter, 10–15% in pre-monsoon and 5–10% during post monsoon season. Normal rainy days exceed 40 annually. Summer monsoon rainfall comes in down pours while winter rainfall comes in light drizzles and is easily absorbed in soils.

During crop season 2015-16, the morning relative humidity ranged between 82.43% to 94.71% and the quantum of rainfall of 0.2 mm and that was received in 12^{th} SMW. The nine treatment combinations of the experiment comprised of three sowing dates viz. 5^{th} November (D_1), 15^{th} November (D_2) and 25^{th} November (D_3) and three cultivars HD-2967(V_1), PBW-502 (V_2) and PBW-154 (V_3) replicated thrice times in two factors RBD randomised block design. The treatment details are as follows $T_1=D_1+V_1$, $T_2=D_1+V_2$, $T_3=D_1+V_3$, $T_4=D_2+V_1$, $T_5=D_2+V_2$, $T_6=D_2+V_3$, $T_7=D_3+V_1$, $T_8=D_3+V_2$ and $T_9=D_3+V_3$.

Data on weather parameters viz., maximum, minimum temperature, rainfall, bright sunshine hours, day length and relative humidity (RH) used for the study were recorded from meteorological observatory, College of Forestry, SHUATS, Allahabad.

The agrometeorological indices viz., GDD, PTU and HTU were calculated for different phenophases by adopting procedure laid out by Rajput (1980). For calculation of GDD, PTU and HTU base temperature was taken as 5^oC.

$$GDD = \sum[(T_{max.} + T_{min.})/2 - T_b],$$

Where, GDD=Growing degree days, T_{max}= Daily maximum temperature, T_{min}= Daily minimum temperature and T_b= Base temperature 5^0C for wheat.

Heliothermal Unit (HTU) for particular phenophases of interest were determined according to the equation:

HTU (°C day hours) = $\sum$ (GDD x BSS), Where, BSS = Bright sunshine hours (hrs).

Photothermal Unit (PTU) was calculated by using the following equation:

PTU = GDD x N, Where, L = Maximum possible day length (hrs).

Hygrothermal Unit (HgTU) was calculated twice in morning and afternoon by using the following equation:

HgTU = GDD x RH, where, RH= relative humidity in morning or afternoon (%)

Heat use efficiency (HUE) for grain was obtained as:

$$HUE = \frac{\text{Total grain yield}}{\text{Accumulated GDD}} \text{ Kg/ha/}^{0}\text{C/day}$$

The Heliothermal Use Efficiency (HTUE) indicates the efficiency of crop to utilize the available bright sunshine hours.

$$HTUE = \frac{\text{Total grain yield}}{\text{Accumulated HTU}} \text{Kg/ha/}^{0}\text{C/day}$$

The Photothermal Use Efficiency (PTUE) indicates the efficiency of crop to utilize the available maximum possible bright sunshine hours.

$$PTUE = \frac{\text{Total grain yield}}{\text{Accumulated PTU}} \text{Kg/ha/}^{0}\text{C/day}$$

The Hygrothermal use efficiency (H_gTUE) indicates the efficiency of crop to utilize the available morning and afternoon relative humidity.

$$H_gTUE = \frac{\text{Total grain yield}}{\text{Accumulated HgTUE}} \text{Kg/ha/}^{0}\text{C/day}$$

The Maximum Temperature Use Efficiency ($T_{MAX}UE$) and Minimum Temperature Use Efficiency ($T_{MIN}UE$) indicates the efficiency of crop to utilizing the available maximum and minimum temperature respectively. However the Mean Temperature Use Efficiency ($T_{MEAN}UE$**)** indicates the efficiency of crop to utilize the available mean temperature. This is also known as Actual Degree Day (ADD) because base temperature is not considered here.

$$T_{MAX}UE = \frac{\text{Total grain yield}}{\text{Accumulated } T_{MAX}} \text{ Kg/ha/}^{0}\text{C}$$

$$T_{MIN}UE = \frac{\text{Total grain yield}}{\text{Accumulated } T_{MEAN}} \text{ Kg/ha/}^{0}\text{C}$$

$$T_{MEAN}UE = \frac{\text{Total grain yield}}{\text{Accumulated } T_{MEAN}} \text{Kg/ha/}^{0}\text{C}$$

Bright Sunshine Use Efficiency (BSSUE) was calculated.

$$BSSUE = \frac{\text{Total grain yield}}{\text{Accumulated Bright Sunshine hours}} \text{ Kg/ha/hour}$$

Results and Discussion

Meteorological condition for wheat crop during 2016-17

The weekly meteorological parameters observed during wheat growth and developmental was presented in the Figure 1. The weekly average maximum and minimum temperatures (Tmax and Tmin) varied between 19.46^{0}C -37.7^{0}C and 8.7^{0}C -18.2°C respectively across seasons. The lowest minimum (8.7^{0}C) temperature received in 2nd standard meteorological week of growing period.

The pan evaporation ranged from 1.89 to 3.55 mm week^{-1} while the morning (RH-I) and afternoon relative humidity (RH-II) varied from 75% - 94.8% and 33.5% - 67.7% respectively. Bright sunshine hours also showed the large fluctuation from 45th to 13th standard metrological week. It achieved the lowest value during 49th week (0.69 hours) followed by 1st week (1.8 hours) of growing period.

Growing degree days and Heliothermal units

Results indicated that the number of days taken to attain various phenological stages varied with dates of sowing as well as due to variety (Table 1). Except at emergence stage when delayed sowing resulted in late emergence, all the stages attained under early sowing (5th November) took more number of days in comparison to delayed sowing. All the stages showed similar pattern. The physiological maturity was maximum (127 days) under 5th November sowing followed by 125.4 days under 15th November and 123.1 days under 25th November sowing. The early attainment of stages under delayed sowing was mainly due to higher temperature experienced by the crop under delayed sowing.

The accumulated thermal units requirement of wheat crop to attain different phenophases varied with sowing dates and varieties (Table 2). The crop sown on 5th November (D_1) accumulated more GDD (1960.65day °C) to attain physiological maturity than 15th November (1899.45 day °C) and 25th November (1822.65 day °C) dates of sowing while regarding cultivars, little variation in thermal requirement was observed. The GDD accumulation was highest in 5th November (D_1) due to longer duration of crop growing period and lowest in 25th November (D_3) sowing due to forced maturity caused by increase in temperature. Though the duration of physiological maturity under 25th November sown crop was 4 days less than that attained under 5th November.

This describes clearly the effect of temperature on phenological stage. Every crop needs a specific amount of GDD to enter its reproductive phase from vegetative phase. Early sowing resulted in absorbing sufficient GDD in relatively more time. While late sown crop experienced higher temperature during later stage in less time. Amarawat *et al.*, (2013) also reported lower consumption of heat units under delayed sowing and they also stated that under late sowing high temperature conditions, the wheat crop completes its life cycle much faster than under normal temperature conditions, but yield less.

Table.1 Phenological development in growth duration of wheat as influenced by sowing time

Sowing Dates	50% Emergence	100% Emergence	CRI	Heading	Flowering	Milking	Physiological Maturity
D_1	7.1	11.7	22.9	84.2	90.1	95.4	127
D_2	6.5	10.7	22.3	80.3	85.3	90.8	125.4
D_3	7.7	11.2	22.1	82.3	85.8	92.6	123.1

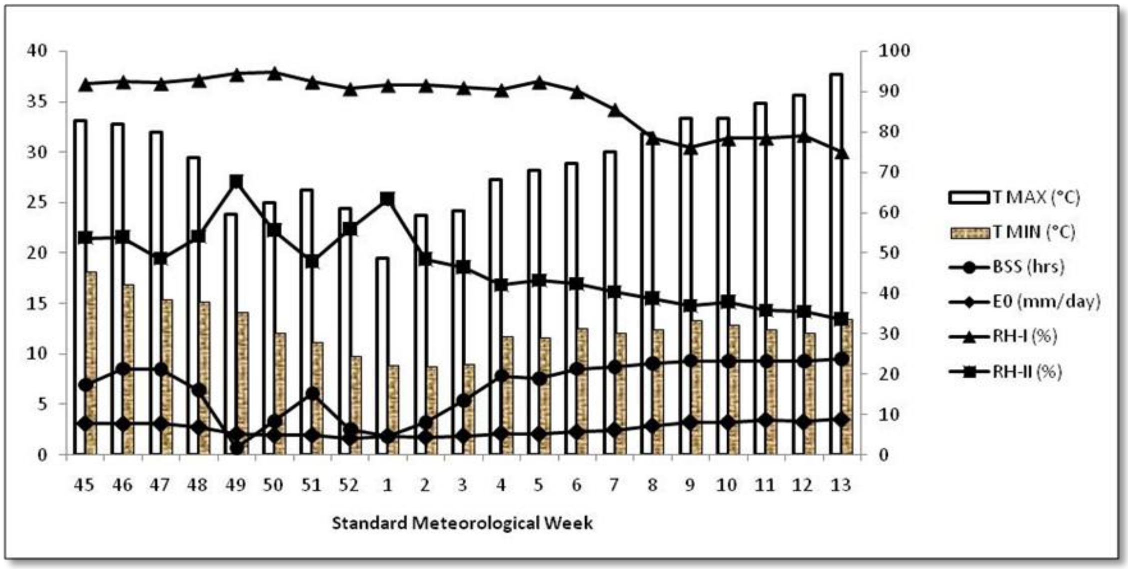
Table.2 Grain yield and different heat units for wheat varieties under different sowing

Sowing Dates	Yield (q/ha)	GDD (°C days)	HTU (°day hrs)	PTU (°day hrs)	HgTU-I (°day hrs)	HgTU-II (°day hrs)
D_1	39.66	1960.65	11952.5	25916.7	174775.2	106560.2
D_2	41.77	1899.45	11323.1	25011.7	167530.5	77533.47
D_3	39.88	1822.65	9734.0	23931.7	162568.1	56074.97

Table.3 Agro-meteorological efficiency index for wheat under different varieties

Varieties	HUE	PTUE	HTUE	H_gTUE-I	H_gTUE-II	$T_{MAX}UE$	$T_{MIN}UE$	$T_{MEAN}UE$	BSSUE
V_1	2.2	0.153	0.33	0.015	0.037	1.44	2.98	2.04	6.59
V_2	2.19	0.167	0.40	0.024	0.053	1.41	2.92	2.0	6.49
V_3	2.02	0.165	0.36	0.021	0.072	1.36	2.80	1.94	6.13

Fig.1 Weather parameters for wheat crop at Allahabad during 2016-17



Similar results were obtained in case of HTU and PTU. As earlier sown wheat crop availed higher accumulated Heliothermal units (HTU), however, with delay in sowing HTU consumption deceased. At physiological maturity of wheat, accumulated HTU was 11952.5°day hrs for D_1 to reach maturity stage and followed by D_2 (11323.1°day hrs) and D_3 (9734°day hrs). This might be due to the presence of cloudiness, lower temperature and lower sunshine hours for more days under timely sown condition in comparison to late sown crop. Similar results are reported by Chakravarty and Sastry (1983).

Crop sown on 5^{th} November required the maximum value of PTU (25,916.7°day hrs) for maturity as compared to other sowing dates. Moreover the Hygrothermal unit-I and II was highest for D_1 followed by D_2 and D_3.

Agro-meteorological efficiencies for different wheat varieties

The different agro-meteorological efficiency of the wheat under different varieties has been given in Table 3. The heat use efficiency was highest in HD-2967 (V1) as 2.2 kg/ha/ ^{0}C/day and lowest in PBW-154 (V3) as 2.02 kg/ha/ ^{0}C/day. Hence, it can be concluded that the timely sown HD-2967(V) had produced highest yield. HUE decreased with the delay in sowing. Similar results were reported by Paul and Sarker (2000), and Gill *et al.*, (2014). The timely sown plants produced higher grain yield by using accumulated heat units efficiently as the temperature was favourable throughout growing period of crop. Therefore the plant will utilize more heat and increase physiological activities that results in higher grain yield. Similarly Amarawat *et al.*, (2013) concluded that the lower HUE in delayed sowing can be expected due to accumulation of comparable GDD to that of early sowing at later crop growth stages. Since both maximum and minimum temperature remained higher during reproductive phase causing detrimental effect on dry matter accumulation. Moreover the value of T_{MAX}UE, T_{MIN}UE, T_{MEAN}UE was found highest in HD-2967 variety as 1.44, 2.98 and 2.04 kg/ha/^{0}C/day respectively while lowest value was obtained in PBW-154 as 1.36, 2.8 and 1.94 kg/ha/ ^{0}C/day. More the temperature use efficiency more will be the production of photosynthates by which the grain yield has increased. These results are in line with Haider *et al.*, (2004). However, HTUE was highest in PBW-502 (0.40kg/ha/^{0}day hrs) followed by PBW-154 (0.36 kg/ha/^{0}day hrs) while PTUE was highest in PBW-502 (0.167kg/ha/degree ^{0}C day) and lowest in HD-2967 (0.153 kg/ha/degree ^{0}C day). Similarly Hygrothermal use efficiency (HgTUE) I and II was found highest in PBW-502 as 0.024 and in PBW-154 as 0.072 kg/ha/^{0}day % respectively. The Bright Sun Shine use efficiency was highest in HD-2967 (6.59 hours/ day %).) and followed by PBW-502 (6.49 hours/day %). The least Bright Sun Shine use efficiency was noticed by PBW-154 (6.13 hours/day %). From the above statement we can conclude that higher the Bright Sunshine use efficiency higher will be the yield. So, we can conclude that the variety HD-2967 sown on 15th November has performed well rather than all other varieties sown on other sowing dates as for as meteorological efficiencies concerned.

The air temperature at different phenophases such as milking stage, grain filling stage and grain developing stage have greater effect on yield. Maximum GDD was accumulated in first date of sowing (5th November) which leads to maximum vegetative growth. In second date of sowing (15th November) accumulated GDD was optimum and yield was maximum. It was also observed that sowing conditions on different phenophases were optimum under second date of sowing (15th November) that resulted maximum yield. In case of Agro-meteorological efficiencies like heat use efficiency, temperature use efficiency, heliothermal use efficiency, photothermal use efficiency, hygrothermal use efficiency-I and II and bright sunshine use efficiencies are concerned, these are Maximum in the variety HD-2967 followed by PBW-502 and PBW-154 respectively under Allahabad condition for 2016-17 Rabi season.

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