Research Article

Phenology and Heat Unit Requirement of Wheat under Different Thermal Environments Irrigation and Fertility Levels at Jabalpur Condition of Madhya Pradesh

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Abstract

A field experiment was conducted during winter season of 2015-16 to study the phenology, GDD, HTU, PTU and HUE of wheat cultivar under three thermal environment (2nd December, 22nd December and 12th January), two irrigations (Three irrigations at CRI + flowering stage + milk stage and Four irrigations at CRI + late jointing stage + flowering stage + milk stage) and four fertility levels (No fertilizer, 60:30:20 N,P_2O_5,K_2O kg/ha,120:60:40 N,P_2O_5,K_2O kg/ha and 180:90:60 N,P_2O_5,K_2O kg/ha). The crop sown on 2nd December attained maximum crop duration (117 days), GDD (1679.9 ^{0}C days), HTU (14206.7 ^{0}C days hours), PTU (18735.7 ^{0}C days hours) and HUE (1.74 kg/ha/^{0}C days). The crop maturity was reduced gradually with delay in sowing. The agro-indices decrease during vegetative stages but increases during reproductive phase. The crop duration, heat indices (GDD, HTU, PTU), HUE and grain yield was significantly superior under the crop sown on 2nd December with four irrigations and application of 180: 90: 60 N,P_2O_5,K_2O kg/ha.

Keywords: Grain yield, GDD, HTU, Irrigation schedules, fertility levels, PTU, sowing time, Temperature, Wheat

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Introduction

Wheat (*Triticum aestivum L.)* is one of the most important *rabi* cereal in Madhya Pradesh and India. In India wheat is grown over an area of about 305.17 lakh ha with a production of 98.38 Million tones and with national productivity of 3216 kg/ha. In state of M.P. it occupy in total 108.3 thousand ha area with the production of 307.7 thousand tones and average productivity of 2478 kg/ha [1]. Wheat being photo and thermo sensitive crop, choice of suitable variety for different sowing time with other agronomic management further gets prime importance. Temperature influences the crop phenology and yield of crop [2]. Plants have a definite temperature requirement before they attain certain phenological stages. Growing degree days (GDD) and photo-thermal units (PTU) for each developmental stage is relatively constant and independent of sowing date, crop variety may modify it considerably [3]. Hence, it becomes imperative to have knowledge of exact duration of phenological stages in a particular crop growing environment and their impact on yield of a particular crop. Therefore, an experiment was conducted to determine the heat unit requirement for popular wheat varieties under different thermal environment, irrigations and fertility levels under Jabalpur condition.

Materials and Methods

The field experiment was carried out at Research Farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, M.P. during *rabi* season 2015-16. The Jabalpur is situated in Kymore plateau and Satpura hill agro climatic zone of Madhya Pradesh at 23^0 09’ N latitude 79^0 59’ E and at an altitude of 411 m above mean sea level. The soil of the experimental site was sandy clay loam with pH 7.5 EC 1.48 ds/m and 0.68% organic carbon. The total rainfall is 135 mm. The experiment was laid out in split split plot design with 3 replications consisted of three sowing dates as main plot (2nd December, 22nd December and 12th January), two irrigation schedules (Three irrigations at CRI + flowering stage + milk stage and Four irrigations at CRI + late jointing stage + flowering stage + milk stage) as sub plots and four fertility levels (No dose, 60:30:20 N,P_2O_5,K_2O kg/ha,120:60:40 N,P_2O_5,K_2O kg/ha and 180:90:60 N,P_2O_5,K_2O kg/ha) as sub sub plot. The crop was grown with all recommended package of practices of the region. Irrigation schedules and fertilizer application was followed as per the treatments. Weather data were collected from the Agrometeorological Observatory, Department of Physics and Agro-meteorology, College of Agriculture Engineering, JNKVV, Jabalpur. Agro-meteorological indices were computed for different phenophases by adopting procedure laid out by different workers. Various heat units were calculated as follows:

- Growing degree days [4],
  $GDD = (T_{max} + T_{min})/2 - T_t$
  (T_{max} and T_{min} are daily maximum and minimum temperature (0 C), T_t is the base temperature, taken as 5^0C.
- Photo thermal units [5],
  PTU = GDD × L
  Where, GDD = Growing degree days, L = Maximum possible day length (hrs)
- Helio-thermal unit [6],
  HTU (°C day hours) = Σ (GDD x SSh)
  (SSH = Bright Sunshine Hours)
- Heat use efficiency [7],
  HUE = (Seed yield/GDD)*100

Results and Discussion

Phenological development – The days required to attain different growth stages was more in 2nd December sowing and it gradually decreased as the sowing was delayed. The crop sown on 2nd December took longest period (117 days) for maturity than 22nd December (107 days) and 12th January (95 days). [8-9] also reported that low temperature at the early vegetative phase and high temperature at the reproductive phase of wheat due to late sowing reduced the number of days for attaining different phenological stages. There were very miserable or no difference in maturity period irrespective of irrigation schedule and fertility levels.

Heat units during crop growth period
Growing degree days (GDD)

GDD varied remarkly due to sowing dates. The crop sown on 2nd December was accumulated maximum GDD at all phonological stages as compared to 22nd December and 12th January sown crop are shown in **Table 1**. The result showed that highest GDD i.e. 1679.9, 1639.5 and 1645.1 ^{0}C days was recorded at maturity when crop sown on 2nd December with four irrigations and application of 180:90:60 N,P_2O_5,K_2O kg/ha respectively. Its value was lowest in January sown crop. This clearly describes the effect of temperature on crop. Lower consumption of heat units under delayed sowing [10]. The differential behaviors to heat unit requirement and days required to reach the various phenological phases could be ascribed solely to its genetic makeup.

Helio-thermal units (HTU)

The accumulated HTU required to attain different phenological stages of wheat are presented in Table 1. The result indicated that highest value of HTU i.e. 14206.7, 13875.4 and 13933.5 ^{0}C day hours was noted for maturity when crop sown on 2nd December, four irrigations with 180:90:60 N,P_2O_5,K_2O kg/ha respectively. While lowest value of heat unit was in delay sowing on 12th January. HTU for different phenological phases decreased with delay in sowing [11-12].

Photo-thermal units (PTU)

The variations in PTU in different treatments at various phenological phases of wheat are presented in Table 1. The crop sown on 2nd December, four irrigations with 180:90:60 N,P_2O_5,K_2O kg/ha attained maximum PTU (18735.7, 18647.5 and 18712 ^{0}C day hours) respectively at maturity as compare to other sowing. The PTU was lowest under late sown crop i.e. 12 January.

Table 1 Accumulated heat units (GDD), helio-thermal unit (HTU) and photo-thermal unit (PTU) of wheat cultivar sown under different environment, irrigation schedules and fertility levels

Treatments	Emergence	CRI	Tillering	Jointing	Booting	Heading	Anthesis	Milk	Dough	Maturity
Duration (days)										
Sowing dates										
D1-2nd Dec.	5.2	22.7	33.8	44.6	61.0	71.6	83.0	93.2	106.0	116.6
D2-22nd Dec.	5.9	21.1	33.0	43.0	57.0	66.0	75.0	82.0	94.3	107.0
D3-12th Jan.	3.1	17.1	30.0	37.0	49.0	57.0	65.0	71.0	79.4	95.0
Irrigation schedules										
I1- CRI+FL+ML	4.6	20.3	32.3	41.7	55.7	65.3	75.0	83.0	94.0	107.0
I2-CRI+LJ+FL+ML	4.8	20.6	32.8	41.7	55.7	65.3	75.0	83.0	94.4	108.0
Fertility levels										
F_1**:**Nodose (Control)	4.7	20.3	32	41	55.7	65.3	75.0	83.0	94.0	104.0
F_2**:**60:30:20 N,P_2O_5,K_2O kg/ha	4.7	20.3	32.3	41.7	55.7	65.3	75.0	83.0	94.0	106.0
F_3**:**120:60:40 N,P_2O_5,K_2O kg/ha	4.7	20.5	32.3	41.7	55.7	65.3	75.0	83.0	94.3	106.0
F_4**:**180:90 :60 N,P_2O_5,K_2O kg/ha	4.7	20.8	33.3	42	55.7	65.3	75.9	83.0	94.5	110.0
GDD (^{0}C day)										
Sowing dates										
D1-2nd Dec.	82.6	290.2	409.5	546.8	717.7	869.5	1059.1	1250.5	1496.0	1679.9
D2-22nd Dec.	50.0	235.9	372.2	490.7	671.4	817.6	974.0	1109.4	1336.5	1624.1
D3-12th Jan.	45.4	188.3	349.8	449.3	643.7	793.6	943.1	1061.5	1216.8	1602.3
Irrigation schedules										
I1- CRI+FL+ML	59.7	238.4	376.5	491.9	673.7	822.9	987.7	1135.7	1346.3	1631.4
I2-CRI+LJ+FL+ML	59.0	237.9	377.9	499.3	681.5	831.0	996.4	1145.3	1353.2	1639.5
Fetility levels										
F_1**:**Nodose(Control)	56.7	238.1	372.2	488.1	669.7	819.0	983.4	1130.6	1342.7	1629.0
F_2**:**60:30:20 N,P_2O_5,K_2O kg/ha	56.8	236.1	375.0	495.6	677.7	826.7	992.0	1140.7	1349.9	1633.8
F_3**:**120:60:40 N,P_2O_5,K_2O kg/ha	59.0	236.0	375.0	495.6	677.7	826.7	992.0	1140.7	1349.9	1633.8
F_4**:**180:90:60 N,P_2O_5,K_2O kg/ha	64.9	242.4	386.5	503.1	685.4	835.2	1000.7	1149.9	1356.5	1645.1
HTU (^{0}C day hours)										
Sowing dates										
D1-2nd Dec.	580.4	2010.1	3035.5	4137.8	5333.7	6647.9	7896.7	9428.8	11516.8	14206.7
D2-22nd Dec.	322.5	1852.4	2622.9	3753.0	5203.3	6177.6	7388.8	8514.2	10619.1	13709.3
D3-12th Jan.	240.6	1247.8	2593.1	3428.9	4738.2	5954.7	7254.7	8402.2	9835.5	13531.8
Irrigation schedules										
I1- CRI+FL+ML	360.5	1683.5	2728.6	3745.9	5063.1	6225.2	7471.8	8736.4	10604.5	13756.5
I2-CRI+LJ+FL+ML	401.8	1723.4	2772.4	3800.6	5120.4	6295.0	7555.0	8827.1	10709.7	13875.4
Fetility levels										
F_1**:**Nodose(Control)	345.0	1666.2	2711.4	3718.6	5035.9	6191.5	7432.5	8687.5	10553.5	13699.0
F_2**:**60:30:20 N,P_2O_5,K_2O kg/ha	376.0	1700.9	2748.0	3773.2	5090.2	6258.9	7511.0	8785.2	10655.5	13814.0
F_3**:**120:60:40 N,P_2O_5,K_2O kg/ha	377.2	1701.5	2750.0	3778.0	5093.6	6260.6	7514.4	8786.8	10658.9	13817.3
F_4**:**180:90:60 N,P_2O_5,K_2O kg/ha	426.4	1745.2	2792.6	3823.2	5147.3	6329.5	7595.7	8867.4	10760.5	13933.5
PTU (^{0}C day hours)										
Sowing dates										
D1-2nd Dec.	739.5	2898.1	4170.6	5600.4	7561.8	9159.5	11218.6	13280.8	16127.2	18735.7
D2-22nd Dec.	556.2	2493.2	3890.3	5206.7	7225.1	8877.1	10663.1	12224.0	14920.4	18466.4
D3-12th Jan.	403.8	1938.7	3779.8	4923.5	7117.0	8844.1	10582.4	12082.3	13935.8	18406.2
Irrigation schedules										
I1- CRI+FL+ML	553.2	2457.3	3944.6	5239.0	7257.6	8942.8	10827.3	12569.0	15041.3	18496.1
I2-CRI+LJ+FL+ML	618.2	2505.7	4001.3	5327.0	7345.1	9039.0	10928.2	12684.9	15166.8	18647.5
Fetility levels										
F_1**:**Nodose(Control)	522.2	2423.7	3919.5	5198.2	7212.6	8899.0	10776.9	12501.7	14980.1	18425.9

F_2:60:30:20 N,P_2O_5,K_2O kg/ha	584.3	2479.0	3969.7	5291.4	7300.0	8986.7	10877.6	12641.4	15102.5	18566.3
F_3:120:60:40 N,P_2O_5,K_2O kg/ha	585.9	2491.0	3970.9	5279.7	7302.5	8995.3	10904.4	12636.4	15106.8	18583.0
F_4:180:90:60 N,P_2O_5,K_2O kg/ha	650.4	2532.5	4031.8	5362.6	7390.2	9082.7	10978.8	12728.4	15226.8	18712.0

Heat use efficiency (HUE)

HUE was calculated by GDD accumulated to produce unit amount of grain yield. The HUE for grain yield was 1.74 kg/ha/^{0}C days and for dry matter ii was 5.42 kg/ha/^{0}C days under 2nd December, whereas lowest HUE was on 12th January (1.15 kg/ha/^{0}C days). The highest HUE on 2nd December crop could be ascribed by proportionate increasing dry matter per each heat unit absorbed. The lowest HUE in delayed sowing can be expected due to accumulation of comparable GDD to that of early sowing at later crop growth stages. This might be due to higher temperature remained during reproductive phase causing detrimental effect on dry matter accumulation and grain yield [10, 13]. HUE was recorded significantly superior on 2nd December (1.74 kg/ha/^{0}C days) with 4 irrigations (1.57 kg/ha/^{0}C days) and 180:90:60 N,P_2O_5,K_2O kg/ha (2.06 kg/ha/^{0}C days) over rest of the treatments.

Grain yield and straw yield

The grain and straw yield of wheat were significantly superior on 2nd December (2.92 and 6.55 t/ha) than 22nd December (2.56 and 5.61 t/ha) and 12th January (1.84 and 4.07 t/ha) sown crop **Table 2**. The higher grain yield may be due to higher GDD, HTU, and PTU as compare to other sowings. The detrimental effect of temperature at later stage of crop development in early and delayed sowing had an adverse effect on grain yield. Significant reduction in grain yield of timely sown wheat, when sowing was delayed beyond 20th Nov. [11] and [14] reported 3-4.1 % decreased in grain yield of each 1^{0}C rise in ambient temperature above 15^{0}C during grain filling stage.

Table 2 Yield and heat use efficiency (HUE) of wheat cultivar sown under different environment, irrigation schedules and fertility levels

Treatments	**Yield (t/ha)**		**HUE (kg/ha/^{0}Cdays)**	
	Grain	**Biological yield**	**Grain yield basis**	**Biological yield basis**
Sowing dates				
D1-2nd Dec.	2.92	9.11	1.74	5.42
D2-22nd Dec.	2.56	8.53	1.58	5.25
D3-12th Jan.	1.84	5.91	1.15	3.69
CD (P= 0.05)	0.599	0.568	-	-
Irrigation schedules				
I1- CRI+FL+ML	2.40	7.79	1.47	4.78
I2-CRI+LJ+FL+ML	2.48	7.91	1.57	4.82
CD (P= 0.05)	0.351	0.594	-	-
Fetility levels				
F_1:Nodose(Control)	1.29	3.16	0.79	1.94
F_2:60:30:20 N,P_2O_5,K_2O kg/ha	2.36	7.61	1.44	4.66
F_3:120:60:40 N,P_2O_5,K_2O kg/ha	2.76	9.39	1.69	5.75
F_4:180:90:60 N,P_2O_5,K_2O kg/ha	3.35	11.15	2.06	6.78
CD (P= 0.05)	0.278	0.599	-	-

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Publication History
Received 02nd Feb 2019
Revised 26th Feb 2019
Accepted 12th Mar 2019
Online 30th Mar 2019