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PHENOLOGY GROWTH AND YIELD OF WHEAT IN RELATION TO AGROMETEOROLOGICAL INDICES UNDER DIFFERENT SOWING DATES

Rajesh Khavse*, Rupesh Deshmukh, Neha Verma and Deepak Kausik

Department of Agrometeorology, Indira Gandhi Krishi Viswavidyalaya, Krishak Nagar, Raipur-492012 (C.G.), India.

Abstract

A field experiment was conducted during *rabi* season of 2012-13 at Indira Gandhi Agriculture University, Raipur (C.G.), India to study the phenology, accumulated growing degree days, photo thermal unit helio thermal unit, heat use efficiency, radiation use efficiency and performance of wheat varieties grown under different sowing dates. The crop was on 25 November took maximum calendar days. Growing degree days, photo thermal unit, helio-thermal unit to attend different phonological stages till maturity, which reduced significantly with subsequent delay in sowing time. The grain yield recorded in 5th December was statically at par with 15 December. The significant reduction in grain yield of timely sown varieties was recorded when sowing was delayed beyond 5th January. Among the varieties higher grain yield of 2807 kg/ha was recorded in varieties Kanchan, which was significant superior over Sujata (2486 kg/ha), GW273 (2447kg/ ha) and Amar (2310 kg/ha) among the varieties Amar took highest calendar days growing degree days, photo thermal unit. Helio thermal unit to reach the maturity. The variety Kanchan recorded the highest grain yield at 05th December sowing as compared to all other sowing date.

Key words : Wheat, environment, GDD, PTU, HTU, RUE and HUE.

Introduction

Wheat (*Triticum aestivum* L.) is an important *rabi* crop of North-Western plains of India. It is the second most important cereal crop after rice. Wheat is a widely adapted crop, it is grown from temperate irrigated to dry and high rainfall areas and from warm humid to dry cold environments. Undoubtedly, this adaptation has been possible due to the complex nature of its genome, which provides a fantastic plasticity to the crop. Wheat is a C_3 plant and such it thrives in cool environment. It is grown under diverse agro-climatic conditions about 29.2 million tons during the season 2010-11 (Anonymous, 2011).

Sowing time of wheat is one of the most important factors that governs the crop phonological development and efficient conversion of biomass in to economic yield. Normal sowing has longer growth duration, which consequently provides an opportunity to accumulate more biomass as compared to late sowing and henceforth manifested in higher grain and biological yield (Singh and Pal, 2003). Whereas in case of delayed sowing, the wheat crop is exposed to sub-optimal temperatures at established and supra-optimal temperature at reproductive phases that leads to forced maturity and reduction in grain yield (Sardana *et al*., 1999). Growing of suitable variety at an appropriate time is essential for ensuring optimum productivity. Being a thermo-sensitive crop, choice of suitable variety for different seeding time further gets prime importance. Temperature is an important environmental factor influencing the growth and development of plants. Influence of temperature on phenology and yield of crop plants can be studied under field condition through accumulated heat units system (Bishnoi *et al*., 1995). Plants have a definite temperature requirement before they attain certain phenological stages. Through accumulation of degree-days for each development stage is relatively constant and independent of sowing date; crop variety may modify, it considerably. Under north Indian condition, the maturity of wheat hastened due to gradual rise in ambient temperature under delayed planting. Hence, it becomes imperative to have knowledge of exact duration of phenol logical stages in a particular crop-growing environment and their impact on

***Author for correspondence:** E-mail: khavse@gmail.com

yield of crop. Therefore, an experiment was planned to determine the phenology and heat unit requirement of promising wheat varieties under different crop growing environment of pain zone of Chhattisgarh.

Materials and Methods

A field experiment was conducted during *rabi* 2012-13 at the Agrometeorology Research Farm, college of agriculture, Raipur. India is situated at an altitude of 289.6 m above mean sea level, 21° 16'N, latitude 81° 36'E longitude. The soil of experimental site was sandy loamy soil having pH (1:2 soil, soil water ratio). The experiment was laid out in factorial RBD design with five date of three replication and 45 treatments combinations consist of five date of sowing *viz*., 25 November, 5 December, 15 December, 25 December and 5 January. While four varieties that is, Kanchan, GW 273, Sujata and Amar. Seeds were sown manually at 20 cm (R × R) spacing in the well prepared field. First irrigation at the sowing time then 20 days interval days after sowing. In regards to fertilizer application full does of phosphorus (60 kg/ha) and 50% nitrogen at sowing time and remaining 25% at first irrigation and 25% at second irrigation. The Agro-meteorology indices growing degree days (GDD), Photothermal Unit (PTU), helio-thermal unit (HTU), heat use efficiency (HUE) were calculated using following formula.

1. $GDD = \Sigma (Tmax + Tmin) / 2 - Tb$

Where,

Tmax, Tmin are the daily maximum and minimum temperature.

'Tb' is the base temperature below which physiological activities are ceased. For wheat crop. 'Tb' is considered as 5 ^{0}C. (Morrison *et al*., 1990).

2. Heat use Efficiency (HUE) = seed yield (kg/ ha / GDD ^{0}C day.

3. Heliothermal use Efficiency (HTUE) = seed yield (kg/ha) / HTU ^{O}C hr.

4. Photothermal use Efficiency (PTUE) = Seed yield (kg/ha) /PTU ^{O}C hr.

Results and Discussion

Phenological studies

The days taken from sowing to emergence, CRI, tillering, ear head emergence, 50% flowering, milking, dough and maturity of four wheat varieties under different thermal environments are given in table 1. Different varieties did not showed remarkable variation in days taken for emergence under different respective thermal environments. The days taken for emergence were 5 to 6 days. The results of phenology of wheat crop under five dates of sowing showed that the duration of different phenological events started decreasing right from tillering and continued in all the stages as the sowing was delayed after 25 November. The decrease in duration at these stages varied differently for different varieties. Also, the highest effect of thermal stress on phonological stages was observed in cv. Sujata and Amar, whereas the least effect of thermal stress was observed in case of Kanchan and GW-273.

Yield and yield attributes

Significantly higher yield (2954 Kg/ha) was recorded under third date of sowing (D_1 and D_2) followed by date of sowing (2836.5, 2743.9 kg/ha) (table 1) and significantly lower yield under fourth date (2107.8 kg/ha) and fourth dates (1920.7 kg/ha). Among the varieties, significantly higher yield was recorded by Kanchan, (2807.1 kg/ha) followed by Amar, GW-273 and Sujata (2486.1, 2447.1 and 2430.4 kg/ha), respectively.

The yield attributing characters were significantly influence by the date of sowing (table 2). The first date of sowing recorded not significantly length of ear head affect by the sowing date, whereas no. of grain per ear head, higher test weight significantly. The fourth date of sowing recorded higher ear head and plant height was significantly not affected the sowing date.

Among the varieties Kanchan recorded significantly higher yield and Sujata were higher ear head/higher test weight.

Heat units

Growing Degree Day (GDD)

The accumulated growing degree days (GDD) for different genotypes under different thermal environments varied considerably from sowing to maturity (table 3). Different wheat varieties responded differently in terms of accumulated GDD at the time of maturity. Overall higher GDD was observed under 25 November sowing (D_1) in varieties Amar and Sujata.

In case of Kanchan higher GDD was noticed under 05 January sowing and lowest was noticed under 15 December sowing, while in variety GW-273 the highest GDD was noticed under 25 November sowing followed by 05 January sowing. The lowest accumulated GDD in GW-273 was recorded under 25 December sowing. In case of wheat variety Sujata the highest accumulated GDD was recorded under 25 December sowing and the lowest GDD was noticed when crop was sown on 05 January. Similarly, in case of variety Amar the highest

Table 1 : Effect of different thermal environment on phenology of wheat varieties.

Crop growth states								
Sowing dates	**Emergence**	**C.R.I.**	**Tillering**	**Ear Emergence**	**50% Flow.**	**Milking**	**Dough**	**Maturity**
Kanchan								
D_1-25 Nov.	5	21	50	64	72	79	89	113
D_2-05 Dec.	5	21	49	63	71	78	87	109
D_3-15 Dec.	5	20	51	63	70	76	85	106
D_4-25 Dec.	6	20	52	63	69	74	83	103
D_5-05 Jan.	6	20	53	64	69	73	81	100
GW-273								
D_1-25 Nov.	5	21	50	64	73	81	92	115
D_2-05 Dec.	5	21	49	63	71	78	89	110
D_3-15 Dec.	5	20	50	63	71	77	87	107
D_4-25 Dec.	6	20	51	63	69	74	83	102
D_5-05 Jan.	6	20	52	64	70	75	82	99
Sujata								
D_1-25 Nov.	5	21	62	75	87	97	106	129
D_2-05 Dec.	5	21	60	72	83	92	100	122
D_3-15 Dec.	5	19	58	68	79	88	96	117
D_4-25 Dec.	6	20	56	64	74	82	89	109
D_5-05 Jan.	6	20	53	61	69	76	83	101
Amar								
D_1-25 Nov.	5	21	61	75	87	97	106	129
D_2-05 Dec.	5	21	59	71	82	91	99	121
D_3-15 Dec.	5	20	58	68	79	88	96	117
D_4-25 Dec.	6	20	56	64	74	82	89	109
D_5-05 Jan.	6	19	54	62	70	77	84	102

Table 2 : Effect of sowing dates on yield and yield attribute of wheat cultivars.

Treatment	Plant height (cm) at maturity	Length of ear head (cm)	Ear head/m^2	No. of grain/ ear head	Test weight (g)	Seed yield (kg/ha.)
Date of sowing						
D_1	97.3	8.2	279.0	37.5	43.7	2743.9
D_2	101.0	8.2	281.0	35.4	43.5	2836.5
D_3	100.0	8.2	313.0	33.6	41.2	2954.5
D_4	96.8	8.1	322.0	33.7	41.8	2107.8
D_5	97.7	8.1	311.0	32.2	37.1	1920.7
S. Em.	0.6	0.1	6.2	1.0	1.1	71.2
CD at 5%	2.8	NS	17.8	2.8	3.1	203.9
Varieties						
V_1	80.9	8.2	303.0	37.1	40.1	**2807.1**
V_2	82.7	8.4	275.0	38.9	41.1	**2447.1**
V_3	116.0	8.1	314.0	29.9	41.5	**2486.1**
V_4	110.7	7.9	312.0	32.0	43.1	**2310.4**
S. Em.	0.5	0.1	5.6	0.9	1.0	63.7
CD at 5%	2.5	0.29	15.9	2.5	NS	182.3
Interaction						
S. Em.	1.2	0.23	12.4	2.0	2.2	142.4
CD at 5%	3.5	0.62	NS	5.6	NS	NS
CV %	3.4	4.79	7.1	9.8	9.2	9.8

D_1: 25 Nov., D_2: 05 Dec., D_3: 15 Dec., D_4: 25 Dec., D_5: 05 Jan.

Table 3 : Accumulated growing degree days (GDD) at different growth stages of wheat varieties under different thermal environments.

Sowing dates	Emergence	C.R.I.	Tillering	Ear emergence	50% Flow.	Milking	Dough	Maturity
Kanchan								
D_1-25 Nov.	90.5	349.2	776.7	964.3	1079.3	1191.7	1373.2	1848.5
D_2-05 Dec.	83.7	315.2	718.7	923.9	1050.3	1185.0	1361.6	1813.8
D_3-15 Dec.	71.8	291.9	730.8	924.7	1057.4	1178.0	1353.3	**1810.2**
D_4-25 Dec.	81.4	303.5	767.5	978.5	1096.5	1195.8	1375.3	1855.2
D_5-05 Jan.	102.0	274.5	830.0	1045.1	1147.5	1226.3	1407.0	**1896.5**
GW-273								
D_1-25 Nov.	90.5	349.2	776.7	964.3	1094.9	1221.2	1431.2	**1891.7**
D_2-05 Dec.	83.7	315.2	718.7	923.9	1050.3	1185.0	1398.7	1835.4
D_3-15 Dec.	71.8	291.9	719.0	924.7	1076.6	1197.6	1390.0	1835.4
D_4-25 Dec.	81.4	303.5	748.1	978.5	1096.5	1195.8	1375.3	**1827.5**
D_5-05 Jan.	102.0	274.5	808.5	1045.1	1167.1	1271.1	1429.6	1870.7
Sujata								
D_1-25 Nov.	90.5	349.2	931.4	1129.4	1339.1	1532.5	1706.6	**2220.5**
D_2-05 Dec.	83.7	315.2	883.0	1069.7	1280.7	1455.2	1619.7	2129.7
D_3-15 Dec.	71.8	274.3	844.3	1021.1	1234.8	1409.5	1579.3	2097.3
D_4-25 Dec.	81.4	303.5	845.4	1000.0	1195.8	1355.4	1511.6	2013.2
D_5-05 Jan.	102.0	274.5	830.0	983.0	1147.5	1293.6	1452.7	**1922.0**
Amar								
D_1-25 Nov.	90.5	349.2	1129.4	1129.4	1339.1	1532.5	1706.6	**2220.5**
D_2-05 Dec.	83.7	315.2	1050.3	1050.3	1260.3	1435.3	1596.9	2101.5
D_3-15 Dec.	71.8	291.9	1021.1	1021.1	1234.8	1409.5	1579.3	2097.3
D_4-25 Dec.	81.4	303.5	1000.0	1000.0	1195.8	1355.4	1511.6	2013.2
D_5-05 Jan.	102.0	259.1	1004.7	1004.7	1167.1	1317.7	1477.1	**1949.0**

GDD at maturity was noticed under 25 November sowing and the lowest GDD was noticed when crop was sown on 05 January.

Photo Thermal Unit (PTU)

Photothermal unit (PTU) for different genotypes under different thermal environment varied considerably at maturity (table 4). Highest PTU was observed under 05 January sowing (D5) in Kanchan and GW-273 varieties, whereas in case of Amar and Sujata the highest PTU was observed under 25 November sowing (D1). In general the PTU from emergence to 50% flowering decreased with delay in sowing from 25 November to 05 January whereas, during grain filling and maturity it is increased when the sowing was delayed by 25 November to 05 January.

Helio-thermal Unit (HTU)

The Heliothermal unit (HTU) for different wheat varieties under different thermal environment during maturity period is given in table 5. All the varieties varied considerably with each other at maturity period. Highest HTU was observed in varieties Amar & Sujata during all the phases of the crop growth. It was observed that in varieties Kanchan and GW-273 HTU increased with delay in sowing from 25 November to 05 January, whereas in case of Amar and Sujata HTU decreased with delay in sowing from 25 November to 05 January.

Heat Use Efficiency (HUE)

Heat Use Efficiency (HUE) for different genotypes under different thermal environments varied considerably (table 6). Higher HUE was observed in wheat variety Kanchan followed by GW-273, but with respect to the sowing dates maximum HUE was observed under 05 December (D_2) sowing followed by 15 December (D_3) sowing and the minimum HUE was observed under 05 January (D_5) sowing.

Higher HUE were observed in wheat varieties Kanchan and GW-273 when sown on 05 December whereas, in Sujata HUE was higher in 15-December and in case of Amar, it was observed highest when sown on 25 December.

Table 4 : Accumulated photothermal units (PTU) at different growth stages of wheat varieties under different thermal environments.

Sowing dates	Emergence	C.R.I.	Tillering	Ear emergence	50% Flow.	Milking	Dough	Maturity
Kanchan								
D_1-25 Nov.	1008.2	3816.8	8471.1	10523.4	11810.2	13098.3	15178.9	20806.5
D_2-05 Dec.	906.8	3416.8	7821.1	10103.9	11551.9	13096.1	15310.0	20557.0
D_3-15 Dec.	777.8	3169.4	7992.1	10214.7	11734.9	13117.0	15220.6	20703.6
D_4-25 Dec.	881.8	3310.2	8498.3	10916.4	12299.9	13490.9	15645.5	21502.6
D_5-05 Jan.	115.3	3002.5	9313.7	11872.8	13102.2	14047.2	16215.6	**22319.4**
GW-273								
D_1-25 Nov.	1008.2	3816.8	8471.1	10532.4	11989.0	13437.0	15843.6	21325.5
D_2-05 Dec.	906.8	3416.8	7821.1	10103.9	11557.9	13096.1	15575.8	20811.4
D_3-15 Dec.	777.8	3169.4	7857.4	10214.7	11954.9	13352.8	15661.6	21006.6
D_4-25 Dec.	881.8	3310.2	8276.0	10916.4	12299.9	13490.9	15645.5	21153.0
D_5-05 Jan.	115.3	3002.5	9067.3	11872.8	13337.4	14585.4	16487.4	**21993.2**
Sujata								
D_1-25 Nov.	1008.2	3816.8	10164.0	12384.9	14787.5	17015.1	19104.3	**25301.8**
D_2-05 Dec.	906.8	3416.8	9634.6	11774.2	14192.3	16253.2	18227.2	24428.8
D_3-15 Dec.	777.8	2976.3	9292.8	11318.9	13798.6	15895.6	17933.2	24311.2
D_4-25 Dec.	881.8	3310.2	9391.7	11162.8	13490.9	15406.7	17281.1	23496.5
D_5-05 Jan.	115.3	3002.5	9313.7	11128.2	13102.2	14858.4	16764.6	22641.2
Amar								
D_1-25 Nov.	1008.2	3816.8	10012.5	12384.9	14787.5	17015.1	19104.3	**25301.8**
D_2-05 Dec.	906.8	3416.8	9481.6	11551.9	13958.5	16015.1	17953.6	24073.0
D_3-15 Dec.	777.8	3169.4	9292.8	11318.9	13798.6	15895.6	17933.2	24311.2
D_4-25 Dec.	881.8	3310.2	9391.7	11162.8	13490.9	15406.7	17281.1	23496.5
D_5-05 Jan.	115.3	2834.6	9544.0	11388.6	13337.4	15144.0	17057.4	22982.0

Table 5 : Accumulated heliothermal units (HTU) at different growth stages of wheat varieties under different thermal environments.

Sowing Dates	Emerg-ence	C.R.I.	Tillering	Ear Emergence	50% Flow.	Milking	Dough	Maturity
Kanchan								
D_1-25 Nov.	702.5	2133.3	5926.8	7733.9	8693.9	9753.1	11032.3	15478.0
D_2-05 Dec.	209.8	2101.8	5708.3	7516.6	8695.4	9702.0	11021.1	15520.0
D_3-15 Dec.	667.6	2508.8	6547.1	8373.0	9098.7	10145.2	11834.5	16293.0
D_4-25 Dec.	704.7	2613.1	6892.3	8345.1	9394.2	10341.8	12164.3	16530.1
D_5-05 Jan.	944.2	2625.7	7135.9	9172.4	10204.8	11011.4	12645.3	**17040.3**
GW-273								
D_1-25 Nov.	702.5	2133.3	5926.8	7733.9	8846.8	10025.6	11469.1	15912.8
D_2-05 Dec.	209.8	2101.8	5708.3	7516.6	8695.4	9702.0	11377.7	15719.2
D_3-15 Dec.	667.6	2508.8	6547.1	8373.0	9258.1	10337.8	12189.1	16540.4
D_4-25 Dec.	704.7	2613.1	6892.3	8345.1	9394.2	10341.8	12164.3	16271.4
D_5-05 Jan.	944.2	2625.7	6983.3	9172.4	10410.6	11464.4	12878.6	**16789.5**
Sujata								
D_1-25 Nov.	702.5	2133.3	7431.5	9190.5	11032.3	12351.3	14025.1	**18952.7**
D_2-05 Dec.	209.8	2101.8	7124.7	8875.8	10328.6	11897.4	13550.2	18254.9
D_3-15 Dec.	667.6	2367.6	7639.6	9018.7	10694.4	12384.1	14126.5	18687.0
D_4-25 Dec.	704.7	2613.1	7562.7	8497.8	10341.8	11963.3	13536.4	17871.9
D_5-05 Jan.	944.2	2625.7	7135.9	8552.0	10204.8	11694.2	13123.5	17274.9

Table 5 continued....

Table 5 continued....

Amar								
D_1-25 Nov.	702.5	2133.3	7301.3	9190.5	11032.3	12351.3	14025.1	**18952.7**
D_2-05 Dec.	209.8	2101.8	7012.5	8695.4	10138.9	11734.6	13310.8	18080.0
D_3-15 Dec.	667.6	2508.8	7639.6	9018.7	10694.4	12384.1	14126.5	18687.0
D_4-25 Dec.	704.7	2613.1	7562.7	8497.8	10341.8	11963.3	13536.1	17871.0
D_5-05 Jan.	944.2	2481.4	7286.7	8766.8	10410.6	11934.6	13374.8	17542.2

Table 6 : Heat use efficiency (HUE) of wheat varieties under different thermal environments.

Varieties	**Heat use efficiency (g/m^2 deg day)**					
	D_1-25 Nov.	**D_2-05 Dec.**	**D_3-15 Dec.**	**D_4-25 Dec.**	**D_5-05 Jan.**	**Mean**
Kanchan	0.48	**0.50**	0.49	0.41	0.38	**0.45**
GW-273	0.41	**0.47**	0.45	0.40	0.34	**0.41**
Sujata	0.34	0.43	**0.44**	0.39	0.38	0.40
Amar	0.37	0.42	0.36	**0.43**	0.38	**0.39**
Mean	0.40	**0.46**	0.43	0.41	**0.37**	0.41

Table 7 : Radiation use efficiency (RUE) of wheat varieties under different thermal environments.

Varieties	**Radiation Use Efficiency (g MJ^{-1})**					
	D_1-25 Nov.	**D_2-05 Dec.**	**D_3-15 Dec.**	**D_4-25 Dec.**	**D_5-05 Jan.**	**Mean**
Kanchan	1.12	**1.17**	1.12	0.97	0.91	1.06
GW-273	0.96	**1.10**	1.02	0.94	0.82	0.97
Sujata	0.82	**1.04**	1.04	0.94	0.91	0.95
Amar	0.89	**1.01**	0.85	1.04	0.92	0.94
Mean	0.95	1.08	**1.01**	0.97	0.89	0.98

Radiation use efficiency (RUE)

Radiation Use Efficiency (RUE) for different genotypes under different thermal environments varied considerably (table 7). On the mean basis higher RUE value was observed under 05 December sowing followed by 15 December, 25 December and 25 November sowing. Among the wheat varieties Kanchan showed better in terms of RUE followed by GW-273, Sujata and Amar. In case all the varieties maximum RUE was observed in 05 December followed by 15 December in Kanchan, GW-273 and Sujata and 25 December for Amar. Lowest RUE was observed under 05 January sowing (D5) in Kanchan and GW273. Whereas RUE is lowest for Sujata 25 November sowing and for Amar, it is lowest in 25 December sowing.

Conclusion

The crop sown on 25th November took a maximum calendar day, GDD, PTU for maturity, which got reduced significantly with subsequent delay in sowing time and recorded lowest value on the 25th December sown crop. The 15th December recorded the highest grain yield, which was statistically at par with 5th December. Higher HUE was observed in wheat varieties Kanchan and GW-273 when sown on 05 December. Among the wheat varieties Kanchan showed better in terms of RUE followed by GW-273, Sujata and Amar. The highest grain yield was recorded in variety Kanchan (2807.1 kg/ha) followed by Amar, GW-273 and Sujata (2486.1, 2447.1 and 2430.4 kg/ha), respectively.

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