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Phenophase prediction model for wheat (*Triticum aestivum*) growth using agro meteorological indices sown under different environments in temperate region of Kashmir

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ABSTRACT

Field experiments were conducted during 2003-04 and 2004-05 on silty clay loam soils at research farm of Sher-e-Kashmir University of Agricultural Sciences and Technology- Kashmir, Shalimar to study the influence of sowing time on phenology and growth of the wheat cultivars and to develop the phenophases prediction model based on the agro meteorological indices. The treatment consisted of three dates of sowing and six cultivars of wheat. The results showed that the wheat sown under temperate region matured in 219 ± 10 days. Early sown wheat crop took more thermal time as compared to normal and late sown. The day length and bright sunshine hours also affected the occurrence of different phenophases of wheat cultivars. Accumulated thermal time(r=0.94) was best agro meteorological indices for prediction of flowering stage in wheat, while physiological maturity was predicted well by using helio thermal unit (HTU) (r=0.95). The heat use efficiency decreased with delay in sowing. The dry matter production (g/m^2) was linearly related with accumulated heat units, HTU and photo thermal indices

Key words: Wheat, phenophases, cumulative heat unit, heliothermal unit, photothermal unit.

Wheat is a second most important food crop of the world and India after rice. Jammu and Kashmir has varied climatic conditions ranging from sub-tropical to temperate cold desert conditions. In Jammu and Kashmir wheat is grown in an area about 2.66 lakh ha with annual production of 4983 thousand quintals with productivity of 19 q ha^{-1}. Almost entire cultivation of wheat is concentrated in Jammu division with production of 4924 thousand quintal. Whereas in Kashmir division, the cultivation of crop is confined to isolate places with an area of 5.8 thousand ha, production of 19 thousand quintal and productivity of 3.2 q ha^{-1} (Anonymous, 2006-07). Climatic conditions of Kashmir valley are favouable for wheat cultivation. The weather conditions that prevail during crop growth period decides yield potential, even though all inputs required by the crop are supplied at the optimum level. Temperature is very important component, which determines sowing time and the productivity of wheat. A change in the optimum temperature during its vegetative or reproductive growth adversely affects the initiation and duration of different phenophases and finally yields of the crop. It is therefore, essential to have knowledge of exact duration of development phases in a particular environment and their association with yield determinants for achieving high yields (Kumari *etal.*, 2009). The concept of growing degree days is based on the concept that real time to attain a phenological stage is linearly related to temperature in the range between base temperature and optimum temperature (Monteith, 1981). HUE i.e. efficiency of heat in terms of dry matter accumulation is an important aspect, which has great practical application. The total heat energy available to any crop is never completely converted to dry matter under even the most favourable agroclimatic conditions. Efficiency of conversion of heat energy into dry matter depends upon genetic factors, sowing time and crop type (Rao *etal.*,1999).It was observed that sunshine hours, day length, rainfall, mean temperature played a major role on the occurrence of emergence, tillering, booting, flowering, milking and physiological maturity stages in temperate region of Kashmir valley sown under different environments.

MATERIALS AND METHODS

Field experiments were conducted at SKUAST-K Research farm of SKUAST-Kashmir at Shalimar campus, Srinagar during 2003-04 and 2004-05. It is situated at 34°052 N latitude ,74°-892 E longitude at an altitude of 1587 meters above sea level. The treatments consist of three dates of sowing viz; 1st October (D_1), 15th October (D_2) and 30th October (D_3) with six cultivars of wheat viz; HS 240 (V_1), HS 295 (V_2), HS 365 (V_3), SKW 191 (V_4), SKW 193 (V_5) and Shalimar wheat-1 (V_6).The same treatments were repeated during 2004-05. The treatments were replicated thrice in split plot design with dates of sowing in main plots and genotypes of wheat in subplots. Crop was raised using appropriate package of practices. Observations on different phenological stages such as emergence, tillering, jointing, booting, flowering, milking, dough and maturity were recorded for every treatment by tagging five plants. Flowering was

Table 1: Effect of sowing dates on occurrence of different phenophases (days to be taken) in wheat cultivars under temperate region (mean of two years).

Treatments	Emergence	Tillering	Jointing	Booting	Flowering	Milking	Dough	Phy. Mat
Sowing dates								
1 October	7.0	36.5	49.0	149.0	173.0	194.7	217.1	226.8
15 October	8.5	40.7	52.0	143.3	168.3	187.8	211.9	223.0
30 October	15.5	94.3	121.7	144.3	167.7	180.9	203.7	207.8
Mean	10.3	57.2	74.2	145.6	169.7	187.8	210.9	219.2
SD±	4.5	32.3	41.1	3.0	2.9	6.9	6.8	10.1
Cultivars								
HS 240	10.3	58.7	76.7	153.7	172.0	191.3	213.5	221.2
HS 295	10.3	56.3	73.0	143.0	169.3	186.3	210.3	218.2
HS 365	10.3	56.3	73.0	140.0	168.3	186.8	209.5	218.2
SKW 191	10.3	57.0	73.3.	140.0	168.3	186.7	210.3	218.2
SKW 193	10.3	58.3	76.3	153.7	171.3	189.5	212.2	221.3
Shalimar wheat-1	10.3	56.3	73.0	143.0	168.7	186.2	209.5	218.2
Mean	10.3	57.2	74.2	145.6	169.7	187.8	210.9	219.2
SD±	0.0	1.1	1.8	6.4	1.6	2.1	1.6	1.6

Table 2: Cumulative thermal times (day °C) acquired to attain different phenophases in wheat under different treatments (mean of two years).

Treatments	Emergence	Tillering	Jointing	Booting	Flowering	Milking	Dough	Pysiological Maturity
Sowing dates								
1 October	82.8	373.6	451.5	579.8	670.3	1003.8	1190.4	1346.3
15 October	70.5	255.8	345.6	525.3	625.2	936.7	1157.9	1317.3
30 October	85.8	191.5	330.8	531.5	587.0	894.7	1060.4	1215.5
Mean	79.7	273.6	376.0	545.5	627.5	945.0	1136.2	1293.0
SD±	8.1	92.3	65.8	29.8	41.7	55.0	67.7	68.7
Cultivars								
HS 240	79.7	280.1	424.1	565.9	665.5	972.8	1160.7	1318.9
HS 295	79.7	270.4	357.3	541.5	606.9	940.5	1125.2	1285.3
HS 365	79.7	270.4	346.6	534.0	610.0	928.4	1125.2	1285.3
SKW 191	79.7	270.7	346.6	534.0	609.4	940.5	1125.2	1285.3
SKW 193	79.7	279.9	424.1	560.2	669.8	959.6	1155.8	1298.0
Shalimar wheat-1	79.7	270.4	357.3	537.6	603.7	928.4	1125.2	1285.3
Mean	79.7	273.6	376.0	545.5	627.5	945.0	1136.2	1293.0
SD±	0.0	4.9	37.6	14.0	31.2	17.8	17.2	13.7

determined when 50 per cent of spikes were visible in the center of the plot. The crop is considered to attain physiological maturity when 95 per cent of the ear head has turned from green to yellow. The dry matter production was determined by cutting one meter of row length from two areas of each plot at various development stages. The weather data were recorded at Agromet Observatory situated at 200 m away from the experimental area. With the help of this meteorological data following agro meteorological indices viz GDD, PTU, HTU were calculated at different stages (Nuttonson, 1955).

The heat use efficiency (HUE) was calculated as

$$HUE = \frac{\text{Dry matter (kg ha}^{-1})}{\text{Cumulative heat unit (°C days)}}$$

RESULTS AND DISCUSSION

Phenology

The early sown (1st October) wheat crop took more day (182) for flowering compared to normal (15th October) an late sowing (30th October). Similar pattern was observed i

Table 3: Effect of sowing dates on Heat Use Efficiency (kg ha^{-1} day^{-1} °C) in wheat cultivars sown under temperate region (mean of the two years).

Treatments	Jointing	Booting	Flowering	Milking	Dough	Maturity	Mean
Sowing dates							
1 October	2.8	9.7	9.4	11.8	11.8	11.3	9.5
15 October	3.3	7.7	10.2	10.1	9.4	8.7	8.2
30 October	4.5	6.9	10.1	9.5	9.2	8.5	8.1
Mean	3.5	8.1	9.9	10.5	10.1	9.5	8.6
Cultivars							
HS 240	3.2	7.5	9.8	8.5	8.3	7.9	7.5
HS 295	3.8	8.8	10.5	11.2	10.9	9.9	9.2
HS 365	3.8	7.7	9.7	11.8	11.3	10.2	9.1
SKW 191	3.9	8.5	9.7	12.2	11.9	11.5	9.6
SKW 193	3.3	8.3	9.6	10.5	10.1	9.5	8.6
Shalimar wheat-1	3.2	7.8	10.1	8.6	8.4	7.8	7.7
Mean	3.5	8.1	9.9	10.5	10.2	9.5	8.6

Table 4: Phenophase prediction model based on different Agro meteorological indices in wheat.

Phenophases	Equation (GDD)	R^2	Equation (HTU)	R^2	Equation (PTU)	R^2
Emergence	Y=0.9263X+70.145	0.27	Y=3.0761X+522.4	0.04	Y=2.447X+831.44	0.02
Tillering	Y= -0.925X+444.68	0.22	Y= -19.986X+2880.6	0.70	Y= -25.066X+4323.2	0.62
Jointing	Y=3.0796X+97.294	0.54	Y= -8.9209X+2866.6	0.36	Y= -7.1685X+4609.8	0.12
Booting	Y=14.223X-1785.6	0.81	Y=17.622X+666.72	0.29	Y=31.346X+1678.2	0.59
Heading	Y=8.8545X-869.66	0.74	Y=99.299X-13909	0.80	Y=117.85X-12678	0.59
Flowering	Y=7.8736X-533.66	0.94	Y=66.809X-7684.1	0.67	Y=77.258X-5348.8	0.75
Milking	Y=9.7998X-930.48	0.95	Y=55.178X-4632.6	0.83	Y=57.218X+936.71	0.77
Dough	Y=6.7773X-192.52	0.97	Y=47.229X-2702.6	0.74	Y=80.099X-2498.3	0.81
Phy. Mat	Y=5.9670X- 159.21	0.86	Y=41.971X-578.8	0.95	Y=56.687X+4183.6	0.88

Where, Y=Cumulative thermal time X= Number of days taken; Y=HTU X= Number of days taken; Y=PTU X= Number of days taken

case of physiological maturity. The early, normal and late sown wheat crop matured in 227, 223 and 208 days, respectively with standard deviation of ±10 days under temperate conditions of Kashmir valley (Table 1). The early sown wheat crop matured early by 19 days compared to late sown due to increase in temperature at reproductive phase. While late sown wheat took more days to complete early stages viz; emergence to jointing stage and it may be attributed to the decrease in mean temperature. The wheat crop after jointing took maximum number of days for next stage (booting) as compared to other stages due to snowfall and freezing conditions. In case of early sown, wheat crop became dormant after jointing, while in late sown wheat, the crop was dormant after attaining crown root initiation and was in agreement with the findings of Mallick *etal* (2006). The standard deviation showed that the days to occurrence of different stages differed with dates and more deviation were observed during tillering (32 days) and jointing (41 days) stage, while physiological maturity also differed by 10 days among these dates of sowing. Among the cultivars HS 240 and SKW 193 took more number of days of reach various stages (Table 1) where as days taken by other cultivars did not vary much. The anthesis stage occurred 8 days earlier in HS 295, HS 365, SKW 191 ans Shalimar wheat-1 over HS 240 and SKW 193. Singh *et al* (2003) also observed similar results of different phenological stages in wheat genotypes under arid environments.

Growing degree days (GDD)

The thermal times accumulated for attaining different phenophases are presented in Table 2 . The wheat crop took 1293 degree days for maturation with a standard deviation of 68 days. The early sown crop required more thermal time in comparison with normal and late sown crop and it might be due to increase in mean temperature which shortened later stages of wheat crop. Similar type of results were found by Agrawal and Upadhyay (2009) for Jabalpur region.The wheat crop after flowering took maximum thermal time for attaining milking stage among various dates of sowing as well as by

different cultivars. Among cultivars HS 240 took higher thermal time for maturity as compared to other cultivars. The Cultivar HS 240, accumulated 1318.9 degree days heat units followed by SKW 193 (1298 degree days) and Shalimar wheat-1 (1293 degree days) for maturity. Accumulation of more heat units by cultivar HS 240 than other cultivars may be due to more days taken by HS 240 to complete growth cycle. Similar findings had been reported by Singh *et al* (2003) for different varieties of wheat.

Heat use efficiency

Heat use efficiency was computed to determine the biomass production per unit of growing degree-day for different wheat cultivars. The heat use efficiency increases with the advancement of the crop age up to milking stage except the early sowing thereafter it decrease due to leaf senescence and biomass accumulation more in grains as compared to other parts of the plant. The heat use efficiency decreased with delay in sowing (Kumari *et al.*,2009).The early sown had higher HUE as compared to normal and late sown wheat crop due to higher biomass production except at jointing (Table 3). The mean HUE were 9.5, 8.2 and 8.1 kg ha^{-1} °C day^{-1} by wheat sown early, normal and late, respectively to attained the physiological maturity. The maximum HUE was found in early sown wheat crop at milking and dough stage compared to normal and late sown.

The heat use efficiency among various cultivars also increased with the advancement of crop growth stage upto milking and decreased thereafter up to physiological maturity due to leaf senescence except the Shalimar wheat-1 cultivar. Among all the treatments the cultivar SKW 191 has found maximum HUE (12.2 kg ha^{-1} $°C^{-1}$ day^{-1}).

Phenophases prediction models based on GDD, HTU and PTU.

Simple linear models were developed between number of days and agro meteorological indices in order to know the occurrence of different growth phenophases and find out the best indices for prediction of particular stage. The regression analyses showed that emergence, jointing, booting, flowering milking and dough stage were better related with thermal time as compared to helio thermal units and photo thermal units. Whereas, tillering, heading and physiological maturity stage could be predicted better with accumulated helio thermal units with accuracy of 70,80 and 95%, respectively. The poor relationships were found with photo thermal units (Table 4).

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