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Agro-meteorological Indices to Predict Plant Stages and Yield of Wheat for Foot Hills of Western Himalayas

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Abstract

In this study, agro-meteorological indices have been calculated and used for prediction of plant stages and yield of wheat under different sowing environments with various phenophases for foot hills of Western Himalayas. To reckon the above necessities, field experiments were carried out during Rabi season of 2007-08 and 2008-09 at the Norman E. Borlaug Crop Research Centre of G. B. Pant University of Agriculture & Technology, Pantnagar (29° N, 79.3° E and 243.8 m above msl). The study revealed that the Higher PTU and HTU were accounted in case of variety PBW-343 followed by WH-542 during all the phenophases of wheat for both the years. Wheat crop sown on 20th November (normal) required less photothermal unit as well as heliothermal unit, while, 09th January (late) sowing accounted higher values of PTU and HTU during crop growth period. Timely sown wheat crop (20th November) produced highest yield, while, with every 25 days delay in sowings reduction in yield was accounted by 13 to 26.1 percent in the year 2007-08, whereas, 14.6 to 29.3 percent in 2008-09.

Keywords: Growing degree days; phenothermal unit; heliothermal unit, wheat genotypes; sowing dates.

1. Introduction

Crop physiological process dependent on integrated atmospheric parameters (Ko et al., 2010), in which temperature is an important weather parameter that affects plant growth, development and yield. Winter crops are vulnerable to high temperature during reproductive stages and differential response of temperature change (rise) to various crops has been noticed under different production environments (Kalra, 2008).

The productivity of wheat is highly variable and mainly affected by rainfall, temperature and solar radiation. Crop is exposed to a variety of weather conditions during its different phenophases of growth, resulting in large variations in growth rate and yield. For quantifying the thermal relation of crops, thermal units approach is widely used (Ramteke et al., 1996) and has been further modified to include photothermal units and heliothermal units (Rao et al., 1999).

The photothermal unit concept provides a reliable index for the progress of the crop that can be used to predict the yield of any crop. Therefore present investigation was undertaken to study the thermal effect on growth and yield of wheat under different sowing environments. Cool weather during vegetative period and warm weather during maturity are ideal requirements for wheat. Influence of different time of sowing as well as temperature on phenology and yield of crop plants can be studied under field conditions through the accumulated heat units system (Shanker et al 1996). The aim of the present study was to predict plant stages and yield of wheat using agro-meteorological indices in foot hills of western Himalayas.

2. Materials and Methods

To perceive the thermal impact on different phenophases and productivity of wheat, field experiments were carried out during Rabi season of 2007-08 and 2008-09 at the Norman E. Borlaug Crop Research Centre (CRC) of G. B. Pant University of Agriculture & Technology, Pantnagar (29° N latitude, 79.3° E longitude and at an altitude of 243.8 m above mean sea level). The experiments were taken in split-plot design (SPD) in alliance of 6 replications with two genotypes viz. PBW-343 and WH-542 as influenced by three sowing dates i.e. 20 November, 15 December and 09 January along. Soil information of the experimental site used for the present study has been shown in Pal et al. (2012). The area lies in the '*Tarai'* belt located in the foot hills of Himalayas and falls under sub-humid subtropical climate with an annual rainfall about 1400 mm, out of which 80 percent is received during mid June to September during SW monsoon. The number of days to attain various phenophases was determined from randomly selected five plants in all the plots visually by the number of days taken from the sowing date to attain respective phenophases upto maturity.

Maximum and minimum temperatures used for study were taken from meteorological observatory of the University that is 20 m away from the experimental site. The growing degree days (GDD) and heliothermal unit (HTU) was calculated according to the formula of Rajput (1980) and photothermal unit was calculated by using the formula of Major et al. (1975) for different phenophases of wheat [viz. emergence (I), crown root initiation (II), tillering (III), jointing (IV), 50% flowering (V), milking (VI) and physiological maturity (VII)].

$$GDD = \sum_{i=1}^{n} \left[\frac{T\max + T\min}{2} \right] - Tb$$

$$PTU = \sum_{i=1}^{n} GDD \times Daylength$$

$$HTU = \sum_{i=1}^{n} GDD \times BSS$$

GDD	Growing Degree Days
HTU	Helio Thermal Units
PTU	Photo Thermal Units
RTD	Relative Temperature Disparity
Tmax	Maximum temperature (°C)
Tmin	Minimum temperature (°C)
Tb	Base temperature (°C) = 10°C
BSS	Bright sunshine hours

3. Results and Discussions

3.1 Photo-thermal unit (PTU)

Photothermal unit from date of emergence to jointing (Ist to IVth stage) accounted higher with 20th November than 15th December sowing, while lowest PTU were observed with the crop sown on 09th January during both the years (Khichar and Niwas, 2007). Moreover, from 50% flowering to physiological maturity higher PTU were recorded with 09th January sowing than the rest during both the years. With maturity of the crop highest PTU (17374.18 in 2007-08 and 17837.52 in 2008-09) was accounted with 09th January sowing than 15th December sown crop (14214.13 in 2007-08 and 15872.68 in 2008-09), while the lowest PTU were recorded in case of crop sown on 20th November (13658.05 in 2007-08 and 15106.76 in 2008-09). Variety PBW-343 accounted non-significantly higher PTU than WH-542 at all the phenological stages of the crop during both the years. PTU increased as the sowings were delayed for all the varieties in both the years (Table 1).

Table 1: Photo-thermal unit (PTU) required for various phenophases of wheat as affected by different treatments.

Treatments	**Photo-thermal unit (PTU) for various phenophases of wheat**													
	2007-08							**2008-09**						
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**
Dates of sowing														
Nov. 20	954	2515	3193	5052	8225	10289	13721	807	2563	3379	5481	9584	11867	15193
Dec. 15	729	1878	2508	3819	8255	10871	14422	817	2091	2646	4406	9539	12294	15927
Jan. 09	735	1676	1903	3757	10184	13640	17222	837	2102	2403	4580	11402	14572	17883
SEm±	40	22	21	44	89	60	104	29	34	17	12	39	85	181

CD at 5%	155	84	81	173	348	235	406	112	134	68	48	154	331	706
Varieties														
PBW-343	798	1995	2528	4242	8974	11789	15395	807	2273	2837	4839	10220	12953	16409
WH-542	814	2051	2541	4176	8802	11411	14849	833	2231	2781	4805	10130	12869	16260
SEm±	21	28	26	46	88	106	161	25	28	26	32	65	48	99
CD at 5%	73	97	90	160	304	367	556	85	98	88	111	225	165	341

3.2 Helio-thermal unit (HTU)

Among the sowing dates, heliothermal unit mostly decreased from date of emergence to jointing (Khichar and Niwas, 2007), while, increment in HTU was accredited from flowering to maturity of the crop, during both the years. Furthermore, with the delayed in sowing HTU increased for all the varieties during both the years. During the study period, among the sowing dates, maximum HTU was recorded at 09th January sowing (11072.39 and 12519.30 in 2007-08 and 2008-09, respectively). Non-significant increase in HTU was observed with variety PBW-343 than WH-542 at all the phenological stages of the crop during both the years (Table 2).

Table 2: Helio-thermal unit (HTU) required for various phenophases of wheat as affected by different treatments.

Treatments	**Helio-thermal unit (HTU) for various phenophases of wheat**													
	2007-08							**2008-09**						
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**
Dates of sowing														
Nov. 20	810	1651	1871	2981	4736	6072	7921	546	1864	2478	3292	5508	7369	9934
Dec. 15	468	1153	1429	2054	4888	6260	8353	371	823	1167	1934	5621	7743	10185
Jan. 09	367	7562	9015	2102	6025	8052	10938	492	972	1104	2662	7673	9805	12566
SEm±	31	85	16	29	62	46	62	11	21	18	12	23	50	12
CD at 5%	121	33	64	112	243	179	244	43	81	74	45	92	194	65
Varieties														
PBW-343	543	1179	1400	2397	5268	6922	9277	469	1228	1602	2636	6298	8332	10947
WH-542	554	1194	1401	2362	5164	6668	8865	470	1211	1564	2622	6237	8279	10842
SEm±	14	69	17	30	52	78	127	15	18	16	22	45	40	65
CD at 5%	48	24	60	103	180	270	440	51	61	54	77	154	139	226

3.3 Yield response of wheat

Timely sown wheat crop (20th November) with an average seasonal air temperature of 16.3 ^{O}C produced highest yield of 4580.3 kg ha^{-1} in 2007-08, while, it was 4080.3 kg ha^{-1} in 2008-09 with an average seasonal air temperature of 17.9 ^{O}C (Pal et al., 2012b) With every 25 days delay in sowings with an increase in average seasonal air temperature (17 to 18.6 ^{O}C) caused reduction in yield (Khichar and Niwas, 2007) by 13 to 26.1 percent in the year 2007-08, whereas, 14.6 to 29.3 percent in 2008-09 (due to increase in average seasonal air temperature from 18.8 to 20.4 ^{O}C) (Fig. 1 and 2). Genotype ‘PBW-343’ recorded highest grain yield followed by the genotype‘WH-542’ in both the years (Table 3). Pal et al. (2012) reported that the significantly highest straw & biological yield was also recorded with crop sown on 20th November with the genotype ‘PBW-343’. Hundal (2004) observed that a 2 ^{0}C increase in temperature in wheat or rice resulted in 15-17 percent decrease in grain yield of both crops but beyond that the decrease was very high in wheat.

3.4 Prediction of a crop stage using agro-meteorological indices

After germination of seed with sufficient moisture record the seeding date and coinciding degree day value by running the degree day accumulation using the base temperature of 5°C for the wheat crop. Watch for that corresponding crop stage to occur in the field until the difference between the beginning and the current accumulation value approaches the table 1 and 2 values. Thereafter, validate the table 1 and 2 values for study area by recording when the crop stage actually occurs in the field. With the time, doing this adjustment to the table values will increase the accurateness of the agro-meteorological indices.

4. Conclusion

It is therefore, concluded that wheat crop sown on 20th November (normal) need to be less photothermal unit as well as heliothermal unit, while, 09th January (late) sowing required higher PTU and HTU during crop growth period. In the year 2007-08, 20th November sowing recorded maximum grain yield to the extent of 13.0 % higher over 15th December and 26.1 % over 09th January sowing indicating optimum thermal regime. Grain yield accounted more in 2008-09 with the crop sown on 20th November sowing which was 14.6 % and 29.3 % higher than 15th December and 09th January sowings, respectively. Overall, the performance of genotype ‘PBW-343’ was accredited to better followed by the genotype‘WH-542’ in both the years. Temperature is one of the most important elements of the climate which determines the potential productivity level particularly for winter crops. The response of wheat crop to different thermal regimes, suggests that under the foot hills of Western Himalayas, the wheat crop sown on 20th November proved to be beneficial as the farmers can keep good harvest.

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