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Growth and yield prediction of wheat in relation to agroclimatic indices under irrigated and rainfed condition

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ABSTRACT

Field experiments were conducted during rabi season of 2005-06 and 2006-07 in irrigated as well as rainfed conditions under subtropical condition of Jammu with three cultivars (PBW-343, RSP-81 and Raj-3765) of wheat sown on normal dates of sowing with four replications. The different agroclimatic indices were derived at different phenophases. The results revealed that crop experienced 1670 oC day, 19584oC day hours and 10371oC day hours accumulated growing degree days (GDD), cumulative photothermal (PTU) and heliothermal units (HTU), respectively for attaining the maturity under irrigated conditions. The variety PBW 343 took higher thermal time (1602oC days) as compared to Raj 3765 (1576 oC days) and RSP81 (1574 oC days) for attaining physiological maturity. Maximum heat use efficiency (HUE) by variety PBW343 (5.87 kgha-1 oC days) was found under irrigated situation as compared to other cultivars. GDD was found best indices for prediction of phenology followed by PTU, HTU.

Key words : Wheat yield prediction, phenophases, agro climatic indices, rainfed & irrigated.

Crop yield prediction is important in every region for advanced planning, formulation and implementation of policies relating to food procurement, distribution and import – export decision. Growth prediction is play vital role for various agronomical operations at proper time in order to get the maximum yield at that area. Wheat is a second most important food crop of the world and India after rice. In Jammu and Kashmir state, wheat is grown about 0.26 million hectare with production of 0.49 million tones and the average yield of 18.9 qha^{-1} of the area (Anonymous, 2007). However, average yield is lower than the country average due to the most of area is under rainfed condition on hills. Wheat is most popular crop grown during winter season in irrigated as well as rainfed condition of sub tropical area under Jammu region in plain as well as hilly area. The growth and productivity of crops depends on the elements of physical environments in a particular ecosystem. 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 yield (Singh *et al*, 2003). Jammu and Kashmir has found diverse climatic condition. Temperature is the single most important factor that affects growth of any plant. Agro climatic model based on thermal indices can play an important role in predicting growth and yield of crops. Temperature based indices such as growing degree days (GDD), heliothermal unit (HTU), photothermal unit (PTU) and heat use efficiency (HUE) can be relatively useful for predicting growth and yield of crop. The concepts of heat growing degree days are 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). Agrometeorological wheat yield forecasting models were developed for the Ludhiana district by Bal *et al*. (2004). The efficiency of conversion of heat energy in term of dry matter depends upon genetic factors, sowing time and crop type (Rao *et al*. 1999).The amount of dry matter production by a crop depends on the distribution of leaf area in time and space in relation to solar energy utilization. Hodges and Kanemasu 1977 developed a model to estimate photosynthesis, respiration and dry matter accumulation as function of LAI and meteorological variable for winter wheat. Using thermal based indices attempts also have been made earlier to predict growth and yield (Hundal *et al*. 2003a, b) of crops using thermal based indices. Keeping this in view, an attempt was made to predict the growth and yield of wheat using Agro climatic indices under sub tropical situation of Jammu.

MATERIALS AND METHODS

Field experiments were conducted during rabi season of 2005-06 and 2006-07 at experimental area of Agrometeorology, SKUAST-J, Chatha, Jammu. (Lat. 320 402 N, long 740 502 E, at of 293 m.a.s.l). The experiment was conducted on sandy loam soil with poor water holding capacity and poor in nitrogen, phosphorous and potash. All recommended practices were followed as per package and practices of SKUAST-J for sub tropical condition of Jammu region.

The experiments consisting three wheat varieties viz.:- PBW-343 (V1), RSP-81(V2) and Raj-3765(V3) were conducted under irrigated as well as rain fed in slit split plot design with four replications during both years of study. The sowing of wheat was done on 18th November in both years of study.

Observations on different phenological stages such as emergence, tillering, jointing, booting, heading, anthesis, milk, dough and maturity were recorded for every treatment by tagging five plants. Anthesis was determined when 50 % of spikes were visible in the center of the plot; the crop reached physiological maturity when 95 % of the ear head has turned from green to yellow. The dry matter were determined by cutting one meter of row length from two areas of each plot at various development stages and dried it on 65+5^{0}C for three days or till constant weight attained. The dried samples were weighted on electronic balance. The weights of samples were converted into weight per meter square.

The agro meteorological indices were calculated by using different weather parameters at different stages following Rajput *et al* (1987).

$$GDD\ (^0\ day) = \sum_a^b [\{(T_{max} + T_{min})/2\} - T_b]$$

$$PTU(^0\ day\ hrs) = \sum_a^b (GDD \times N)$$

$$HTU\ (^0\ day\ hrs) = \sum_a^b (GDD \times n)$$

$$HUE\ (gm/m2/^0C\ day) = \{\sum_a^b DM / \sum_a^b GDD\}$$

Where GDD – growing degree days (^{0}day), T_{max} & T_{min} = daily maximum & minimum temperature (^{0}C). T_b=base temperature for wheat 40C (Nuttonson, 1955), a= starting date of phenophase of the interest, b= ending date of phenophase of the interest, PTU- photo thermal unit (^{0}day hrs), and HTU- helio thermal unit (^{0}day hrs). n= actual bright sunshine hours of the day, N= maximum possible day length of the location (List 1964), HUE- heat use efficiency (g m^{-2} day^{-1}), DM- above ground dry matter (g m^{-2}) accumulation during phenophase of interest.

RESULTS AND DISCUSSION

The grain and biological yield were differed significantly within irrigated and rainfed condition (Table 1). The grain yield and biological yield of wheat is found higher about 13 and 8 per cent under irrigated and rainfed condition, respectively. The standard error of mean was found 48.23 kg ha^{-1} for grain yield, while 174.83 kg ha-1 for biological yield among irrigated and rainfed condition of Jammu region. The variety PBW 343 gives higher grain yield (39.8 q ha^{-1}) than RSP81 (36.3 q ha^{-1}) and Raj 3765 (34.7 q ha^{-1}). The grain and biological yield of wheat also differs significantly among varieties with standard error of mean 45.21 and 95.84 kg ha^{-1}, respectively. The biological yield of variety RSP81 found higher followed by PBW 343 and Raj 3765 (Table 1). This was found due to the difference in height of the plant because variety RSP 81 is taller as compared to PBW343 and Raj3765.

Thermal units and phenophases

The wheat crop sown under irrigated condition took less thermal time as compared to rainfed condition under subtropical zone of Jammu and it differed significantly (Table 1). The variety PBW 343 took higher GDD (1602^{0}days) as compared to Raj 3765 (1576^{0}days) and RSP81 (1574^{0}days). The variety Raj 3765 matured earlier than RSP 81 and PBW 343 under irrigated condition, while under rainfed PBW 343 matured earlier than Raj 3765 and RSP 81. Similar findings had been reported by Singh *et al*. (2003) for different varieties of wheat under Haryana condition.

The PTU at emergence and crown root initiation stage of different cultivars behave the similar pattern as in case of GDD under both conditions. PBW 343 and Raj 3765 took equal PTU under irrigated as well as rainfed condition, but RSP 81 variety took higher photoperiod under irrigated condition compared to rainfed condition for attaining the jointing stage. For physiological maturity PBW 343 took more PTU units under rainfed compared to irrigated condition, while RSP81 took more PTU compared to PBW 343 and Raj 3765 under irrigated condition, Raj 3765 took less photo thermal units for maturation under rainfed condition. The photo thermal unit were found significantly differ between irrigated & rainfed condition as well as among varieties (Table1). The variety PBW343 took more photo thermal unit for maturation, while less by Raj 3765.

The HTU were found non-significantly differ

Table. 1 : Effect of different treatments on gain yield, biological yield and various meteorological indices in wheat crop (mean of two years).

Treatments	GY	BY	Σ HU	Σ HTU	Σ PTU	GYHUE	BYHUE
Irrigated	3947	8522.71	1572.45	8898	18270	2.52	5.41
Rainfed	3444	7876.21	1596.48	9054	19082	2.16	4.91
CD at 5%	297	N.S	9.01	N.S.	453	0.26	N.S.
SEd	68	247.25	2.06	40	104	0.06	0.18
SEm	48	174.83	1.46	28	73	0.04	0.13
V1	3979	8675	1602	9104	19139	2.49	5.39
V2	3633	8719	1574	8946	18528	2.31	5.54
V3	3474	7203	1576	8878	18361	2.21	4.55
CD at 5%	147	312	N.S	140	245	0.12	0.26
SEd	63	135	16	60	106	0.05	0.11
SEm	45	95	11.39	43	75	0.04	0.08

GY- Grain Yield (kg ha^{-1}), BY-Biological Yield (kg ha^{-1}), "HU- Accumulated heat unit(^{0}days), "HTU-Accumulated Heliothermal Unit (^{0}days Hrs), " PTU –Accumulated Photothermal Unit (^{0}days Hrs), HUE- Heat use efficiency (g $m^{-2}/^0day^{-1}$), GYHUE-Grain yield heat use efficiency (kg ha^{-1} day^{-1}), BY HUE- Biological yield heat use efficiency (kg ha^{-1} day^{-1}).

Table 2 : Multiple regression model for growth and yield of wheat crop based on agro meteorological indices for sub tropical condition of Jammu.

	Multiple regression equation	R^2	Adj. R^2
Flowering (Days)	Y=51.37+0.424AHU-0.0448APTU+0.0217AHTU	0.97	0.96
Phy. Mat. (Days)	Y= -26.76+0.30177AHU-0.0182APTU+0.00275AHTU Where Y= No. of days,	0.95	0.94
Yield $kgha^{-1}$	Y= -3743+2.44AHU-0.0053APTU+0.0060AHTU+1591.79HUE	0.98	0.96

between irrigated and rainfed condition, whereas among varieties it differed significantly (Table1). The variety PBW343 took maximum heliothemal unit for maturation, while minimum by Raj 3765. Mallick *et al*. (2006) also reported such types of result in wheat under Punjab region. The accumulated heliothermal unit for all stages was much higher under rainfed as compared to irrigated situation by different wheat cultivars. The cultivar RSP 81 took more accumulated heliothermal unit for jointing, flowering and milking stage as compared to PBW343 and Raj 3765, while for dough and maturity stage, the PBW343 and RSP81 took same heliothermal units and less by Raj 3765 under irrigated condition. Under rainfed condition PBW343 attained more heliothermal unit for flowering stage. For milking and dough stage, the wheat variety Raj 3765 took more HTU than the RSP 81 and PBW343, vice versa for attaining the physiological maturity under rainfed condition.The wheat variety took different heliothermal unit under irrigated as well as rainfed condition for attaining different phenophases. It showed that the bright sunshine hours and moisture availability affected the occurrence of phenophases in wheat cultivars.

Heat use efficiency and yield

The grain and biological yield heat use efficiency differed significantly and found more in case of irrigated (2.52 and 5.41 g m^{-2} day^{-1}) compared to rainfed condition(2.16 and 4.91 g m^{-2} day^{-1}). The grain yield heat use efficiency of different varieties viz. PBW343, RSP81 and Raj 3765 were recorded 2.49, 2.31 & 2.21 kg m^{-2} day^{-1}, respectively. The maximum biological yield heat use efficiency was observed in variety RSP 81 followed by PBW343 and Raj 3765 due to more difference in biomass accumulation (Table1). The heat use efficiency increased with the advancement of the crop up to milking stage there after it decreased due to leaf senescence and biomass accumulation more in grains as compared to other parts of the plant. The HUE was higher under irrigated condition

than rainfed condition due to more biomass production. Heat use efficiency of variety PBW343 was higher than that of RSP81 and Raj 3765 at all phenophases except CRI and Jointing stage under irrigated condition. Under rainfed condition HUE of variety Raj 3765 higher compared to RSP 81 and PBW 343. The HUE found maximum at dough stage under both conditions among all varieties. The variety PBW343 (5.8 kg $ha^{-1}day^{-1}$) has been found maximum heat use efficiency followed by RSP 81 (5.7 $kgha^{-1}day^{-1}$) and Raj 3765 (5.2 $kgha^{-1}days^{-1}$) under irrigated condition due to more biomass at this stage. These findings are in conformation with Kaur *et al*. (2004). At physiological maturity heat use efficiency was found maximum in PBW343 and minimum by Raj 3765 under irrigated condition; whereas under rainfed condition it was found reverse.

The step wise regression model was work out with help of different agro meteorological indices in order to find out the final multiple regression model for prediction of most important phenophases (flowering) and physiological maturity of wheat crop under subtropical region of Jammu region. These stages (flowering and physiological maturity) predicted well in advance with the help of meteorological indices with accuracy of 97 and 95 percent, respectively. The grain yield of wheat crop is also predicted 98 percent accurately with these meteorological indices with adjusted regression coefficient is 0.96. It shows that the grain yield of wheat is predicted well in advances accurately with help of these agro meteorological indices under sub tropical condition of Jammu region (Table 3).

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