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Effect of Weather Variables on the Yield of Early, Timely and Late Sown Wheat in the Tarai Region

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ABSTRACT

The crop-weather relationships of wheat (*Triticum aestivum*) were studied through correlation and linear multiple regression analysis based on 20 years (1975-76 to 1994-95) data under the conditions of Tarai region. Effect of weekly and seasonal weather conditions during different growth phases of wheat were quantified to predict pre-harvest crop yield. For early, timely and late sown wheat, the seasonal average variation in maximum temperature were (23.8-25.8, 23.4-25.9, and 23.9-27.4^{0}C) ; minimum temperature (8.3-10.9, 7.8-10.7 and 6.9-11.o^{0}C) ; maximum relative humidity % (83.0-92.8, 83.0-95.7 and 83.5-94.9) ; minimum relative humidity % (38.1'-46.2, 38.2-49.5 and 37.0-47.5) ; rainfall (83.2-198.6, 77.4-198.6 and 70.2-189.5 mm) ; number of rainy days (5-25, 5-25 and 5-24) ; bright sunshine hours (6.8-8.3, 6.8-8.2 and 6.5-8.4) ; wind velocity (2.9-5.0, 2.7-5.8 and 2.8-6.4 Km hr^{-1}), respectively. In early sown wheat, no weather variable was significantly correlated, however, in timely sown wheat wind velocity was significantly correlated (r=-0.848) at LSD (p=0.05) and in late sown wheat duration of bright sunshine hours (r=0.843) and wind velocity (r=-0.970) at LSD (p=0.05) and (P=0.0l), respectively to grain yield. The flowering stage (PCGS4) was found to be most influencing to the grain yield of early, timely and late sown wheat. Wheat yield can be predicted in all the three conditions through correlation coefficient analysis.

Introduction

In India wheat (*Triticum aestivum*) is cultivated mainly during *Rabi* season (November to April), when the crop is raised under early (Ist week of November), timely (3rd week of November) and late (Ist week of December) sown conditions by the cultivators (*Agarwal et al.*, 1972 ; Kampawat and Rathore, 1989). The influence of weather variables in agriculture is dominant at every stage starting from the time of sowing to harvesting of the crop, compared to all other factors, limiting crop yield. In early sown wheat, the crop takes long duration of time, therefore, involvement of weather variables increases as compared to the crop of timely and late sown conditions. Consequently chances of yield varying risk factors increase. As such, the knowledge of weather variables in relation to yield of wheat is of paramount importance. Keeping this in view the objective of the present investigation was to quantify the effect of weather variables on early, timely and late sown wheat in the *Tarai* region.

Materials and Methods

The present study was undertaken based on experimental data on wheat grown during *Rabi* season (November to April) for twenty years (1975-76 to 1994-95) at Pantnagar (28^{0}58' to 29^{0}1' N and 79^{0}24' to 79^{0}31' E at an altitude of 244 m above mean sea level). The region lies in the *Tarai* belt (an area of about 2.5 x 10^6 ha) of Uttar Pradesh in northern India below the foot hills of Himalayas. Wheat is the main cultivated crop during *Rabi* season in the region. The climate of the region is humid subtropical. The soils belong to Mollisols order of USDA Soil Taxonomy. Recommended dwarf, high yielding, rust and lodging resistance wheat varieties (CPAN-3004, RAJ 3077, PDV-220, K-8704, PBW-34 and HD 2329) were used for early, timely and late sown conditions. The same amount of nutrients and water were applied to all these varieties. Also the recommended cultural practices were followed for raising crops. The details of physiological crop growth stages for early, timely and late sown conditions of wheat are shown in Fig. I.

These physiological growth stages and their combinations were used to derive regression equations between the crop yield (Y) as dependent variable and growth stagewise average values of weather variables viz; maximum temperature (X_1), minimum temperature (X_2). maximum relative humidity (X_3), minimum relative humidity (X_4), rainfall (X_5), number of rainy days (X_6), duration of bright sunshine hours (X_7) and wind velocity (X_8) as independent variables with computer model 486 by the equation :

$$Y = A + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 \quad ....(1)$$

Where, A is the constant, b1 to b8 are the respective partial regression coefficients. The multiple coefficients r and coefficient of determination R^2 were obtained using above equation to know the extent of variation in yield of wheat by the combined effect of all the weather variables.

The weather variable data were collected from the Agrometeorological Observatory situated in the vicinity of the study area. Data on grain yield of wheat were collected from the record of the University Farm for the crop seasons of 20 years (1975-76 to 1994-95).

To test the regression equation for predicting the wheat yield under early, timely and late sown conditions the weather data for two crop growing seasons during the years 1993-94and 1994-95 were used. As per standard procedure it was predecided that if the actual and predicted yield differences would be less than 20% the method should be considered as promising for employing respective regression equation to predict the yield of wheat in the region under study. The correlation coefficients were determined on weekly basis. Among various correlation coefficients determined, the one of them having highest value was selected to workout multiple regression analysis. The yield of wheat was estimated through the derived regression equations and compared with the actual yields.

Results and Discussion

Variation of weather variables : Weather variables were averaged according to standard meteorological weeks for 20 years (1975-76 to 1994-95) to find out the variation during crop season. The maximum temperature differed at the time of sowing of early, timely and late sown wheat. It followed a decreasing order from early to late sown condition (28.6, 26.1 and 23.7^{0}C, respectively). During the crop growing season maximum temperature decreased gradually to a lowest value (20.3^{0}C) in the first week of January when early and timely sown wheat were at the stage of $PCGS_2$ and late sown wheat just completed the $PCGS_1$ stage (Fig. 1.). However, at the time of harvest the maximum temperature was highest (38.9^{0}C). The variation of maximum temperature at the time of sowing for early, timely and late sown wheat were 12.6, 10.4 and 7.6^{0}C, respectively. It gradually decreased up to 6.0^{0}C in the 3rd week of January, thereafter, again increased gradually to a highest value (19.9^{0}C) at the time of dough stage.

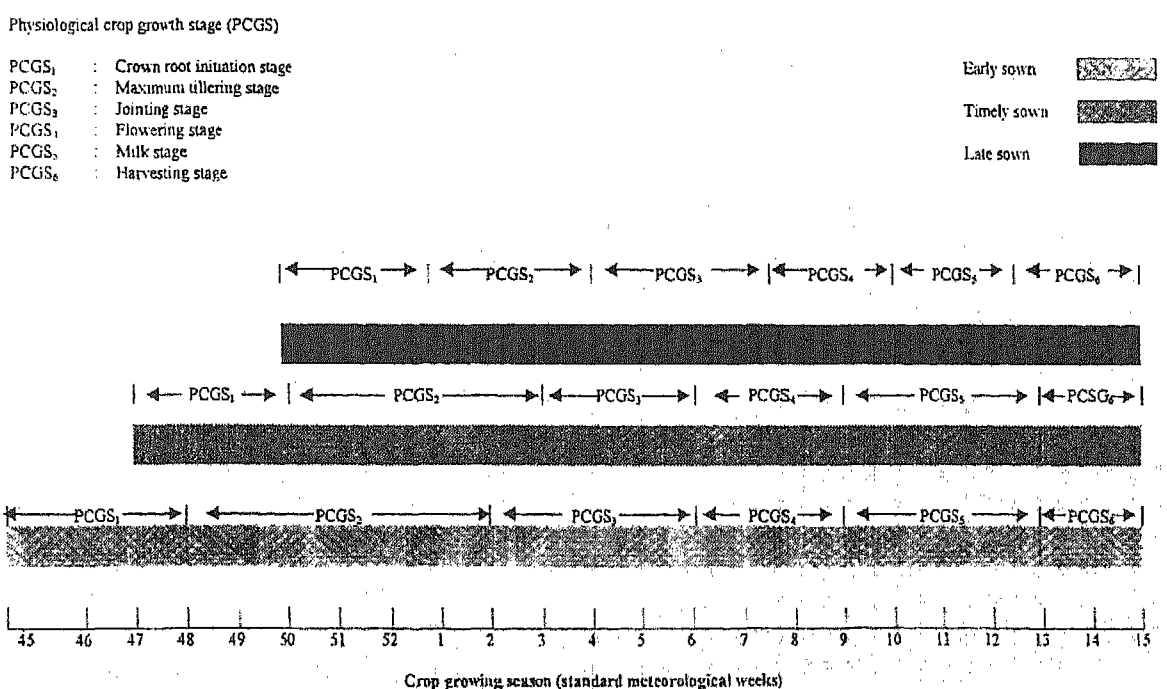

Fig. 1. Calendar of physiological crop growth stages of early, timely and late sown wheat at Pantnagar

The variation of maximum relative humidity at 712 LMT was found in the increasing order for early, timely and late sown wheat and highest (98%) in the first week of January, thereafter, decreased gradually to a minimum (52%) in the 2nd week of April at dough stage of wheat. The minimum relative humidity at 1412 LMT was found in the increasing order (52-82%) till the first week of January having erratic increment pattern, thereafter, it decreased as low as 10% at the harvesting stage.

The rainfall distribution was quite erratic during crop season of wheat having coefficient of variation as high as 168.1% in the 8th week (19-25 February). It can be inferred from the observed meteorological data that the distribution and prediction of rainfall in the area is quite uneven and hence, more realistic forecasting is difficult. The seasonal average of rainfall for early, timely and late sown wheat were 123, 122.8 and 117.4 mm having the coefficient of variation 32.1, 31.9 and 36.0%, respectively. The seasonal average number of rainy days were 12.9, 12.5 and 11.5 having the coefficient of variation 40.5, 40.8 and 45.3%, respectively. The variation of bright sunshine duration for early, timely and late sown wheat showed a decreasing trend (9.7 to 8.7 hrs) up to mid of January, thereafter, it increased gradually to a highest value (11.5 hrs) at dough stage. The variation in wind velocity during crop season showed an increasing trend from sowing to dough stage (4.9-12.1 Km hr^{-1} highest and 1.6-4.7 Km hr^{-1} lowest). The seasonal average wind velocity were 4.2, 4.3 and 4.7 Km hr^{-1} having a coefficient of variation 20.3, 21.6 and 23.9%, respectively for early, timely and late sown wheat in the area.

Weather variables and grain yield relationship : The average wheat yield for 20 crop seasons (1975-76 to 1994-95) showed erratic trend in the range of 29.4 to 53.0, 30.5 to 56.6 and 22.8 to 42.7 q ha^{-1} in early, timely and late sown conditions. In general, wheat yield in timely sown condition was more as compared to early and late. Further more, wheat yields were almost equal in early and late sown conditions, however, the difference in crop duration was much wider. The coefficients of variation were 15.1, 13.2 and 14.4% under respective conditions. The year wise variations in grain yield may be considered more pronounced due to variation in weather variables and their interrelationship effects rather than factors involved in raising crop (Jain *et al.*, 1992; Rajendra Kumar and Madan, 1995).

The linear correlation analysis (Table 1) shows that in early sown wheat no weather variable was significantly correlated with grain yield though, maximum temperature, number of rainy days and duration of bright sunshine hours were positively correlated with grain yield. Minimum temperature, maximum relative humidity, rainfall and wind velocity were negatively correlated. In timely sown wheat wind velocity was significantly correlated with grain yield ($r = -0.848$) at LSD, ($p=0.05$), while relationship with other variables were not significant. In late sown wheat the wind velocity was negatively correlated with grain yield ($r=-0.970$) at LSD, ($p=0.05$), but the duration of bright sunshine hours was positively correlated with grain yield ($r=0.843$) at the same LSD. However, other variables were not significantly correlated with yield. These results were expected because early sown wheat takes longest duration (145 days) as compared to timely and late sown wheat (Fig. 1). In case of timely sown wheat the prevailing favourable wind velocity and temperature played important role in producing higher yield. It may be due to optimum vegetative growth and reduced lodging as compared to early sown wheat. In case of late sown wheat bright sunshine hours and wind velocity played important role in reducing the yield. Short duration of bright sunshine and low temperature during vegetative growth phase and longer duration of bright sunshine hours, high temperature and desiccated high velocity wind (7.5 Km hr^{-1}) during reproductive growth phase jointly have detrimental effect on wheat crop.

A perusal of physiological growth stage wise regression equations indicates that the coefficient of determination (% R^2) for early timely and late sown wheat were 73.29, 71.30 and 70.85, respectively. The respective equations were developed as follows :

$$Y = 64.14-0.2754X_1 + 0.540X_2 + 0.189X_3 -0.7126X_4-0.6401X_5 + 2.237X_6 - 2.341X_7 -5.333X_8 \quad ....(2)$$

$$Y = 66.99-0.7422X_1 + 0.9128X_2 + 0.2745X_3 -0.48006X_4 + 0.9228X_5 - 1.4974X_6 + 0.966X_7 - 6.1205X_8 \quad ....(3)$$

$$Y = 52.6099 + 0.7543X_1 + 0.1813X_2 + 0.1626X_3 + 0.1123X_4 - 0.4141X_5 - 0.1574X_6 - 1.87278X_7 -3.15012X_8 \quad ....(4)$$

Table 1. Relationship between weather variables and grain yield for early, timely and late sown wheat at Pantnagar

Weather variables	Correlation coefficient (r)		
	Early sown	Timely sown	Late sown
Max. Temp. (^{0}C)	0.751	0.452	-0.544
Min. Temp. (^{0}C)	-0.621	-0.138	-0.621
Max. R.H. (%)	-0.254	0.276	-0.003
Min. R.H. (%)	-0.181	0.052	-0.152
Rainfall (mm)	-0.134	-0.146	-0.256
No. of rainy days	0.101	0.151	0.135
Duration of bright sunshine (hrs.)	0.304	0.509	0.843*
Wind velocity (km hr^{-1})	-0.719	-0.848*	-0.970*

r = Correlation coefficient between wheat yield and seasonal average weather variables.

* Significant at LSD, p=0.05

Table 2. Observed, estimated and predicted grain yield for early, timely and late sown wheat at Pantnagar through (a) physiological crop growth stagewise regression analysis (PCGSRA) and (b) correlation coefficient regression analysis (CCRA) methods

Year	Observed grain yield (q ha^{-1})			Estimated grain yield (q ha^{-1})					
				(a) PCGSRA method			(b) CCRA method		
	Early sown	Timely sown	Late sown	Early sown	Timely sown	Late sown	Early sown	Timely sown	late sown
1975-76	41.0	46.8	33.8	43.6	71.5	57.8	32.7	44.1	32.4
1976-77	53.0	56.8	36.4	66.7	107.5	43.5	52.9	58.I	39.7
1977-78	33.5	37..9	35.5	69.2	96.7	67.8	34.1	41.7	37.3
1978-79	29.4	30.5	27.2	43.4	75.8	25.8	30.3	31.7	26.8
1979-80	42.1	45.1	26.8	46.8	57.7	35.7	42.5	46.3	29.4
1980-81	32.5	42.5	22.8	71.8	61.2	43.1	30.7	41.3	25.1
1981-82	43.7	44.3	36.4	23.7	101.5	34.8	41.5	44.4	33.2
1982-83	49.4	56.6	41.7	51.8	51.5	40.3	47.8	58.1	40.9
1983-84	43.5	47.2	37.1	109.8	42.3	32.8	42.7	43.3	37.5
1984-85	31.3	39.0	33.6	71.7	77.3	31.7	33.4	41.0	32.8
1985-86	41.5	42.0	36.0	41.5	101.4	43.5	41.7	41.5	39.5
1986-87	47.2	47.8	30.5	58.6	43.5	39.7	46.8	46.5	31.2
1987-88	46.8	46.8	34.8	21.8	75.3	32.3	45.7	45.2	33.7
1988-89	41.9	40.9	30.5	25.8	101.2	71.3	43.1	39.8	29.3
1989-90	43.9	44.5	35.4	41.1	33.1	55.8	44.7	43.1	35.5
1990-91	43.6	40.2	32.7	49.1	47.8	40.9	42.8	39.7	31.8
1991-92	45.7	45.4	37.5	57.8	45.8	51.2	44.8	44.1	36.2
1992-93	46.5	48.2	38.6	61.3	71.4	45.6	45.1	47.5	33.8
				Predicted yield (q ha-1)					
1993-94	44.0	44.7	38.4	16.5	13.3	25.6	43.2	48.5	32.7
1994-95	50.9	49.5	42.7	14.1	11.3	46.3	49.8	51.6	43.5

Hence, in all the three cases flowering stage was more responsible for causing variation in grain yield of wheat depending upon the suitability of weather variables.

Prediction of grain yield

Linear multiple regression equations were developed following the procedure of Subramayya and Rupa Kumar (1980) and Gupta and Singh (1988). The correlation coefficient values for early sown wheat were : duration of bright sunshine hours (r=0.785), maximum temperature (r= -0.789), minimum temperature (r= -0.962), maximum relative humidity (r=0.842), minimum relative humidity (r=0.842), rainfall (r=0.937), number of rainy days (r=-0.522) and wind velocity (r=-0.827). For timely sown wheat the corresponding values were : (r=0.890), (r=-0.976), (r=-0.968), (r=0.837), (r=0.839),(r=-0.802), (r=0.604) and (r= -0.976). For late sown wheat the corresponding values were : (r= 0.785), (r= -0.789), (r= -0.962), (r= 0.875), (r=0.842), (r=0.937), (r= -0.421) and (r= -0.827). The % R^2 values for early, timely and late sown wheat were 94.6, 85.9 and 80.1, respectively. The respective equations were developed as follows:

$$Y = 49.35-0.346X_1+0.07665X_2-0.7106X_3 +0.3980X_4-0.1867X_5-0.1807X_6-2.217X_7 -0.8497X_8 \quad ....(5)$$

$$Y = 58.60-1.333X_1+1.0246X_2-0.04009X_3 +0.2839X_4-0.1108X_5 + 2.2762X_6 + 0.6180X_7- 2.2483X_8 \quad ....(6)$$

$$Y = 26.325 + 0.2603X_1 + 2.666X_2 + 0.1172X_3 + 0.04995X_4 - 0.4552X_5- 2.971X_6+1.629X_7- 0.1663X_8 \quad ...(7)$$

The observed, estimated and predicted yield for early, timely and late sown wheat by two methods of analysis for the period of 1975-76 to 1994-95 are presented in Table 2. The data indicate that the highest correlation coefficient technique shows good degree of similarity in which variation is recorded within the extreme limit of 20% and hence, more accurate as compared to the crop growth stagewise analysis technique which shows high variation beyond the 20% of the limit. This may be attributed to the fact that grain yield is the result of accumulative effect of all the states of crop growth. A single stage can only affect the accumulation of biomass, which may be different for stage to stage of the crop (Asana and Basu, 1962 ; Shanker and Gupta, 1987).

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