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Effect of temperature and rainfall on wheat yield in south western region of Punjab

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ABSTRACT

A study was conducted to evaluate the effect of temperature and rainfall on historical wheat yields in south western region of Punjab. The technology trend at Bathinda indicated that over the past 25 years wheat yields have increased at the rate of 82.1 kg ha^{-1} $year^{-1}$. Maximum, minimum temperature and rainfall from December to March for each pentad years 1977-81 to 1997-2001 were analyzed. Temperatures during February and March revealed significant effects on wheat yield. The maximum temperature of 25.6 ^{O}C and minimum temperature of 10.8 ^{O}C during grain filling period resulted in highest yield of wheat. Compared to first pentad, the percent increase in average yield during second, third, fourth and fifth pentad was 9.7, 20.3, 49.4 and 60.3 percent, respectively. The grain yield revealed positive correlation with minimum temperature but no trends were observed for other parameters. The regression models are in good agreement between the observed and predicted values of wheat yield.

Key words: Temperature, rainfall, wheat yield, technology trend, Punjab, regression model

Wheat is one of the most important food crops in India and is grown under diverse agro-climatic conditions. In Punjab, it occupies nearly 3.3 million ha and represents 45 % of the annual cropped area. The variation in yield of agricultural crops is largely due to changes in the weather parameters during the growing period. Temperature plays an important role during the vegetative growth and grain formation of wheat crop (Marcellous and Single, 1972). Parry and Swaminathan (1992) revealed that an increase of 0.5 ^{O}C temperature resulted in reduced duration of wheat crop by seven days with decrease in yield by 0.5 tonnes per hectare in north India. Hundal (2004) observed that a 2 ^{O}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. Wardlaw *et al* (1980) and Rawson (1986) reported that the effect of temperature was more important during the grain formation period than that of any other climatic parameter. Chaurasia *et al* (1995) observed that the weather conditions at the post anthesis stage play an important role in the wheat yield. The present study was conducted to establish the relationship of wheat yield with the climatological parameters in south western region of Punjab where rice-wheat or cotton-wheat are the major crop rotations.

MATERIALS AND METHODS

Study area

Bathinda district situated in the south western part Punjab having sufficiently long record of weather parameters was selected for this study. The study area falls under semi-arid climate where evaporation exceeds rainfall throughout the year; hence the contribution of rainfall towards moisture storage in the soil is almost negligible. Application of chemical fertilizers is necessary to meet the nutrient requirement for realizing yield potential of different crops.

Wheat yield for the period, 1976-77 to 2003-04 for Bathinda district as reported in Statistical Abstract of Punjab have been used. The period of 25 years was split into pentads (1976-77 to 1980-81, 1981-82 to 1985-86, 1986-87 to 1990-91, 1991-92 to 1995-96 and 1996-97 to 2000-2001). The daily meteorological data for wheat growing season were collected and correlated with grain yield of wheat for the five pentads.

RESULTS AND DISCUSSION

Technological trend analysis of wheat yield

The past actual yield for south western region of Punjab was regressed against time to develop a linear predictive model to assess the rate at which wheat yield has increased over time due to advancement in

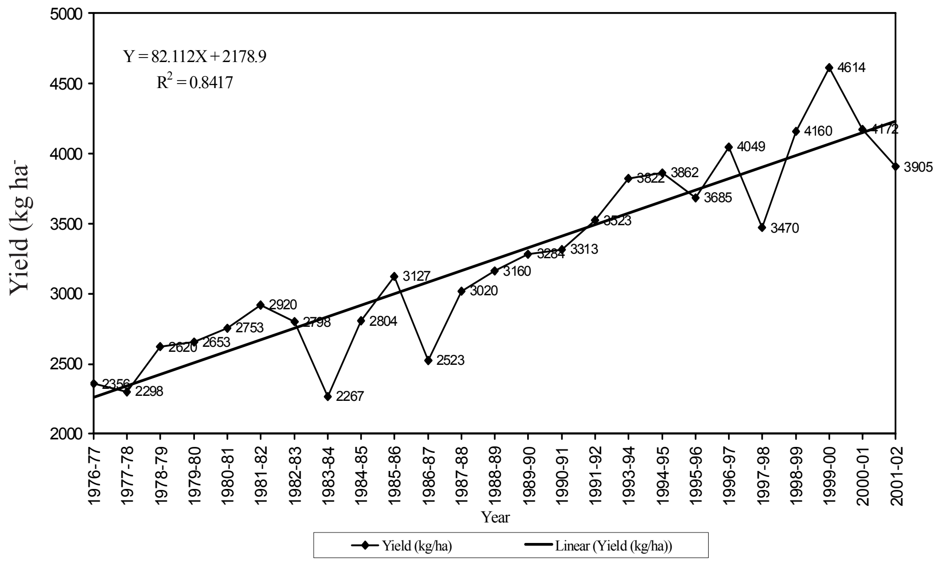

Fig. 1: Historical wheat yield and trend at Bathinda in Punjab.

technology (Fig.1.). Wheat yields in south western region of Punjab have increased over the past 25 years at the rate of 82.1 kg ha^{-1} $year^{-1}$. The actual inter-seasonal variation in yield would presumably be due to a combination of variations in weather conditions and fluctuations in the degree to which the farmer's practice are optimized each crop season. The technology model predicted yield was in accordance with the advancement in technology, i.e., improvement in farmer's practices, introduction of improved varieties etc. The negative deviation in actual yield compared to technology model predicted yield indicated that the intra-seasonal weather was probably unfavourable in some part of the crop season and vice versa.

The perusal of the actual wheat yields and technology trend model predicted wheat yields revealed that during the first, second, third, fourth and fifth pentad highest wheat yields were obtained during the crop year 1978-79 (+7.43), 1981-82 (+8.51), 1989-90 (-1.35), 1993-94 (+6.47) and 1999-00 (+11.84), respectively and lowest wheat yields were obtained during the crop years 1977-78 (-1.96), 1983-84 (-25.09), 1986-87 (-22.16), 1995-96 (-1.47) and 1997-98 (-12.49), respectively (Fig 1). During the third pentad (1986-87 to 1990-91) though the actual wheat yield have increased from 2523 to 3313 Kg ha^{-1} but it was invariably less than the technology model predicted yield and the deviation ranged from -1.35 % (1989-90) to -22.16 % (1986-87). This may be attributed to the unfavourable intra-seasonal weather parameters in some parts of the crop season.

Pentad-wise average wheat yield

The wheat yield has almost doubled in a span of 25 years from 1977 to 2001 (Fig 1.). The actual average wheat yield in five pentads viz. 1977-81 to 1997-2001and the technology trend model predicted average wheat yield (Table 1) show that during the first and fourth pentad the average wheat yield are +4.6 and +3.6 %, respectively more than the model predicted yield and during the third pentad the average wheat yield was -5.7 % less than the model predicted yield. In comparison to first pentad, percent increase in the actual and technology model predicted wheat yields are also shown here. The adoption of improved varieties of wheat and better management practices perhaps resulted in continuous increase in the wheat yield in the region. However, the increase in actual wheat yield in four pentads over the first pentad was less than the predicted wheat yield which may be due to unfavourable weather in some part of the crop season.

Wheat yield and climatic parameters

Average wheat yields for the particular years corresponding to selected range of maximum and minimum temperature in each of the three months

Table 1: Comparison of actual and technology trend model predicted average wheat yield for five pentads

Pentad period	Average wheat yield (kg ha^{-1})		Deviation (%)	% increase over 1st Pentad	
	Actual	Predicted		Actual	Predicted
1977 -81	2536	2425	+4.6	-	-
1982 -86	2783	2836	-1.9	9.7	16.9
1987 -91	3060	3246	-5.7	20.7	33.9
1992 -96	3788	3657	+3.6	49.4	50.8
1997-01	4064	4067	-0.1	60.3	67.7

Table 2: Frequency of years and wheat yield at different range of temperatures experienced in January, February and March.

Range of Tmax (^{0}C)	Yield (kg ha^{-1})	No. of years	Range of Tmin (^{0}C)	Yield (kg ha^{-1})	No. of years
			January		
<17	4160	1	<4	3000	6
17-19	4238	2	4-6	3175	14
19-21	3139	19	6-8	3572	4
>21	2721	3	>8	3523	1
			February		
<20	3606	3	<5	2267	1
20-22	2977	8	5-7	3235	8
22-24	3464	9	7-9	3238	14
>24	2948	5	>9	3722	2
			March		
<26	3468	4	<11	3139	5
26-28	3118	14	11-12	3189	8
28-30	3662	4	12-13	3280	9
>30	2994	3	>13	3475	3

January, February and March are presented in table 2. The comparison reveals that maximum temperature in the range 17-19 ^{O}C during January, less than 20 ^{O}C during February and 28-30 ^{O}C during March were the most favourable for better wheat yield. However, the maximum temperature more than 21^{O}C, 24^{O}C and 30^{O}C during the month of January, February and March, respectively, resulted in lowest yield. On the other hand, minimum temperature in the range of 6-8 ^{O}C in January, more than 9^{O}C in February and 13^{O}C in March were found favourable for yield whereas minimum temperature less than 4^{O}C, 5^{O}C and 11^{O}C during the months of January, February and March respectively were less favourable. Similar results were reported by Chaurasia *et al* (1995) for the central Punjab region.

Regression analysis

Step wise regression analysis was conducted to evaluate the cumulative effect of selective meteorological parameters on wheat yield during January, February and March (Table 3). The highest multiple correlation coefficients i.e. r=0.73, 0.37 and 0.58 was observed for the month of January, February and March, respectively, by considering all three meteorological parameters. Regressions were validated with field data for the crop years 2001-02, 2002-03, 2003-04.

The observed and predicted grain yields of wheat and percent error in yield are presented in Table 4. The perusal of the data revealed that the percent error was less when equation 4, 1 and 3 were employed to predict the wheat yield on the basis of January, February and March weather, respectively. On the basis of these three equations it can be concluded that during January maximum temperature is negatively correlated and rainfall is positively correlated to wheat yield; during February maximum and minimum temperature are

Table 3: Regression analysis between grain yield and meteorological parameters during January, February and March

No.	Regression equation
January	
1	Y= 8329.93 - 293.59Tmax + 142.67Tmin +2.18RF
2	Y= 8281.65 - 289.54Tmax + 148.77Tmin
3	Y= 2458.26 + 157.58Tmin + 1.89RF
4	Y= 9175.739 - 302.23Tmax + 2.44RF
February	
1	Y= 1996.67 + 0.24Tmax+171.62Tmin -0.80RF
2	Y= 1996.67 + 0.24Tmax+171.62Tmin -0.80RF
3	Y=1939.52 + 180.97Tmin - 0.29RF
4	Y=3225.30 + 0.30Tmax + 0.26RF
March	
1	Y= 2399.4-81.33Tmax+289.0Tmin-16.78RF
2	Y=1606.43-108.69Tmax +160 Tmin
3	Y=961.63 + 215.68Tmin - 13.98RF
4	Y=4351.04 - 30.53Tmax - 13.35RF

Tmax- Maximum temperature (^{0}C), Tmin – Minimum Temperature (^{0}C) and RF –Total monthly rainfall
(1), (2), (3) and (4) are the equation numbers

Table 4: Observed and predicted grain yield (kg ha^{-1}) of wheat with weather during the months of January, February and March (2001-02 to 2003-04)

Year	Equation No.	Observed	Predicted			% Error		
			Jan	Feb	March	Jan	Feb	March
2001-02	1		3134	3392	3481	-19.7	-13.1	-10.9
	2	3905	3184	3368	3284	-18.5	-13.8	-15.9
	3		2978	3405	3571	-23.7	-12.8	-8.5
	4		3343	3232	3444	-14.4	-17.2	-11.8
2002-03	1		4016	3725	4456	-3.9	-10.9	6.6
	2	4180	4061	3655	3824	-2.8	-12.6	-8.5
	3		3301	3698	4213	-21.0	-11.5	0.8
	4		3957	3245	3417	-5.3	-22.4	-18.2
2003-04	1		4288	3313	3866	10.1	-14.9	-0.7
	2	3895	4298	3282	3540	10.4	-15.7	-9.1
	3		3495	3310	3929	-10.3	-15.0	0.9
	4		4093	3235	3409	5.1	-16.9	-12.5

positively correlated and rainfall is negatively correlated to wheat yield; and during March minimum temperature is positively correlated and rainfall is negatively correlated to wheat yield.

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