

Short Communication

Cotton yield prediction for Punjab using weather based statistical models

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Variation in crop yield over years has two components. One is the more or less systematic rise in yield derived from improved cultivars, better crop management, and the interaction between cultivars and management (Bolton, 1981). The second component is erratic and mostly related to meteorological variables. Evaluation of crop responses to management practices needs there-fore to consider these sources of interannual variation in yield. Interannual variation in yield can be analysed using several tools including multivariate analysis and crop simulation models. Even powerful standard statistics may be limited in biological meaning, however, while crop simulation models have their own problems (Monteith, 1996; Passioura, 1996; Sinclair and Seligman, 1996; Sadras and Trapani, 1999). An alternative approach uses simple, agronomically meaningful models based upon few, key environmental variables.

The study was conducted using the dataset of 1980-2010. The weather data for the period under study for four locations of Punjab namely Amritsar, Ludhiana, Patiala and Bhatinda, well representing the state were collected from the meteorological observatories of IMD. The average drawn from these four stations were used as average weather data of Punjab. The weather data of crop season i.e. kharif season were taken into consideration (from 16th to 45th SMWs).

The cotton crop yield data for Punjab state as a whole for american cotton (*Gossypium hirsutum*) as well as total cotton which includes american cotton and Desi cotton (*Gossypium arboretum*) were collected from State Agriculture Department of Punjab for last 31 years (1980-2010). The year wise yield variations in american as well as total cotton are presented in Fig. 1. The variation in yield from 1980 to 2003 was very low and this is because of the corresponding area under each crop. The total cotton comprises of american as well as desi cotton and the share of american cotton to the total cotton was very high as compared to the desi cotton which in tern reduced

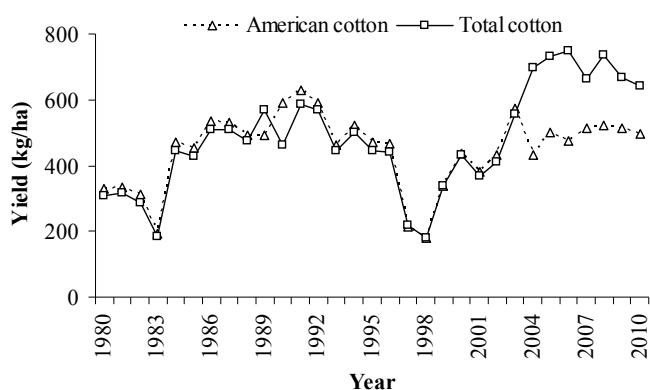


Fig. 1: Temporal variation in average yield of american and total cotton in Punjab

the gap between two cottons. During 2004 and onwards the Bt cotton was introduced which replaced the desi cotton and the increased share of Bt cotton to the total cotton contributed higher yields to the total cotton which reproduced the large variations between yields of american and total cotton.

Simple statistics were used to draw inferences by correlating weather parameters with cotton yield and the weather parameters significantly affecting the yield were worked out separately for american as well as total cotton yield. The statistically significant weather parameters were then regressed with yield and simple regression models for american and total cotton yield prediction were developed. The models were developed using dataset of 1980-2008 and the model prediction were validated with the independent dataset of 2009 and 2010.

The different weather parameters which significantly (at $p < 0.05$) influenced the yield were worked out. The different variables used are described in Table 1. The yield of cotton was influenced differently by different weather parameters at different time of crop stage. The maximum temperature during 45th SMW showed a significantly +ve correlation. In case of rainfall the significant -ve correlation were found and the rainfall of 16th, 42nd and 45th SMWs were with significant correlation with yield and the average of these three weeks were

Table 1: Correlation coefficients (significant at $p < 0.05$) between weather variables and cotton yield

Weather variable	Yield American cotton	Variable description
Tmax_45	0.42	Av. maximum temperature for 45 th SMW (°C)
RF_16,42,45	-0.70	Av. rainfall of 16 th , 42 nd and 45 th SMWs (mm)
RHe_40,42	-0.43	Av. RH evening of 40 th and 42 nd SMWs (%)
SSH_22,43	0.42	Av sunshine hours of 22 nd and 43 rd SMWs (hrs)
Total cotton		
Tmax_38	-0.37	Av. maximum temperature for 38 th SMW (°C)
Tmax_45	0.41	Av. maximum temperature for 45 th SMW (°C)
RF_16,27,31,32	-0.69	Av. rainfall of 16 th , 27 th , 31 st and 32 nd SMWs (mm)
SSH_16,25	-0.45	Av sunshine hours of 16 th and 25 th SMWs (hrs)

worked out which explained the american cotton yield variability significantly with r value of 0.7. The morning time relative humidity failed to explain American cotton yield significantly, whereas, evening time

relative humidity of 40th and 42nd SMWs were found with significant -ve correlation. The sunshine hours of 22nd and 43rd SMWs showed positive correlation and average of these two weeks improved the correlation.

In case of total cotton yield it was found that the maximum temperature of 38th SMW has the significant -ve correlation, whereas, the 45th SMW showed significant +ve correlation. On the other hand the minimum temperature failed to explain yield variability significantly. The rainfall occurred during 16th, 27th, 31st, 32nd and 34th SMWs were exerted -ve effect on total cotton yield and the average rainfall of 16th, 27th, 31st, and 32nd SMWs showed a significantly better correlation with r value of 0.69. The sunshine hours also showed -ve correlation and SSH of 16th and 25th SMWs were significantly explained the yield variability of total cotton.

Table 2: Predicted yield and deviations from actually observed

Year	Total cotton yield			American cotton yield		
	Observed	Predicted	Deviation%	Observed	Predicted	Deviation%
2009	512	455	-11.1	667	613	-8.1
2010	498	563	13.0	641	585	-8.7
RMSE	61.1	55.0				
MBE	4.0	-55.0				

Using the weather variables, the regression models were developed separately for american and total cotton yield. The equation developed for american cotton yield was R^2 value of 0.72 and for total cotton yield prediction the regression model developed was R^2 value of 0.65. These models were developed using dataset of 1980-2008 and the models were validated with 2009 and 2010 data which was not included for model development. The validation results are presented in Table 2. The model predicted american cotton yield very efficiently and the results showed that the prediction was 613 and 585 kg ha⁻¹ against the observed values of 667 and 641 kg ha⁻¹ for 2009 and 2010, respectively. The tendency of model prediction was towards underestimation with 8.1 and 8.7 percent deviation from the actually observed for 2009 and 2010, respectively. In case of total cotton yield prediction, the model predictions were in acceptable limits (<15 percent of the observed).

$$\text{Yield}_{\text{american cotton}} = -931 + 49.5 \text{Tmax_45} - 26.2 \text{RF_16,42,45} - 3.1 \text{RHe_40,42} + 11.4 \text{SSH_22,43} \quad (R^2=0.72)$$

$$\text{Yield}_{\text{total cotton}} = 748 - 22.8 \text{Tmax_38} + 31.7 \text{Tmax_45} - 11.5 \text{RF_16,27,31,32} - 29.1 \text{SSH_16,25} \quad (R^2=0.65)$$

The MBE (mean bias error) showed that the model prediction for total cotton was towards overestimation, whereas, for american cotton to tendency of model was towards underestimation.

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