Original Research Article

Weather based cotton yield forecasting models for South Gujarat region

ABSTRACT

An attempt has been made to developed the pre - harvesting forecasting models for cotton yields using (1995-2020) weather and yield data for Bharuch and Surat districts respectively. Models were validated for three years (2018-2020). Good agreements have been realized between actual and predicted yield with similar trends of deviation at pre - harvest stage. R^2 values were 0.78 to 0.93 for both districts and stages respectively. Hence, these models can be used for forecasting cotton yield in mid – season (F_1) and pre - harvest stage (F_2) which is very useful to government authorities to plan the sugarcane production more efficiently. The estimated cotton yields during kharif, the year 2022 were 769 kg/ha and 870 kg/ha for F_1 & F_2 stage in Bharuch district and 1209 kg/ha and 1454 kg/ha for F_1 & F_2 stage in Surat district, respectively.

Key words: *Cotton, weather parameter, yield forecast*

INTRODUCTION

"Cotton is the world's most important fiber crop. Cotton is still principal raw material for the world's textile industry. Cotton belongs to family Malvaceae, which is cultivated in India with different species namely *Gossipium arboreum* L., *Gossipium hirsutum* L., *Gossipiumbarbadense* L. and *Gossipium herbaceum* L. In India, cotton occupies about 13.48 million hectares area with a total production of 36.07 million bales (170 kg. of each) at an average productivity 455 kg ha^{-1}" (Anon., 2021). "Cotton is the important textile fiber and one of the important cash crop cultivated in many countries. It contributes about 80 percent of the raw material of textile industry in the country providing livelihood for more than 100 million people involved in production, processing, trading and marketing" (Chikkallavar, 2019).

The growth, development and yield of the cotton crop is considerably affected by abiotic factors, i.e. air temperature, relative humidity, rainfall and radiation. In cotton, 60 percent of the field losses are due to weather as compared to 30 percent in other crops like cereals, oilseeds and pulses. This major constraint in cotton production is because of climate influences not only the growth, development and reproductive activities of the crop, but also it influences the prevalence of pest, diseases and nutrient availability throughout the cropping season.

"Climate and weather is a basic input in agriculture. The growth, development and yield of the crops depends on the suitability of solar radiation, temperature, humidity etc. Yields are controlled by the weather parameters. Therefore, optimization of agricultural production, the knowledge of weather in advance is essential" (Ghadekar S. R., 1991). If we understand the inter linkage of changing day to day weather and crop growth and development, we can estimate the effect on growth and development at each stage of crop. For the estimation of growth and yield forecasting tool is very useful.

"Accurate early warning of crop failures can go a long way in mitigating the undesirable effects like price rise and agrarian distress through public policy". Xiao *et. al.*, (2019) Investigating the relationship between pandemic diseases and weather factors is significant for establishing weather-pest forecasting models and improving the long-term prediction of pests and diseases. Hendricks and Scholl (1943) have done pioneering work at Indian Agricultural Statistic Research Institute, New Delhi and developed models which required small number of parameters to be estimated while taking care of distribution pattern of weather over the crop season. "Composite models, combining biometrical characters and weather variables were developed" by Mehta *et al.,* (2000). The present study was undertaken to investigate the feasibility of estimating the yield of cotton crop based on weather variables using past weather records for Bharuch and Surat district.

MATERIALS AND METHODS

Weather data on daily basis at Bharuch and Surat districts were collected from agrometeorological surface observatories situated in respective districts and cotton yield data for the years 1995 to 2021 were collected from Agriculture and Statistics Department, Government of Gujarat to develop yield forecasting models. The daily weather weather parameter such as maximum temperature ^{0}C (Tmin), minimum temperature ^{0}C (Tmin), morning relative humidity % (RH1), afternoon relative humidity % (RH2) and rainfall mm (Rain) were used to compute the weekly averages from the planting to harvesting period of the *kharif* cotton crop (22^{nd} to 46^{th} Standard Meteorological Weeks (SMW)) weekly weather data for growing season of cotton crop i.e., 22^{nd} to 42^{nd} SMW for mid-season (F_1) stage, 22^{nd} to 46^{th} SMW for pre-harvest (F_2) stage were used for cotton crop yield forecasting for different districts of South Gujarat.

Indian Agricultural Statistical Research Institute (IASRI), New Delhi suggested the methodology for crop yield forecasting models under major growing districts were developed using stepwise regression analysis. "Weather variables are used as independent variables which

are related to crop responses such as yield and to account for the technological changes some function of time is used as independent variables. IASRI modified the model of Hendricks and Scholl by expressing the effects of changes in weather variables on yield as function of respective correlation coefficients between yield and weather variables. This explains the relationship in a better way as it gives appropriate weightage to different periods. Under this assumption, the models were developed for studying the effects of weather variables on yield" [Yadav et al. 2018; Kulkarni et al. 2022]. These models are found to be better than the one suggested by Hendricks and Scholl at IASRI (Agrawal and Mehta, 2007). The forecast model finally recommended is as follows

$$Y = A_0 + \sum_{i=1}^{p} \sum_{j=0}^{1} a_{ij} Z_{ij} + \sum_{i \neq i'=1}^{p} \sum_{j=0}^{1} a_{ii'j} Z_{ii'j} + cT + e$$

Where,

$$Z_{ij} = \sum_{w=1}^{m} r_{iw}^{j} X_{iw} \text{ and } Z_{ii'j} = \sum_{w=1}^{m} r_{ii'w}^{j} X_{iw} X_{ii'w}$$

A_0, α_{ij}, $\alpha_{ii'j}$ and c are constant

Z_{ij} is generated variable (individual)

$Z_{ii'j}$ is generated variable (interaction form)

X_{iw} is the value of i^{th} weather variable under study iw^{th} week

$X_{ii'w}$ is the value of i^{th} weather variable under study ii' w^{th} week

r_{iw} is correlation coefficient of yield with i^{th} weather variable in w^{th} period

$r_{ii'w}$ is correlation coefficient (adjusted for trend effect) of yield with product of i^{th} and i'^{th} weather variables in w^{th} period

mis period of forecast

p is number of weather variables used

T is the time trend

e is random error distributed as N $(0,\sigma^2)$

For each weather variable, two weather indices were developed, one as simple accumulation of weather variable and the other one as weighted accumulation of weekly weather variable, weights being correlation coefficients of weather variable in respective weeks with yield (adjusted for trend effect, if present). Similarly, for interaction of weather variables, indices

were generated using weekly products of weather variables taking two at a time (Table 1). Stepwise regression technique was used to select the important weather indices. These weighted coefficients were finally regressed with the district yield to find out the final model. The final models were selected on the basis of R^2 and the value of significance of F test.

Table 1: Weather indices used in models using composite weather variables

	Simple weather indices					Weighted weather indices				
	Tmax	Tmin	Rain	RH1	RH2	Tmax	Tmin	Rain	RH1	RH2
Tmax	Z10					Z11				
Tmin	Z120	Z20				Z121	Z21			
Rain	Z130	Z230	Z30			Z131	Z231	Z31		
RH1	Z140	Z240	Z340	Z40		Z141	Z241	Z341	Z41	
RH2	Z150	Z250	Z350	Z450	Z50	Z151	Z251	Z351	Z451	Z51

RESULTS AND DISCUSSION

Mid - season (F_1) forecast of *kharif* cotton crop

Forecasted yield and equations of models were developed for the year 2022 given in Table 2. Coefficient of determination (R^2) has been significant at 5% probability level for cotton in two districts of South Gujarat. The forecasting models were able to explain inter annual variation in the cotton production to the extent of 78% for Bharuch and 79% for Surat. Table 2 indicates the results of the forecast yield which are satisfactory and the performance of the yield forecasting is acceptable. The best agrometeorological indices to incorporate in the agrometeorological yield for cotton crop was selected like temperatures, relative humidity and rainfall. Out of which more influences the yield in cotton crop can be noted by equation as RH1 (Z41) and Time trend for Bharuch district and Time trend and RH2 (Z51) for Surat district. The results showed that the forecasted yields for mid - season were 769 and 1209 kg ha^{-1} for Bharuch and Surat district respectively, for the year 2022 (Table 2).

Pre - harvest (F_2) forecast of *kharif* cotton crop

Pre – harvest (F_2) stage cotton yield forecast model developed using weather data from 22^{nd} to 46^{th} SMW for obtaining R^2 and significance of F test. There was quite good relationship was found between actual yield and weather variables among the districts and the forecasting models were able to explain inter annual variation in the cotton production to the extent of 80% for Bharuch and 93% for Surat. (Table 2). Cotton

yield forecast model for F_2 stage relied on Tmax x Tmin (Z121), time trend and RH1 (Z41) for Bharuch district and time trend, Tmin x RH2 (Z251), Tmax x Rain (Z131), Tmax x RH1 (Z141), Tmax x RH1 (Z140) and Tmin x Rain (Z231) for Surat district. The results showed that the forecasted yields for pre - harvest were 870 and 1454 kg ha^{-1} for Bharuch and Surat district respectively, for the year 2022 (Table 2).

Table 2: Yield forecast models of *kharif* cotton for Bharuch and Surat districts of South Gujarat

District	Crop Stage	Regression equation	R^2	F	Forecasted yield for the year 2022
Bharuch	F_1	Y = 2203.934 + 11.976*Z41 + 11.127*Time	0.78	34.61	769
	F_2	Y = 596.500 + 0.501*Z121 + 12.362*Time + 4.942*Z41	0.80	25.21	870
Surat	F_1	Y = (-687.476) + (45.094*Time) + (15.891*Z51)	0.79	36.30	1209
	F_2	Y = -3704.432 + 50.085*Time + 0.316*Z251 + 0.178*Z131 + 0.369*Z141 + 0.033*Z140 + -0.182*Z231	0.93	37.08	1454

Validation of the *kharif* cotton yield forecast model

The validation of model for the year 2018 to 2020 are shown in Table 3. Result revealed that yield forecast is better for Bharuch and Surat district during F_1 and F_2 stages in all years. The forecasted sugarcane yields for Bharuch and Surat districts are within acceptable error limit (± 15 %) in three of the years of validation, however, Surat district found higher error. This has indicated that the models can be used for prediction of cotton yield in the Bharuch and Surat districts.

Table 3: Validation of *kharif* cotton yield forecast models for Bharuch and Surat districts of South Gujarat

Year	F_1			F_2		
	O	F	Error (%)	O	F	Error (%)
			Bharuch			
2018	515	592	14.9	515	569	10.4
2019	454	504	11.1	454	434	-4.4

2020	473	516	9.0	473	419	-11.3
			Surat			
2018	1093	1338	22.4	1093	934	-14.6
2019	664	730	10.0	664	591	-10.9
2020	498	572	14.8	498	601	20.7

O = Observed yield (kg ha^{-1}), F = Forecasted yield (kg ha^{-1})

CONCLUSION

The present study was carried out to examine the usefulness of pre-harvest estimates of *kharif* cotton yield for South Gujarat through statistical model. R^2 values were good fit and per cent error of validation was ± 15 % for both districts. The results revealed that agrometeorological yield models explained the yield variability due to variations in morning relative humidity and evening relative humidity for F1 stage, for F2 stage found combine of weather variables viz., Tmax, Tmin with combination of RH1, RH2 and rainfall for cotton played crucial role in yield determination. Therefore, it could be used for yield forecasting satisfactorily for cotton yield in South Gujarat region.

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