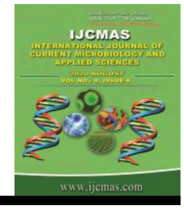
Int.J.Curr.Microbiol.App.Sci (2020) *9*(8): 3979-3985

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 9 Number 8 (2020)**
Journal homepage: http://www.ijcmas.com



Original Research Article https://doi.org/10.20546/ijcmas.2020.908.458

Crop Yield Forecasting of Sorghum (*Sorghum bicolor* L.) by using Statistical Technique for Tapi and Surat Districts of South Gujarat, India

Ashok Patidar[1], S. K. Chandrawanshi[1*] and Neeraj Kumar[2]

[1]*Agricultural Meteorological Cell, Department of Agricultural Engineering, N. M. College of Agriculture, Navsari Agriculture University, Navsari- 396 450 (Gujarat), India*
[2]*Krishi Vigyan Kendra Piproudh Katni, J.N.K.V.V., Jabalpur 483445, Madhya Pradesh, India*

**Corresponding author*

ABSTRACT

Keywords

RMSE, Regression models, Yield forecasting

Article Info

Accepted:
28 July 2020
Available Online:
10 August 2020

Regression models by Hendrick and Scholl technique were developed on sorghum for Tapi and Surat districts of South Gujarat. The daily weather data were used in the study as indicator in crop yield prediction were collected for a period of 32 years. The 28 year data was used for development of the model. The validation of model was done using data set of 2010, 2011, 2012 and 2013. The stepwise regression analysis was executed by trial and error method to obtain finest combination of predictors, significant at 5 % level. Crop yield forecasting models gave good estimates and produce error percent within acceptable range. The study reveled that the percent forecast error for different years were varied from 5.06 to 23.16 for yield forecasting models in Tapi district and -15.73 to 2.76 for yield forecasting models in Surat district for sorghum crop. Lowest RMSE observed in model-2 for both districts with value 11.21 and 8.5 for Tapi and Surat, respectively.

Introduction

Sorghum (*Sorghum bicolor* L.) is one of the globally important cereal crop after wheat, maize, rice and barley. Sorghum is a unique crop among the major cereals and the staple food and fodder of the world's poor and most food-insecure populations, located primarily in the semi arid tropics. In India, sorghum occupies about 5.82 million hectare with total production of 5.39 millions tones with an average productivity of 926 kg/ha. Maharastra, Karnataka, Andhra Pradesh, Gujarat, Tamilnadu and Madhya Pradesh are the major sorghum cultivated states. The area under sorghum cultivation in the country has remained more or less unsatble in the last two decades. The production has registered a significant increase in the last decade, which is practicably more during *Kharif* seasons (Anon, 2014).

Chowdhary and Das (1993) made a multiple regression model for forecasting the *Kharif* food production of India, using Indian SW monsoon rainfall as one of the parameters of the model. Yield foecasting utilizes crop and weather data over long period of time pertaining to locations under consideration. Crop yield indifferent years are affected due to technological change, system productivity and climatic variability. Multiple regression analysis is to include a number of independent parameters at the same time for predicting the significance of a dependent parameter, (Snedecor and Cochran, 1967). In the study, the multiple linear regression equation fitted to the weekly weather parameters treating one as independent parameter and other as dependent parameters. Stepwise process starts with a simple regression model in which most extremely correlated one independent parameter was only incorporated at first in the company of a dependent parameter. Correlation coefficient is further examined in the practice to find an additional independent parameter that explains the major portion of the error remaining from the initial regression model. Until the model includes all the significant contributing parameters, linear regression analysis is used to find the relationship between the response variable *i.e.* yield and the predictor variables, which are maximum and minimum temperature, rainfall and relative humidity. The crop simulation models can predict crop as a function of soil, climate and genetic coefficients. Variability in agricultural production is due to the deviation in weather conditions, especially for rainfed production system Srivastava *et al.*,(2014).

Fisher (1924); Hendrick and Scholl (1943) have suggested model which requires small number of parameters to estimate yield while taking care of distribution pattern of weather over the crop seasons. Fisher utilized weekly weather data. He assumed that the effect of change in weather variables in successive week would not be abrupt or erratic but an orderly one that follow some mathematical laws. This explain relationship in better way as it gives appropriate weightage to weather in different weeks. With this assumptions, the model were developed for studying the effect of weather variables on yield using complete crop seasons data whereas forecast model utilized partial crop seasons data. Regression equation have also been developed for forecasting paddy yield, for estimation of sugarcane yield and for wheat yield (Kumar *et al.*, 2016).

Materials and Methods

Tapi and Surat districts was selected for forecasting of sorghum yields. Crop yield of Tapi and Surat districts data for the period of last 32 years (1985 to 2016) were produced from Directorate of Agriculture, Gujarat state. Weather data were analyzed for Tapi and Surat districts of similar period. Out of 32 years data base, the 28 year data were used for development of the model and rest four years yield data (2010, 2011, 2012 and 2013) were used for validation of the model. Weekly mean data of maximum temperature (Tmax)^{o}C, minimum temperature (Tmin)^{o}C, morning relative humidity (RH-I) % (7.30 h), afternoon relative humidity (RH-II) % (14.30 h), and rainfall (RF) mm were considered according to growing period of sorghum crop. Tapi and Surat districts weekly weather data of growing season of sorghum crop.

SPSS software (version – 16) was used for the statistical analysis and to develop multiple regression modle based on different weather variable. SPSS version 16.0 runs under windows, Mac OS 10.5. with the help of SPSS software co-efficient of determination (R^2), F-value, standard error, *etc.* were calculated.

Computing deviation

Relative deviation (in per centage) were calculated from the normal curves, which show approximately accurate linear relationship between deviations and crop yields. The deviations were calculated as follows:

RD (%) = Observed Yield – Predicted Yield/ Predicted yield * 100

Development of weather indices for yield forecasting meodel-1

$$Z_{ij} = \sum_{w=1}^{m} \sum_{j=0}^{1} r^{j}_{iw} X_{iw}$$ and

$$Z_{ii'j} = \sum_{w=1}^{m} r^{j}_{ii'w} X_{iw} X_{i'w}$$

Where,

Z_{ij} is the developed weather indices of i^{th} weather parameter for j^{th} weight.

$Z_{ii'j}$ is the developed weather indices of product of i^{th} and i'^{th} weather parameter for j^{th} weight.

r_{iw} is correlation coefficient of de-trended Y with i^{th} weather parameter in w^{th} week.

$r_{ii'w}$ is correlation coefficient of de-trended observed yield (Y)with product of i^{th} and i'^{th} weather parameter.

m is week of forecast.

i= 1,2,...,p
j=0,1
w=1,2,...,m

Development of weather indices for yield forecasting model-2

$$Q_{ij} = \frac{\sum_{w=1}^{n} r^{j}_{iw} X_{iw}}{\sum_{w=1}^{n} r^{j}_{iw}}$$ and

$$Q_{ij} = \frac{\sum_{w=1}^{n} r^{j}_{ii'w} X_{iw} X_{i'w}}{\sum_{w=1}^{n} r^{j}_{ii'w}}$$

Where,

Q_{ij} is un-weighted (for j=0) and weighted (for j=1) weather indices for i^{th} weather parameter

$Q_{ij'j}$ is the unweighted (for j=0) and weighted (for j=1) weather indices for interaction between i^{th} and i'^{th} weather parameters.

X_{iw} is the value of the i^{th} weather parameter in w^{th} week,

r_{iw} or $r_{ii'w}$ is correlation coefficient of yield adjusted for trend effect with i^{th} weather parameter or product of i^{th} and i'^{th} weather parameter in w^{th} week, n is the number of weeks considered in developing the indices.

Development of model

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

Where,

Y is the observed rice Yield.
A_0 is the general mean.
Z_{ij} and $Z_{ii'j}$ are the weather indices.
a_{ij} and $a_{ii'j}$ are the regression coefficients of Z_{ij} and $Z_{ii'j}$ weather indices.
p is number of weather parameters used.
c is the regression coefficients of trend parameter.
T is the trend parameter.
e is the error term.

In this approach, for each weather variable, two type of indices were developed, one as simple total values weather variable in different periods and the other one as weighted total, being correlation coefficients between yield/de-trend yield and weather variable in respective period. On similar lines, for studying join effect, un-weighted and weight indices for interaction were computed with products of weather variables.

The weighted and unweighted weather variables were developed with their interaction with each other by taking two at a time Tripathi *et al.,* (2012). Stepwise regression techniques was used to select important weather indices. The models were validated with independent data set of years 2010, 2011, 2012 and 2013.

The models were compared on the basis of adjusted coefficient of determination R^2_{adj} as follows:

$$R^2_{adj} = 1 - \frac{SS_{res}/(n-p)}{SS_t/(n-1)}$$

Where,

$ss_{res}/(n\text{-}p)$ is the residual mean square
$ss_t/(n\text{-}1)$ is the total mean sum of square.

From the fitted models, sorghum yield were forecasted for the years 2014-15 and were compared on the basis of Root Mean Square Error (RMSE).

$$RMSE = \left[\frac{1}{n}\sum_{i=1}^{n}(O_i - E_i)^2\right]^{1/2}$$

Where,

O_i and the E_i are the observed and forecasted values of crop yield, respectively and n is the number of years for which forecasting will be done.

Selection of model was made based on adjusted R^2 value for each method and selecting best model through RMSE value among the method.

Results and Discussion

A total number of four models were developed using different meteorological parameters. Weekly meteorological parameters of important growth stage from flowering to maturity were taken into consideration. A list of 4 model with their coefficient of determination has been given in Table1.

The values of adjusted R2, model equations, pre-harvest SMW No. and model name are presented in Table1. It can be observed from Table 1 that the value of adjusted R2 for model-1 was 55.8 per cent and for model-2 was 60.5 per cent in Tapi district. Similarly in Surat district the value of adjusted R2 for model-1 was 60.5 per cent and for model-2 61.6 per cent. Therefore, model-2 selected as a best model for both districts. The best fit forecasting model equation for estimating the pre-harvest rice yield was found to be appropriate in the 1stSMW (five week before the harvest of crop). This indicated 60.5 per cent variation accounted by weather indices T, Q451 (Interaction of evening RH and Rainfall weighted with correlation coefficient), Q21 (Minimum temperature weighted with correlation coefficient) and Q121 (Interaction of maximum and minimum temperature weighted with correlation coefficient) for Tapi district and 61.6 per cent variation accounted by weather indices T, Q451 (Interaction of evening RH and Rainfall weighted with correlation coefficient), Q20 (Minimum temperature unweighted) and Q11 (Maximum temperature weighted with correlation coefficient) for Surat district of South Gujarat.

Comparison of result obtained through the study of the existing methods, the values of RMSE, forecast error percent, forecast yield, actual yield, forecasting SMW No. and model No. are presented in Table 2. It can be observed from table that, the per cent forecast error for different years were varied from 5.06 to 23.16 for yield forecasting models in Tapi district and -15.73 to 2.76 for yield forecasting models in Surat district. Lowest forecast range found in model-2 for both Tapi and Surat districts. Lowest RMSE observed lowest in model-2 for both districts with value 11.21 and 8.5 for Tapi and Surat, respectively.

Table.1 Meteorological yield models of Sorghum crop based on the weekly weather data

Model Name	Model	Adj. R^2
	Tapi	
Model-1	$Y = 3644.0 + 19.64T + 0.042Z_{250} – 0.009Z_{350} –5.24Z_{10}$	55.8
Model-2	$Y = -2011.50 + 36.56T + 0.005Q_{451} +3.53Q_{21} –0.06Q_{121}$	60.5
	Surat	
Model-1	$Y = -2011.45 + 36.57T + + 0.317Z_{451}+ 233.23Z_{21} – 3.60Z_{121}$	60.5
Model-2	$Y = 975.05 + 35.22T + 0.004Q_{451} – 11.02Q_{20} – 1.46Q_{11}$	**61.6**

Table.2 Comparison between yield forecasting models

Model No.	Year	Forecast Yield	Actual Yield	Forecast error (%)	RMSE	Adj. R^2
			Tapi			
Model-1	2010	987	1160	14.91	12.28	55.8
	2011	949	1109	14.43		
	2012	836	1088	23.16		
	2013	1032	1087	5.06		
Model-2	2010	1058	1160	8.79	11.21	60.5
	2011	965	1109	12.98		
	2012	915	1088	15.90		
	2013	1003	1087	7.73		
			Surat			
Model-1	2010	1255	1160	-8.19	9.81	60.5
	2011	1216	1109	-9.65		
	2012	1100	1088	-1.10		
	2013	1258	1087	-15.73		
Model-2	2010	1227	1160	-5.78	8.5	**61.6**
	2011	1175	1109	-5.95		
	2012	1058	1088	2.76		
	2013	1213	1087	-11.59		

Validation

The actual and forecast yields for period of (2010-2013) and various error analysis of independent data have been presented in table 2. The regression models were validated with four years (2010 and 2013) of independent data set. The data exposed that sorghum yield forecasting models showed that their reliability by producing error below 23.16 % (Table-2).

The error structure for Tapi district for models-1and model-2 RMSE value are 12.28 and 11.21 respectively and Surat district for models-1and model-2 RMSE value are 9.81 and 8.5 respectively.

From the Table-2 revealed that for forecasting the sorghum yield, the yield forecasting model-2 was found better with lower RMSE. Further, the yield forecasting model-2 was also found better as compared to yield forecasting model-1. As it provided lower forecast error Hence model-2was selected as best among two forecasting models for both Tapi and Surat districts.

In conclusion the forecasting models were developed based on modified Hendrock and Scholl technique for sorghum crop by using past year yield and weather data. In this technique time trend weighted and un-weighted indices were utilized.

The combined effect of weather variables viz. minimum temperature, maximum temperature, rainfall, relative humidity afternoon and evening for sorghum played crucial role in yield determination. All models gave the good estimates for yield forecast by giving higher regression coefficient and lower error per cent during validation period. Hence combination of weather and yield data is appropriate and consistent option for yield forecasting.

Acknowledgements

The authors are thankful to Indian Agriculture Statistical Research Institute, New Delhi and India Meteorological Department, New Delhi for facilitating this work. Authors are also grateful to anonymous reviewer for his valuable comments to improve the quality of paper.

References

Anonymous (2014). Area production and yield of principle crops. *Agricultural statistics at a Glance. http://www.mospi.nic.in.*

Chowdhary, A. and Das, H. P., (1993). Sowthwest monsoon rains and *kharif* production. *Mausam*, 44(4): 381-394.

Fisher, R. A. (1924). The influence of rainfall on the yield of wheat at Rothamsted, London. *Phillphins Trans Roy Society*.

Hendick, W. A. and Scholl, J. E. (1943). Techinque in measuring joint relationship on joint effect of temperature and precipitation on crop yield. *North Carolina Agriculture Expert Statistics Techniques Bulletin.*

Kumar, N., Pisal, R. R., Shukla, S. P. and Pandey, K. K, (2016). Crop yield forecasting of paddy and sugarcane through modified Hendrick and Scholl techniques for South Gujarat. *Mausam*, 67 (2): 405-410.

Snedecor, G. W. and Cochran, W. G. (1967). Statistical methods. *The lowa university press, Ames, lowa, 6^{th} ed.*

Srivastava, R. K., Halder, D. K. and Panda, R. K. (2014). Prediction of rice yield with DSSAT crop simulation model and multiple linear regression analysis. *Agriculture and food engineering department. IIT, Khadagpur*- 721 302.

Tripathi, M. K., Mehra, B., Chattopadhyay, N. and Singh, K. K. (2012). Yield prediction of sugarcane and paddy for districts of Uttar Pradesh. Journal of Agrometeorology, 14(2): 173-175.

How to cite this article:

Ashok Patidar, S. K. Chandrawanshi and Neeraj Kumar. 2020. Crop Yield Forecasting of Sorghum (*Sorghum bicolor* L.) by using Statistical Technique for Tapi and Surat Districts of South Gujarat, India. *Int.J.Curr.Microbiol.App.Sci.* 9(08): 3979-3985.
doi: https://doi.org/10.20546/ijcmas.2020.908.458