Journal of Agrometeorology 17 (1) : 130-132 (June 2015)

Short communication

Development of statistical model for forecasting chickpea productivity of Rajkot district in Gujarat state

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India is the largest producer of gram in the world having an area of 8.74 million hectares and 7.35 million tone of production. It accounts 60% of area and production of world and 34.6% area and 48.4% production of total pulses of India (Singh, 2010). Gujarat accounts 2.46% of area and 2.80% of production of country and occupies an area of 2.15 lack hectares with a production of 2.10 lack tone with an average of 977 kg ha^{-1}.

The weather variables like rainfall, maximum and minimum temperature, relative humidity and sunshine hours affect growth and development in different ways and at different times during the growth cycle of the crop. The relationship between crop yields and weather parameters can be identified with the help of multiple regression models (Agrawal and Mehta, 2001).

With a view to development of forecasting model of chickpea for Rajkot district of Gujarat by using combined effect of weather parameters, the chickpea yield data of Rajkot district for the years 1981 to 2010 was obtained from the Department of Economics, J.A.U., Junagadh and the meteorological data of Rajkot (Lat: 22° – 18‘ N, Long: 70° – 56‘ E) was collected from Dry Farming Research Station, Targhadiya for the corresponding period.

Weekly averaged data of weather variables *viz.* minimum temperature (X_1), maximum temperature (X_2), morning relative humidity (X_3), afternoon relative humidity (X_4), sunshine hours (X_5) and total annual rainfall of past year (X_6) were collected for growing season of chickpea in Rajkot distract for the years under consideration. The sowing of chickpea mainly concentrated around third week of October in Gujarat. Hence the data pertaining to the weather parameters for the period 42nd week to 7th week of next year were included in the present study.

For selecting the best regression equation among the number of independent variables, the stepwise regression procedure was used (Draper and Smith, 1966). Statistical computer software Microstat was used for the analysis of the data with the probability level 0.05 and 0.1 to remove the variables using weekly weather variables.

With a view to assess the accuracy and capability of forecasts at an interval of weeks, four models were fitted, considering up to 12, 13, 14 and 15 weeks after sowing during the crop period. The details of variables included in model 12 weeks crop period are given in Table 1& 2. The time trend variable was included in this analysis as an explanatory variable.

$$Y = A_0 + \sum_{i=1}^{p}\sum_{j=1}^{w} a_{ij}X_{ij} + bR + cT$$

The mathematical expression of this approach,

Where,

Y = Average chickpea yield of district in kg/ha

$\mathbf{A_0}$ = Constant

$\mathbf{X_{ij}}$ = Observed value of ith weather variable in jth week i = 1,2,... p = 6 and j = 1,2,...w = 12, 13, 14, 15

R = Total rainfall of past season of the district in mm.

T= Year number included to correct for the long term upward or downward trend in yield (T = 1,2…t=30**)**

$\mathbf{a_{ij}}$, **b** and **c** are partial regression coefficients associated with each $\mathbf{X_{ij}}$, rainfall and time trend **(T)** respectively.

To determine the effect of week wise weather variables on chickpea yield, the variables which appeared in the equation and had significant partial regression coefficient were considered to have influence on chickpea production. The results presented in two parts for each crop period for the model. First part deals with fitted regression equations and second part deals with their corresponding simulated

Table 1: Regression equations for 12week crop period of Rajkot district

Variables	12- week models for different years			
	Model-I (25 year)	Model-II (26 year)	Model-III (27 year)	Model-IV (28 year)
Constant	2531.20	1551.74	1381.82	1371.51
T	13.20**	20.48**	21.66**	21.72**
X_{205}	-53.71**	-58.47**	-54.95**	-54.93**
X_{211}	12.22**	17.62**	13.88**	13.87**
X_{301}	4.55**	5.21**	6.28**	6.28**
X_{304}	6.87**	6.84**	6.29**	6.27**
X_{401}	4.76**	2.88**	2.47**	2.47**
X_{402}	-5.66*	-1.99*	-3.87*	-3.87*
X_{409}	0.14*	-0.67*	0.87*	0.87*
X_{502}	-71.32**	-38.40**	-78.38**	-78.47**
X_{508}	43.77**	65.69**	36.14**	36.17**
X_{510}	-74.71**	-57.51**	-5.85**	-4.69**
X_{512}	-18.12**	-18.95**	10.51**	10.47**
S.E.	157.11	167.27	155.88	150.59
R^2(%)	**85.5**	**83.2**	**85.6**	**86.3**

*Significant at 5% level. ** Significant at 1% level.

Table 2: Simulated forecast values for 12week crop period of Rajkot district (Week wise approach)

Year	Observed yield (kg ha^{-1})	(12- week) Predicted values (kg ha^{-1})			
		Model-I 25 years	Model-II 26 years	Model-III 27 years	Model-IV 28 years
2006-07	1203	919(23.60)	— —	—	
2007-08	1112	919(17.35)	995(10.52)	—	—
2008-09	1867	1299(30.42)	1204(35.51)	1118(40.11)	—
2009-10	1415	1618(14.34)	1560(10.24)	1502(6.14)	1500(6.00)
2010-11	1380	1656(20.00)	1551(12.39)	1462(5.94)	1456(5.50)

Figures in ( ) are percent deviation from observed yield.

forecasts for subsequent years not including for obtaining the regressions.

The result presented in case of 12 week period model, revealed that variables such as time trend (T), 11th week of maximum temperature (X_{211}), 1st& 4th week of morning relative humidity (X_{301},X_{304}), afternoon relative humidity of 1st week (X_{401}) and 8th week of sunshine hours (X_{508})were significantly and positively affected but in case of 5th week of maximum temperature (X_{205}), afternoon relative humidity of 2nd week (X_{402}) and 2nd, 10th and 12th week of sunshine hours (X_{502}, X_{510}, X_{512})were negatively influenced on yield of chickpea. The weeks correspond to vegetative, flowering and maturity stages of the chickpea crop. The coefficient of determination ranged from 83.2 to 86.3% (Table 1). The simulated forecasts

obtained from these prediction equations, showed 5.5 to 35.5 % deviation from the recorded chickpea yield of the Rajkot district (Table-2).

In case of 13 week crop period result suggested that there is a positive and significant effect of time trend (T), maximum temperature of 11th week (X_{211}), morning relative humidity of 4th & 10th week ($X_{304,}$ X_{310}) and bright sunshine hours of 8th week (X_{508}) in all four models. The negative and significant influence on chickpea crop is observed in case of maximum temperature of 5th week (X_{205}), morning relative humidity of 3rd and 9th week (X_{303},X_{309}) and bright sunshine hours of 1st, 10th & 12th week ($X_{501,}$ $X_{510,}$ X_{512}) corresponding to the vegetative, flowering and maturity stages of the crop. The coefficient of determination (R^2) varied from 82.0 to 82.8% and the predicted values showed 5.14 to 28.56 per cent deviation from recorded yield of Rajkot district.

The result of the 14 week period model showed that, the effect of time trend (T), maximum temperature of 11th week (X_{211}), morning relative humidity of 1st week (X_{301}) and bright sunshine hours of 8th week (X_{508}) were positive and significant. The negative and significant effect influence on chickpea crop is observed in case of maximum temperature of 5th& 14th week (X_{205}, X_{214}), sunshine hours of 10th& 12th week ($X_{510,}$ X_{512}). The weeks correspond to sowing, flowering and maturity stages of chickpea crop. The coefficient of determination (R^2) varied from 76.58 to 77.87 % and the deviation in predicted values varied from 4.31 to 67.89 per cent.

The analyzed result of 15 week period model result revealed that out of all the variables the effect of time trend (T), maximum temperature of 11th week (X_{211}), morning relative humidity of 1st week (X_{301}) and bright sunshine hours of 8th week (X_{508}) were positive and significant. The negative and significant effect influence on chickpea crop is observed in case of maximum temperature of 5th& 12th week ($X_{205,}$ X_{212}), sunshine hours of 10th& 12th week ($X_{510,}$ X_{512}). The weeks correspond to vegetative and flowering stages of chickpea crop. The coefficient of determination varied from 75.2 to 76.2 % and the deviation in predicted values varied from 3.9 to 63.7 per cent.

In Rajkot district, the minimum temperature did not influence the chickpea yield. The effect of maximum temperature was found to be beneficial during 11th week (X_{211}), which corresponded to maturity stage. The detrimental effect of maximum temperature was found during 5th week (X_{205}), which corresponded to vegetative stage. The positive response of morning relative humidity on chickpea yield was observed during 4th week (X_{304}), which corresponded to vegetative stage. The effect of evening relative humidity did not influence the chickpea crop yield. The effect of sunshine hours was observed to be beneficial during 8th week (X_{508}), which corresponded to flowering stage of the chickpea crop. The unfavorable impact also observed during 2nd, 10th and 12th week, (X_{502}, X_{510}, X_{512}), which corresponded to establishment and maturity stage.

Chickpea is a Rabi (winter) crop. The effect of rainfall (X_6) on chickpea yield for different weeks, with their corresponding meteorological week (MSW) revealed that there is no significant effect of rainfall on chickpea crop in all district.

The results of Rajkot district revealed that among the four approaches under study, two models were identified for the pre-harvest forecast of chickpea. As far as earliest pre-harvest forecasts model concerned, in case of using original weather variables (week wise approach), the model of 12 weeks crop period could be suggested as a pre-harvest forecast model. The variation explained by this model was very high (86.30%) and error of simulated forecast were less than 6 percent. This model could be utilized for pre-harvest forecast 4 weeks before expected harvesting period of chickpea crop.

The recommended model for Rajkot district is,

$$Y = 1371.51 + 21.72\ T - 54.93^{**}\ X_{205} + 13.87^{**}\ X_{211} + 6.28^{**}\ X_{301} + 6.27^{**}\ X_{304} + 2.47^{**}\ X_{401} - 3.87^{*}\ X_{402} + 0.87^{*}\ X_{409} - 78.47^{**}\ X_{502} + 36.17^{**}\ X_{508} - 4.69^{**}\ X_{510} + 10.47^{**}\ X_{512}\ (R^2 = 86.30\%)$$

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Received : March 2014 ; Accepted : December 2014