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Research Article

PREHARVEST FORECASTING OF MUSTARD YIELD ON THE BASIS OF WEATHER VARIABLES IN BANASKANTHA DISTRICT OF GUJARAT

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Abstract: To suggest most suitable pre-harvest forecasting model on mustard crop for Banaskantha district of Gujarat state past 32 years (1982-83 to 2013-14) weather data (weekly average of maximum and minimum temperature, morning and evening relative humidity, bright sunshine hours/day and rainfall (mm) from 42nd to 3rd meteorological standard weeks (MSW) were collected from the Agro-Meteorological Observatory, Agronomy Instruction Farm, S. D. Agricultural University, Sardarkrushinagar. The time trend was also included as independent variable. The data on average mustard yield (dependent variable) of Banaskantha district were obtained from the Directorate of Agriculture, Gujarat state, Gandhinagar. The step-wise regression procedure was employed by using 28 years data. The prediction equations and forecast of subsequent years were obtained separately for 26 to 28 years data set. The positive and significant effect of rainfall was observed. Effect of time trend was not observed suggested that technological advancement was not found significant with the mustard yield. The correlation coefficient as weight approach was found superior compared to other approaches. This approach provided suitable pre-harvest forecasting model predicting yield 4 weeks before actual harvest and explained more than 51 % variation in mustard yield.

Keywords: *Forecast, Time trend, Weather variables, Mustard yield, Step-wise regression*

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Introduction

In India, rapeseed-mustard is grown in diverse agro-climatic conditions ranging from north-eastern/north-western hills to down south under irrigated/rainfed, timely/late sown and mixed cropping. Mustard is the common name for several herbaceous plants in the genera Brassica and Sinapis of the Brassicaceae family. Indian mustard (*Brassica juncea* L.) is originally from the foothills of Himalayas. Indian mustard is an annual herbaceous plant. It is also known as Rai, Mohari, Tikkiya, Serso. Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana, Gujarat and West Bengal states accounted for nearly 86.5 percent area and 91.4 percent production of rapeseed-mustard in the country during 2012-13. The productivity of Haryana, Gujarat, Rajasthan, Uttar Pradesh and Madhya Pradesh was above 1000 kg/ha in the descending order. There was reduction in area and production of rapeseed-mustard in Gujarat, Uttar Pradesh and Rajasthan. The importance of timely and reliable forecast of area and yield of major crops need not be over-emphasized for the country like India where, the economy is mainly based on agricultural production. The pre-harvest estimates of crop yields are considered mainly as an aid to conjecture the final production and therefore, sufficient attention needs to be paid towards their improvement. Pre-harvest yield forecast is one of the important tools in taking policy decisions with greater confidence in matters relating to food procurement and its distribution, price, export-import and for exercising several administrative measures for storage and marketing of agricultural commodities. Plenty of literature on yield forecasting of different crops is available but, such information is very scanty for mustard crop, being rapeseed-mustard ranks 2nd in terms of production, after soybean, however, due to more oil content (ranging from 35 to 45 %) rapeseed-mustard ranks 1st in terms of oil yield among all oilseeds crops. Therefore, an attempt was made to quantify the effect of weather parameters and technological advancement on mustard crop for Banaskantha district of Gujarat state. Sizeable literature is available wherein authors have used either biometrical variables [1] or weather variables [2, 3] in pre-harvest yield forecasting of various crops. But, Chaudhari *et al*. (2015) [4] used weather parameters for mustard yield forecasting at Gandhinagar, Gujarat.

Material and methods

In present study, an attempt has been made to formulate a relationship for predicting the mustard yield (Y) by investigating the influences of important weather variables *viz*., maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, bright sunshine hours and rainfall (X_i's) on the mustard crop. To estimate the effect of weather variables with technological advances, the average yield (productivity) data of mustard for the year 1982-83 to 2013-14 were collected from Annual Season and Crop Reports of respective years, published by Directorate of Agriculture, Gujarat State, Gandhinagar (Anonymous, 1982-2014) [5]. Due to technological advancement, the time trend (T) was considered as one of the independent variable in the study. The weekly averaged data of weather variables *viz*., (1) maximum temperature (ºC), (2) minimum temperature (ºC), (3) morning relative humidity (%), (4) evening relative humidity (%), (5) bright sunshine hours/day and (6) Annual rainfall (mm) were collected for the period of the growing season of mustard in Banaskantha district for the years 1982-83 to 2013-14 from the Agro-Meteorological Observatory, Agronomy Instruction Farm, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. Following three different approaches (models) (Agarwal *et al.,* 1980) [6] were studied.

Standard week-wise approach

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

Table-1 *Variables selected, coefficient of determination (R^2) and range of forecast errors in week-wise approach*

Variables selected		R^2 and simulated forecast errors (%)		
		1982-83 to 2007-08 (Model I)	1982-83 to 2008-09 (Model-II)	1982-83 to 2009-10 (Model-III)
(I) 11 weeks model X_{406} and X_{509}	R^2	33.9	15.7	23.1
	S.E.	194.71	211.8	207.84
	% deviation	-29.23 to 36.37	1.53 to 24.88	15.01 to 24.52
(II) 12 weeks model X_{405}, X_{504}, X_{506} and X_{509}	R^2	33.6	45.4	22.4
	S.E.	197.37	197.77	210.59
	% deviation	-12.71 to 33.91	19.06 to 58.94	14.80 to 24.39
(III) 13 weeks model Annual rainfall, X_{405}, X_{413} and X_{509}	R^2	33.6	45.4	22.4
	S.E.	197.37	179.77	210.59
	% deviation	-12.71 to 33.91	15.66 to 40.02	14.80 to 24.39
(IV) 14 weeks model Annual rainfall, X_{405}, X_{413} and X_{509}	R^2	33.6	45.4	22.4
	S.E.	197.37	179.77	210.69
	% deviation	-12.71 to 33.91	15.66 to 40.02	14.80 to 24.39

Table-2 *Selected Variables, coefficient of determination (R^2) and range of forecast errors in week number as weight approach*

Variables selected		R^2 and simulated forecast errors (%)		
		1982-83 to 2007-08 (Model I)	1982-83 to 2008-09 (Model-II)	1982-83 to 2009-10 (Model-III)
(I) 11 weeks model Z_{31}, Z_{32} and Q_{341}	R^2	37.3	37.1	35.7
	S.E.	189.62	186.76	193.81
	% deviation	-9.2 to 30.18	9.11 to 31.04	7.05 to 32.25
(II) 12 weeks model Z_{30}, Z_{31} and Q_{341}	R^2	35	33.8	32.2
	S.E.	193.08	191.59	198.96
	% deviation	-13.90 to 22.24	12.49 to 22.80	8.36 to 19.75
(III) 13 weeks model R, Z_{31} and Q_{341}	R^2	39.9	39.9	35.3
	S.E.	185.74	182.5	194.38
	% deviation	-6.87 to 30.88	14.05 to 31.11	9.51 to 41.76
(IV) 14 weeks model R, Q_{341} and Q_{452}	R^2	23.1	36.7	19.9
	S.E.	205.68	187.24	212.02
	% deviation	-13.63 to 35.19	12.80 to 29.82	18.16 to 34.56

Table-3 *Selected variables, coefficient of determination and range of forecast errors in correlation coefficient as weight approach*

Variables selected		R^2 and simulated forecast errors (%)		
		1982-83 to 2007-08 (Model I)	1982-83 to 2008-09 (Model-II)	1982-83 to 2009-10 (Model-III)
(I) 11 weeks model Z'_{42}, and Z'_{50}	R^2	36	34.9	40.6
	S.E.	302.51	297.55	311.35
	% deviation	14.44 to 28.01	13.29 to 62.87	8.64 to 47.02
(II) 12 weeks model Z'_{42}, and Q'_{450}	R^2	35.1	34	16.3
	S.E.	188.98	187.41	216.76
	% deviation	12.18 to 79.29	12.40 to 74.11	21.36 to 33.77
(III) 13 weeks model Z'_{42}, Z'_{50}, Z'_{51}, and Q'_{152}	R^2	40.9	39.5	34.6
	S.E.	184.11	183.14	195.38
	% deviation	13.37 to 85.17	12.29 to 85.47	2.51 to 61.04
(IV) 14 weeks model Z'_{11}, Z'_{42}, Z'_{51}, and Q'_{321}	R^2	32	51.1	19.4
	S.E.	193.38	168.16	212.72
	% deviation	12.51 to 92.67	11.51 to 74.22	6.60 to 22.26

Table-4 *Regression coefficients of mustard yield on time trend and different generated weather variables using correlation coefficients as weight approach (14 weeks)*

Variables in the Equation	Years					
	1982-83 to 2007-08 (Model-I)		1982-83 to 2008-09 (Model-II)		1982-83 to 2009-10 (Model-III)	
Constant	-1741.27	(-54.109)	1797.56	-166.821	2083.889	-336.347
Z'11 (Linear weight of correlation coefficients to maximum temperature)	-		-		-72.625**	-29.036
Z'42 (Quadratic weight of correlation coefficients to eve. rel. humi.)	-53.504**	-15.925	-43.476**	-12.733	-	
Z'51 (Linear weight of correlation coefficient to bright sunshine hours)	-		-11.722*	-4.247	-	
Q'321(Linear weight of correlation coefficients to cross products of mor. rel. humi. and minimum temperature)	-		0.219*	-0.101	-	
S. E.±	193.38		168.16		212.723	
R^2 (%)	32		51.1		19.4	

Figures in parenthesis indicate standard error, *Significant at 5 % level, ** Significant at 1 % level.

Where,
Y = Average mustard yield of Banaskantha district (kg/ha),
A_0 = Constant
X_{ij} = Observed value of i^{th} weather variable in j^{th} week, (i = 1, 2, …….p and j = 1,2,…,w= 11, 12, 13 and 14)
p = Number of weather variables (p = 1,2,…,5)
w = Week identification
T = Year number included to correct the long term upward or downward trend in mustard yield (T= 1 to 28)
R = Annual rainfall
a_{ij} , b and c are partial regression coefficients associated with each X_{ij} and time trend and annual rainfall respectively.

By taking week number as weight

$$Y = A_0 + \sum_{i=1}^{p}\sum_{j=0}^{2} a_{ij} Z_{ij} + \sum_{i \neq i'=1}^{p}\sum_{j=0}^{2} b_{ii'j}.Q_{ii'j} + cT + dR$$

Where,
Y = Average mustard yield of Banaskantha district (kg/ha),
A_0 = Constant,
T = Year number included to correct the long term upward or downward trend in mustard yield,
P = Number of weather variables (p = 1, 2,...,5).
R = Annual rainfall
a_{ij}, $b_{ii'j}$, c and d are partial regression coefficients associated with each Z_{ij}, $Q_{ii'j}$, time trend and annual rainfall respectively (i ≠ i' = 1,2,...,p and j = 0,1,2).
Z_{ij} and $Q_{ii'j}$ (taking interaction of variables) were generated (Agrawal *et al*., 1980) using following formula:

$$Z_{ij} = \frac{\sum_{w=1}^{n} w^j . X_{iw}}{\sum_{w=1}^{n} w^j} \; and \; Q_{ii'j} = \frac{\sum_{w=1}^{n} w^j . X_{iw} . X_{i'w}}{\sum_{w=1}^{n} w^j}$$

Here, Z_{ij} and $Q_{ii'z}$ were generated as first and second order variables defined as under:
n = Number of weeks up to the time of forecast,
w = Week identification, and
X_{iw} = Value of the i^{th} weather variable in w^{th} week. (i ≠ i' = 1, 2,…p = 5 and j = 0,1,2)
$X_{i'w}$ = Value of the i'^{th} weather variable in w^{th} week

By taking correlation coefficient as weight

$$Y = A_0 + \sum_{i=1}^{p}\sum_{j=0}^{2} a_{ij} Z_{ij} + \sum_{i \neq i'=1}^{p}\sum_{j=0}^{2} b_{ii'j}.Q_{ii'j} + cT + dR$$

Where,
Y = Average mustard yield of Banaskantha district (kg/ha)
A_0 = Constant.
T = Year number included to correct for the long term upward or downward trend in mustard yield, and
p = Number of weather variables (p = 1,2...,5).
R = Annual rainfall
a_{ij}, $b_{ii'j}$, c and d are partial regression coefficients associated with each Z'_{ij}, $Q'_{ii'j}$ time trend and annual rainfall respectively. (i ≠ i' = 1,2,...,p and j = 0,1,2)
Z'_{ij} and $Q'_{ii'j}$ are generated first and second order variables defined as under,

$$Z'_{ij} = \frac{\sum_{w=1}^{n} r_{iw}^j . X_{iw}}{\sum_{w=1}^{n} r_{iw}^j} \; and \; Q'_{ii'j} = \frac{\sum_{w=1}^{n} r_{ii'w}^j . X_{iw} . X_{i'w}}{\sum_{w=1}^{n} r_{ii'w}^j}$$

N = number of weeks up to the time of forecast
W = week identification (w=1,2,…, n=11, 12, 13 and 14)
X_{iw} = value of the i^{th} weather variable in the w^{th} week
(i≠i' = 1,2,… ,p and j=0,1,2)
r_{iw} = correlation coefficient of yield with the i^{th} weather variable in the w^{th} week
$r_{ii'w}$ = correlation coefficient of yield with the product of the i^{th} and i'^{th} weather variable in the w^{th} week. Using these approaches the forecast models were fitted based on step wise regression technique [7] and simulated forecast errors were worked out for the subsequent years which were not included in fitting the model.

Results and discussion

Week-wise approach

The values of standard error (S. E.), coefficient of determination (R^2) and deviation from average yields are given in [Table-1]. The 11 weeks crop period model revealed that S. E. ranged from 194.71 to 211.80. The variables explained 15.7 to 33.9 percent variation in the yield of mustard crop. The simulated forecast obtained from regression equation showed -29.23 to 36.37 percent deviations from observed yields. The 12 weeks crop period model revealed that 4 variables explained 22.40 to 45.40 percent variation in the yield of mustard crop. The simulated forecast obtained from model ranged from -12.71 to 58.94 percent deviations from observed yields. Standard error ranged from 197.37 to 210.59. The 13 weeks crop period model revealed that S. E. ranged from 179.77 to 210.59. The variables explained around 22.40 to 45.40 percent variation in the yield of mustard crop. The simulated forecast obtained from regression equation showed -12.71 to 40.02 percent deviations from observed yields. The 14 weeks crop period model revealed that 4 variables explained around 22.40 to 45.40 percent variation in the yield of mustard crop. The simulated forecast obtained from regression equation showed -12.71 to 40.02 percent deviations from observed yields. The 14 weeks crop period model revealed that 4 variables explained 22.40 to 45.40 percent variation in the yield of mustard crop. The simulated forecast obtained from model ranged from -12.71 to 40.02 percent deviations from observed yields. Standard error was ranged from 179.77 to 210.69.

Week number as weight approach

In this approach, generated weather variables (week number as weight) were used. The values of S. E., R^2 and deviation from average yields are presented in [Table-2]. The 11, 12, 13, and 14 weeks crop period models revealed that variation explained by these set of equations ranged from 19.90 to 39.90 percent, standard error ranged from 182.50 to 212.02 and the deviation between predicted and observed yields ranged from -13.90 to 41.76 percent. Therefore, none of the models could be considered as suitable for pre-harvest forecasting of mustard yield under this approach.

Correlation coefficient as weight approach

Using four different crop periods, three models were fitted under this approach. The values of S. E., R^2 and deviation from average yields are presented in [Table-3]. It could be observed from the above results that the variation explained (*i.e*., R^2) by fitted models, ranged from 16.30 to 51.10 percent for all the three models. The deviation between observed yield and forecasted yield in percent ranged from 2.51 to 85.47 percent. Among the equations fitted under this approach, in model of 12 and 14 weeks crop period of model-III, R^2 was low. In case of 14 weeks of model-II, R^2 was reasonably high *i.e*., 51.1 percent with minimum standard error (168.12) and the simulated forecast was ranging from 11.51 to 74.22 percent, but for early forecast (4 weeks before harvest) the 14 weeks of 27 years, model-II was found suitable for forecasting mustard yield under this approach as compared to rest of the models. Varmora *et al*. (2004) [8] reported forecasting models for predicting wheat yield based on generated weather variables using correlation coefficient as weight. The present findings are on similar line. This is also in similar with the findings of Chaudhary *et al*. (2015) in mustard crop. Among the different models fitted under three approaches, the model identified as suitable pre-harvest forecast models for Banaskantha district was using generated variables (correlation coefficient as weight) of 14 weeks of 27 years (model-II) because of minimum standard error with high R^2 (51.1 %). The detailed results of this model are given in [Table-4] and [Table-5]. The beneficial effect of second order generated variables Q'321 (Linear weight of correlation coefficients to cross products of morning relative humidity and minimum temperature) on mustard productivity was observed significantly. At least 4 weeks before actual harvest of the crop, reliable pre-harvest forecasting of mustard yield in Banaskantha district can be made using generated weather variables, correlation coefficient as weight (14 weeks) approach by the following model:

$Y = 1797.560 - 43.476^{**}Z'_{42} - 11.722^{*}Z'51 + 0.219^{*}Q'_{321}$
R^2 = 51.1 % (168.16)

Table-5 *Simulated forecasts based on the fitted equations (14 weeks)*

Year	Observed Yield (kg/ha)	Simulated forecasts (kg/ha)					
		1982-83 to 2007-08 (Model-I)		1982-83 to 2008-09 (Model-II)		1982-83 to 2009-10 (Model-III)	
2008-09	1135	930.19	(18.04)				
2009-10	1602	899.29	(43.86)	953.08	(40.50)		
2010-11	1540	302.140	(80.38)	396.92	(74.22)	1217.13	(22.26)
2011-12	1561	1362.62	(12.51)	1381.24	(11.51)	1457.96	(6.60)
2012-13	1788	1288.86	(27.91)	1391.32	(22.18)	1288.74	(29.92)
2013-14	1702	1285.53	(92.67)	1238.22	(27.24)	1332.04	(21.73)

Application of research: Study of preharvest forecasting of mustard

Research Category: Agro-Meteorology

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Study area / Sample Collection: Agro-Meteorological Observatory, Agronomy Instruction Farm, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar

Cultivar / Variety name: Mustard (*Brassica juncea* L.)

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
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References

[1] Jha M.P., Jain R.C. and Singh D. (1981) *Indian Journal of Agricultural Sciences*, 51 (11), 757-61.
[2] Khistaria M.K., Varmora S.L., Dixit S.K., Kalola A.D. and Rathod D.N. (2004) *Journal of Agrometeorology*, 6 (sp. issue), 197-203.
[3] Malik R.K. and Gupta B.R.D. (2000) *Journal of Agro meteorology*, 2(1), 83-87.
[4] Chaudhari C.M.; Thaker M.B and Patel N.V. (2015) *International Journal of Science and Research*, 6(14),132-138.
[5] Anonymous (1982-2014) *Annual season and crop reports and final forecast reports of respective years, published by Directorate of Agriculture, Gujarat state, Ahmedabad*.
[6] Agrawal R., Jain R.C., Jha M.P. and Singh D. (1980) *Indian Journal of Agricultural Sciences*, 50(9), 680-84.
[7] Draper N.R. and Smith H. (1966) *Applied regression analysis. John Wiley & Sons, New York*.
[8] Varmora S.L., Dixit S.K., Patel J.S. and Bhatt H.M. (2004) *Journal of Agro meteorology*, 6 (2), 223-228.