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Preharvest forecasting of castor 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 for Banaskantha district of Gujarat state The weather data for past 27 years (1982-83 to 2008-09) *viz.*, weekly average of maximum and minimum temperature, morning and evening relative humidity, bright sunshine hours/day and weekly total rainfall (mm) from 32[nd] to 52[nd] 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 castor 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 23 years data. The prediction equations and forecast of subsequent years were obtained separately for 21 to 23 years data set. The positive and significant effect of the time trend and beneficial effect of weekly total rainfall were observed. The correlation coefficient as weight approach was found superior compared to other approaches. This approach provided suitable pre-harvest forecasting model predicting yield 12 weeks before actual harvest and explained more than 94 % variation in castor yield. The deviations between the predicted and actual yields ranged from -19.85 % to 12.32 %.

Key words: Forecast, weather variables, castor yield, multiple linear regression.

Castor [*Ricinus communis* (L.)] is an important non-edible oil seed crop of arid and semi-arid regions of India. The crop has wide adaptability and grown in tropical, sub-tropical and temperate regions of the world. India being the largest castor producer in the world produced 11.90 lakh tonnes from an area of 8.59 lakh hectares with a productivity of 1385 Kg/ha during 2010-11. (Anonymous 2011). Weather is a major factor affecting crop production in India. 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 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 castor crop, being largely grown in Gujarat, where castor seed and castor oil are economically important products. Therefore, an attempt was made to quantify the effect of weather parameters and technological advancement on castor crop for Banaskantha district of Gujarat state. Sizeable literature is available wherein authors have used either biometrical variables (Jha *et al.*, 1981) or weather variables (Khistaria *et al.*, 2004 and Malik

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et al., 2000) in pre-harvest yield forecasting of various crops. But, Kokate *et al.* (2000) used jointly both biometrical and weather variables for rice yield forecasting at Dapoli, Maharashtra.

MATERIALS AND METHODS

In present study an attempt has been made to formulate a relationship for predicting the castor 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 castor crop. To estimate the effect of weather variables with technological advances, 27 years yield data from 1982-83 to 2008-09 were collected from Annual Season and Crop Reports of respective years, published by Directorate of Agriculture, Gujarat state, Gandhinagar (Anonymous 1982-2009). Due to technological advancement, the time trend (T) was considered as one of the independent variable in the study. The weekly averages of weather variables viz., maximum temperature (X_1), minimum temperature (X_2), morning relative humidity (X_3), evening relative humidity (X_4), bright sunshine hours (X_5) and rainfall (X_6)from 32[nd] to 52[nd] meteorological standard week (MSW) of the respective year were collected from the Agro-Meteorological Observatory, Agronomy Instruction Farm, S. D. Agricultural University, Sardarkrushinagar. Following three different approaches (models) (Agarwal *et al.*, 1980) were studied.

Standard week-wise approach

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

Where,

Y = Average castor 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 = 6 and j = 1,2,...,w = 17, 18, 19, 20 and 21

T = Year number included to correct the long term upward or downward trend in castor yield (T = 1 to 21)

a_{ij} and b are partial regression coefficients associated with each X_{ij} and time trend respectively.

By taking week number as weight :

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

Where,

Y = Average castor yield of Banaskantha district (kg/ha)

A_0 = Constant

T = Year number included to correct the long term upward or downward trend in castor yield

p = No. of weather variables (p=1,2,...,6)

a_{ij}, $b_{ii'j}$ and c are partial regression coefficients associated with each Z_{ij}, $Q_{ii'j}$ and time trend respectively (ii' = 1,2,...,p and j=0,1,2)

Z_{ij} and $Q_{ii'j}$ are generated as first and second order variables defined as under,

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

n = number of weeks up to the time of forecast

w = week identification (w=1,2,...,n=17, 18, 19, 20 and 21)

X_{iw} = value of the i^{th} weather variable in w^{th} week ($i \neq i'$ = 1,2,...,6 and j=0,1,2)

By taking correlation coefficient as weight

$$Y = A_0 + \sum_{i=1}^{p} \sum_{j=0}^{2} a_{ij} Z'_{ij} + \sum_{i}^{p} \sum_{i'=1}^{} \sum_{j=0}^{2} b_{ii'j} . Q'_{ii'j} + cT \quad (iii)$$

Where,

Y = Average castor yield of Banaskantha district (kg/ha)

A_0 = Constant

a_{ij}, $b_{ii'j}$ and c are partial regression coefficients associated with each Z'_{ij}, $Q'_{ii'j}$ and time trend respectively. (ii' = 1,2,…,p and j = 0,1,2)

T = Year number included to correct for the long term upward or downward trend in castor yield

p = No. of weather variables (p=1,2,...,6)

Z'_{ij} and $Q'_{ii'j}$ are generated first and second order variables defined as under,

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

n = number of weeks up to the time of forecast

w = week identification (w=1,2,…, n=17, 18, 19, 20 and 21)

X_{iw} = value of the i^{th} weather variable in the w^{th} week ($i \neq i'$ = 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 (Draper and Smith, 1966) and simulated forecast errors were worked out for the subsequent years which were not included in fitting the model. The variables included in the models corresponding to the three periods (1982-83 to 2002-03, 1982-83 to 2003-04 and 1982-83 to 2004-05) differed. Thus, a common model for all the three periods was fitted using multiple regression approach. This model included all those independent variables, which appeared in one or the other models corresponding to three periods.

RESULTS AND DISCUSSION

Week-wise approach

The values of standard error (S. E.), coefficient of determination (R^2) and deviation from average yields are summarized in Table 1. The 17 weeks crop period model revealed that S. E. ranged from 218 to 232. The variables explained 76.2 to 76.9 per cent variation in the yield of castor crop. The simulated forecast obtained from regression equation showed -17.31 to 12.48 per cent deviations from observed yields. The 18 weeks crop period model revealed that 5 variables explained 81.8 to 83.6 per cent variation in the yield of castor crop. The simulated forecast obtained from model ranged from -38.87 to 17.30 per cent deviations from observed yields. Standard error ranged from 189 to 195. The 19 weeks crop period model revealed that S. E. ranged from 124 to 132. The variables explained around 93 per cent variation in the yield of castor crop. The simulated forecast obtained from regression equation showed -39.01 to 17.79 per cent deviations from observed yields.

The 20 weeks crop period model revealed that 7 variables explained 80 to 82 per cent variation in the yield of castor crop. The simulated forecast obtained from model ranged from -56.26 to 15.44 per cent deviations from observed yields. Standard error was ranged from 209 to 215. The 21 weeks crop period model revealed that S. E. ranged from 123 to 132. The variables explained around 94 per cent variation in the yield of castor crop. The simulated forecast obtained from regression equation showed -32.11 to 12.98 per cent deviations from observed yields. Among the models fitted under this approach, in models of 17, 18 and 20 weeks crop period R^2 was low (76.20 to 83.60 %) and deviations of simulated forecasts was ranging from -56.26 % to 17.30 %. While in case of 19 and 21 weeks crop period, R^2 was high (around 94 %), minimum standard error of estimate and deviations of simulated forecasts ranged from -39.01 % to 14.79 %, but for early forecast (11 weeks before harvest) the 19 weeks of 22 years (model-II) was found suitable for forecasting castor yield under this approach.

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 17, 18, 19, 20, and 21 weeks crop period models revealed that variation

Table 1 Variables selected, coefficient of determination and range of forecast errors in week-wise approach

Variables selected		R^2 and simulated forecast errors (%)		
		1982-83 to 2002-03 (Model I)	1982-83 to 2003-04 (Model-II)	1982-83 to 2004-05 (Model-III)
(I) 17 weeks model X_{204}, X_{215}, X_{314}, X_{505}, X_{508} and X_{510}	R^2	76.20	76.90	76.90
	S.E.	232.20	225.49	218.35
	% deviation	-17.31 to 11.41	-16.53 to 12.48	-16.35 to 12.47
(II) 18 weeks model X_{314}, X_{417}, X_{505}, X_{510} and X_{610}	R^2	83.10	83.60	81.80
	S.E.	195.76	189.90	193.91
	% deviation	-38.87 to 13.10	-36.41 to 15.05	-33.66 to 17.30
(III) 19 weeks model X_{314}, X_{418}, X_{502}, X_{505}, X_{509}, X_{510} and X_{610}	R^2	93.40	93.50	93.40
	S.E.	132.07	128.26	124.60
	% deviation	-39.01 to 12.36	-37.35 to 13.72	-36.45 to 17.79
(IV) 20 weeks model X_{314}, X_{505}, X_{508}, X_{510}, X_{518}, X_{610} and X_{615}	R^2	82.40	82.70	80.30
	S.E.	215.72	209.43	215.34
	% deviation	-56.26 to 8.28	-53.22 to 10.89	-48.58 to 15.44
(V) 21 weeks model X_{314}, X_{418}, X_{502}, X_{505}, X_{509}, X_{510}, X_{517} and X_{610}	R^2	93.90	94.10	94.00
	S.E.	132.38	127.57	123.32
	% deviation	-32.11 to 11.19	-30.54 to 12.14	-29.62 to 12.98

explained by these set of equations ranged from 59 to 70 per cent, standard error ranged from 234 to 259 and the deviation between predicted and observed yields were large. Therefore, none of the models could be considered as suitable for pre-harvest forecasting of castor yield under this approach.

Correlation coefficient as weight approach

Using five 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 87.60 % to 94.60 % for all the three models. The deviation between observed yield and forecasted yield in per cent ranged from -20.39 % to 12.32 %. Among the equations fitted under this approach, in model of 20 and 21 weeks crop period, R^2 was low (around 88 %) and deviations of simulated forecasts was ranging from -20.39 % to 11.83 %. While, in case of 17 and 19 weeks models R^2 was around 90 % and deviations of simulated forecasts was ranging from -19.65 % to 9.28 %. But in case of 18 weeks model R^2 was reasonably high *i.e.* 94 % and the simulated forecast was -19.85 % to 12.32 %, but for early forecast (12 weeks before harvest) the 18 weeks of 21 years, model-I was found suitable for forecasting castor yield under this approach as compared to rest of the models. Varmora *et al.* (2004) reported forecasting models for predicting wheat yield based on generated weather variables using correlation coefficient as weight. The present findings are on similar line.

Among the different models fitted under three approaches, two models were identified as suitable pre-harvest forecast models for Banaskantha district, first from using week wise original weather variables of 19 weeks of 22 years (model-II) and the second also using generated variables (correlation

Table 2 Variables selected, coefficient of determination and range of forecast errors in week number as weight approach.

Variables selected		R^2 and simulated forecast errors (%)		
		1982-83 to 2002-03 (Model I)	1982-83 to 2003-04 (Model-II)	1982-83 to 2004-05 (Model-III)
(I) 17 weeks model Q_{132} and Q_{251}	R^2	63.10	64.30	59.00
	S.E.	255.07	248.83	259.90
	% deviation	-30.07 to 2.71	-29.44 to 3.22	-26.98 to 5.27
(II) 18 weeks model Q_{132} and Q_{251}	R^2	66.00	67.10	61.30
	S.E.	244.84	238.82	252.57
	% deviation	-42.66 to -3.95	-41.98 to -3.44	-38.07 to -0.51
(III) 19 weeks model Q_{122}, Q_{132} and Q_{251}	R^2	68.90	70.00	65.00
	S.E.	241.10	234.43	246.31
	% deviation	-23.63 to 11.72	-23.28 to 11.99	-17.88 to 17.06
(IV) 20 weeks model Q_{122}, Q_{132} and Q_{251}	R^2	67.60	68.70	63.90
	S.E.	253.50	246.19	257.10
	% deviation	-33.23 to 13.07	-32.35 to 13.55	-27.19 to 20.27
(V) 21 weeks model Q_{122}, Q_{131} and Q_{251}	R^2	67.60	68.80	65.90
	S.E.	246.11	239.17	243.41
	% deviation	-21.63 to 14.25	-21.69 to 14.20	-16.75 to 19.25

Table 3: Variables selected, coefficient of determination and range of forecast errors in week number as weight approach.

Variables selected		R^2 and simulated forecast errors (%)		
		1982-83 to 2002-03 (Model I)	1982-83 to 2003-04 (Model_II)	1982-83 to 2004-05 (Model_III)
(I) 17 weeks model T, Z'_{21}, Q'_{132}, Q'_{251}, Q'_{351} and Q'_{450}.	R^2	90.40	90.30	89.80
	S.E.	147.35	146.28	145.07
	% deviation	-19.65 to 7.89	-16.26 to 9.28	-19.04 to -1.36
(II) 18 weeks model T, Z'_{21}, Q'_{122}, Q'_{132}, Q'_{351}, Q'_{450} and Q'_{561}	R^2	94.60	94.30	93.50
	S.E.	115.03	116.03	119.70
	% deviation	-17.99 to 10.85	-17.85 to 12.32	-19.85 to -1.24
(III) 19 weeks model T, Z'_{21}, Q'_{122}, Q'_{132}, Q'_{351}, and Q'_{450}	R^2	90.90	91.10	90.70
	S.E.	143.62	139.71	138.67
	% deviation	-16.68 to 8.15	-15.20 to 9.18	-14.51 to 5.27
(IV) 20 weeks model T, Z'_{21}, Q'_{132}, Q'_{351}, and Q'_{450}	R^2	88.40	88.70	88.60
	S.E.	156.40	152.29	148.64
	% deviation	-20.34 to 10.81	-18.90 to 11.83	-20.22 to 10.86
(V) 21 weeks model T, Z'_{21}, Q'_{130}, Q'_{351}, and Q'_{450}	R^2	88.00	87.90	87.60
	S.E.	159.40	158.33	154.89
	% deviation	-20.39 to 6.57	-17.44 to 8.36	-19.65 to 7.25

coefficient as weight) of 18 weeks of 21 years (model-I). Among these two 18 weeks of 21 years (model-I), the model using generated weather variables (correlation coefficient as weight) could be preferred because of minimum standard error, high R^2 (>94 %) and less deviation of simulated forecast from actual yields. The detailed results of this model are given in Table 4 and 5. The positive and significant effect of time trend in castor yield was observed, indicating paramount importance of castor production technology. The beneficial effect of first order generated variable Z'_{21} (Linear weight of correlation coefficients to minimum temperature) and second order generated variables Q'_{450} (Zero weight of correlation coefficients to cross products of evening relative humidity and bright sunshine hours) and Q'_{561} (Linear weight of correlation coefficients to cross products of bright

Table 4 Regression coefficients of castor yield on time trend and different generated weather variables using correlation coefficients as weight approach (18 weeks)

Variables in the equation	Years		
	1982-83 to 2002-03 (Model-I)	1982-83 to 2003-04 (Model-II)	1982-83 to 2004-05 (Model-III)
Constant	-3054.75 (847.50)	-3206.18 (843.80)	-3180.36 (870.30)
Trend	40.26** (7.58)	39.31** (7.60)	38.39** (7.81)
Z'_{21} (Linear weight of correlation coefficients to minimum temperature)	114.33** (19.05)	118.53** (18.83)	113.91** (19.13)
Q'_{122} (Quadratic weight of correlation coefficient to cross products of maximum temperature and minimum temperature)	-2.42** (0.77)	-2.48** (0.78)	-2.37** (0.80)
Q'_{132} (Quadratic weight of correlation coefficient to cross products of maximum temperature and morning relative humidity)	0.21 (0.36)	0.23 (0.36)	0.38 (0.36)
Q'_{351} (Linear weight of correlation coefficients to cross products of morning relative humidity and bright sunshine hours)	-0.03 (0.01)	-0.03 (0.01)	-0.02 (0.01)
Q'_{450} (Zero weight of correlation coefficients to cross products of evening relative humidity and bright sunshine hours)	6.71** (1.35)	6.78** (1.36)	5.95** (1.27)
Q'_{561} (Linear weight of correlation coefficients to cross products of bright sunshine hours and rainfall)	0.70 (0.33)	0.73* (0.33)	0.73* (0.34)
S. E.	115.03	116.03	119.70
R^2 (%)	94.60**	94.30**	93.50**

Figures in parenthesis indicate standard error

* Significant at 5 % level of significance ** Significant at 1 % level of significance

sunshine hours and rainfall) on castor productivity were observed significantly. At least 12 weeks before actual harvest of the crop, reliable pre-harvest forecasting of castor yield in Banaskantha district can be made using generated weather variables, correlation coefficient as weight (18 weeks) approach by the following model:

$$Y = -3054.75 + 40.26^{**} T + 114.33^{**} Z'_{2r}{}^{1} - 2.42^{**} Q'_{12r}{}^{2} + 0.21 Q'_{13r}{}^{2} - 0.03 Q'_{35r}{}^{1} + 6.71^{**} Q'_{45r}{}^{0} + 0.70 Q'_{56r}{}^{1}$$

$(R^2 = 94.60\%)$

Table 5 Comparison between observed and predicted yield based on the fitted equations (correlation coefficients as weight approach) (18 weeks)

Year	Observed Yield (kg/ha)	Simulated forecasts (kg/ha) 1982-83 to 2002-03	1982-83 to 2003-04	1982-83 to 2004-05
2003-04	2084	2231 (-7.04)	-	-
2004-05	1712	1526 (10.85)	1501 (12.32)	-
2005-06	2132	2451 (-14.95)	2426(-13.77)	2433(-14.11)
2006-07	1552	1831 (-17.99)	1797(-15.77)	1855(-19.52)
2007-08	2225	2624 (-17.93)	2622(-17.85)	2667(-19.85)
2008-09	2159	2174 (-0.68)	2146 (0.58)	2186 (-1.24)

Figures in parenthesis are per cent deviations from observed yield.

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