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# A STUDY ON PRE-HARVEST FORECAST OF MAIZE YIELD USING STATISTICAL MODEL FOR HIMACHAL PRADESH

1. Maize (*Zea mays* L) is known as Queen of Cereals due to its diverse usages and highest genetic yield potential among the cereals. Agriculture contributes over 45 per cent to the net state domestic product. It is main source of income and employment in Himachal. Maize is the important crop of the state in kharif season. This crop is sown mostly under rain fed conditions and irrigation is done on only 5 per cent of its area. The production of maize which was 67.3 thousand tonnes in 1951-52 has gone up to 724.2 thousand tones in the year 2014-2015 (Anonymous, 2015). Kangra, Mandi, Sirmaur and Chamba districts are major producers of maize. In India, it is cultivated in most of the states throughout all the seasons. As the demand for maize is increasing due to its multiple uses, it should be kept in consideration that the spatio-temporal variations in projected changes in temperature and rainfall are likely to lead to differential impacts on maize yield in different regions in India (Kattarkandi, *et al*. (2010). Reliable and timely forecasts are essential for agriculture policy making and also for crop production, marketing, storage and transportation decision. This helps in managing risk associated with these activities (Tripathi *et al*., 2012). Based on crop weather studies, crop yield forecast models are prepared for estimating yield much before actual harvest of the crops. By use of empirical-statistical models using correlation and regression technique crops yield are forecasted on an operational basis for the country. Due to uncertainty and dependence on the monsoon onset and weather conditions, estimation of crop yield in India is difficult. The success or failure of agriculture crop production is mainly determined by weather parameters. Out of the total annual crop losses a substantial portion is because of aberrant weather. The loss could be minimized by making adjustment with coming weather through timely and accurate weather forecasting. The production of crop and prediction of crop yield have direct impact on year to year national and international economies and play an important role in the food management (Hayes and Decker, 1996). Yield forecasting utilizes crop and weather data over long period of time pertaining to locations under considerations. Analysis of data provides near real time information about the crop state in quality and quantity with the possibility of early warning, so that timely interventions can be planned and undertaken. Chowdhury and Das (1993) made a multiple regression model for forecasting the kharif food production of India. A number of statistical techniques such as multiple regression, principal component analysis and agro-meteorological models (Baweja, 2002; Bazgeer *et al*., 2008 and Ravi Kiran and Bains, 2007) have been used to quantify the response of crops to weather. Yield forecasting models

based on weather factors were constructed by Agrawal *et al*. (1986); Mallick *et al*. (2007); Rao *et al*. (2012) and Munu *et al*. (2013). Weather based models were developed to forecast the yield of maize one month prior to harvest at IASRI, New Delhi (Agrawal and Mehta, 2007). Ramawat *et al*. (2012) used CERES-Maize model for determining the genotypic coefficients of important varieties of maize with experimental data collected during two field experiments conducted in Palampur, Himachal Pradesh. Crop yield forecast were estimated twenty days before harvesting of maize crop using Info crop model by Vashisth *et al.* (2015) at IARI, New Delhi. The deviation of average actual yield from average pre-harvest crop yield was 5.5 per cent in maize. Ghosh *et al*. (2014) reported that the performance of the district level yield forecast model developed using composite weather indices in predicting yields at district level for various major crops in different states of the country is quite satisfactory. In Himachal Pradesh models capable of forecasting maize are yet to be tested. Keeping above facts in view, the present study was undertaken.

2. Total ten districts were selected for forecasting of maize yields. District wise crop yield data for the period of last 30 years (1985-2015) were collected from Directorate of Agriculture, government of Himachal Pradesh. Weather data were analyzed for each districts of similar period. The daily data on weather parameters such as Temperature (maximum and minimum), Relative humidity (morning and evening), amount of rainfall has been collected from Met. Centre, Shimla.

Yield forecast models of maize for different districts of state have been prepared using long term crop yield data as well as long period data of weekly values of weather variables from 22nd to 41st standard meteorological week for respective districts. Weekly average data on weather variables have been used for the study namely, $X_1$ - Maximum temperature (°C), $X_2$ - minimum temperature (°C), $X_3$ - Relative humidity Morning (%), $X_4$ - Relative humidity Evening (%), $X_5$ - Rainfall (mm). The forecast models were developed using the crop season data, *i.e*., mid season (F2) and has been used for our study. Out of 30 year data base, the 28 year data were used for the development of the model and rest two years data (2014 and 2015) were used for validation of the model. The observed yield after harvest was compared with the simulated yield.

*Yield forecast model*

The yield forecast models developed based on modified Hendricks and Scholl Model (Agrawal *et al*., 1986) using composite weather indices for generation of operational yield forecast. The model (Agrawal and Mehta, 2007) finally recommended was of the form

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

where,

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

Here, Y is the maize yield (tones/hec).

$r_{iw}$ is correlation coefficient of yield with *i*-th weather variable in *w*-th period.

*rii'w* is correlation coefficient (adjusted for trend effect) of yield with product of *i*-th and *i'*-th weather variables in *w*-th period.

*m* is period of forecast,

a, b and c are constants,

'*T*' is year number included to correct for the long term upward or downward trend in yield.

*p* is number of weather variables used = 5

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

For each weather variable, two variables were generated - one as simple accumulation of weather variable and the other one as weighted accumulation of weekly data on weather variable, weights being the correlation coefficients of weather variables, in respective weeks with yield. Similarly, for joint effect of weather variables, weekly interaction variables were generated using weekly products of weather variables taking two at a time Tripathi *et al*. (2012). Stepwise regression was used to select significant generated variables $Z_{ij}$ and $Z_{ii'j}$.

Similarly, indices were also generated for interaction of weather variables, using weekly products of weather variables taking two at a time. Combination of weather variables for weather indices, thus, generated are presented in Table 1. Weather variables used for this model are maximum temperature (Tmax), minimum temperature (Tmin), rainfall (Rf), morning relativehumidity (RH I) and evening relative humidity (RH II). Stepwise regression technique was used to select the important weather indices.

**TABLE 1**

**Weather indices used in models using composite weather variables**

| Weather variables | Simple weather variables | | | | | Weighted weather variables | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ |
| $T_{max}$ | Z10 | | | | | Z11 | | | | |
| $T_{min}$ | Z120 | Z20 | | | | Z121 | Z21 | | | |
| RF | Z130 | Z230 | Z30 | | | Z131 | Z231 | Z31 | | |
| $RH_I$ | Z140 | Z240 | Z340 | Z40 | | Z141 | Z241 | Z341 | Z41 | |
| $RH_{II}$ | Z150 | Z250 | Z350 | Z450 | Z50 | Z151 | Z251 | Z351 | Z451 | Z51 |

**TABLE 2**

**The maize yield forecast models for different districts of Himachal Pradesh developed for 2014**

| District | Equation | Weather elements | RMSE | $R^2$ | S. E. |
|---|---|---|---|---|---|
| Kangra | Y = 482.354 + 84.766*Z11 + 0.320*Z151 | Tx, Tx*RHII | 326.7 | 0.45 | 242.37 |
| Chamba | Y = 3767.643 + 0.613*Z141 - 2.771*Z50 + 21.090*Z51 | Tx*RHI, RHII | 479.3 | 0.48 | 346.11 |
| Bilaspur | Y = 39.033 + 16.860*Time + 67.116*Z11 + 0.168*Z251 + 0.057*Z351 | Time, Tx, Tn*RHII, RF*RHII | 351.9 | 0.69 | 220.33 |
| Sirmaur | Y = 3889.511 + 22.315*Time + 13.052*Z11 + 0.085*Z131 | Time, Tx, Tx*RF | 384.9 | 0.70 | 290.69 |
| Solan | Y = 2653.028 + 23.176*Time + 0.742*Z241 + 2.661*Z41 | Time, Tn*RHI, RHI | 272.1 | 0.60 | 230.24 |
| Shimla | Y = -2497.808 + 23.083*Time + 44.790 *Z21 + 0.078*Z451 | Time, Tn, RHI*RHII | 278.9 | 0.82 | 187.03 |
| Hamirpur | Y = 334.783 + 2.257*Z121 + 0.347*Z141 + 0.002*Z340 | Tx*Tn, Tx*RHI, RF*RHI | 284.0 | 0.71 | 168.25 |
| Una | Y = 3575.840 + 15.630*Time + 67.611 *Z11 + 0.054*Z131 | Time, Tx, Tx*RF | 210.9 | 0.70 | 165.33 |
| Mandi | Y = 5126.836 + 26.966*Time + 47.793 *Z11 - 0.031*Z130 + 0.479*Z251 | Time, Tx, Tx*RF, Tn*RHII | 329.4 | 0.69 | 196.79 |
| Kullu | Y = 279.157 + 31.085*Time + 2.990*Z121 - 0.546*Z151 + 0.088*Z240 + 0.249*Z451 | Time, Tx*Tn, Tx*RHII, Tn*RHI, RHI*RHII | 349.6 | 0.85 | 215.65 |

Model performance was evaluated by calculating the different statistical parameters, *viz*., Standard Error (SE), correlation coefficient and Root Mean Square Error (RMSE). The RMSE describe the mean absolute deviation between observed and simulated and accuracy of model is characterized by lower RMSE.

3. Weekly weather data from 22nd to 41st week were utilized to develop maize yield forecast models for Kangra, Chamba, Bilaspur, Sirmaur, Solan, Shimla, Hamirpur, Una and Mandi districts for obtaining highest $R^2$ and lowest model error. The general weather conditions prevailed during the Kharif period in different districts of the state observed maximum mean weekly temperature ranging between 25.4-34.1 °C in 2014 and 26.6-31.8 °C in 2015 in Kangra district, 22-34.1 °C in Chamba in 2014 and 24.6-31.9 °C in 2015, 29.7-42.0 °C and 29.4-36.2 in Bilaspur, 25.9-38.2 and 26.2-34.1 °C in Sirmaur, 26.3-35.1 and 26.2-34.1 °C in Solan, 22.0-30.4 and 21.0-26.2 °C in Shimla, 29.9-41.2 and 29.6-35.8 °C

**TABLE 3**

**The maize yield forecast models for different districts of Himachal Pradesh developed for 2015**

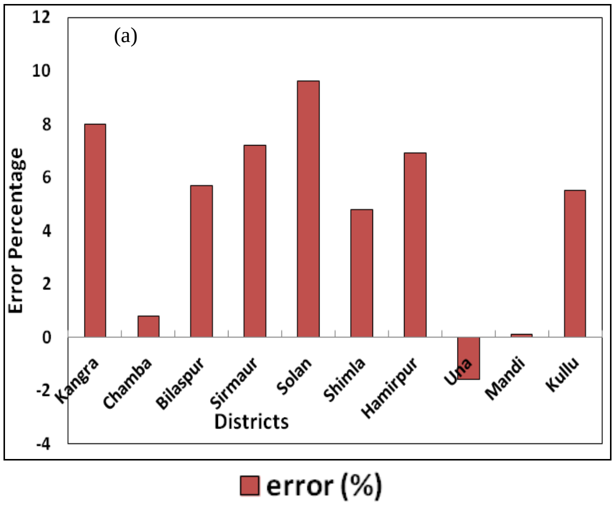
| District | Equation | Weather elements | RMSE | $R^2$ | S. E. |
|---|---|---|---|---|---|
| Kangra | Y = 737.8 + 48.08*Z11 + 0.320*Z151 | Tx, Tx*RHII | 196.8 | 0.43 | 167.38 |
| Chamba | Y = 3853.42 + 0.492*Z141 + 0.42*Z151 | Tx*RHI, Tx*RHII | 477.9 | 0.44 | 363.10 |
| Bilaspur | Y = 693.353 + 20.589*Time - 0.081*Z140 + 0.626*Z141 + 0.050*Z351 - 1.07*Z40 | Time, Tx*RHI, RF*RHII, RHI | 307.0 | 0.67 | 187.81 |
| Sirmaur | Y = 1308.49 + 50.21*Time + 1.837*Z241 - 0.103*Z250 + 3.987*Z31 | Time, Tn*RHI, Tn*RHII, RF | 339.5 | 0.82 | 191.30 |
| Solan | Y = 3966.06 + 16.383*Time + 0.264*Z151 + 0.105*Z231 + 8.26*Z41 | Time, Tx*RHII, Tn*RF, RHI | 294.8 | 0.69 | 205.41 |
| Shimla | Y = -1001.83 + 45.46*Time + 0.147 *Z231 + 0.426*Z241 | Time, Tn*RF, Tn*RHI | 89.6 | 0.89 | 149.20 |
| Hamirpur | Y = 2511.86 + 74.4*Z21 + 0.056*Z451 | Tn, RHI*RHII | 281.0 | 0.59 | 167.70 |
| Una | Y = 1992.73 + 27.28*Time + 15.50 *Z11 + 1.53*Z141 + 0.359*Z151 | Time, Tx, Tx*RHI, Tx*RHII | 214.5 | 0.90 | 98.89 |
| Mandi | Y = -1578.73 + 17.416*Time + 193.95*Z21 + 0.062*Z351 | Time, Tn, RF*RHII | 309.3 | 0.75 | 160.35 |
| Kullu | Y = -74.44 + 54.09*Time + 0.172*Z131 + 0.062*Z140 + 0.129*Z251 | Time, Tx*RF, Tx*RHI, Tn*RHII | 356.7 | 0.89 | 214.67 |

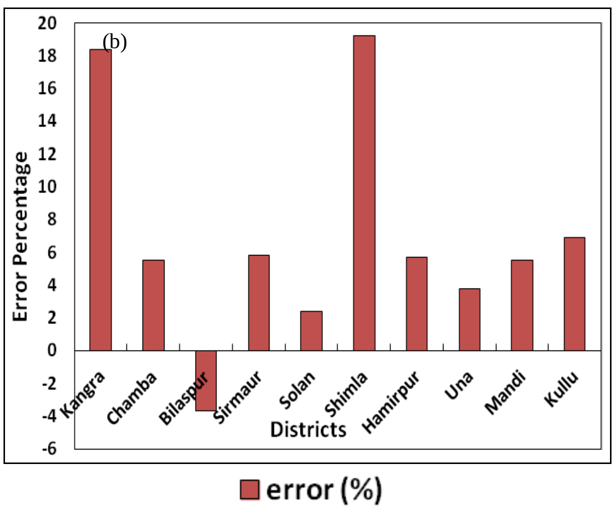
**TABLE 4**

**Observed and forecasted maize yield (kgha$^{-1}$) in 2014 and 2015 for various districts of Himachal Pradesh.**

| S. No. | Districts | 2014 | | 2015 | | % deviation (±) | |
|---|---|---|---|---|---|---|---|
| | | Observed yield | Forecasted yield | Observed yield | Forecasted yield | 2014 | 2015 |
| 1. | Kangra | 2072.4 | 1440.94 | 1678.7 | 1960.5 | 8.0 | 18.4 |
| 2. | Chamba | 3075.9 | 2976.92 | 2465.0 | 3224.8 | 0.8 | 5.5 |
| 3. | Bilaspur | 2217.7 | 1910.76 | 1924.6 | 2259.7 | 5.7 | -3.7 |
| 4. | Sirmaur | 3238.9 | 2895.29 | 2787.3 | 3397.2 | 7.2 | 5.8 |
| 5. | Solan | 2588.6 | 2607.53 | 2464.8 | 2476.2 | 9.6 | 2.4 |
| 6. | Shimla | 2873.5 | 1883.92 | 2100.8 | 2990.8 | 4.8 | 19.2 |
| 7. | Hamirpur | 1458.3 | 1779.17 | 1720.9 | 1491.6 | 6.9 | 5.7 |
| 8. | Una | 2391.0 | 2124.89 | 2097.6 | 1759.0 | -1.6 | 3.8 |
| 9. | Mandi | 2820.8 | 2512.54 | 2719.1 | 2879.6 | 0.1 | 5.5 |
| 10. | Kullu | 4142.7 | 3567.80 | 2870.7 | 3235.3 | 5.5 | 6.9 |

in Hamirpur, 30.7-43.6 and 39.1-31.6 °C in Una, 28.7-39.0 and 28.3-33.8 °C in Mandi and 26.4-35.9 and 27.8-33.3 °C in Kullu during respective seasons. Similarly, minimum mean temperature recorded in various districts ranged between 14.5-20.8 (2014) and 15.2-17.9 °C (2015) in Kangra, 11.1-18.1 and 10.6-19.0 °C in




**Figs. 1(a&b).** District-wise validation of forecast model for maize during (a) 2014 (b) 2015

Chamba, 18.0-23.0 and 16.7-23.2 °C in Bilaspur, 13.1-24.8 and 18.1-22.5 °C in Sirmaur, 11.1-20.0 and 11.9-22.0 °C in Solan, 13.1-20.1 and 12.7-17.0 °C in Shimla, 19.7-24.4 and 16.4-23.5 °C in Hamirpur, 31.6-39.1 and 13.3-20.9 °C in Una, 11.9-22.3 and 16.9-22.9 °C in Mandi and 10.9-21.5 and 11.0-21.0 °C in Kullu district during respective years. During 2014 it is observed that rainfall over the state as whole was deficit in all the monsoon months, *viz*., June (-47%), July (-31%), August (-42%) and September (-39%). However, district wise Districts Hamirpur (-9%), Kullu (-10%), Mandi (-3%), Sirmaur (33%), Solan (-4%) and Una (-9%) had received normal precipitations in the month of July, however in the month of August only three districts *viz*., Hamirpur (-4%), Mandi (1%) and Una (5%) received normal. Rest of the districts received deficit rainfall in the months during monsoon-2014. Improvement in the precipitation noticed during monsoon-2015. Eight districts (Bilaspur (-8%), Hamirpur (-13%), Kangra (3%), Kullu (22%), Mandi (-4%), Shimla (30%), Solan (6%) and Una (41%) in the month of July-2015 and six districts (Bilaspur (-9%), Hamirpur (-3%), Kangra (-8%), Mandi (-9%), Shimla (4%) and Una (48%) in the month August-2015 received normal or excess precipitation during monsoon-2015.

The regression equation developed between different weather parameters is shown in Tables 2 & 3. The final yield forecast function using important weather variables along with its $R^2$ value has been presented for 2014 and 2015. $R^2$ value which is measure of goodness of fit indicates the generated weather variables are able to explain up to 90% variation in the maize yield and remaining 10% variation being due to some unexplained factors not included in the present study. The value of the yield forecasted for different districts of the state for the year 2014 and 2015 are presented in the Table 4. The forecasted value was compared by observed value after the harvest. The percentage deviation of observed value by the simulated value ranged between -0.10 to 9.60 for the year 2014 all being within the acceptable limits while, the % deviation in yield for the year 2015 ranged between 2.4 to 19.2 and it was noticed that deviations are higher for Kangra and Shimla districts as compared to other districts where it was within acceptable level.

As per the observed yield, Kullu district shows highest productivity (4142.7 kg $ha^{-1}$) in 2014 and 2015 (2870.7 kg $ha^{-1}$) followed by Sirmaur (3238.0 kg $ha^{-1}$ and 2787.3 kg $ha^{-1}$) and lowest productivity was recorded in Hamirpur district (1458.3 and 1720.9 kg $ha^{-1}$) in the respective years (Table 4). Yield forecast models for the major maize producing districts have been developed and their performance has been validated against the observed yield. Prediction is best for Kullu and Shimla district with highest Correlation (cc = 0.82) and (cc = 0.85) for respective districts in 2014. During 2015 was best for Una (cc = 0.90) and Shimla (cc = 0.89) districts with comparatively less RMSE value for Una (214.5 kg $ha^{-1}$) and Shimla (89.6 kg $ha^{-1}$) in 2015 (Tables 2&3). Maize yield forecasts along with observed yield in 2014 and 2015 for various districts of Himachal Pradesh are presented in Table 4. The results of validation of forecasts for these years presented graphically in Figs. 1(a&b) show that during 2014 per cent deviation between the observed and the predicted yield is minimum for Mandi and Chamba districts being almost close to the observed value. On the other hand in 2015 minimum deviation was calculated for Solan followed by Bilaspur and slightly higher than the acceptable limit for Kangra and Shimla districts and may be due to high fluctuations in annual crop yield. The predicted maize yields for most of the districts are within acceptable error limit (±10%) in both the years of validation; however, % deviation was higher only for a few districts.

4. A statistical model using composite weather indices has been used for developing the district level yield forecast models and their performance is studied. The data on the weekly weather variables starting from 22nd (1st week of June) to 41st week (3rd week of October) have been utilized to forecast the maize yield. Thus, 20 weeks data of weather variables have been used for development of models. Similarly crop yield data from 1985 to 2015 have been used for validation of model. According to $R^2$ value the performance of the model in predicting yields at district level for maize crop is best for Una, Kullu and Shimla districts and quite satisfactory for other districts also. The model is simple and can be used for district, agro climatic zone and state level forecast.

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**Reference**

Agrawal, R., Jain, R. C. and Jha, M. P., 1986, "Models for studying rice crop-weather relationship", *Mausam*, **37**, 1, 67-70.

Agrawal, R. and Mehta, S. C., 2007, "Weather based forecasting of crop yields, pests and diseases - IASRI Model", *J. Ind. Soc. Agril. Statist.*, **6**, 2, 255-263.

Anonymous, 2015, "Progress-department of Agriculture: Himachal Pradesh", http:// hpagriculture.com/achievements.htm.

Baweja, P. K., 2002, "Predicting grain yield in maize: canopy temperature based regression indices", *J. Agrometeorology*, **4**, 2, 177-179.

Bazgeer, S., Kamali, G. A., Eslamian, S. S., Sedaghakerdar, A. and Moradi, I., 2008, "Pre-harvest wheat yield prediction using agrometeorological indices for different regions of Kordestan Province", *Iran. Res. J. Env. Sci*., **2**, 4, 275-280.

Chowdhary, A. and Das, H. P., 1993, "Southwest monsoon rains and kharif production", *Mausam*, **44**, 4, 381-394.

Ghosh, K., Balasubramanian, R., Bandopadhyay, S., Chattopadhyay, N., Singh K. K. and Rathore, L. S., 2014, "Development of crop yield forecast models under FASAL - A case sudy of kharif rice in West Bengal", *J. Agrometeorology*, **16**, 1, 1-8.

Hayes, M. J. and Decker, W. L., 1996, "Using NOAA AVHRR data to estimate maize production in the United States Corn Belt", *Int. J. Remote Sens*., **17**, 3189-3200.

Kattarkandi, B., Soora, N. K. and Aggarwal, P. K., 2010, "Simulating impacts, potential adaptation and vulnerability of maize to climate change in India", *Mitigation and Adaptation Strategies for Global Change*, **15**, 413-431.

Mallick, K., Mukherjee, J., Bal, S. K., Bhalla, S. S. and Hundal, S. S., 2007, "Real time rice yield forecasting over Central Punjab region using crop weather regression model", *J. Agrometeorology*, **9**, 2, 158-166.

Munu, D., Hussain, R., Sarma, A., sarmah, K. and Deka, R. L., 2013, "Yield prediction of winter rice employing meteorological variables in central and upper Brahmaputra valley zone of Assam", *J. Agrometeorology*, **15**, 1, 162-166.

Ramawat, N., Sharma, H. L. and Kumar, R., 2012, "Simulation, validation and application of CERES-Maize Model for yield maximization of maize in North Western Himalayas", *Appl. Eco. Env. Res*., **10**, 3, 303-318.

Rao, V. U. M., Nair, Linitha, Rao, B. B. and Kumar, P. V., 2012, "Climatic sensitivity of mustard crop in Northern India: An assessment of yields in future climates from real time data, "*J. Agrometeorology*, **14** (Special Issue), 10-18.

Ravi, K. and Bains, G. S., 2007, "Thermal time requirement and heat use efficiency in summer green gram", *J. Agrometeorology*, **9**, 1, 96-99.

Tripathi, M. K., Mehra, B., Chattopadhyay, N. and Singh, K. K., 2012, "Yield prediction of sugarcane and paddy for districts of Uttar Pradesh", *J. Agrometeorology*, **14**, 2, 173-175.

Vashisth, A., Choudary, M., Joshi, D. K. and Baloda, R., 2015, "Preharvest yield forecast in maize-mustard cropping system under semi arid region using crop simulation model", *Int. J. Trop. Agri*., **33**, 2, 1059-1067.

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