Bangladesh J. Bot. **54**(3): 587-592, 2025 (September) DOI: https://doi.org/10.3329/bjb.v54i3.84425

# WEATHER BASED WHEAT YIELD PREDICTION MODEL FOR THE STATE OF HIMACHAL PRADESH, INDIA

**SANGITA SHARMA***

*Regional Horticultural Research and Training Station, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, Mashobra, Shimla-171007(HP)*

*Keywords:* Forecasting, Yield, Climatic variables, Wheat, Percent error, Statistical model

**Abstract**

Yield forecast models of wheat for different districts of state have been prepared using long term crop yield data as well as weather data from 48$^{th}$ week to 11$^{th}$ standard meteorological week for respective districts. The data from the period of 1990-2020 has been used in developing the forecast model and the remaining two years data from 2021-2022 has been used for the validation of the models. Model performance was evaluated by calculating the different statistical parameters *viz.* Standard Error (SE), Correlation Coefficient and Root Mean Square Error (RMSE). According to $R^2$ value, the performance of the model in predicting yields at district level was quite satisfactory for all the districts. The percentage deviation between the observed and simulated yield ranged between acceptable limit i.e. ±10%. The model is simple and can be used for predicting the wheat yield at district, agro climatic zone and state level.

## Introduction

Wheat is the predominant rabi season crop of Himachal Pradesh. It is cultivated mostly in sub-tropical and low hills such as Una, Hamirpur, Bilaspur, Kangra, Chamba, Sirmaur and Solan districts. The state experiences inadequate and erratically distributed rainfall during critical stages of wheat growth resulting in poor germination and seedling growth of the crop. Climatic parameters and attack of insect-pests are the variables which define the agricultural productivity of any region (Nayak *et al.* 2023). Therefore, the direct effects of the climatic factors and pests on crop growth and development have always been a subject of detailed investigation. Weather variables affect the crop differently during different stages of growth period. Proper forecast of important commercial crops is necessary for future planning and policy making. 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.

The objective of the yield forecast is to give a precise, scientific, sound and independent forecasts of crops' yield as early as possible during the crops' growing season by considering the effect of the weather and climate. The CERES-Wheat simulation model was used by Nain *et al.* (2004) to forecast the wheat yield for 16 major wheat growing districts of Uttar Pradesh at pre harvest stage. By coupling technology trend with weather variables, models were developed by Mallick *et al*. (2007). Previously a number of statistical techniques such as multiple regression, principal component analysis and agro-meteorological models (Ravi Kiran and Bains 2007, Bazgeer *et al*. 2008, Munu *et al*. 2013) have been used to quantify the response of crops to weather. 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 was quite satisfactory. Efforts in the past has been made in Himachal Pradesh by several researchers to develop statistical models based on time series data on crop-yield and weather variables for the pre-harvest crop yield forecast (Sharma *et al.* 2017, Singh and Sharma 2017, Verma *et al.* 2017).

*Author for correspondence: <sangitasharmaento@gmail.com>.

Since productivity forecast could help in estimating the production and making decisions regarding export and import policies, distribution and price structure and for exercising measures for storage and marketing. The present study was undertaken to develop suitable pre-harvest forecasting model based on weather variables using past weather and yield records of different districts of Himachal Pradesh.

## Materials and Methods

Total ten districts were selected for forecasting of wheat yields. The yield figures of wheat for the period of last 30 years (1990-2020) collected from Directorate of Agriculture, Government of Himachal Pradesh has been used for the present study. The daily data on weather parameters such as Temperature (maximum and minimum), Relative humidity (morning and evening) and amount of rainfall for last 30 years have been collected from Met Centre, Shimla.

Yield forecast models of wheat 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 48$^{th}$ to 11$^{th}$ standard meteorological week for respective districts. Weekly average data on weather variables have been used for the study namely, $X_1$-Maximum temperature ($^oC$), $X_2$-minimum temperature ($^oC$), $X_3$-Relative humidity (Morning) (%), $X_4$- Relative humidity(evening)(%), $X_5$- Rainfall (mm). The data from the period of 1990-2020 have been used in developing the forecast model and the remaining two years data from 2021-2022 have been used for the validation of the models. The statistical model was validated at pre harvest stage (F3) corresponding to 15$^{th}$ April.

The yield forecast models developed based on modified Hendricks and Scholl Model 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,

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

Here Y is the wheat yield (tones/hec)

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

$r_{ii'w}$ 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. 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 (Tripathi *et al.* 2012). Combination of weather variables for weather indices, thus, generated are presented in Table 1. Weather variables used for this model are maximum temperature ($T_{max}$), minimum temperature ($T_{min}$), rainfall (RF), morning relative humidity ($RH_I$) and evening relative humidity ($RH_{II}$). 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 (Varshneya *et al.* 2010).

**Table 1. Weather indices used in models using composite weather variables.**

| Weather variables | Simple weather variables | | | | | Weighted weather variables | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | X1 | X2 | X3 | X4 | X5 | X1 | X2 | X3 | X4 | X5 |
| $T_{max}$ | 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 |

## Results and Discussion

The crop yield was simulated at pre harvest stage using statistical model. The regression equations developed between different weather parameters shown in Table 2 indicated that the maximum temperature was the most important parameters common in all the models for wheat crop in most of the 10 districts under study of Himachal Pradesh and agrees with the findings of Singh *et al*. (2022). The final yield forecast function using important weather variables along with its $R^2$ value has been presented for 2021-2022 (Table 2). $R^2$ value which is measure of goodness of fit indicated that the generated weather variables explained 54 to 94% variation in the wheat yield in different districts which were in conformity with the results observed by Singh *et al.* (2014) and Vashisth *et al.* (2014). The simulated value was compared by observed value after the harvest. The percentage deviation of observed value by the simulated value ranged between -0.3 to -9.5 (Fig. 1) and it was noticed that deviation was lowest for Mandi district it means that model was best for the Mandi district and yield forecasted was almost close to the observed yield followed by Kangra and Solan districts as compared to other districts where it was within acceptable level. As model is purely weather based, excess/low rainfall along with more dry weeks situation could be the reason for yield variation, as similar findings was also observed by Neeraj *et al.* (2016) and Giri *et al.* (2017).

As per the average of recent ten years, Sirmaur district showed highest productivity (1969.1 kg/ha) followed by Bilaspur (1930.0 kg/ha).Yield forecast models for the major wheat producing districts had been developed and their performance had been validated against the observed yield for 2021-2022. Prediction was best for the Solan district with highest Correlation (cc= 0.94) and comparatively less RMSE value (94.5 kg/ha) followed by Shimla, Kangra and Bilaspur districts with values 0.92, 0.85 and 0.82, respectively. Wheat yield forecast for Solan district showed their dependency on number of variables viz., $T_{max}$ ($Z_{11}$), weighted product of $T_{max}$ and $RH_I$ ($Z_{241}$), $RH_I$ ($Z_{40}$) and $RH_{II}$ ($Z_{50}$) and also affected by time trend. The Sirmaur model forecasted the highest maize yield (2414.1 kg/ha) followed by Solan model (2173.6 kg/ha) while Mandi model forecasted lowest wheat yield for (1362.7 kg/ha)

(Table 2). The predicted wheat yields for most of the districts were within acceptable error limit (±10%) for all the districts. Verma *et al.* (2017) predicted the wheat yield using simulated and statistical model at district scale in Himachal Pradesh. The yield was found to be more reliable in pre-harvest stage for Kangra district.

**Table 2. Pre-harvest wheat yield forecast models for different districts of Himachal Pradesh.**

| District | Equation | Weather Elements | Predicted yield (Kg/ha) | Average yield (Last 10 yrs) (Kg/ha) | RMSE | $R^2$ | S.E | Error (%) 2021-22 |
|---|---|---|---|---|---|---|---|---|
| Bilaspur | Y=1928.59+0.187* Z131+7.69*Z41+5.77*Z51 | Tx*RF, $RH_I$, $RH_{II}$ | 1820.9 | 1930.0 | 339.9 | 0.82 | 177.9 | -9.4 |
| Chamba | Y=2801.14+0.094*Z141 | Tx*$RH_I$ | 1887.0 | 1771.2 | 315.6 | 0.63 | 222.9 | -4.6 |
| Hamirpur | Y=1347.66+0.075*Z341 | RF*$RH_I$ | 1512.7 | 1517.3 | 235.4 | 0.69 | 181.2 | -9.5 |
| Kangra | Y=856.720.030*Z140+0.069* Z341+2.526*Z51 | Tx*$RH_I$,RF*RHI, $RH_{II}$ | 1761.8 | 1647.8 | 225.0 | 0.85 | 98.9 | 2.1 |
| Kullu | Y=2075.43-3.94* Time+2.91*Z121 | Time, Tx*Tn | 1505.7 | 1646.1 | 177.6 | 0.54 | 150.1 | 9.3 |
| Mandi | Y=1218.42+0.246* Z151+59.76*Z21 | Tx*RHII, Tn | 1362.7 | 1500.6 | 249.6 | 0.66 | 164.7 | -0.3 |
| Shimla | Y=476.14+18.97* Time+1.045*Z231 +4.38*Z51 | Time, Tn*RF, $RH_{II}$ | 2002.5 | 1620.7 | 223.0 | 0.92 | 97.9 | 4.5 |
| Sirmaur | Y=2851.64+0.148* Z141+0.593*Z151 | Tx*$RH_I$, Tx*$RH_{II}$ | 2414.1 | 1969.1 | 326.9 | 0.71 | 262.7 | 7.5 |
| Solan | Y=679.02+34.34*Time+0.795* Z141+0.555*Z40+3.159*Z51 | Time, Tx*$_{RHI,}$ $RH_I$, $RH_{II}$ | 2173.6 | 1900.1 | 208.6 | 0.94 | 94.5 | -3.8 |
| Una | Y=1651.16+264.37* Z21+0.037*Z240 | Tn, Tn*$RH_I$ | 1583.0 | 1832.0 | 283.9 | 0.65 | 204.1 | 8.0 |

$$\% \text{ deviation} = \frac{(\text{Predicated Yield} - \text{Observed Yield})}{\text{Observed Yield}} \times 100$$

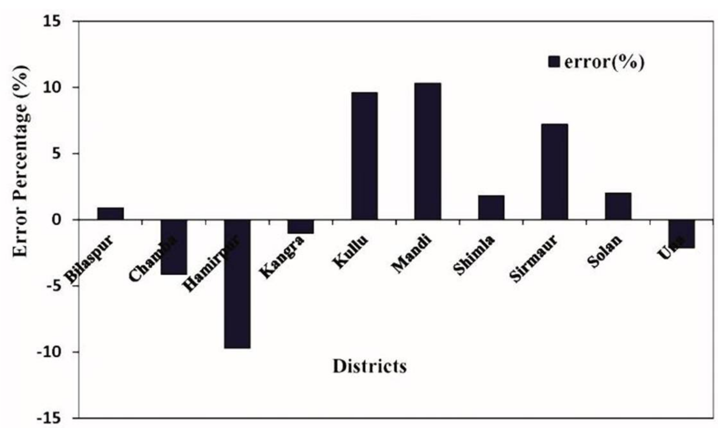


Fig. 1. District-wise validation of forecast model for wheat during 2021-22.

The combined effect of weather variables played crucial role in wheat yield determination. According to $R^2$ value the performance of the model in predicting yields at district level for wheat crop was best for Solan district and quite satisfactory for other districts also. The maximum and minimum temperatures in combination with relative humidity have formed most important agro meteorological indices, which can be useful in forecasting of yield of wheat crop in the region. The percentage deviation between the observed and simulated yield ranged between acceptable limit i.e. ±10% for all the districts. The validation results showed excellent prediction for all the ten districts of Himachal. Hence combination of weather and yield data is appropriate and consistent option for yield forecasting.

**Acknowledgements**

The paper is based on the findings of research project on “Forecasting Agricultural Output using Space, Agrometeorology and Land based observations (FASAL)” funded by IMD, Pune. The author is thankful to Director General of meteorology for encouraging for paper writing. She is equally grateful to State Agriculture Department for providing crop yield data.

## References

Agrawal R and Mehta SC 2007. Weather based forecasting of crop yields, pests and diseases-IASRI Model. J. Ind. Soc. Agril. Statist. **61**: 255-263.

Bazgeer S, Kamali GA, Eslamian SS, 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**: 275-280.

Ghosh K, Balasubramanian R, Bandopadhyay S, Chattopadhyay N, Singh KK and Rathore L 2014. Development of crop yield forecast models under FASAL- a case study of kharif rice in West Bengal. J. Agromet. **16**: 1-8.

Giri AK, Bhan M and Agrawal K K 2017. District wise wheat and rice yield predictions using meteorological variables in eastern Madhya Pradesh. J. Agromet. 19**(**4):366-368.

Mallick K, Mukherjee J, Bal SK, Bhalla SS and Hundal SS 2007.Real time rice yield forecasting over Central Punjab region using crop weather regression model. J. Agromet. **9**:158-166.

Munu D, Hussain R, Sarma A, Sarmah K and Deka RL 2013.Yield prediction of winter rice employing meteorological variables in central and upper Brahmaputra valley zone of Assam. J. Agromet. **15**:162-166.

Nayak RK, Sharma S and Singh J 2023. Major Insects Pests of cereals crops in India and their management. *In:* Pest Management Strategies in Pulses and Cereal Crops. Kumar A Hasan W Verma B and Singh CP (Eds), pp. 205-216. Kripa Drishti Publications, Pune, Maharashtra, India.

Nain AS, Dadhwal VK and Singh TP 2004. Use of CERES-Wheat model for wheat yield forecast in central Indo-Gangetic Plains of India. J. Agri. Sci. **142**: 59-70.

Neeraj K, Pisal RR, Shukla SP and Pandey K 2016. Crop yield forecasting of paddy and sugarcane through modified Kendrick and Scholl technique for South Gujarat. Mausam **67**: 405-410.

Ravi K and Bains GS 2007. Thermal time requirement and heat use efficiency in summer green gram. J. Agromet. **9**: 96-99.

Sharma S Singh M and Bhan SC 2017. A study on pre-harvest forecast of maize yield using statistical model for Himachal Pradesh. Mausam **68**: 369-374.

Singh A, Nagar V, Tanwar N, Shahi UP and Bhan SC 2022. Use of statistical models in yield forecasting of wheat, mustard and potato crop in western districts of Uttar Pradesh, India. Int. J. Env. Climate Change **12**: 66-72.

Singh M and Sharma S 2017. Forecasting of maize yield at pre-harvest stage using climatic variables. J. Agromet. **19**: 167-169.

Singh RS, Patel CB, Yadav MK and Singh KK 2014. Yield forecasting of rice and wheat crops for eastern Uttar Pradesh. J. Agromet. **16**:199-202.

Tripathi MK, Mehra B, Chattopadhyay N and Singh KK 2012. Yield prediction of sugarcane and paddy for districts of Uttar Pradesh. J. Agromet. **14**:173-175.

Varshneya MC, Chinchorkar SS, Vaidya VB and Pandey V 2010. Forecasting model for seasonal rainfall for different regions of Gujarat. J. Agromet. **12**: 202-207.

Vashisth A, Singh R, Choudary M 2014.Crop yield forecast at different growth stage of wheat crop using statistical model under semi arid region. J. Agroeco. Nat. Res. Manag. **1**: 1-3.

Verma K, Rana RS, Thakur S and Salaria S 2017. Comparison of simulated and statistical model prediction of wheat at district scale yield under sub-temperate climate of North Western Himalayas. Int. J. Pure and Appl. Biosci. **5**: 1035-1050.

*(Manuscript received on 17 March, 2024; revised on 17 September, 2025)*