Indian Journal of Ecology (2024) 51(1): 187-190
DOI: https://doi.org/10.55362/IJE/2024/4214

Manuscript Number: 4214
NAAS Rating: 5.38

Yield Prediction in Maize (*Zea Mays*) using Weather Parameters under Subtropical and Intermediate Regions of North-Western Himalayas

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Abstract: For prediction of maize yield in the north western Himalayas two districts Jammu and Udhampur belonging to different agro climatic conditions i.e. subtropical and intermediate regions were selected. For running yield prediction model at F2 stage (Flowering) and F3 stage (Pre harvest) of maize crop long term weekly climatic data of Jammu and Udhampur districts from 1997 to 2021 (24 years) was collected from different departments related to Agriculture and Meteorology. For validation yield prediction model field experiments on maize crop were conducted during kharif season 2020 and 2021 at SKUAST-J main campus Chatha. Pre harvest yield prediction model for maize crop has been prepared by using this data. For prediction of maize yield at F2 and F3 stage the long-term data from 26th to 36th and 26th to 40th standard meteorological week (SMW) from 1997 to 2021 was used. Further composite weather variables were studied for developing yield forecast model. Simple and weighted weather indices have been prepared for individual weather variable and for their interaction with time. The yield forecast model were able to explain the variation in the grain yield of maize crop in subtropical Jammu region which was to the tune of 2.57 and -14.70 at F2 Stage and -3.00 and 9.70 during F3 stage where as in intermediate Udhampur district variation in F2 was 9.15 and 2.15 whereas during F3 stage -1.37 and 0.20 percent during *kharif* 2020 and *kharif* 2021.The predicted yield of maize crop for most of the stages are within acceptable error limit (+10 percent) in both the years of validation.

Keywords: Agro climatic, Maize, Forecast, Model, Prediction, Weather, Yield

Yield forecasting within the growing season would facilitate proper planning and more proficient management of grain production, handling and marketing of yield. The pre harvest yield prediction is also required for policy decisions like storage, pricing, marketing, import, export etc of grains. Weather is the main component that influence yield of crop. Crop models based on weather can provide trustworthy forecast of crop yield in advance of harvest and also forewarning of pests and diseases attack of pests and diseases attack so, that suitable plant protection measures could be taken up timely to protect the crops. Forecasting Agricultural Output using Space, Agrometeorology and Land based observations (FASAL) is an important project operational at Ministry of Agriculture cooperation and Farmer's Welfare, New Delhi through India Meteorology Department. The mandate of this project is to subject multiple crop yield forecast for various major crops under different agro climatic zones of the states at initial stage (F1), mid-season (F2) and pre-harvest (F3) stages.

Maize is the staple food and plays vital role in food security. In India, Maize is grown on 9.89-million-hectare area with production and productivity of 31.65 million tonnes and 3199 kg/ha (Anonymous 2021). In Jammu division maize is grown on 207.05-thousand-hectare area with average production of 42.40 lakh quintals and productivity of 2048 kg/ha (Anonymous 2022). In Subtropical conditions of Jammu district maize is grown in *kharif* season which contribute 6.32 percent in total area and 6.03 percent in total production of maize in Jammu division whereas intermediate region, Udhampur district contribute 15.11 percent in total area and 15.80 percent in total maize production in the Jammu division. Therefore, forecasting of maize yield is important for economic planning by policy makers in the government. For that reason the study has been undertaken to develop the model for maize yield by analysing the weather variables using weather and yield records of Jammu and Udhampur districts of Jammu region.

MATERIAL AND METHODS

Long term climate data was collected from Department of Finance revenue, Government of Jammu and Kashmir UT and weather data collected from Indian Meteorological Department of Jammu and Udhampur District from 1997-2021.Geographically Jammu is located at latitude of 32^{0}.73'N

and longitude of 74^0.52'E with altitude of 308 meters above mean sea level where as Udhampur is located in intermediate region at latitude of 32^0.55'N and longitude of 75^0.09'E with elevation of 742 meters above mean sea level. The daily weather data was used for calculating weekly as well as monthly data in which the growth period of maize crop lies except the harvesting period were used to develop the district level yield forecast model. The standard meteorological week SMW wise weather data from 26th - 36th were used to develop weather-based yield prediction regression models for F_2Pre flowering stage and 26th to 40th for Pre harvesting stage of maize crop for above said two selected districts. The variable simple weather indices such as maximum temperature Tmax., minimum temperature Tmini. rainfall RF, relative humidity morning RH1 and relative humidity evening RH2 were used in the study. Different weather indices were generated using weekly values of weather parameters during the maize growing period and their weighted values using correlation (Table 1). To study the combined effects of weather variables on maize yield, the model used for studying effect of individual weather variables had also been extended by including interaction terms as per IASRI, New Delhi suggested by Hendricks and Scholl (1943) further modified by Agrawal et al (1980) for expressing effects of changes in weather variables on yield of maize in the crop growing period as a second degree polynomial in respective correlation coefficient between yield and weather variables . The modified statistical model given by Agrawal et al (1980) used in present study for district wise yield predictions equations for maize crop is as under:

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

Where

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

Where,

Y = Variable to forecast or seed yield of Maize

$X_{iw}/X_{ii'w}$= w is the value of i^{th} / i^{th} weather variable under study in the w^{th} week

r_{iw}/r_{iiw}= is correlation coefficient of yield with i^{th} weather variable/product of i^{th} and i^{th} weather variables in w^{th} week , respectively, m is the week of forecast, p is the number of weather variables used and c is the random error distribution as N $(0,\sigma^2)$

In this model, two weather indices (simple - Zi0 and weighted - Zi1) accumulation of weekly weather variable, weights being correlation coefficients of weather variables in respective weeks with yield. Similarly, indices were also generated for interaction of weather variables, using weekly products of weather variables taking two at a time. Simple and weighted weather variables thus generated are presented in Table 1. Regression analysis was used for fitting equation taking year and weather as independent variable and yield as dependent variable using the SPSS software. Weather scores for each year at different phases of crop growth of maize crop in Jammu and Udhampur district obtained through these discriminant functions were used along with inputs and time trend as regressors in model development through stepwise regression. The weighting coefficients in these equations are achieved in an empirical manner using standard statistical procedures, such as multivariable regression analysis. For the validation of the above said prediction model, field experiments were conducted at SKUAST-J, Chatha, Jammu during *kharif* 2020 and 2021. The experiments were conducted in randomized block design with three replications consisting of three sowing environments and three varieties of Maize grown popularly in the region.

RESULTS AND DISCUSSION

Forecast: The weather based statistical model for forecast of maize crop at two stages (F_2 and F_3) were developed by using 24 years of data sets and validated for two years 2020 and 2021. The seed yield prediction model for maize crop for subtropical Jammu district and intermediate Udhampur districts was validated for two years 2020 and 2021. In the prediction model, coefficient of determination was significant in Jammu and Udhampur districts. The R^2 value at F_2 and F_3 (Pre harvesting) stage in Jammu district ranged between 0.55 to 0.79 whereas for Udhampur district ranged between 0.71 to 0.91.

Weather indices: The best agro meteorological indices to incorporate in the agro meteorological yield forecast model at F_2 and F_3 stage in maize crop was Tmax (Z11), T min (Z21), Tmax X Tmin (Z121), Tmin XRF (Z230),RF X RH II (Z350). In Udhampur district, the best agro meteorological indices at F_2 (pre flowering stage) and F_3 (pre harvesting stage) were Tmax (Z11), RH II(Z51), Tmax X Tmin (Z121), Tmax X RH II (Z141), RFXRH I(Z 341) and RF XRH II(Z351).Similar, results were also reported by Patel et al (2018). The validation of results of statistical model during *kharif* 2020 and results reported that the percent deviation in maize yield at F_2 stage was 2.57 percent and 9.15percent in Jammu and Udhampur district whereas at F_3 stage the percent deviation in maize yield in Jammu and Udhampur district were -3.00

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

Weather parameters	Simple weather indices					Weighted weather indices				
	Tmax	Tmin	RF	RHI	RHII	Tmax	Tmin	RF	RHI	RHII
Tmax	Z10					Z11				
Tmin	Z120	Z20				Z121	Z21			
RF	Z130	Z230	Z30			Z131	Z231	Z31		
RHI	Z140	Z240	Z340	Z40		Z141	Z241	Z341	Z41	
RHII	Z150	Z250	Z350	Z450	Z50	Z151	Z251	Z351	Z451	Z51

Table 2. Yield prediction model at F_2 and F_3 stage of maize crop for Jammu and Udhampur districts

District	Year	Stage	Equation	R^2
Jammu	2020	F_2	Y = 8.137+0.0001*Z351+0.014*Z121	0.67
	2020	F_3	Y = -1.175+0.544*Z11+0.0001*Z230	0.79
	2021	F_2	Y= -26.63+5.07*Z21	0.55
	2021	F_3	Y = - 4.28+1.286*Z11+0.262	0.69
Udhampur	2020	F_2	Y = 25.86+0.009*Z121+0.0001*Z341	0.74
	2020	F_3	Y = -0.138+0.728*Z11	0.71
	2021	F_2	Y = -5.46+0.223*Z51+0.829*Z11+0.014*Z141	0.91
	2021	F_3	Y = 0.069 + 0.168*Z51+0.0003*Z351	0.82

Table 3. Yield prediction model at F_2 and F_3 stages of maize crop for different districts of Jammu region

Seed yield (q/ha)	Year	Jammu	Udhampur
Observed	2020	18.57	20.05
	2021	15.98	20.39
Forecasted yield at F2 stage	2020	19.06 (2.57)	22.07 (9.15)
	2021	18.25 (-14.21)	19.96 (2.11)
Forecasted yield at F3 stage	2020	18.04 (-3.00)	19.78 (-1.37)
	2021	14.43 (9.70)	20.35 (0.20)

Parenthesis are variation /error (±) in the seed yield (Percentage)

percentand-1.37 percent). In 2021 the percent deviation in maize yield in Jammu district at F_2 and F_3 stage were -14.21 percent and 9.70 percent. Similarly, for Udhampur district the percent deviations at F2 and F3 stage were 2.11 and 0.20 percent in 2021 it might be due to deviation in weather parameters during maize growing period. Similar findings were also reported by Chandrahas et al (2010). The results indicate that this model had predicted seed yield of maize crop within acceptable error/ variation limit ±10 percent in both the year of validation study for Jammu and Udhampur districts except at F_2 stage in 2021 for Jammu district where error limit is more than ±10 percent. Predicted yield was very closer to observed yield, therefore it suggested that these prediction models can be used for yield forecasting and planning purpose in the region. The results showed that agro meteorological yield model explained the yield variability due to variations in minimum and maximum temperatures together with relative humidity with respect to major maize growing districts of Jammu Province. Temperatures and rainfall are very important weather parameters influencing maize yield (Maitah et al 2021).Comparatively variable trend in maximum, minimum temperature, relative humidity and rainfall was recorded in weather parameters during F_2 and F_3 forecast of maize crop in Udhampur district during *kharif* 2020 and 2021.The maximum temperature recorded during F_2 stage from 26th - 36th SMW during *kharif* 2020 and 2021 was 31.1^{0}C and 31.5 ^{0}C which was well near average normal Tmax 31.0 ^{0}C recorded during 26th-36th SMW and the extent of variation was only 0.1^{0}C and 0.5^{0}C from the normal values . Further at F3 Stage 26th-40th SMW there was increase in maximum temperature to the tune of 0.6^{0}C and 0.4^{0}C from the average normal maximum temperature 30.6^{0}C recorded in maize crop during particular period. The average normal minimum temperature in maize crop during F2 stage was 21.8 ^{0}C and F3 stage was 21.0 ^{0}C. During *kharif* 2020 the extent in variation from the normal minimum temperature values at F_2 and F_3 was +1.2^{0}C and +1.3^{0}C whereas during *kharif* 2021the extent in variation from the normal values was +1.3^{0}C and +1.6^{0}C. The rainfall data showed that there was a substantial variation in rainfall during both the crop growing years. Further, in comparison to normal rainfall 1329.4 mm during the F_2 stage 26th -36th SMW in maize crop, the *kharif*

2020 received 3.07 percent more rainfall and *kharif* 2021 received 15.57 percent less rainfall during the respective crop growing period. At pre harvesting stage F_3 26th - 40th SMW, there was decrease in 4.89 and 13.76 percent rainfall during *kharif* 2020 and 2021 when compared with normal rainfall 1440.7 mm during that particular crop growing period. Further, in Jammu district, deviation in weather parameters viz., maximum, minimum temperature, relative humidity and rainfall was recorded at F_2 and F_3 stage from the normal values during maize growing periods. The average normal maximum temperature at F_2 stage 26-36th SMW for maize crop was 34.5^{0}C and the extent of variation in maximum temperature during *kharif* 2020 and 2021 from normal values was -0.1^{0}C and +0.5 ^{0}C. Similarly, there was increase in average minimum temperature +1.5^{0}C and +1.3 ^{0}C at F_2 stage from the normal average minimum temperature 34.5^{0}C recorded during 26 to 36th SMW in Jammu district and during F_3 stage the extent in variation in average minimum temperature was to the tune of +1.4^{0}C and +1.5 ^{0}C from the normal average minimum temperature at F_3 stage during the maize growing period in Jammu district in both the *kharif* seasons. Deviation in total rainfall was also recorded during maize growing period in Jammu district. Further, maize crop received 3.82 and 5.51 percent more rainfall in comparison to normal seasonal rainfall 756.5 mm received during 26th -36th SMW at F2 stage. There was decrease in 5.96 percent and increase in 2.32 percent rainfall in comparison to normal seasonal rainfall 835.2 mm received during (26th - 40th SMW) at F3 stage in maize crop. Variation in relative humidity was also recorded at F_2 and F_3 stage in both the districts.Yield of Maize crop is influenced by the amount of rainfall and phenological stage at which crop received rainfall. Similar results were also reported by Banotra et al 2017.

Received 08 August, 2023; Accepted 28 November, 2023

CONCLUSION

Temperatures (maximum and minimum) together with relative humidity (morning and evening) and rainfall were significant agro meteorological indices for deciding maize productivity in the Jammu and Udhampur districts. The pre harvested grain yield prediction can be reasonably accurate with R^2 (between 0.67 to 0.91). The performance of yield forecast model for forecasting yield in Jammu and Udhampur district is quite satisfactory. Therefore, it could be used for maize yield forecasting in other districts of Jammu division also.

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