Journal of Agrometeorology 18 (1) : 146-148 (June 2016)

Short communication

Climate variability and impact on productivity of rice in central Punjab

P. K. KINGRA

School of Climate Change and Agricultural Meteorology
Punjab Agricultural University, Ludhiana 141 004, India
e-mail: pkkingra@pau.edu

Rice is the predominant crop of north-west India including Punjab. Punjab covering only 1.54% of the geographical area of India, contributes nearly 28% of rice to the central pool of foodgrains (Annonymous 2015). The state of Punjab, which has earned a name of 'Granary of India', has contributed upto 60% of rice to central pool of foodgrains. Punjab produces about 10% rice of the country and 2% rice of the world. The state is also credited with highest irrigated area (99%) and highest cropping intensity (191%) in the country. In addition to this, because of the advent of high yielding varieties and improved technology, Punjab has undergone a phenomenal increase in crop productivity of during last many decades. Rice productivity in the state has increased from 1.5 to 4.7 t ha^{-1} from 1960-61 to date. But because of global warming, the region is experiencing fluctuating weather conditions leading to decline in agricultural productivity. Because of oscillating weather conditions, large year-to-year fluctuations in crop productivity are observed in the region.

Singh *et al* (2013) have reported higher biomass production, radiation use efficiency, grain number and grain yield of rice under elevated CO_2 conditions. Hundal and Kaur (2007) reported that with an increase in temperature by 1°C, the yield of rice decreased by 3% under Punjab conditions. Mathauda *et al* (2000) also reported that warming scenarios will have adverse impact on rice productivity through the advancement in maturity and reduction of source size coupled with poor sink strength in Indian Punjab, which clearly indicates that rice productivity is going to be adversely affected because of climatic warming scenarios in the region.

The present study was thus initiated to analyse the climate variability during rice growing period and its impact on crop productivity by developing agrometeorological rice yield forecasting models so as to quantify the influence of climatic variations on rice productivity for agricultural sustainability and food security in the region. Long-term meteorological records during a period of 45 years (1970 to 2014) for Ludhiana were collected from the Agrometeorological Observatory, School of Climate Change & Agricultural Meteorology, Punjab Agricultural University, Ludhiana. The data on rice grain yield was collected from the historical records covering the same period of 45 years. The meteorological data included daily maximum and minimum temperatures, relative humidity, wind speed, sunshine hours, rain amount and number of rainy days during growing period of rice.

Trend analysis and variability in long-term climatic records during the rice growing period were studied to assess the long-term climatic variability during crop season and its impact on grain yield. Variability in these parameters was studied by time scale regression analysis. Trend and variability in long-term yield of rice was also studied by regression analysis. The relationships between rice yield and weather parameters during its growing period were studied by conducting correlation analysis. The sensitive periods and weather parameters with good correlation with crop yield were identified based on the correlation analysis. The critical periods during which these weather parameters significantly influenced the crop yield, were identified and used to develop multiple linear regression models for predicting the influence of these parameters on crop yields. To study the impact of weather variability on yield of rice, the multiple linear regression models were used to study the relationships of yield with weather parameters prevailing during their growing seasons.

Long-term climatic variability analysis during rice growing period indicated no significant variation in maximum temperature, but significant increase in minimum temperature (@ 0.06°C $year^{-1}$) has been observed (Table 1). Sunshine hours have decreasing (@ 0.02hrs day^{-1}) trend. As rice being a tropical crop, requires higher sunshine hours, significant decrease in sunshine hours can lead to severe implications on rice productivity in the region. Thus, increasing minimum temperature and decreasing sunshine hours can have significant negative impact on crop

Table 1 : Long-term climatic variability (1970 – 2014) during rice growing period in central Punjab

Parameter	Regression equation	R^2	Trend	Annual rate of change
Maximum temperature (°C)	Y = -0.011 X + 35.01	0.046	↓	-0.01°C
Minimum temperature (°C)	Y = 0.055 X + 23.84	0.659	↑	0.06°C
Sunshine hours (hrs day^{-1})	Y = -0.022 X + 8.429	0.100	↓	-0.02 hrs day^{-1}
Wind speed (km day^{-1})	Y = -0.030 X + 6.045	0.459	↓	-0.03 km day^{-1}
Morning relative humidity (%)	Y = 0.13 X + 78.25	0.234	↑	0.13%
Evening relative humidity (%)	Y = 0.223 X + 52.24	0.288	↑	0.22%
Rainfall (mm)	Y = 2.546 X + 532.8	0.020	↑	2.55mm
Number of rainy days (days)	Y = 0.047 X + 24.57	0.011	↑	0.05 days

Table 2 : Deviation of rice yield and weather parameters from normal at critical periods during low and high yielding years

Year	Yield (kg ha^{-1})	T_{max} SMW 25-30	T_{max} SMW 34-40	SSH SMW 29-30	SSH SMW 31-33	RH_{even} SMW 25-29	RH_{even} SMW 37-41
2000	-433	-1.9	0.6	-3.3	1.8	13.0	-2.0
2001	-483	-2.1	1.0	-1.6	0.6	18.4	-0.4
2004	253	-0.1	0.0	1.3	-0.5	2.9	9.8
2009	312	0.4	-0.7	0.5	-0.5	1.8	13.6
Normal	4380	35.7	33.6	6.8	6.7	52.8	46.6

productivity in the region.

It has been observed that higher daytime temperature, sunshine hours and lower afternoon relative humidity during vegetative growth and lower daytime temperature, sunshine hours and higher afternoon relative humidity are favourable for obtaining higher rice yields. The high yielding years (2004 and 2009) had higher daytime temperature, sunshine hours and low afternoon relative humidity during vegetative growth and lower daytime temperature, sunshine hours and high afternoon relative humidity during reproductive growth whereas reverse weather conditions were observed during low yielding years (2000 and 2001) (Table 2). Correlation conducted between weekly weather parameters and rice yield indicates that same weather parameters have variable impact during different growth stages of the crop. Daytime temperature, sunshine hours and afternoon relative humidity are found to have most significant impact on yield of rice.

Based on the critical periods and weather parameters identified during correlation studies, multiple regression relationships were developed between weather parameters and yield of rice. The model involving weather parameters namely daytime temperature, sunshine hours and relative humidity during different growth stages of the crop explained 80 per cent variation in crop yield. Model I

Table 3 : Validation of the model for prediction of rice productivity

Year	Actual yield (kg ha^{-1})	Predicted yield (kg ha^{-1})	Departure (%)
2013	4424	4584	+3.6
2014	4354	4490	+3.1

$$Y = 9015.67 – 41.86 X_1 - 109.48 X_2 + 82.94 X_3 + 32.65 X_4 - 17.63 X_5 + 15.60 X_6 \quad (R^2=0.80^*)$$

Where,

Y = Rice yield (kg ha^{-1});

X_1 = Mean maximum temperature (SMW 25 - 30),

X_2 = Mean maximum temperature (SMW 34 - 40),

X_3 = Mean Sunshine Hours (SMW 29 - 30),

X_4-= Mean sunshine hours (SMW 31 – 33),

X_5 = Mean evening relative humidity (SMW 25 - 29),

X_6 = Mean evening relative humidity (SMW 37 -41)

The model was validated with two years (2013 & 2014) of data. The model predicted rice grain yield of 4584 and 4490 kg ha^{-1} during 2013 and 2014 respectively which was in good agreement with the actually recorded rice grain yield of 4424 and 4354 kg ha^{-1} with departure of predicted yield from actual 3.6 and 3.1% respectively (Table 3). Kaur *et al* (2015) also developed rice yield deviation prediction models which predicted rice yield within the range of -3.07 to 11.26 %. Very good agreement between the actual and predicted rice yield indicates that the model based on weather conditions prevailing during crop growing period can be used successfully for pre-harvest prediction of crop productivity so that timely measures can be taken for ensuring food security under unfavorable weather conditions.

The study concludes that in view of the importance of prevailing weather conditions during crop growing period, agrometeorological models can be used very effectively for pre-harvest crop yield prediction and policy planning for ensuring food security under changing climatic scenarios.

REFERENCES

Annonymous. (2015). Statistics of Punjab Agriculture. Punjab Agricultural University, Ludhiana.

Devi, M., Hussain, R., Sarma, A., Sarmah, K. and Deka, R. L. (2013). Yield prediction of winter rice employing meteorological variablesin central and upper Brahmputra valley of Assam. *J. Agrometeorol.*, 15 (Special Issue-I): 162 – 166.

Hundal, S. S. and Kaur, P. (2007). Climatic variability and its impact on cereal productivity in Indian Punjab. *Current Science,* 92 (4): 506 – 512.

Kaur, P., Bala, A., Sandhu, S. S. and Gill, K. K. (2015). Yield gap in rice and wheat productivity in different agroclimatic zones of Punjab. *J. Agrometeorol.*, 17(1): 127 – 130.

Mathauda, S. S., Mavi, H. S., Bhangoo, B. S. and Dhaliwal, B.K. (2000). Impact of projected climate change on rice production in Punjab (India). *Tropical Ecology,* 41(1): 95-98.

Singh, S. S., Mukherjee, J., Kumar, S. and Idris, M. (2013). Effect of elevated CO_2 on growth and yield of rice crop in open top chamberin sub-humid climate of eastern India. *J. Agrometeorol*., 15(1): 1 – 10.

Received : September 2015 ; Accepted : November 2015