PRE HARVEST FORECASTING MODELS BASED ON STEPWISE REGRESSION ANALYSIS (SRA) AND PRINCIPAL COMPONENT ANALYSIS (PCA) ON YIELD OF CHICKPEA AND PIGEON PEA FOR CHHATTISGARH PLAIN

M.Sc. (Agriculture) Thesis

by

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DEPARTMENT OF AGRICULTURAL STATISTICS AND SOCIAL SCIENCE (L.)
COLLEGE OF AGRICULTURE
INDIRA GANDHI KRISHI VISHWAVIDYALAYA
RAIPUR (C.G.)

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Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur

by

Gaind Lal

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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CERTIFICATE - I

This is to certify that the thesis entitled "**Pre Harvest Forecasting Models Based on Stepwise Regression Analysis (SRA) and Principal Component Analysis (PCA) on yield of Chickpea and Pigeon pea for Chhattisgarh plain"** submitted in partial fulfillment of the requirements for the degree of **"Master of Science in Agriculture Statistics"** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Gaind Lal** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or (certificate awarded etc.) has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

Chairman

Date: 20/12/2017

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

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Member	:	Dr. Hulas Pathak	....
Member	:	Mr. J.L. Chaudhary	....

CERTIFICATE - II

This is to certify that the thesis entitled **"Pre Harvest Forecasting Models Based on Stepwise Regression Analysis (SRA) and Principal Component Analysis (PCA) on yield of Chickpea and Pigeon pea for Chhattisgarh plain"** submitted by **GaindLal**to the Indira Gandhi KrishiVishwavidyalaya, Raipur, in partial fulfillment of the requirements for the degree of **Master of Science** in the **Department of Agriculture Statistics** has been approved by the examiner Student's Advisory Committee after oral examination.

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Date: 12/12/2017

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Faculty Dean ....

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LIST OF ABBREVIATIONS/NOTATIONS

%	Percentage
et al.	And others
Max. temp	Maximum temperature
Min. temp	Minimum temperature
RH-I,RH-II	Relative humidity
$Z_{0.}$, $Z_{1.}$ and T	Unweighted, weighted, Time trend and . indicates the variable number
Q..0 and Q..1	Interaction of variable I and II variable, 0 and 1 have their usual meaning
1,2,3,4,5,6,7 with Z and Q	Maximum Temperature, Minimum Temperature, Relative Humidity-I and II, Sun Shine (hrs), Rainfall, Wind Velocity.
SRA	Stepwise Regression Analysis
PCA	Principal Component Analysis
PC	Principal Component
R^2	Coefficient of Determination
CGPZ	Chhattisgarh Plain Zone
RAI, BSP, DUG, RNG, MHS, ,DMT, KWD, KRB and JNG	Raipur, Bilaspur, Durg, Rajnandgaon, Mahasamund, Dhamtari, Kawardha, Korba and Janjgir.
SMW	Standard Meteorological Weeks

THESIS ABSTRACT

a.	Title of the Thesis	:	"Pre Harvest Forecasting Models Based on Stepwise Regression Analysis (SRA) and Principal Component Analysis (PCA) on yield of Chickpea and Pigeon pea for Chhattisgarh plain"
b.	Full Name of the Student	:	Gaind Lal
c.	Major Subject	:	Agricultural Statistics
d.	Name and Address of the Major Advisor	:	Dr. K. K. Pandey, Assistant Professor Department of Agri. Statistics, SKCARS Kawardha
e.	Degree to be awarded	:	M.Sc. (Ag) Statistics

Signature of student

Signature of Major Advisor

Date:

Signature of Head of Department

ABSTRACT

The present investigation covers under the study of individual effect of weather variables, joint effect of weather variables forecasting model developed through stepwise regression technique following the concept of older studies by the different scientists in this direction for many crops. The principal component analysis has been also taken for the development of forecasting model. Time series data on yield for 25 years (1990-91 to 2014-15) for 4 Districts, Seventeen year for 5 districts has been procured from Directorate of Agricultural, Govt. of Chhattisgarh. The weekly meteorological data (1990-91 to 2014-15) procured from IGKV, Raipur for Chickpea and Pigeon pea crop period data.

District wise result found for both the crops viz. chickpea and pigeonpea. Individual effect of all the weather variables has almost similar result. Combined result of Chhattisgarh plain zone found highly significant for all the variables with chickpea and pigeonpea. Moreover, joint effect of the weather variables found highly significant for all the weather variables under condition of Chhattisgarh plain zone for chickpea and pigeonpea.

The models has been developed through Step wise regression analysis on districts level as well as zone level all the models found highly significant at 0.1% level of significance for both the crops. The value of R^2 for the model on Zone Level is 91% and 5 (Q_{261}, Q_{271}, Q_{131}, Q_{370} and T) variable entered into models for chickpea crop. Moreover, the value of R^2 for the model on Zone Level is 78% and 2 (Q_{121} and Z_{41}) variable entered into models for Pigeonpea crop. The model has been also found significant.

The model has been also developed by Principal Component Analysis on districts level and zone level as well. Models fitted with 2 Principal Components (PC1 and PC2) and Time trend (T). Models are highly significant and R^2 value 85% and 69% for Chickpea and Pigeonpea respectively for CG plain Zone is also highly significant at 1% level of significance.

These are useful to farmers to decide in advance their future prospects and possible course of action. Thus, reliable and timely pre-harvest forecasting of crop yield is very important. In statistical model approach, one or several variables (representing weather or climate) are related to crop responses such as yield and yield contributing characters.

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Major Advisor

शोध सारांश

अ.	शोध का शीर्षक	:	क्रमबद्ध प्रतिगमन विश्लेषण और प्रमुख कारक विश्लेषण द्वारा छत्तीसगढ़ के मैदानी क्षेत्र के लिए चना एवं अरहर फसल की कटाई के पूर्व पैदावार के पूर्वानुमान हेतु मॉडल विकसित करना
ब.	छात्र का नाम	:	गैंदलाल
स.	प्रमुख विषय	:	कृषि सांख्यिकी
द.	प्रमुख मार्गदर्शक का नाम एवं पता	:	डां. के. के. पाण्डेय, सहायक प्राध्यापक, कृषि सांख्यिकी विभाग, इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर, छ.ग.
ई	डिग्री से सम्मानित किया जायेगा	:	एम.एस.सी. कृषि सांख्यिकी

छात्र के हस्ताक्षर

प्रमुख मार्गदर्शक के हस्ताक्षर

दिनांकः

विभागाध्यक्ष के हस्ताक्षर

सार / शोध सारांश

वर्तमान अध्ययन मे मौसम चर का व्यक्तिगत प्रभाव एवं मौसम चर के संयुक्त प्रभाव के अध्ययन हेतु सामान्य प्रतिगमन विश्लेषण विधि का प्रयोग किया गया और R^2 के मान द्वारा उचित प्रभाव की गणना की गयी। पूर्वानुमान हेतु मॅाडल विकसित करने के लिए पुरानी अवधारणा क्रमबद्ध प्रतिगमन विश्लेषण, जिसको पूर्व मे विभिन्न वैज्ञानिकों द्वारा अनेक फसलों दर्शाया जा चुका है। प्रमुख कारक विश्लेषण द्वारा पूर्वानुमान हेतु मॅाडल विकसित करने के लिए 25 साल के मौसम आंकड़े (साप्ताहिक) एवं उत्पादन आंकड़े (वार्षिक), चना एवं अरहर फसल का 1990 से 2014 तक जिलेवार आंकडों का संग्रहण किया गया।

विश्लेषणों के अधार पर जिलेवार मौसम चर का व्यक्तिगत प्रभाव चना एवं अरहर फसल पर परिणाम संतोष जनक एवं सार्थक है। वही मौसम चर का संयुक्त प्रभाव चना एवं अरहर फसल के लिए छत्तीसगढ़ के मैदानी क्षेत्र मे सार्थक प्रभाव दिखा है। जिला स्तर पर क्रमबद्ध प्रतिगमन विश्लेषण मॅाडल उच्च सार्थक है ठीक

उसी प्रकार संभाग स्तर पर सार्थकता चना एवं अरहर फसलों मे सार्थकता स्तर 0.01% देखा गया। कमबद्ध प्रतिगमन विश्लेषण मॉडल पूरे संभाग में चना फसल के लिए R^2 का मान 91% सार्थकता स्तर पर है तथा इसके मॉडल मे 5 चर (Q_{261}, Q_{271}, Q_{131}, Q_{370} और T) शामिल हैं। इसी प्रकार अरहर फसल मे R^2 का मान 78% सार्थक तथा इसके मॉडल मे 2 चर (Q_{121} और Z_{41}) शामिल हैं।

जिला एवं संभाग स्तर प्रमुख कारक विश्लेषण द्वारा समान मॉडल विकसित किया गया जिसमें छत्तीसगढ़ के मैदानी क्षेत्र के मॉडल में 2 प्रमुख कारक (PC1, PC2 और T) शामिल हैं। जिसमें चना एवं अरहर फसल का R^2 मान कमशः 78% तथा 85% सार्थक पाया गया।

फसल की पैदावार हेतु किसानो के लिए क्योंकि भविष्य को ध्यान मे रखते हुये कटाई के पूर्व मूल्य निर्धारण का कार्य किया जा सकता है। यह शुद्व एवं समयबद्ध कटाई पूर्व फसल उपज का पूर्वानुमान के लिए एक मजबूत सांख्यिकी मॉडल है जो कि उपज पर दो या दो से अधिक के मौसम चरों द्वारा प्रभाव कारी होता है।

कृषि सांख्यिकी एवं सामाजिक विज्ञान;एल
कृषि महाविद्यालय,रायपुर

Pandey
डॉ के के पाण्डेय
प्रमुख मार्गदर्शक

CHAPTER-I

INTRODUCTION

Forecast of the crop production at suitable stages of crop period before the harvest are vital for rural economy. On the other hand, forecasts of crop yields are important for advance planning formulation and its implementation. Forecasting is also vital for crop procurement, distribution, price structure and import export decisions etc. These are useful to farmers to decide in advance their future prospects and course of action. Thus, reliable and timely pre-harvest forecasting of crop yield is very important. To meet such needs, crop forecasts under the prevalent system in India are being issued by the Directorate of Economics and Statistics, Ministry of Agriculture, New Delhi. The final estimates based on objective crop-cutting experiments are of limited utility as those become available quite later after the crop harvest. The Statistical techniques employed for forecasting purposes should be able to provide objective, consistent and comprehensible forecasts of crop yield with reasonable precisions well in advance before the harvest. Several studies have been carried out to forecast crop yield using weather parameters etc.

These are useful to farmers to decide in advance their future prospects and possible course of action. Thus, reliable and timely pre-harvest forecasting of crop yield is very important. In statistical model approach, one or several variables (representing weather or climate) are related to crop responses such as yield and yield contributing characters. Therefore, there is a need to develop area specific forecasting models based on time series data to help the policy makers for taking effective decisions to counter adverse situations in food production. The forecasting of crop yield may be done by using three major objective methods (i) biometrical characteristics (ii) weather variables and (iii) agricultural inputs (Agrawal *et al.* 2001).

Weather variables affect the crop differently during different stages of growth period. Among the meteorological variables, rainfall, temperature and soil moisture are some of the important elements, which significantly affect crop yields, The meteorological parameters and yield data using the phenological periods, in which weather elements illustrate significant correlation with crop yield, Statistical models based on time series data on crop-yield and weather variables. Agrawal *et al.*, 1980;

Pulses occupy an important place in Indian agricultural economy and nutritional security as they constitute 10 to 15 per cent of India's food grain diet. Pulses are important food crops due to their high protein content 20 to 25 per cent, carbohydrates 55 to 60 per cent, rich in calcium, various amino acids and iron also, (Sahu *et al*, 2015) and also known as ***"Poor Man's Meat" and "Rich Man's Vegetable".*** Pulses are leguminous because nearly 43% of all Indians are vegetarian (urban-48% rural-41%). According to 2014 figures, Chickpea (*Cicer arietinum* L.) is one of the most important grain legumes which is traditionally cultivated in marginal areas and saline soils, Pigeonpea (*Cajanus cajan* L.Mill sp.) is the second most important pulse crops of India after chickpea which is grown predominantly under rainfed conditions.

India is the largest producer and consumer of pulses in the world accounting for 33 per cent of the world area and 22 per cent of world production and about 30 per cent of consumption. Madhya Pradesh is India's largest pulse producing state with 26% share in overall production. It is followed by Maharashtra and Rajasthan. By the 2050 we will able to sustain our production and we turned to net importer to net exporter for pulses if every things goes as per plan. Another unique feature is its source of livelihood and still not a commercial business.

Chickpea is most important pulse crop of India in terms of both area and production. In India, chickpea is grown over an area of 8.52 million ha with production of 8.83 million tonnes and average productivity of 1036 kg ha^{-1}(Sahu *et al*, 2015). Madhya Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Gujarat, Andhra Pradesh and Karnataka are the major chickpea producing states sharing over 95 % area.

Chhattisgarh is a predominantly tribal region in the eastern part of India. State has three agroclimatic zones, i.e. Chhattisgarh plains, Bastar plateau and Northern hill region. The sixteen districts (Raipur, Durg, Rajnandgaon, Bilaspur, Dhamtari, Mahasamund, Korba, Kawardha, Janjgeer, Kanker, Balodabazar, Gariyaband, Bemetara, Mungeli, Balod, Raigarh) constitute basically the Chhattisgarh plains area of Chhattisgarh. The plateau region comprises of Bastar, Dantewada, Kanker, Narayanpur, Bijapur, Kondagaon and Sukma. Chhattisgarh State has total geographical area of 137.90 lakh ha with net sown area of 46.77 lakh ha in this State. (*www.agridept.cg.gov.in*).

In Chhattisgarh, chickpea is grown over an area of 393.78 thousand ha with an annual production of 433.158 thousand tonnes and an average productivity of 1100 kg ha-1. Pigeonpea is an important pulse crop of India after chickpea. It is grown an area of 3.88 M ha with the production of 3.17 MT and productivity of 849 kg ha. In Chhattisgarh it occupied an area of 134.43 thousands ha with production of 90.06 thousands tones and productivity of 670 kg ha-1. Chhattisgarh is an important State as it contributed about 5.72 per cent of the total annual pulses area, Production and productivity in Chhattisgarh during 2010-11 were 0.81 (Mha), 0.49 million ton and 605 kg/ha respectively (State of Indian Agriculture, 2012-13).

Crop yield is mostly affected by technological changes and weather variability. It can be assumed that the technological factors will increase yield smoothly through time and therefore, year or other parameters of time can be used to study the overall effect of technology on crop yield. The variability both within and between seasons is the second and uncontrollable sources of variability in yields Weather variables affect the crop differently during different stages of development. Thus, the distribution pattern of weather variables over the crop season is such that whole season is divided to in finer intervals. However, doing so will increase number of variables in the model and in turn a large number of parameters will have to be evaluated from the data and sufficient number of observations may not be available Multivariate techniques such as principal Components, discriminant function etc. can be employed to tackle such problems.

It may also be possible that the auxiliary variables used in the regression model at district level may be highly correlated and may vitiate the final results. In such situations, principal component analysis can be performed and first few principal components may be used as the independent variables in the regression model at the district level for the development of the estimators for block-level estimates of crop-production. Principal component analysis is a method of extracting important variables (in form of components) from a large set of variables available in a data set. It extracts low dimensional set of features from a high dimensional data set with a motive to capture as much information as possible. With fewer variables, visualization also becomes much more meaningful. PCA is more useful when dealing with 3 or higher dimensional data. It is always performed on a symmetric correlation or covariance matrix. This means the matrix should be numeric and have standardized data.

Forecast models based on principal components of biometrical characters have also been developed, a number of statistical techniques such as multiple regression, principal component analysis, Markov chain analysis (Ram Subramanian and Jain, 1999).The approach using weather variables is normally based on time series data. Based on these data mostly regression models are fitted. Quantitative crop yield forecasts are generally carried out by means of multiple regression models. Composite models, combining biometrical characters and weather variables were developed by Mehta *et al.* (2000).

Various organizations in India and abroad are engaged in developing methodology for pre harvest forecast of crop yield. Various approaches have been developed. Prominent among are the pre-harvest forecasting approaches based on models that utilize data on crop biometrical characters, weather variables, farmers eye estimates, agro meteorological conditions, remotely sensed crop reflectance observations, input of crop-production etc. The approach using weather variables is normally based on time series data during the last few years considerable work has been carried out in developing the pre-harvest forecast statistical models.

Therefore, in view of the above consideration there is a need for developing an objective methodology for pre-harvest forecasting. This involves building up suitable pre-harvest statistical model which has certain merits over the traditional forecasting method. An attempt has been made to study about effect of individual weather variables, effect of interaction effect of weather variables, development of suitable pre-harvest forecast model by Stepwise regression analysis and Principle Component Analysis with the following objectives:

1). To study the effect of Individual weather variables on Chickpea and Pigeon pea productivity.

2). To study the interaction effect of weather variables on Chickpea and Pigeon pea productivity.

3). To develop suitable pre-harvest forecast model based on composite weather variables (SRA).

4). To develop the pre-harvest forecast models based on Principal Component Analysis (PCA).

CHAPTER-II
REVIEW OF LITERATURE

The review of literature in the work done on the past is essential to understand fully the problem in depth. This chapter deals with the review of studies on research to the objective of present study.

2.1. Study on Individual and Joint effect of weather variables:

Jain *et al.* (1984) gave a new approach for forecasting. He constructed principal component of biometrical characters for sorghum crop. These are plant population /plot , plant height, length of ear head , no. of healthy ear head /plant ,circumferences of ear head , number of green leaves pe plant and length and width of leaves. Under this study be found that plant population /plot, plant height number of green leaves per plant are significantly correlated with yield. The principal components were obtained by using data of one or more one point of time.

Wight *et al.* (1984) studied on population of yields, a mean and various confidence intervals around the mean can be calculated as the forecast yield and its associated confidence intervals. The forecast procedure was tested using 55 years (1917-1971) of weather records and 12 years (1967-1978) of actual yield and soil water data for an upland range site in eastern Montana. An expected two thirds of the field measured yields were within a standard deviation of the forecasted yields for the April, May, and June forecasts.

Pioneer work in this context has been done by Hendricks and Scholl (1943) has been modified (Agrawal *et al.* 1980; 1983; Jain *et al.* 1985) by expressing effect of changes in weather variables on yield in the W^{th} week as Second degree polynomial in correlation coefficient between yield and weather variable in W^{th} week. At I.A.S.R.I, New Delhi several models were attempted based on Weather indices, discriminant function analysis and water balance technique at district level. This is expected to explain the relationship in a better way as it gives appropriate weight age to different periods. Under this assumption, the models were developed for studying the effects of weather variable on yield using complete crop season data, where is forecast models utilized partial crop season data. These models were found to be better than the one suggested by Hendricks and Scholl (1943).

Jain *et al.* (1985) used this method for forecasting with growth indices as explanatory variables and found better than conventional linear regression models weather variables used as explanatory variables.

These models were further modified **(Agrawal *et al.* 1986)** by expressing the effects of changes in weather variables on yield in W^{th} week as a linear function of respective correlation coefficient between yield and weather variables, has trend effect on yield was found to be significant, its effect was removed from yield while calculating correlation coefficient of yield with weather variables to be used as weights effects of second degree term of weather variables also studied. The result indicated that (i) the models using correlation coefficient based on yield adjusted for trend effects were better than the ones using simple correlation coefficient, (ii) inclusion of quadratic terms of weather variables and also the second power of correlation coefficient did not improve the model.

This model was used to forecasting yield of rice and wheat in different situation viz (i) rainfed area having deficient rainfall (rice) , (ii) rainfed area having adequate rainfall (rice)and irrigated area (wheat) . the result revealed that reliable forecasts can be obtained using this approach when the crops are 10-12 weeks old , i.e around two and half months before harvest . this approach was also used to develop forecast models for sugarcane (Mehta *et al* . 2000).

Rahman *et al. (*2005) studied on weather-crop yield-forecasting model to estimate prospective production of Aus rice in Jessore and Rajshahi districts of Bangladesh. This model showed the relationship between the crop yield and input weather parameters influencing the crop yield (Aus rice). The model evaluated using a multiple regression and ridge regression techniques. Ridge regression simulation study is used to perform sensitivity analysis. The agro climatic variables and others non-climatic variables were used in the study.

Hansen *et al.* (2006) Seasonal climate prediction offers the potential to anticipate variations in crop production early enough to adjust critical decisions. Until recently, interest in exploiting seasonal forecasts from dynamic climate models (e.g. general circulation models, GCMs) for applications that involve crop simulation models has been hampered by the difference in spatial and temporal scale of GCMs and crop models, and by the dynamic, nonlinear relationship between meteorological variables and crop response. Although GCMs simulate the atmosphere on a sub-daily time step, their coarse spatial resolution and resulting distortion of day-to-day variability limits the use of their daily output. Crop models have used daily GCM output with some success by either calibrating simulated yields or correcting the daily rainfall output of the GCM to approximate the statistical properties of historic observations. Stochastic weather generators are used to disaggregate seasonal forecasts either by adjusting input parameters in a manner that captures the predictable components of climate, or by constraining synthetic weather sequences to match predicted values.

Agrawal and Mehta (2007) viewed the fact that weather affects crops; several weather based models have been attempted for forecasting crop yield for various crops at selected districts/agro climatic zones/states. The models utilised weekly/fortnightly weather data and, in some cases, agricultural inputs at district level. The techniques induced development of suitable weather indices which were used as regrt"ssors in the models, discriminant function analysis and water balance technique. Using these approaches, reliable forecast of crop yield can be provided before harvest - 21/2months (rice and wheat), 1*Y2*month (sorghum), I month (m?he) and in middle of September in sugarcane. Pests and diseases, major factors limiting the production, are also influenced by weather conditions.

Mishra *et al.* (2008) considered empirical and dynamic rainfall forecasts improve model-based prediction of sorghum yields, two methods (regression and stochastic disaggregation) for linking rainfall forecasts with crop simulation, three levels of production technology and four forecast dates (15 May, June, July and August) based on predictors observed from the preceding month, for the period of available data (1957–1998). Accuracy of yield forecasts generally decreased with lead-time.

Priya and Suresh (2009) studied suitable statistical model developed for forecasting the yield of the sugarcane in Coimbatore district (1981-2004) using the yield data and fortnightly weather variable viz. average daily maximum and minimum temperature, relative humidity in the morning and evening and total fortnightly rainfall. The forecast model was developed using generated weather variables as regressors in model.

Kumar, *et. al.* (2011) In this study an attempt has been made to develop Crop Yield Forecasting models to map relation between climatic data and crop yield. Present study was undertaken for forecasting rice yield by adaptive neuro fuzzy inference system (ANFIS) technique based on time series data of 27 years, yield and weather data (w.e.f. 1981-82 to 2007-08) obtained from G. B. Pant University of Agriculture and Technology, Pantnagar, District Udham Singh Nagar, Uttarakhand, India.

Sawa and Ibrahim (2011) aimed at presenting models for the prediction of millet and sorghum. Daily rainfall records and crop yield per hectare for three decades (1976-2005) were used to develop forecast models for the yield of millet and sorghum in the semi-arid region of Northern Nigeria on the basis of dry spell parameters. Frequencies of dry spells of 5, 7, 10 and equal to or greater than 15 consecutive days were determined. Bivariate correlation analysis, stepwise regression (forward selection) and double log multiple regression were then used to develop models for the prediction of the yield of the two crops.

Verma *et al.* (2011) Forecasting of crop production is one of the most important aspects of agricultural statistics system. Crop production forecasting comprises crop identification, area estimation and predicting the yield of the crop. To estimate wheat yields in the study districts, zonal spectral–trend-agrometeorological (agromet) model has been generated using the statistical method of factor analysis. The study has been conducted for zone-II comprising of Karnal, Kaithal, Jind, Panipat, Sonipat and Rohtak districts of Haryana state. Remote sensing based wheat acreage and model predicted yields have been compared with Department of Agriculture (DOA) estimates by computing percent relative deviation. Zonal model developed on the basis of time series data from 1978-79 to 2000-01 has been used to predict the wheat yields for the period 2001-02 to 2007-08. The overall results indicate that the integrat ion of remote sensing data with trend based yield and weather variables provides an immense scope to improve the efficiency and reliability of wheat yield forecasts. Zonal yield models provided considerable improvement in the district-level yield forecasts by showing good agreement with the real time data.

Palta singh *et al.* (2012) have rightly said that rainfall and temperature are the two important weather factors that affect crop yields due to their direct and indirect influences on agricultural practices. This study has negated the method of direct use of meteorological factors (either monthly or seasonal), in multiple regression analysis to measure weather impact on crop yield where rainfall and temperature are incorporated in the model as increasing monotonic functions of yield. With evidences from Odisha, where agriculture is rainfed and weather-dependent, the study has advocated the incorporation of 'aridity index' variable in the regression model.

Pandey *et al.* (2013) formulated to determine an economic study on marketable and marketed surplus of chickpea in Satna District of Madhya Pradesh during agricultural year 2008-09. Primary data were collected by used suitable sampling technique. The secondary data were collected from the different sources i.e. from agricultural statistics of M.P. Total sample size was categorized according to land holding viz. small (0-2 ha), medium (2-4 ha) and large (4 and above ha). In addition for each category marketed and marketable surplus were calculated. 10 wholesalers and 10 retailers were also randomly selected from trading in Satna district. Area under chickpea was 1.72 ha,(2008-09) which contributed 26.91% of gross cropped area. Under the methodology multiple linear regression were used for evaluating the percent contribution of different recourses on marketed surplus. Correlation coefficient being calculated between each and every explanatory variable. Lack of knowledge of recommended practices was the first and foremost constraint faced by the producers i.e. 69.00 per cent. Some suggestions for formers and some for government were given for policy making strategy.

Pandey *et al.* (2013*)* in made to develop models for forecasting rice yield at district level on the basis of weather variables. Weekly data (of 19 meteorological weeks) on seven weather variables over a span of 21 years period (1989-90 to 2009-10) has been used along with the annual rice production data for Faizabad district (eastern UP). Stepwise regression was used to screen out the important weather variables and multiple regression approach was subsequently employed to estimate model parameters. The model –I was evolved as best for yield forecasting out of five model evaluated, R2 and RMSE of this model comes out to be 71.2%, 0.733 respectively followed by model V with R2 and RMSE 51.25% 1.2524 respectively.

Kumar *et. al.* (2014) were developed multiple regression models for yield forecasting of paddy, sugarcane and wheat for two districts of Gujarat (Navsari and Bharuch). The historical weather and crop yield data of 31 years of Navsari (1980-2010) and 27 years of Bharuch (1984-2010) were used. The data of de-trend yield and generated weather variables for 27 years of Navsari (1980-2006) and 23 years of Bharuch (1984-2006) were used for generation of the model for both districts. Significant weather variables are obtained on the basis of highest R2 and significant P-value. The multiple regression analysis was executed by trial and error method. The models were validated with 4 years independent data set (2007 to 2010) of these two districts. During the validation period, Navsari district model deviations for paddy, sugarcane and wheat were between -7.30 to 3.41%, 1.68 to 2.05% and -8.27 to 11.51% respectively. Similarly Bharuch model deviations for paddy, sugarcane and wheat were between 5.35 to 11.76%, -12.65 to 7.18% and -12.07 to 6.86% respectively.

Pandey *et al. (*2014) in made to develop models for forecasting rice yield at district level on the basis of weather variables. Weekly data (of 19 meteorological weeks) on seven weather variables over a span of 21 years period (1989-90 to 2009-10) has been used along with the annual rice production data for Faizabad district (Eastern U.P.). Stepwise regression was used to screen out the important weather variables and multiple regression approach was subsequently employed to estimate model parameters. Sunshine hours along with maximum and minimum temperatures come out to be most significant weather variables for forecasting of rice yield. The proposed model contains combination of weighted and unweighted weather variables and explains 90% of the variability of rice production. The model has been thorough validated using pertinent residual diagnostics plots and thus can used for forecasting purposes.

Rachel, *et al.* (2014) carried out to examine the trends of important weather parameters and their effect on the production of cereal crops in Solan district of Himachal Pradesh. The descriptive statistics and regression analysis revealed no significant trend in all the selected weather parameters in annual, seasonal and monthly basis for the period (1984 – 2011). In Regression analysis cubic and quadratic functions (non significant) were found to be the best fit.There was no significant correlation of individual weather parameters with crop yields but in case of multiple regression analysis some effects were observed indicating thereby that crops yields are influenced by combinations of weather parameters.

Vashisth (2014) Forecast of crop production before harvests are required for storage, pricing, marketing, import, export etc. The main factors affecting crop yield is weather. Weather variability causes the losses in the yield. Use of weather can be done for crop production forecast. Weather plays an important role in crop growth. Therefore model based on weather parameters can provide reliable forecast in advance for crop yield. A statistical model is used for crop yield forecast at different growth in wheat crop. This model use, maximum and minimum temperature, rainfall, morning and evening relative humidity during crop growing period and last thirty year yield data of that crop.

Yadav *et al.* (2014) Applied of principal component analysis in developing statistical models for forecasting crop yield. The time series data on wheat yield and weekly weather variables, *viz.*, Minimum and maximum temperature, Relative Humidity, Wind- Velocity and Sun-Shine hours pertaining to the period 1990 to 2010 in Faizabad district of Uttar Pradesh have been used in this study. Weather indices have been constructed using weekly data on weather variables (Agrawal *et al.*, 1983).

Four models had been developed using principal component analysis as regressor variables including time trend and wheat yield as regressand. The model 1 and 3 have been found to be most appropriate on the basis of R2adj, percent deviation of forecast, RMSE (%) and PSE for the forecast of wheat yield two months before the harvest of the crop.

Annu *et al. (*2015) studied some statistical models for pre-harvest forecast of wheat yield based on biometrical characters in situation of normal and late sowing of wheat have been developed in the present paper. In both the situations, linear multiple regression model (model-I), where biometrical characters are used in the original form, has been found to be the best forecasting model as it has consistently smaller percent standard errors for the forecast yield of wheat along with maximum value of R^2adj.

Azfar *et al.* (2015) dealt with use of principal component analysis of weekly data on weather variables for developing rapeseed & mustard yield forecast model for Farizabad district of U.P. Time series data on rapeseed & mustard yield and weekly data of six weather variable for the crop season for 22 year (1990-91 to 2011-12) have been used to develop weather indices. In all ,six models have been developed and have been used to forecast yield for three subsequent years (2009-10 to 2011-12).

Chaudhary *et al.* (2016) the crop production directly or indirectly depends on weather parameters. Therefore, weather is an important factor for agriculture practice. Present investigation was done to examine three types of model using meteorological weather variables and mustard crop yield (Productivity) in Gandhinagar district of Gujarat state in India. Data were used for mustard crop during the time period 1980-81 to 2014-15. The stepwise regression analysis was employed for mustard crop to determine a set of explanatory variable, which satisfied the equation and explain maximum variation in yield. Average mustard yield was considering as dependent variable and weather variables like Maximum and Minimum Temperature in degree Celsius, Relative Humidity in morning and evening in percentage, Sunshine hours per day and Annual Rainfall in mm as independent variables. Finally, the model which has provided the earliest forecast with high coefficient of determination, t value and minimum percentage deviation from the observed mustard average yields of Gandhinagar district was consider as suitable pre harvest forecast model.

Garde *et al.* (2015) weather situation and effect on crop production. Pre harvest forecasting is true essence, is a branch of anticipatory sciences used for identifying and foretelling alternative feasible future. Crop yield forecast provided useful information to farmers, marketers, government agencies and other agencies. In this paper Multiple Linear Regression (MLR) Technique and discriminant function analysis were derived for estimating wheat productivity for the district of Varanasi in eastern Uttar Pradesh.

Marviya (2015) India is the largest producer of gram in the world having an area of 8.74 million hectares and 7.35 million tone of production. Weekly averaged data of weather variables viz. minimum temperature (X1), maximum temperature (X2), morning relative humidity (X3), afternoon relative humidity (X4), sunshine hours (X5) and total annual rainfall of past year (X6) were collected for growing season of chickpea in Rajkot distract for the years under consideration. The sowing of chickpea mainly concentrated around third week of October in Gujarat. Hence the data pertaining to the weather parameters for the period 42nd week to 7th week of next year were included in the present study. As far as earliest preharvest forecasts model concerned, in case of using original weather variables (week wise approach), the model of 12 weeks crop period could be suggested as a pre-harvest forecast model. The variation explained by this model was very high (86.30%) and error of simulated forecast were less than 6 percent. This model could be utilized for pre-harvest forecast 4 weeks before expected harvesting period of chickpea crop.

Pandey *et al.* (2015) Rice is the major crop of Uttar Pradesh, which covers about 36.5 per cent area of total gross-cropped area in Uttar Pradesh. The present study mainly deals with the effect on weather variables. The study has been undertaken for rice crop in the district of Faizabad, Uttar Pradesh, India. The present study is formulated to determine the individual and joint effect of weather variables on rice yield. On the basis of R2, we found that individually sun shine (hr) is more important with 67.57 followed by wind velocity and rainfall with 48.63 and 46.74, respectively. The joint effect of weather variables is also playing an important role in case of rice crop. According to R2 more important combination is rainfall & wind velocity with 82% followed by rainfall & sunshine hr and wind velocity & sun shine hr 63% and 53.8, respectively.

Panwar *et al.* (2015) studied trend analysis has been done through linear and non-linear approaches. In which for each weather variable two indices have been developed, one as simple total of values of weather parameter in different weeks and the other one as weighted total, weights being correlation coefficients between detrended yield and weather variable in respective weeks. Weather indices based regression models were developed using weather indices as independent variables while detrended yield (residuals) was considered as dependent variable. Time series yield data of 30 years (1971-2010) and weather data for the year 1970-71 to 2009-10 have been utilized. The models have been used to forecast yield in the subsequent three years 2008-09 to 2009-10 (which were not included in model development). The approach provided reliable yield forecast about two months before harvest.

Parbat *et al.* (2015) statistical model of crop yield forecast for rice and jute crops for the year 2012-to 2014 of all districts of Bihar (for rice) and 6 districts of Bihar (for jute). The statistical model is based on the correlation and regression approach in which weather parameters . It is seen from the study that for rice the yield departure from actual ranges -10 % to 12 % and -20 % to 35 % during the years 2012 to 2014. It has been brought out that the yield prediction model used operationally in India Meteorological Department (IMD) and incorporated the weather data in the yield analysis.

Sahu *et al.* (2015) developed models for the study of trend analysis of the Tur and Gram for the three districts (Sarguja, Koria and Jaspur). Linear and Quadratic Models has been used for Sarjuja and Koria and used for Sarguja, Koria and Jaspur district. Present study period was 1979-80 to 2012-13, which divided into three group i.e. period- I (Pre-establishment of IGKV, Raipur: 1979-80 to 1986-87), period-II

(Post-establishment of IGKV, Raipur and pre-period of M.P. and C.G. partition: 1987-88 to 1997-98), and period-III (Post-period of M.P. and C.G. partition:1998-99 to 2012-13). CGR (%), CV (%) and Instability Index have been calculated for the respective periods and all three models. The studies is very necessary not only for understanding the growth trends and magnitude of fluctuations in crop production, but are also useful for scientific planning and effective implementation of agricultural developmental atdifferent levels.

Srivastava *et al* (2015) A full-fledged algorithm for performing statistical forecasting and estimating the agricultural yield for a variety of Rabi and Kharif crops has been developed. A model for forecasting of crop yield based on historical data and pertinent external climatic information was developed. The technique included development of suitable weather indices which were used as regressors in the model, determining their suitable weights for the true determination and minimizing the error term. Apart from the crop produce, pests and diseases, major factors limiting the production, are also influenced by weather conditions. Therefore, an ordinal logistic model was developed for forewarning of important pests/diseases in rice, mustard, pigeon pea, sugarcane, groundnut, mango, sugarcane, cauliflower, sorghum, banana, citrus, soyabean and cotton at various locations. The forewarnings through these models can prove to very useful in taking timely control measures. Finally, to facilitate a graphical user interface for the rural community, a windows based application was developed for the same. Subject Classification: MSC Primary 62-07.

Verma *et al.* (2015) attempted to estimate the yields of cotton hybrids using the principal components of the plant biometrical characters spread over five six successive stages within the growth period of cotton crop. The results indicate the possibility of yield prediction of cotton hybrids RCH 134BG I, RCH 134BG II and Bioseeds 6488BG II, one month ahead of the harvest time. The estimated yields of these hybrids during *kharif*, 2011-2012 were 30.96 q/ha, 31.51q/ha and 31.53q/ha against the observed yields 30.24 q/ha, 29.42q/ha and 32.72q/ha, respectively.

2.2. The studies conducted using Stepwise Regression Analysis

Kumar *et al*. (2016) developed models by modified Hendrick and Scholl technique on paddy and sugarcane for six districts of south Gujarat. The data on the yield and weather parameters were analyzed for 27 years. The 25 year data was used for development of the model. The validation of model was done using data set of 2010 and 2011. The stepwise regression analysis was executed by trial and error method to obtain the finest combination of predictors   Crop yield forecasting for year 2012 based on validated model was made for the districts of Navsari, Surat, Bharuch, Valsad, Narmada and Tapi.

Pandey *et al. (*2016) to development of pre harvest models for pre harvesting forecasting of rice yield at district level on the basis of generated weather variables. Weekly data (14 meteorological weeks) because Time of the pre harvest forecast is 14th week 2½ month before harvesting flowering stage and seven weather variables over a span of 20 years period (1995 to 2014) has been used along with the annual rice production data for respective year for eastern UP. The data of de-trend yield and generated weather variables for 18 years of has been used for generation of and 2014). The (PPE) ranging - 4.32 to 10.56 % from the observed yield for all 5 models. Total five models were validated with 2 year independent data set (2013 correlation has been found 0.68 between Z231 (Weighted interaction between MaxT and MinT). Significance of models are obtained by on the basis of highest R^2 (86%) and by (P-value) (0.08). MBE (Mean Biased Error), RMSE (Root Mean Square Error) and PE (Percent Error) has been used for the Error analysis. On the basis of R^2 and other parameter the model IV has been found best.

Pandey *et al.* (2016) The present study has been carried out for the development of pre-harvest forecast model of rice at district level on the basis of weather variables. Weekly data of 14 meteorological weeks on seven weather variables under rice crop season over a span of 21years period (1989-90 to 2009-10) have been used along with the annual rice production data for Faizabad district of eastern Uttar Pradesh. Generated weather variable (56 weighted, unweighted and joint +1 Time trend) has used under the stepwise regression to screen out the important weather variables and multiple regression approach was subsequently employed to estimate model parameters. Q140 (unweighted interaction between maximum temperature and rainfall and Q451 (Weighted interaction between rainfall and Wind velocity) and time trend comes out to be most significant weather variables for forecasting of rice yield. The proposed model contains combination of weighted and unweighted weather variables and explains 76% (significant at 1% level of significance) of the variability of rice production in terms of R2. The model has been developed for 19 years data and validated for 2 years data. Predicted yield for the 2009 is 23.765 and 2010 is 24.31 with deviation 0.021% and -5.69 % respectively, RMSE (1.498) for the model is also calculated for the validation.

Srivastava *et. al.* (2016) to find out the impact of rainfall, temperature and growing degree day (GDD) on the larval incidence and peak population of *Helicoverpa armigera* on chickpea and its growth in the Bundelkhand Agroclimatic zone of Madhya Pradesh. Besides, an attempt was also made to examine the association with weather variables of rising and falling phase of the larval population of *Helicoverpa armigera*. It was found that there was not any significant impact of monthly (September and October) rainfall on the larval population but the monthly rainfall of January and February significantly influenced the incidence of the pod borer and GDD plays a vital role in increasing and decreasing of its peak population. Minimum temperature and rainfall play a crucial role for larval incidence and its population growth. Growing degree day from 1st January to 15th February were presented in relation to the number of peak larval population in chickpea. A multiple regression equation was also developed. It was found that if the cumulative growing degree day from 1st January to 15th February ≥350 degree day and weekly minimum temperature ranged from 6 to 12 °C along with number of rainfall events < 5 days, then number of larval population of *H. armigera* in chickpea is high and vice-versa.

2.3. Some of the studies conducted using Principal Component Analysis for modeling /forecasting purposes are discussed here as given below.

Sudesh *et al.* (2016) zonal wheat yield models based on weather data of 1978-79 to 2009-10 for Hisar, Bhiwani, Sirsa and Fatehabad districts comprising the western zone of Haryana have been developed. Multiple linear regression and principal component analyses have been carried out for the purpose. The validity of the models have been tested for the post sample periods, i.e., 2010-11, 2011-12, 2012-13, 2013-14 and 2014-15. The overall results show a preference for using prediction equations based on principal component analysis in terms of capturing percent deviations from the real time yields.

Yadav *et al.* (2016) In the present paper, an application of discriminant function analysis of weather variables (minimum & maximum temperature, Rainfall, Rainy days, Relative humidity 7 hr & 14 hr, Sunshine hour and Wind velocity)for developing suitable statistical models to forecast pigeon-pea yield in Faizabad district of Eastern Uttar Pradesh has been demonstrated. Time series data on pigeon-pea yield for 22 years (1990-91 to 2011-12) have been divided into three groups, *viz*., congenial, normal, and adverse based on de-trended yield distribution. Considering these groups as three populations, discriminant function analysis using weekly data on eight weather variables in different forms has been carried out. The sets of discriminant scores obtained from such analysis have been used as regressor variables along with time trend variable and pigeon-pea yield as regressand in development of statistical models. In all nine models have been developed. The forecast yield of pigeon-pea have been obtained from these models for the year 2009-10, 2010-11 and 2011-12, which were not included in the development of the models. The model 4 and 9 have been found to be most appropriate on the basis of R2adj, percent deviation of forecast, percent root mean square error (%RMSE) and percent standard error (PSE) for the reliable forecast of pigeon-pea yield about two and half months before the crop harvest.

2.4. Model Development: At a Glance

At district levels model based on time series data on weather variables has also been developed with the technique of Discriminant function analysis (Rai and Chandrahas, 2000). A long series of 25 year has been classified into three groups viz ; congenial, normal and adverse and linear quadratic Discriminant function were fitted. These functions have been used to find weather score for each year at different phase of crop growth and were used as regression along with the trend variable in the forecast model. The study showed that a good forecast of rice yield can be made about two months before crop harvest.

In another approach based on water balance techniques, model for rainfed crops using weighted stress indices have been developed for rice- Raipur, sorghum – Delhi & Prabhani and maize- Delhi. in this approach , water deficit / surplus has been worked out at different phase of crop growth and using suitable weights , accumulated weighted stress index has been developed for each year which was used as regressor in the forecast models , this technique provide forecast six weeks before harvest for rice. These studies, carried out at District level, revealed data requirement of about 25-30 year for reliable forecast. Such a long series may not be available for most of the locations. Therefore, models development was attempted at agro-climatic zone level. The models were developed by pooling the data of various districts within the zone so that a long series could be obtained in a relatively shorter period. Models were developed for wheat in Vindhya plateau zone and for rice in Chattisgarh plain & Baster plateau zone taken together (as a portion of Baster district falls under Chhattisgarh plains where remaining under Baster plateau zone and yield figures are available at district level only) . Agriculture inputs, previous year yield and moving average of yield were taken as the variable taking care of technology change. Different strategies for pooling district level data for the zone level adopted. Result revealed that reliable forecast can be obtained using this methodology at 12 weeks i.e about 2 months before at zone level also. The data requirement reduced to 10-15 years as against 25 years(approx) for district level models the studies also revealed that forecast models will be appropriate to forecast the yield of zone even if data for some district within the zone are not available at model development stage (Agrawal *et al* . 2001).this approach was further studies in detail for various district and agro climatic zones of utter Pradesh for one major *kharif* crop (rice) ,one major *rabi* crop (wheat), and long duration crop (sugarcane) so as to come out with a suitable methodology for forecasting crop yield at state level. The results of this study indicated that reliable forecast for rice and wheat can be obtained when crop is 11 weeks old i.e two and half months before harvest. Reliable forecast for sugarcane can be obtained in middle of September using data of 14 fortnights (starting from march first fortnight) (Agrawal *et al.* 2005).

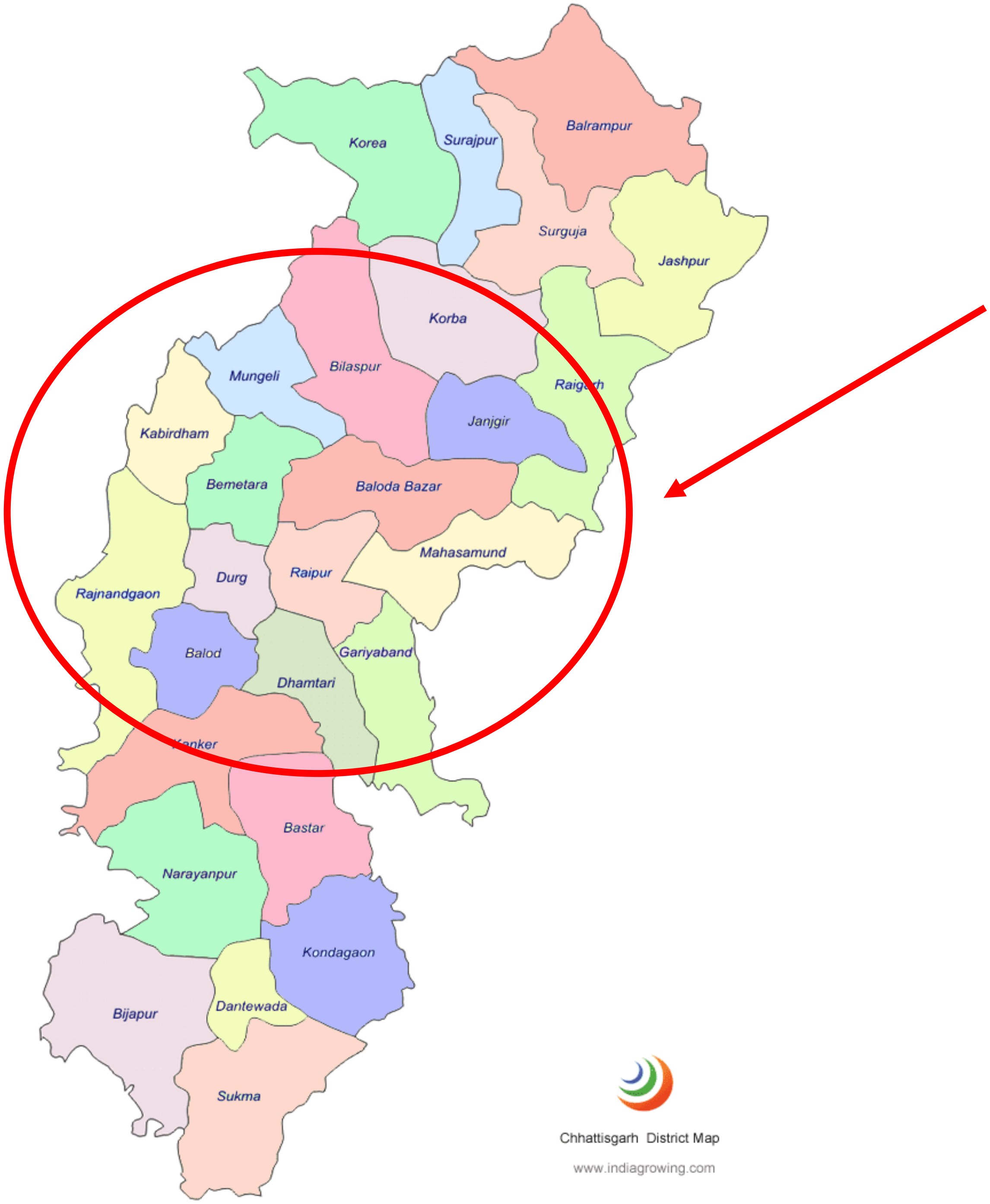
Pandey *et al.* (2017) studied to identify a most important weeks for wheat yield at district level. Weekly data of 18 meteorological weeks on (47th to 52nd weeks on first year and 1st to 12th Standard Meteorological Weeks, SMW for 2nd year) on minimum temperature over a span of 20 year (1995 to 2015) has been used along with the annual wheat production data (used as detrened yield for fitting of model) for Faizabad district of eastern U.P. Distribution of temperature has been recorded for wheat crop. Yield of wheat crop was recorded yearly for the study. The effect of temperature has been calculated for every week and joint effect of all weeks. The effect of temperature for every week has been calculated as correlation coefficient and regression coefficient (R^2) on wheat yield. The model for every week has been developed and testing through F-test. The pattern of temperature has also been depicted through graph. The first week of crop period has been found as most important week i.e. 61% followed by last week 60% (in terms of Coefficient of determination, R^2).

CHAPTER-III
MATERIALS AND METHODS

3.1 Area and Crop Covered:-

The sixteen districts (Raipur, Durg, Rajnandgaon, Bilaspur, Dhamtari, Mahasamund, Korba, Kawardha, Janjgeer, Kanker, Balodabazar, Gariyaband, Bemetara, Mungeli, Balod and Raigarh) out of 27 are chosen basically for the Chhattisgarh plains Zone. Out of these seventeen districts only 9 districts (Raipur, Durg, Rajnandgaon, Bilaspur, Dhamtari, Mahasamund, Korba, Kawardha and Janjgeer) are taken for the study. Which is situated between Korba (22.5472° N, 82.6483° E) to Dhamtari (20.6118° N, 81.7787°E) and Kawardha (22.0991° N, 81.2519° E) to Mahasamund (21.1091° N, 82.0979° E). Five Districts of CPZ namely Balodabazar, Gariyaband, Bemetara, Mungeli and Balod are added afterward in 2012. Two districts Kanker and Raigarh are not added in the study because only few parts of these two districts are covered under CPZ.

CPZ has average annual rainfall of about 1050 mm and is liberally sourced by the different rivers and its tributaries. Soils are deep alluvial, medium to medium heavy textured but are easily ploughable. The favorable climate, soil and the availability of ample irrigation facilities make growing of chickpea and pigeon pea a natural choice for the area. Chickpea and pigeon pea crop is generally cultivated during the rabi season and Kharif season respectively because during this period it provides a better environment for the cultivation of the crops.


Korea
Surajpur
Balrampur
Surguja
Jashpur
Korba
Bilaspur
Mungeli
Kabirdham
Janjgir
Bemetara
Baloda Bazar
Mahasamund
Durg
Raipur
Rajnandgaon
Balod
Gariyaband
Dhamtari
Bastar
Narayanpur
Kondagaon
Bijapur
Dantewada
Sukma
Chhattisgarh District Map
www.indiagrowing.com

Data description:-

3.1.1 Yield data:-

Time series data on yield for Chickpea and pigeon pea crop for 25 years (1990-91 to 2014-15) for Raipur, Durg, Rajnadgaon and Bilaspur Districts. Seventeen year (1998-99 to 2014-15) for Dhamtari, Mahasamund, Korba, Kawardha and Janjgir have been procured from the published booklets and official website (http://agridept.cg.gov.in/index.htm) of the Directorate of Agricultural, Govt.of Chhattisgarh.

3.1.2 Weather data:-

The District wise weekly meteorological data (1990-91 to 2014-15) procured from the department of Agro meteorology, Indira Gandhi Agriculture University, Raipur (CG.) and used for the different districts along with Chhattisgarh plain Zone for Chickpea and Pigeon pea crop. The data have been collected up to the 17 weeks of the chickpea crop cultivation which include 43rd SMW from first year to 7th SMW from 2nd year and 30 meteorological week data for the Pigeon pea which include 27rd SMW from first year to 4th SMW from 2nd year. The data on seven weather variables viz. Maximum Temperature (Tmax) °C, Minimum Temperature (Tmin) °C, Morning Relative Humidity (RH-I)%, Afternoon Relative Humidity (RH-II)%, Bright Sunshine hours (SS) hours/day, Rainfall (mm) and Wind Velocity (WV) have been used in the study.

3.2 Statistical Methodology:-

Crop yield is affected by technological change and weather variability. Technological change includes the impact of increased fertilizer applications, improved management practices, pest and diseases control, improved genetic qualities of seed and other technological factors design to increase yield. It can be assumed that the technological factors will increase yield smoothly through time and, therefore, years or some other parameter of time can be used to study the overall effect on yield.

Weather variability both within and between season is the second and only uncontrollable source of variability in yields.

Weather variables affect the crop differently during different stages of development. These effects are manifested through plant characteristic like height, number of branches, leaf area and number of pods etc. which ultimately affect the yield. Further, weather may also create conditions which may be favorable or unfavorable for the growth of diseases and pests, thereby affecting the crop yield. The effect of weather parameters at different growth stages of the crop may help in understanding their response in terms of final yield and also provide a forecast of crop yield in advance of harvest. The extent of weather influences on crop yield depends not only on the magnitude of weather variables but also on the distribution pattern of weather over the crop season which, as such, calls for the necessity of dividing the whole crop season into fine intervals. This will increase number of variables in the model and in turn a large number of numbers of constants will have to be evaluated from the data. This will require a long series of data for precise estimation of constants which may not be available in practice.

However, in order to study the individual effect of weather variable and joint effect of pair of weather variables, the procedures laid down **Agrawal *et al.* 1986** have been applied. They expressed the effect of change in weather variables on yield in w^{th} week as a linear function of respective correlation coefficients between yield and weather variables. As trend effect on yield is generally expected to be considerable one, its effect need to be removed from yield while calculating correlation coefficients of yield with weather variables to be used as weights.

3.2.1. Individual effect of weather variables:-

In order to study the effect of individual weather variable, two new variables from each weather variable are generated as follows:

Let X_{iw} be the value of i^{th} (i = 1,2,…p) weather variable at w^{th} weeks (w = 1,2,…..n). in this study n is 17 for Check pea and 30 for the pigeon Pea .

Let r_{iw} be the simple correlation coefficient between weather variable X_i at W-th week and crop yield over a period of K years. The generated variables are then given by

$$Z_{ij} = \sum_{w=1}^{n} r_{iw}^{j} x_{iw} \Big/ \sum_{w=1}^{n} r_{iw}^{j} \qquad ; j = 0,1$$

For j = 0 , we have un weighted generated variable

$$Z_{i0} = \sum_{w=1}^{n} X_{iw} \Big/ n$$

and weighted generated variables

$$Z_{i1} = \sum_{w=1}^{n} r_{iw} X_{iw} \Big/ \sum_{w=1}^{n} r_{iw}$$

For each year.

The following model is then fitted to study the effect of individual weather variable

$$Y = a_0 + a_1 z_{i0} + a_2 z_{i1} + a_3 T + \varepsilon \qquad ; i = 1,2,\ldots..p$$

where Y is yield ; T is variable expressing time effect, a_0, a_1, a_2 and a_3 are parameters of the model to be estimated for the effect of variables and ε is error term supposed to follow normal distribution with mean zero and variance σ2.

The above model is fitted using multiple regression method for each weather variable. The study consist of 9 districts and CPZ.

3.2.2. Joint effect of weather variables on crop yield:-

For studying the joint effect of two weather variables on crop-yield, the model in sub section **3.2.1** has been extended by including interaction terms in the model as follows:

$$Q_{ii',j} = \sum_{w=1}^{n} r_{ii',w}^{j} X_{iw} X_{i'w} \Big/ \sum_{w=1}^{n} r_{ii',w}^{j} \qquad ;j = 0,1$$

where $r_{ii',w}$ is the correlation coefficient between crop yield Y and product of weather variables X_{iw} and $X_{i'w}$. Clearly, we have two generated variables (interaction term)

$$Q_{ii',0} = \sum_{w=1}^{n} X_{iw} X_{i'w} \Big/ n \, ,$$

un weighted,

and

$$Q_{ii',1} = \sum_{w=1}^{n} r_{ii',w}^{j} X_{iw} X_{i'w} \Big/ \sum_{w=1}^{n} r_{ii',w}$$

the weighted one.

Including these two interaction terms in the model given sub-section **(3.2.1),** we have a new model to study the effect of joint weather variables as

$$Y = a + \sum_{i=1}^{2} \sum_{j=0}^{1} b_{ij} Z_{ij} + \sum_{j=0}^{1} b_{ii',j} Q_{ii'j} + cT + \varepsilon$$

Where b_{ij} and $b_{ii',j}$ are parameters (regression coefficients) of the model, and other terms have already been explained previous model **(sub-section-3.2.1).** The above model is fitted using multiple regression method for each weather variable. The study consist 9 district and CPZ.

3.2.3 Forecast Model based on weather variables through Step wise Regression Analysis (SRA):-

Let m denotes the week (w = 1,2,…m) at which pre-harvest forecast of crop-yield need to be released. Using the weekly data on m weeks of p weather variables (p= 7 here), new weather variables and interaction components have been generated with respect to each weather variable following the procedures laid down in the sub-section((3.2.1) and (3.2.2)). Forecast model has been developed considering all generated variables simultaneously including time trend (T). The model used is similar to one described in section (3.2.2), which can be written as

Model – I : $$Y = a + \sum_{i=1}^{p} \sum_{j=0}^{2} b_{ij} z'_{ij} + \sum_{i \neq i'=1'}^{p} \sum_{j=0}^{2} b_{ii'j} Q_{ii'j} + CT + \in$$

Where

$$Z_{ij} = \sum_{w=1}^{m} r_{iw}^{j} X_{iw} \Big/ \sum_{w=1}^{m} r_{iw}^{j}$$

and $$Q_{ii',j}^{'} = \sum_{w=1}^{m} r_{ii',w}^{j} X_{iw} X_{i'w} \Big/ \sum_{w=1}^{m} r_{ii',w}^{j}$$

X_{iw} is the value of the i^{th} weather variable in w^{th} week, $r_{iw}/r_{ii'w}$ is correlation coefficient of yield adjusted for trend effect with i^{th} weather variable/product of i^{th} and i'^{th} weather variable in w^{th} week.

This procedure is based on the method given by **Agrawal *et al*. (1986)** for developing forecast model using weather indices. In this procedure the entire 17 weeks data (w = 1, 2,…17) for Chick pea and 30 week data on Pigeon Pea a year have been utilized for constructing weighted and un weighted weather indices of weather variables along with their interactions. The weighted indices are weighted average of the weather variables over weeks, weights being the correlation coefficients between the yield and the respective weather variable. The un-weighted indices are the simple average of the weather variables over the weeks. Similarly the unweighted and weighted indices of interactions between the weather variables have been obtained using product of weather variables (taking two at a time). In all 56 indices (28 weighted and 28 un weighted) consisting of 07 weighted weather indices and 07 unweighted weather indices; 21 weighted interaction indices and 21 unweighted interaction indices have been obtained. Considering these 56 indices and trend as regressors and yield as dependent variable, forecast model will be developed by using stepwise regression method for each district and for the CPZ.

Development of Pre harvest forecast model using Principal component analysis:

PCA is a multivariate technique for data reduction. It is a mathematical function, which does not require user to specify the statistical model or assumption about distribution of original variables. It may also be mentioned that principal components are artificial variables and often it is not possible to assign physical meaning to them. Further, since principal component analysis transforms original set of correlated variables to new set of uncorrelated variables, it is worth stressing that if original variables are uncorrelated, than there is no point in carrying out principal component analysis. The theory of principal component analysis is available in many standard books on multivariate analysis (Anderson, *et al.,* 1984).

Let X_{ij} be the value of j^{th} biometrical character (j= 1, 2,...p) corresponding to i^{th} varieties of experiment (i= 1, 2,...n). The PCA for $x_{ij's}$ will be carried out. Let PC_1, PC_2, ...PC_K be first K (K< P) principal components explaining variability about more than 70 to 90 percent of the total variation in $x_{ij's}$. Using these K principal components as regressor variables and varieties yield (y_i) as regressand, the following linear multiple regression model for pre-harvest forecast of crop yield has been proposed.

$$Y_i = \beta_0 + \beta_1 PC_{1i} + \beta_2 PC_{2i} + ... + \beta_k PC_{ki} + e_i \qquad , i= 1, 2, ...n.$$

Where Y_i is the crop yield of the i^{th} plot; β_0, β_1, β_2 β_k are model parameters and e_i is error term assumed to follow independently normal distribution with mean 0 and variance σ^2. The aforesaid model is fitted with the data by least square technique.

The stepwise analysis has been used for the study of effect (individual and joint) on yield for the both the crop and for the model Development by using multiple regression analysis and principal component analysis.

Measures for validation and comparison of the models

Two procedures have been used for the comparison and the validation of the developed models. These procedures are given bellow.

Coefficient of determination (R^2) and (R^2_{adj})

The models were validated on the basis of **(R^2) and (R^2_{adj})** which can be computed from the formula given by **Drapper and Smith (1988).**

It is in general used for checking the adequacy of the model. R^2 is given by the following formula

$$R^2 = 1 - \frac{ss_{res}}{ss_t}$$

Where ss_{res} and ss_t are the residual sum of square and the total sum of square respectively.

R^2 never decreases when a regressed is added to the model, regardless of the value of the contribution of the variable in the model. Therefore, it is difficult to judge whether an increase in R^2 is really important. So it is preferable to use Adjusted R^2 when models to be compared are based on different number of regressed.

Adjusted R^2 is given by the following formula

$$R_{adj}^2 = 1 - \frac{ss_{res}/(n-p)}{ss_t/(n-1)}$$

where $ss_{res}/(n\text{-}p)$ is the residual mean square and $ss_t/(n\text{-}1)$ is the total mean square. The total mean square is constant regardless of how many variables are in the model. On adding a regressed in the model Adjusted R^2 increases only if the addition of the regressed reduces the residual mean square. It also penalizes for adding terms that are not helpful, so it is very important in evaluating and comparing the regression models.

Percent Deviation:-

The formulae for computation of Percent Deviation of forecast yield from actual yield are given by Mohd. Azfar *et al.* (2015) this measures the deviation (in percentage) of forecast from the actual yield data. The formula for calculating the percent deviation of forecast is given below:

$$\textit{Percentage deviation} = \frac{\text{(Actual yield- Forecasted yield)}}{\text{(Actual yield)}} \times 100$$

CHAPTER-IV

RESULTS AND DISCUSSION

This chapter deals with the results obtained by analyzing the data collected for a Period of twenty five years (i.e., from 1990-91 to2014-15) for the different districts of Chhattisgarh plain zone of Chhattisgarh State. The results obtained so far from the data of present investigation have been divided and presented here under the following four sections:

4.1 Individual Effect Weather Variables.

4.2 Joint effect of Weather Variables.

4.3 Model based on Stepwise Regression Analysis (SRA).

4.4 Model based on Principal Component Analysis (PCA).

4.1. Individual effect Weather Variables

In the present section new weather variables (unweighted and weighted mean of weekly weather data) for all weather variables have been used to study the effect of individual weather variable.

4.1.1. Individual effect of Maximum Temperature for Plain zone on chickpea

The multiple regression equation obtained is:

$$\mathbf{Y} = 1372.3 - 78.0\,\mathbf{Z_{10}} + 47.4\,\mathbf{Z_{11}} + 17.6\,\mathbf{T}$$

Generated variable Z_{10} (unweighted individual variable) has been found significant at 5% and Z_{11} (weighted individual variable) has been found significant at 5 % level and Time trend also found significant at 0.1% level. The coefficient of determination (R^2) has been found to be 71 % which is significant at 0.1% level. The summary of the result is given in table 4.1.1.The results indicate that weighted mean of Maximum Temperature during the entire period of crop production has been found to be relatively more important to exhibit its effect on crop yield.

Table-4.1.1. Individual effect of Max. Temperature for Plain zone on chickpea.

	Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Max Temp	Intercept	1372.3	767.6133	0.09	0.001	0.71***
	Z_{10}	-78.0*	30.63555	0.02		
	Z_{11}	47.4*	20.35142	0.03		
	T	17.6***	3.575137	0.001		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

4.1.2. Individual effect of MinimumTemperature for Plain zone on chickpea

The multiple regression equation obtained is

$$\mathbf{Y} = 760.38 - 92.88\ \mathbf{Z_{20}} + 73.40\ \mathbf{Z_{21}} + 15.77\ \mathbf{T}$$

Generated variable Z_{20} (unweighted individual variable) has been found significant at 1 % level, Z_{21} (weighted individual variable) has been found significant at 1 % level and Time trend also found significant at 0.1% level. The coefficient of determination (R^2) has been found to be 73 % which is significant at 0.1% level. The summary of the result is given in table 4.1.2. The results indicate that weighted mean of Minimum Temperature during the entire period of crop production has been found to be relatively more important to exhibit its effect on crop yield.

Table-4.1.2. Individual effect of Min.Temperature for Plain zone on chickpea.

	Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Max Temp	Intercept	760.38**	254.2112	0.006	0.001	0.73***
	Z_{20}	-92.88**	32.05056	0.008		
	Z_{21}	73.40**	24.30922	0.006		
	T	15.77***	3.802182	0.0004		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

4.1.3. Individual effect of Relative Humidity-I for Plain zone on chickpea

The multiple regression equation obtained is

$$\mathbf{Y} = 670.03 + 17.32\ \mathbf{T}$$

Generated variable Time trend also found significant at 0.1% level. The coefficient of determination (R^2) has been found to be 62 % which is significant at 0.1% level. The summary of the result is given in table 4.1.3. The results indicate that weighted mean of Relative Humidity-I during the entire period of crop production has been found to be relatively more important to exhibit its effect on crop yield.

Table-4.1.3.Individual effect of RH-I for Plain zone on chickpea.

	Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
RH-I	Intercept	670.03	960.291	0.49	0.001	0.62^{***}
	T	17.32^{***}	4.680745	0.001		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

4.1.4. Individual effect of Relative Humidity-II for Plain zone on chickpea

The multiple regression equation obtained is

$$\mathbf{Y} = 497.46 + 17.28\ \mathbf{T}$$

Generated variable Time trend also found significant at 0.1% level. The coefficient of determination (R^2) has been found to be 64 % which is significant at 0.1% level. The summary of the result is given in table 4.1.4. The results indicate that weighted mean of Relative Humidity-II during the entire period of crop production has been found to be relatively more important to exhibit its effect on crop yield.

Table.4.1.4 Individual effect of RH-II for Plain zone on chickpea.

	Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
RH-II	Intercept	497.46^{**}	170.6189	0.008	0.001	0.64^{***}
	T	17.28^{***}	3.810727	0.0001		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

4.1.5. Individual effect of Sunshine for Plain zone on chickpea

The multiple regression equation obtained is

$$\mathbf{Y} = 584.31 - 50.87\, \mathbf{Z_{51}} + 14.78\, \mathbf{T}$$

Generated variable Z_{51} (weighted individual variable) has been found significant at 1 % level and Time trend also found significant at 0.1% level. The coefficient of determination (R^2) has been found to be 71 % which is significant at 0.1% level. The summary of the result is given in table 4.1.5.The results indicate that weighted mean of Sunshine during the entire period of crop production has been found to be relatively more important to exhibit its effect on crop yield.

Table-4.1.5. Individual effect of Sunshine for Plain zone on chickpea.

	Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
SS	Intercept	584.31^{*}	275.8892	0.04	0.001	0.71^{***}
	Z_{51}	-50.87^{**}	18.49826	0.01		
	T	14.78^{***}	3.668575	0.0006		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

4.1.6. Individual effect of Rainfall for Plain zone on chickpea

The multiple regression equation obtained is

$$\mathbf{Y} = 502.72 + 13.31\, \mathbf{Z_{60}} - 9.07\, \mathbf{Z_{61}} + 14.89\, \mathbf{T}$$

Generated variable Z_{60} (unweighted individual variable) has been found significant at 5 % level, Z_{61} (weighted individual variable) has been found significant at 0.1% level and Time trend also found significant at 0.1% level. The coefficient of determination (R^2) has been found to be 80 % which is significant at 0.1% level. The summary of the result is given in table 4.1.6. The results indicate that weighted mean of Rainfall during the entire period of crop production has been found to be relatively more important to exhibit its effect on crop yield.

Table-4.1.6. Individual effect of Rainfall for Plain zone on chickpea.

	Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
RF	Intercept	502.72***	34.51294	0.001	0.001	0.85***
	Z_{60}	13.31*	6.25689	0.04		
	Z_{61}	-9.07***	1.53144	0.001		
	T	14.89***	2.184938	0.001		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

4.1.7. Individual effect of Wind velocity for Plain zone on chickpea

The multiple regression equation obtained is

$$\mathbf{Y} = 622.08 + 405.63\,\mathbf{Z_{70}} - 435.3\,\mathbf{Z_{71}} + 16.2993\,\mathbf{T}$$

Generated variable Z_{70} (unweighted individual variable) has been found significant at 5 % level, Z_{71} (weighted individual variable) has been found significant at 5 % level and Time trend also found significant at 0.1% level. The coefficient of determination (R^2) has been found to be 70 % which is significant at 0.1% level. The summary of the result is given in table 4.1.7. The results indicate that weighted mean of Wind velocity during the entire period of crop production has been found to be relatively more important to exhibit its effect on crop yield.

Table-4.1.7. Individual effect of Wind velocity for Plain zone on chickpea.

	Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
WV	Intercept	622.08***	119.4206	0.001	0.001	0.70***
	Z_{70}	405.63*	179.606	0.03		
	Z_{71}	-435.3*	173.5792	0.02		
	T	16.2993***	3.266191	0.001		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

4.1.8. Individual effect of Maximum Temperature for Plain zone on Pigeonpea

The multiple regression equation obtained is

$$\mathbf{Y} = 5150.52 + 178.86\,\mathbf{Z_{10}} - 324.7\,\mathbf{Z_{11}} - 17.72\,\mathbf{T}$$

Generated variable Z_{10} (unweighted individual variable) has been found significant at 5% and Z_{11} (weighted individual variable) has been found significant at 0.1% level and Time trend also found significant at 0.1% level. The coefficient of determination (R^2) has been found to be 76 % which is significant at 0.1% level. The summary of the result is given in table 4.1.8. The results indicate that weighted mean of Maximum Temperature during the entire period of crop production has been found to be relatively more important to exhibit its effect on crop yield.

Table-4.1.8. Individual effect of Max. Temperature for Plain zone on Pigeonpea.

	Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
	Intercept	5150.52**	1466.193	0.002		
Max	Z_{10}	178.86^{+}	103.4754	0.09	0.001	0.76***
Temp	Z_{11}	-324.70***	90.22105	0.001		
	T	-17.72***	4.351666	0.0005		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

4.1.9. Individual effect of MinimumTemperature for Plain zone on Pigeonpea

The multiple regression equation obtained is

$$\mathbf{Y} = 4520.72 + 260.79\, \mathbf{Z_{20}} - 417.22\, \mathbf{Z_{21}}$$

Generated variable Z_{20} (unweighted individual variable) has been found significant at 10 % level and Z_{21} (weighted individual variable) has been found significant at 1 % level. The coefficient of determination (R^2) has been found to be 68 % which is significant at 0.1% level. The summary of the result is given in table 4.1.9. The results indicate that weighted mean of MinimumTemperature during the entire period of crop production has been found to be relatively more important to exhibit its effect on crop yield.

Table-4.1.9. Individual effect of Min.Temperature for Plain zone on Pigeonpea.

	Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Min. Temp.	Intercept	4520.72***	1203.533	0.001	0.001	0.68***
	Z_{20}	260.79+	138.1994	0.07		
	Z_{21}	-417.22**	150.1674	0.01		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

4.1.10. Individual effect of Relative Humidity-I for Plain zone on Pigeonpea

The multiple regression equation obtained is

$$\mathbf{Y} = 4520.72 - 10.50\ \mathbf{T}$$

Generated variable Time trend also found significant at 0.1% level. The coefficient of determination (R^2) has been found to be 61 % which is significant at 0.1% level. The summary of the result is given in table 4.1.10. The results indicate that weighted mean of Relative Humidity-I during the entire period of crop production has been found to be relatively more important to exhibit its effect on crop yield.

Table-4.1.10. Individual effect of RH-I for Plain zone on Pigeonpea.

	Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
RH-I	Intercept	-2343.1	2470.793	0.35	0.001	0.61***
	T	-22.49***	5.991718	0.001		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

4.1.11. Individual effect of Relative Humidity-II for Plain zone on Pigeonpea

The multiple regression equation obtained is

$$\mathbf{Y} = 333.74 + 27.66\ \mathbf{Z_{41}} - 19.36\ \mathbf{T}$$

Generated variable Z_{41} (weighted individual variable) has been found significant at 5 % level and Time trend also found significant at 0.1% level. The coefficient of determination (R^2) has been found to be 67 % which is significant at

0.1% level. The summary of the result is given in table 4.1.11. The results indicate that weighted mean of Relative Humidity-II during the entire period of crop production has been found to be relatively more important to exhibit its effect on crop yield.

Table-4.1.11. Individual effect of RH-II for Plain zone on Pigeonpea.

	Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
RH-II	Intercept	333.74	504.7416	0.51	0.001	0.67^{***}
	Z_{41}	27.66^{*}	10.69261	0.02		
	T	-19.36^{***}	5.373371	0.001		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

4.1.12. Individual effect of Sunshine for Plain zone on Pigeonpea

The multiple regression equation obtained is

$$\mathbf{Y} = 1429.57 - 119.41\,\mathbf{Z_{50}} - 9.57\,\mathbf{Z_{51}} - 22.36\,\mathbf{T}$$

Generated variable Z_{50} (unweighted individual variable) has been found significant at 5 % level, Z_{51} (weighted individual variable) has been found significant at 1 % level and Time trend also found significant at 0.1% level. The coefficient of determination (R^2) has been found to be 66 % which is significant at 0.1% level. The summary of the result is given in table 4.1.12. The results indicate that weighted mean of Sun shine during the entire period of crop production has been found to be relatively more important to exhibit its effect on crop yield.

Table-4.1.12. Individual effect of Sunshine for Plain zone on Pigeonpea.

	Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
SS	Intercept	1429.57***	398.405	0.001	0.001	0.66***
	Z_{50}	-119.41*	65.54236	0.08		
	Z_{51}	-9.57**	3.68359	0.01		
	T	-22.36***	5.292058	0.0003		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

4.1.13. Individual effect of Rainfall for Plain zone on Pigeonpea

The multiple regression equation obtained is

$$\mathbf{Y} = 787.23 + 8.46\,\mathbf{Z_{60}} - 1.16\,\mathbf{Z_{61}} - 26.5\,\mathbf{T}$$

Generated variable Z_{60} (unweighted individual variable) has been found significant at 5 % level, Z_{61} (weighted individual variable) has been found significant at 1% level and Time trend also found significant at 0.1% level. The coefficient of determination (R^2) has been found to be 68 % which is significant at 0.1% level. The summary of the result is given in table 4.1.13. The results indicate that weighted mean of Rainfall during the entire period of crop production has been found to be relatively more important to exhibit its effect on crop yield.

Table-4.1.13. Individual effect of Rainfall for Plain zone on Pigeonpea.

	Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2(Adj)
RF	Intercept	787.23***	128.6298	0.001	0.001	0.68***
	Z_{60}	8.46*	4.1566	0.05		
	Z_{61}	-1.16**	0.393456	0.007		
	T	-26.5***	4.81147	0.001		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

4.1.14. Individual effect of Wind velocity for Plain zone on Pigeonpea

The multiple regression equation obtained is

$$\mathbf{Y} = 787.32 - 367.64\ \mathbf{Z_{70}} + 299.07\ \mathbf{Z_{71}} - 22.99\ \mathbf{T}$$

Generated variable Z_{70} (unweighted individual variable) has been found significant at 1 % level, Z_{71} (weighted individual variable) has been found significant at 1% level and Time trend also found significant at 0.1% level. The coefficient of determination (R^2) has been found to be 67 % which is significant at 0.1% level. The summary of the result is given in table 4.1.14. The results indicate that weighted mean of Wind velocity during the entire period of crop production has been found to be relatively more important to exhibit its effect on crop yield.

Table-4.1.14. Individual effect of Wind velocity for Plain zone on Pigeonpea.

	Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
WV	Intercept	787.32**	228.5089	0.002	0.001	0.67***
	Z_{70}	-367.64**	124.0908	0.007		
	Z_{71}	299.07**	95.97726	0.005		
	T	-22.99***	5.160188	0.0002		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

Table-4.1.15. Individual effect of All Districts for Plain zone on Chickpea.

Name of District	Name of Parameter	Most significant Variable Entered in Model	Coefficient of Entered Variable	R^2 (Adjusted)
Raipur	Max	T	22.40***	0.69***
	Min	T	20.90***	0.63***
	RH-1	T	20.30***	0.64***
	RH-2	T	22.55***	0.61***
	BSS	T	20.85***	0.63***
	RF	T	20.69***	0.73***
	WV	T	19.73***	0.64***

Bilaspur	Max	T	23.38***	0.67***
	Min	T	24.54***	0.73***
	RH-1	T	20.59***	0.66***
	RH-2	T	22.52***	0.68***
	BSS	T	23.08***	0.75***
	RF	T	21.71***	0.71***
	WV	T	23.54***	0.64***
Durg	Max	T	21.49***	0.56***
	Min	T	23.84***	0.60***
	RH-1	T	18.95***	0.54***
	RH-2	T	21.85***	0.55***
	BSS	T	20.82***	0.63***
	RF	Z_{61}	-12.12***	0.69***
		T	21.03***	
	WV	T	19.83***	0.51***
Rajnandgaon	Max	T	19.95***	0.64***
	Min	T	18.73***	0.65***
	RH-1	T	16.63***	0.59***
	RH-2	T	18.29***	0.60***
	BSS	T	17.50***	0.66***
	RF	T	17.16***	0.63***
	WV	T	17.95***	0.59***
Mahasamund	Max	Z_{11}	-108.83**	0.61***
	Min	Z_{21}	218.12***	0.71***
	RH-1	T	7.74***	0.68***
	RH-2	Z_{41}	48.66***	0.71***
	BSS	Z_{51}	97.17*	0.47**
	RF	Z_{61}	2.50**	0.62***
	WV	Z_{71}	-733.1***	0.75***
Dhamtari	Max	T	27.37***	0.83***
	Min	Z_{21}	116.65**	0.82***
	RH-1	T	25.48**	0.72***
	RH-2	T	23.30***	0.63***
	BSS		T	61***
	RF	T	28.6**	0.71***
	WV	T	24.46***	0.79***
Kawardha	Max	T	17.90**	0.73***
	Min	Z_{21}	116.17**	0.72***
	RH-1	T	14.16^{+}	0.61***
	RH-2	Z_{41}	36.007***	0.81***
	BSS	Z_{51}	-184.29***	0.72***
	RF	T	17.77**	0.64***

	WV	T	17.37^{*}	0.53^{**}
Korba	Max	T	15.68^{**}	0.50^{**}
	Min	Z_{21}	85.87^{**}	0.61^{***}
	RH-1	Z_{31}	23.07^{**}	0.57^{**}
	RH-2	Z_{41}	15.59^{***}	0.67^{***}
	BSS	Z_{51}	-139.95^{***}	0.70^{***}
	RF	T	14.8^{*}	0.52^{**}
	WV	Z_{71}	-258.9^{**}	0.58^{**}
Janjgir	Max	T	25.28^{**}	0.63^{***}
	Min	Z_{21}	168.21^{*}	0.68^{***}
	RH-1	Z_{31}	30.04^{***}	0.84^{***}
	RH-2	T	21.89^{**}	0.75^{***}
	BSS	Z_{51}	-262.96^{**}	0.73^{***}
	RF	T	27.62^{***}	0.71^{***}
	WV	Z_{71}	-558.4^{***}	0.80^{***}

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Table 4.1.15 indicates that the value of R^2 on sunshine hours for Mahasamund, wind velocity for Kawardha and Relative humidity-I, Maximum Temperature, Rainfall and wind velocity for Korba found significant at 1% level of significance and rest the variables for all the districts found significant at 0.01% level of significance.

Table-4.1.16. Individual effect of All Districts for Plain zone on Pigeonpea.

Name of District	Name of Parameter	Most significant Variable Entered in Model	Coefficient of Entered Variable	R^{2} (Adjusted)
Raipur	Max	Z_{11}	-253.48^{***}	0.78^{***}
		T	-15.94^{***}	
	Min	Z_{21}	-285.11^{**}	0.69^{***}
	RH-1	T	-17.27^{***}	0.66^{***}
	RH-2	T	-15.70^{***}	0.73^{***}
	BSS	T	-18.04^{***}	0.72^{***}
	RF	T	-23.05^{***}	0.73^{***}

	WV	T	-18.79***	0.69***
Bilaspur	Max	T	-23.21***	0.76***
	Min	T	-27.67***	0.65***
	RH-1	T	-28.67***	0.63***
	RH-2	T	-26.54***	0.70***
	BSS	Z_{51}	12.16***	0.72***
		T	-28.25***	
	RF	Z_{61}	-0.71***	0.77***
		T	-35.86***	
	WV	T	-28.81***	0.69***
Durg	Max	Z_{11}	-404.79***	0.65***
	Min	Z_{21}	-430.46**	0.62***
	RH-1	T	-13.88*	0.44***
	RH-2	Z_{41}	27.93***	0.63***
	BSS	Z_{51}	46.40***	0.68***
	RF	Z_{61}	-3.14***	0.68***
		T	-22.43***	
	WV	Z_{71}	220.74***	0.58***
Rajnandgaon	Max	T	-22.41***	0.79***
	Min	T	-18.53*	0.64***
	RH-1	T	-21.64***	0.72***
	RH-2	T	-22.64***	0.73***
	BSS	T	-26.77***	0.75***
	RF	T	-30.04***	0.68***
	WV	T	-25.79***	0.70***
Mahasamund	Max	Z_{11}	-132.5**	0.59***
	Min	Z_{21}	-173.18***	0.54**
	RH-1	Z_{31}	54.33*	0.31*
	RH-2	Z_{41}	33.68**	0.51**
	BSS	Z_{51}	-35.38**	0.62***
	RF	Z_{61}	-1.63***	0.69***
	WV	Z_{71}	20.64***	0.57**
Dhamtari	Max	Z_{11}	-160.31**	0.62***
	Min	Z_{21}	-81.04***	0.50**
	RH-1	Z_{31}	76.94*	0.33*
	RH-2	Z_{41}	32.12*	0.56**
	BSS	Z_{51}	-52.44***	0.64***
	RF	Z_{61}	-0.30***	0.70***
	WV	Z_{71}	-24.98***	0.54**
Kawardha	Max	Z_{11}	-190.6**	0.63***
	Min	Z_{21}	-137.3***	0.60***
	RH-1	Z_{31}	112.92**	0.46**

	RH-2	Z_{41}	40.84*	0.58**
	BSS	Z_{51}	-47.00**	0.60***
	RF	Z_{61}	-2.37***	0.64***
	WV	Z_{71}	-10.11***	0.59***
Korba	Max	Z_{11}	-205.15***	0.64***
	Min	Z_{21}	-113.40***	0.54**
	RH-1	Z_{31}	134.21**	0.38*
	RH-2	Z_{41}	42.99**	0.58**
	BSS	Z_{51}	-68.80***	0.71***
	RF	Z_{61}	-1.90***	0.70***
	WV	Z_{71}	-40.87***	0.65***
Janjgir	Max	Z_{11}	-268.30***	0.66***
	Min	Z_{21}	-247.86***	0.51**
	RH-1	Z_{31}	101.39*	0.35*
	RH-2	Z_{41}	61.58**	0.58**
	BSS	Z_{51}	-72.40**	0.65***
	RF	Z_{61}	-1.68***	0.73***
	WV	Z_{71}	104.24***	0.57**

Table 4.1.16 indicates that the value of R^2 on Relative humidity-I for Mahasamund, Dhamtari and Janjgir found the significant at 5% level of significance and rest the variables for all the districts found significant either 1% or 0.01% level of significance.

4.2. Joint effect of Weather Variables

Total seven variables i.e. (individual unweighted (02), weighted (02) and interaction variable (02) (unweighted and weighted) and Time trend, Most of the interaction variables fond not significant or very less significant at the time of Step wise regression, only significant variables entered into model and fitted for the study of joint effect of weather variables.

4.2.1. Joint effect of Max. Temp and Min. temp for Plain zone on chickpea

Table 4.2.1 indicates that the variable maximum temperature and minimum temperature along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

Y=371.11+ 18.47**T**

Table-4.2.1.Joint effect of Max. Temp and Min. temp for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	371.11^{+}	32.041	0.08	0.001	0.63^{***}
T	18.47^{***}	4.097	0.001		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.$

Out of seven variables time trend (T) found highly significant at 0.1% level of significance. The value of Coefficient of determination (R^2) found (63 %) high significant at 0.1% level of significance.

4.2.2. Joint effect of Max. Temp and RH-I for Plain zone on chickpea

Table 4.2.2 indicates that the variable maximum temperature and relative humidity-I along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

Y=362.110+ 19.34 **T**

Table-4.2.2. Joint effect of Max. Temp and RH-I for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	362.110	39.06	0.62	0.001	0.67^{***}
T	19.34^{***}	5.84	0.001		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) found highly significant at 0.1% level of significance. The value of Coefficient of determination (R^2) found (67%) high significant at 0.1% level of significance.

4.2.3. Joint effect of Max. Temp and RH-II for Plain zone on chickpea

Table 4.2.3 indicates that the variable maximum temperature and relative humidity-II along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y= 462.11+ 21.54\ \mathbf{T}$$

Table-4.2.3. Joint effect of Max. Temp and RH-II for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	462.11^{*}	41.26	0.04	0.001	0.62^{***}
T	21.54^{***}	4.38	0.001		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) found highly significant at 0.1% level of significance. The value of Coefficient of determination (R^2) found (62%) high significant at 0.1% level of significance.

4.2.4. Joint effect of Max. Temp and Sun Shine for Plain zone on chickpea

Table 4.2.4 indicates that the variable maximum temperature and Sun Shine along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y= 816.072 -1.254\ \mathbf{Q_{151}} + 15.551\ \mathbf{T}$$

Table-4.2.4. Joint effect of Max. Temp and Sun Shine for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	816.072	144.699	0.17		
T	15.55^{***}	3.423	0.001	0.001	0.70^{***}
Q_{151}	-1.25^{*}	.504	0.02		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) found significant at 0.1% level of significance, Q_{151} (weighted interaction of maximum and sunshine) found significant at 5% level, The value of Coefficient of determination (R^2) found (70%) high significant at 0.1% level of significance.

4.2.5. Joint effect of Max. Temp and Rainfall for Plain zone on chickpea

Table 4.2.5 indicates that the variable maximum temperature and rainfall along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 533.109 - 0.283\, \mathbf{Q_{161}} + 15.498\, \mathbf{T}$$

Table-4.2.5. Joint effect of Max. Temp and Rainfall for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	533.109	32.608	0.40		
T	15.49^{***}	2.248	0.001	0.001	0.84^{***}
Q_{161}	-0.28^{***}	.052	0.001		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) and Q_{161} (weighted interaction of maximum and rainfall) found significant at 0.1% level, the value of Coefficient of determination (R^2) found (84%) high significant at 0.1% level of significance.

4.2.6. Joint effect of Max. Temp and Wind velocity for Plain zone on chickpea

Table 4.2.6 indicates that the variable maximum temperature and wind velocity along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 471.110 + 20.46\, \mathbf{T}$$

Table-4.2.6. Joint effect of Max. Temp and Wind velocity for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	471.110	46.041	0.75	0.001	0.64^{***}
T	20.46^{***}	3.097	0.001		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) found significant at 0.1% level of significance. The value of Coefficient of determination (R^2) found (64%) high significant at 0.1% level of significance.

4.2.7. Joint effect of Min. Temp and RH-I for Plain zone on chickpea

Table 4.2.7 indicates that the variable minimum temperature and Relative humidity-I along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 204.332 - 0.97\, \mathbf{Q_{230}} + 1.30\, \mathbf{Q_{231}} + 10.37\, \mathbf{T}$$

Table-4.2.7. Joint effect of Min. Temp and RH-I for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	204.332	228.674	0.35		
T	10.37^{**}	3.307	0.005	0.001	0.80^{***}
Q_{231}	1.30^{***}	.278	0.001		
Q_{230}	-0.97^{**}	.307	0.005		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) and Q_{230} (unweighted interaction of minimum and relative humidity-I) found significant at 1 % level, Q_{231} (weighted interaction of minimum and relative humidity-I) found significant at 0.1 % level. The value of Coefficient of determination (R^2) found (80%) high significant at 0.1% level of significance.

4.2.8. Joint effect of Min. Temp and RH-II for Plain zone on chickpea

Table 4.2.8 indicates that the variable minimum temperature and Relative humidity-II along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 465.807 + 0.207\, \mathbf{Q_{241}} + 13.83\, \mathbf{T}$$

Table-4.2.8. Joint effect of Min. Temp and RH-II for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	465.80^{*}	39.959	0.03		
T	13.83^{***}	3.509	0.001	0.001	0.72^{***}
Q_{241}	0.207^{***}	.070	0.008		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) and Q_{241} (interaction of minimum temperature and relative humidity-II) found significant at 0.1% level of significance, the value of Coefficient of determination (R^2) found (72%) high significant at 0.1% level of significance.

4.2.9. Joint effect of Min. Temp and Sun Shine for Plain zone on chickpea

Table 4.2.9 indicates that the variable minimum temperature and sun shine along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y= 868.070 - 41.93\, \mathbf{Z_{51}} + 14.61\, \mathbf{T}$$

Table-4.2.9. Joint effect of Min. Temp and Sun Shine for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	868.070^{+}	170.268	0.08		
T	14.61^{***}	3.722	0.001	0.001	0.70^{***}
Z_{51}	-41.93^{*}	17.435	0.02		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) found highly significant at 0.1% level of significance, Z_{51} (weighted sunshine) found significant at 5% level. The value of Coefficient of determination (R^2) found (70%) high significant at 0.1% level of significance.

4.2.10. Joint effect of Min. Temp and Rainfall for Plain zone on chickpea

Table 4.2.10 indicates that the variable minimum temperature and rainfall along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y= 528.420 - 0.44\, \mathbf{Q_{261}} + 14.91\, \mathbf{T}$$

Table-4.2.10. Joint effect of Min. Temp and Rainfall for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	528.420**	31.438	0.005		
T	14.91***	2.226	0.001	0.001	0.86***
Q_{261}	-0.44***	.077	0.001		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

Out of seven variables time trend (T) and Q_{261} (weighted interaction between minimum temperature and rainfall) found significant at 0.1 % level. The value of Coefficient of determination (R^2) found (86%) high significant at 0.1% level of significance.

4.2.11. Joint effect of Min. Temp and Wind velocity for Plain zone on chickpea

Table 4.2.11 indicates that the variable minimum temperature and wind velocity along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 536.561 + 9.41\, \mathbf{Q_{270}} - 8.96\, \mathbf{Q_{271}} + 14.99\, \mathbf{T}$$

Table-4.2.11. Joint effect of Min. Temp and Wind velocity for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	536.561**	99.169	0.007		
T	14.99***	2.991	0.001	0.001	0.75***
Q_{271}	-8.96**	2.564	0.002		
Q_{270}	9.41*	4.221	0.03		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

Out of seven variables time trend (T) found significant at 0.1% level of significance, Q_{270} (unweighted interaction between minimum temperature and wind velocity) found significant at 5% level, Q_{271} (weighted interaction between minimum temperature and wind velocity) found significant at 1% level. The value of Coefficient of determination (R^2) found (75%) high significant at 0.1% level of significance.

4.2.12. Joint effect of RH-I and RH-II for Plain zone on chickpea

Table 4.2.12 indicates that the variable relative humidity-I and relative humidity-II along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y= 471.110 + 20.46 \mathbf{T}$$

Table-4.2.12. Joint effect of RH-I and RH-II for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	471.110	46.041	0.39	0.001	0.64^{***}
T	20.46^{***}	3.097	0.001		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) found highly significant at 0.1% level of significance. The value of Coefficient of determination (R^2) found (64%) high significant at 0.1% level of significance.

4.2.13. Joint effect of RH-I and Sun shine for Plain zone on chickpea

Table 4.2.13 indicates that the variable relative humidity-I and sun shine along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y= 868.070 - 41.93 \mathbf{Z_{51}} + 14.61 \mathbf{T}$$

Table-4.2.13. Joint effect of RH-I and Sun shine for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	868.070	170.268	0.22		
T	14.61^{***}	3.722	0.001	0.001	0.70^{***}
Z_{51}	-41.93^{*}	17.435	0.02		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) found highly significant at 0.1% level. Z_{51} (weighted sunshine) found significant at 5% level. The value of Coefficient of determination (R^2) found (70 %) high significant at 0.1% level of significance.

4.2.14. Joint effect of RH-I and Rainfall for Plain zone on chickpea

Table 4.2.14 indicates that the variable relative humidity-I and rainfall along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 500.966 + 0.153\ \mathbf{Q_{360}} - 0.101\ \mathbf{Q_{361}} + 14.92\ \mathbf{T}$$

Table-4.2.14. Joint effect of RH-I and Rainfall for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	500.966	34.046	0.44	0.001	0.85^{***}
T	14.92^{***}	2.150	0.001		
Q_{361}	-0.101^{***}	.017	0.001		
Q_{360}	0.153^{*}	.068	0.03		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) and Q_{361} (weighted interaction between relative humidity-I and wind rainfall) found significant at 0.1% level, Q_{360} (unweighted interaction between relative humidity-I and wind rainfall) found significant at 5% level, the value of Coefficient of determination (R^2) found (85%) high significant at 0.1% level of significance.

4.2.15. Joint effect of RH-I and Wind velocity for Plain zone on chickpea

Table 4.2.15 indicates that the variable relative humidity-I and wind velocity along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 471.110 + 20.46\ \mathbf{T}$$

Table-4.2.15. Joint effect of RH-I and Wind velocity for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	471.110	46.041	0.15	0.001	0.64^{***}
T	20.46^{***}	3.097	0.001		

***P<0.001, **P<0.01, *P<0.05, $^{+}$P<0.1

Out of seven variables time trend (T) found significant at 0.1% level of significance. The value of Coefficient of determination (R^2) found (64%) high significant at 0.1% level of significance.

4.2.16. Joint effect of RH-II and Sun shine for Plain zone on chickpea

Table 4.2.16 indicates that the variable relative humidity-II and wind sun shine along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y= 868.070 - 41.93 \mathbf{Z_{51}} + 14.61 \mathbf{T}$$

Table-4.2.16. Joint effect of RH-II and Sun shine for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	868.07^{+}	170.268	0.10		
T	14.61^{***}	3.722	0.001	0.001	0.70^{***}
Z_{51}	-41.93^{*}	17.435	0.02		

***P<0.001, **P<0.01, *P<0.05, $^{+}$P<0.1

Out of seven variables time trend (T) found significant at 0.1% level, Z_{51} (weighted Sun shine) found significant at 5% level. The value of Coefficient of determination (R^2) found (70 %) high significant at 0.1% level of significance.

4.2.17. Joint effect of RH-II and Rainfall for Plain zone on chickpea

Table 4.2.17 indicates that the variable relative humidity-II and wind rainfall along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y= 502.752 + 13.298 \mathbf{Z_{60}} - 9.07 \mathbf{Z_{61}} + 14.89 \mathbf{T}$$

Table-4.2.17.Joint effect of RH-II and Rainfall for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	502.75***	34.523	0.001	0.001	0.85***
T	14.89***	2.185	0.001		
Z_{61}	-9.07***	1.531	0.001		
Z_{60}	13.298*	6.258	0.04		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

Out of seven variables time trend (T) and Z_{61} (weighted rainfall) found significant at 0.1% level of significance, Z_{60} (unweighted rainfall) found significant at 5% level of significance, The value of Coefficient of determination (R^2) found (85%) high significant at 0.1% level of significance.

4.2.18. Joint effect of RH-II and Wind velocity for Plain zone on chickpea

Table 4.2.18 indicates that the variable relative humidity-II and wind velocity along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y= 471.110 + 20.46 \mathbf{T}$$

Table-4.2.18. Joint effect of RH-II and Wind velocity for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	471.110**	46.041	0.004	0.001	0.64***
T	20.46***	3.097	0.001		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

Out of seven variables time trend (T) found significant at 0.1% level, The value of Coefficient of determination (R^2) found (64%) high significant at 0.1% level of significance.

4.2.19. Joint effect of Sun Shine and Rainfall for Plain zone on chickpea

Table 4.2.19 indicates that the variable sunshine and rainfall along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$Y = 782.092 - 26.91\ \mathbf{Z_{51}} - 6.81\ \mathbf{Z_{61}} + 12.54\ \mathbf{T}$

Table-4.2.19. Joint effect of Sun Shine and Rainfall for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2
Intercept	782.09*	120.348	0.02		
T	12.54***	2.637	0.001	0.001	0.85***
Z_{61}	-6.81***	1.392	0.001		
Z_{51}	-26.91*	12.571	0.04		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) and Z_{61} (weighted rainfall) found significant at 0.1% level of significance, Z_{51} (weighted sunshine) found significant at 5% level of significance, The value of Coefficient of determination (R^2) found (85 %) high significant at 0.1% level of significance.

4.2.20. Joint effect of Sun Shine and Wind velocity for Plain zone on chickpea

Table 4.2.20 indicates that the variable sunshine and wind velocity along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$Y = 868.070 - 41.93\ \mathbf{Z_{51}} + 14.61\ \mathbf{T}$

Table-4.2.20. Joint effect of Sun Shine and Wind velocity for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	868.070	170.268	0.32		
T	14.61***	3.722	0.001	0.001	0.70***
Z_{51}	-41.93*	17.435	0.02		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) found significant at 0.1% level of significance, Z_{51} (weighted sunshine) found significant at 5% level of significance, The value of Coefficient of determination (R^2) found (70%) high significant at 0.1% level of significance.

4.2.21. Joint effect of Rainfall and Wind velocity for Plain zone on chickpea

Table 4.2.21 indicates that the variable rainfall and wind velocity along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y= 502.752 + 13.29 \mathbf{Z_{60}} -9.07 \mathbf{Z_{61}} +14.89 \mathbf{T}$$

Table-4.2.21. Joint effect of Rainfall and Wind velocity for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	502.75^{***}	34.523	0.0006		
T	14.89^{***}	2.185	0.001	0.001	0.85^{***}
Z_{61}	-9.07^{***}	1.531	0.001		
Z_{60}	13.29^{*}	6.258	0.04		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) and Z_{61} (weighted rainfall) found significant at 0.1 % level of significance, Z_{60} (unweighted rainfall) found significant at 5% level of significance, The value of Coefficient of determination (R^2) found (85%) high significant at 0.1% level of significance.

4.2.22. Joint effect of Max. Temp and Min. temp for CG plain on pigeonpea

Table 4.2.22 indicates that the variable maximum temperature and minimum temperature along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y=11336.798 -240.82 \mathbf{Z_{11}} - 357.69 \mathbf{Z_{21}} +6.75 \mathbf{Q_{121}}$$

Table-4.2.22.Joint effect of Max. and Min. Temp for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	11336.798	1242.559	0.34		
Z_{11}	-240.82^{***}	46.446	0.001	0.001	0.81^{***}
Z_{21}	-357.69^{***}	88.211	0.001		
Q_{120}	6.75^{*}	3.012	0.03		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables Z_{11} (weighted maximum temperature) and Z_{21} (weighted minimum temperature) found significant at 0.1% level of significance, Q_{120} (unweighted interaction of maximum temperature and minimum temperature) found significant at 5% level of significance. The value of Coefficient of determination (R^2) found (81%) high significant at 0.1% level of significance.

4.2.23. Joint effect of Max. Temp and RH-I for CG plain on pigeonpea

Table 4.2.23 indicates that the variable maximum temperature and relative humidity-I along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 6366.093 - 1.96\ \mathbf{Q_{131}} - 19.23\ \mathbf{T}$$

Table-4.2.23. Joint effect of Max. Temp and RH-I for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	6366.093	1245.774	0.89		
T	-19.23^{***}	4.351	0.001	0.001	0.75^{***}
Q_{131}	-1.96^{***}	0.457	0.001		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) and Q_{131} (weighted interaction of maximum temperature and relative humidity-I) found significant at 0.1% level of significance. The value of Coefficient of determination (R^2) found (75%) high significant at 0.1% level of significance.

4.2.24. Joint effect of Max. Temp and RH-II for CG plain on pigeonpea

Table 4.2.24 indicates that the variable maximum temperature and relative humidity-II along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 6452.245 - 188.17\ \mathbf{Z_{11}} - 19.03\ \mathbf{T}$$

Table-4.2.24.Joint effect of Max. Temp and RH-II for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	6452.245	1313.936	0.32		
T	-19.03^{***}	4.473	0.001	0.001	0.74^{***}
Z_{11}	-188.17^{***}	45.458	0.001		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) and Z_{11} (weighted maximum temperature) found significant at 0.1% level of significance, the value of Coefficient of determination (R^2) found (74%) high significant at 0.1% level of significance.

4.2.25. Joint effect of Max. Temp and Sun Shine for CG plain on pigeonpea

Table 4.2.25 indicates that the variable maximum temperature and Sun Shine along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y= 5468.822 -148.88 \mathbf{Z_{11}} -1.82 \mathbf{Q_{151}} - 16.23 \mathbf{T}$$

Table-4.2.25. Joint effect of Max. Temp and Sun Shine for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	5468.822	1242.295	0.78		
T	-16.23^{***}	4.166	0.001	0.001	0.79^{***}
Z_{11}	-148.88^{**}	43.685	0.003		
Q_{151}	-1.82^{*}	0.726	0.02		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) found significant at 0.1% level, Z_{11} (weighted maximum temperature) found significant at 1 % level, Q_{151} (weighted interaction of maximum temperature and sunshine) found significant at 5% level of significance, The value of Coefficient of determination (R^2) found (79%) high significant at 0.1% level of significance.

4.2.26. Joint effect of Max. Temp and Rainfall for CG plain on pigeonpea

Table 4.2.26 indicates that the variable maximum temperature and rainfall along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 5985.900 - 171.93\ \mathbf{Z_{11}} - 0.03\ \mathbf{Q_{161}} - 16.05\ \mathbf{T}$$

Table-4.2.26. Joint effect of Max. Temp and Rainfall for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	5985.900	1203.721	0.18	0.001	0.79^{***}
T	-16.05^{***}	4.228	0.001		
Z_{11}	-171.93^{***}	41.652	0.001		
Q_{161}	-0.03^{*}	.014	0.02		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) and Z_{11} (weighted maximum temperature) found significant at 0.1% level, Q_{161} (weighted interaction of maximum temperature and rainfall) found significant at 5% level of significance, The value of Coefficient of determination (R^2) found (79%) high significant at 0.1% level of significance.

4.2.27. Joint effect of Max. Temp and Wind velocity for CG plain on pigeonpea

Table 4.2.27 indicates that the variable maximum temperature and wind velocity along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 6452.245 - 188.17\ \mathbf{Z_{11}} - 19.03\ \mathbf{T}$$

Table-4.2.27.Joint effect of Max. Temp and Wind velocity for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	6452.245	1313.936	0.65	0.001	0.74^{***}
T	-19.03^{***}	4.473	0.001		
Z_{11}	-188.17^{***}	45.458	0.001		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) and Z_{11} (weighted maximum temperature) found significant at 0.1% level of significance, the value of Coefficient of determination (R^2) found (74%) high significant at 0.1% level of significance.

4.2.28. Joint effect of Min. Temp and RH-I for CG plain on pigeonpea

Table 4.2.28 indicates that the variable minimum temperature and Relative humidity-I along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 43.033 - 215.80\,\mathbf{Z_{21}} + 56.22\,\mathbf{Z_{31}}$$

Table-4.2.28.Joint effect of Min. Temp and RH-I for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	43.033^{**}	1672.047	0.01		
Z_{21}	-215.80^{***}	33.110	0.001	0.001	0.75^{***}
Z_{31}	56.22^{***}	14.895	0.001		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables Z_{21} (weighted minimum temperature) and Z_{31} (weighted relative humidity-I) found significant at 0.1% level of significance, the value of Coefficient of determination (R^2) found (75%) high significant at 0.1% level of significance.

4.2.29. Joint effect of Min. Temp and RH-II for CG plain on pigeonpea

Table 4.2.29 indicates that the variable minimum temperature and Relative humidity-II along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 3673.940 - 201.10\,\mathbf{Z_{21}} + 21.44\,\mathbf{Z_{41}}$$

Table-4.2.29.Joint effect of Min. Temp and RH-II for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	3673.940	768.003	0.19		
Z_{21}	-201.10^{***}	31.107	0.001	0.001	0.79^{***}
Z_{41}	21.44^{***}	4.672	0.001		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables Z_{21} (weighted minimum temperature) and Z_{41} (weighted relative humidity-II) found significant at 0.1% level, the value of Coefficient of determination (R^2) found (79%) high significant at 0.1% level of significance.

4.2.30. Joint effect of Min. Temp and Sun Shine for CG plain on pigeonpea

Table 4.2.30 indicates that the variable minimum temperature and sun shine along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y= 5868.881 + 304.53 \mathbf{Z_{20}} - 528.55 \mathbf{Z_{21}}$$

Table-4.2.30. Joint effect of Min. Temp and Sunshine for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	5868.881	765.958	0.36		
Z_{21}	-528.55^{***}	130.672	0.001	0.001	0.67^{***}
Z_{20}	304.53^{*}	137.339	0.03		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables Z_{20} (unweighted minimum temperature) found significant at 5% level, Z_{21} (weighted minimum temperature) found significant at 0.1 % level, the value of Coefficient of determination (R^2) found (67%) high significant at 0.1% level of significance.

4.2.31. Joint effect of Min. Temp and Rainfall for CG plain on pigeonpea

Table 4.2.31 indicates that the variable minimum temperature and rainfall along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 5868.881 + 304.53\ \mathbf{Z_{20}} - 528.55\ \mathbf{Z_{21}}$$

Table-4.2.31. Joint effect of Min. Temp and Rainfall for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	5868.881^{*}	765.958	0.02		
Z_{21}	-528.55^{***}	130.672	0.001	0.001	0.67^{***}
Z_{20}	304.53^{*}	137.339	0.03		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables Z_{20} (unweighted minimum temperature) found significant at 5% level, Z_{21} (weighted minimum temperature) found significant at 0.1 % level, the value of Coefficient of determination (R^2) found (67%) high significant at 0.1% level of significance.

4.2.32. Joint effect of Min. Temp and Wind velocity for CG plain on pigeonpea

Table 4.2.32 indicates that the variable minimum temperature and wind velocity along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 5868.881 + 304.53\ \mathbf{Z_{20}} - 528.55\ \mathbf{Z_{21}}$$

Table-4.2.32.Joint effect of Min. Temp and Wind velocity for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	5868.881^{+}	765.958	0.06		
Z_{21}	-528.55^{***}	130.672	0.001	0.001	0.67^{***}
Z_{20}	304.53^{*}	137.339	0.03		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables Z_{20} (unweighted minimum temperature) found significant at 5% level, Z_{21} (weighted minimum temperature) found significant at 0.1 % level, the value of Coefficient of determination (R^2) found (67%) high significant at 0.1% level of significance.

4.2.33. Joint effect of RH-I and RH-II for CG plain on pigeonpea

Table 4.2.33 indicates that the variable relative humidity-I and relative humidity-II along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y= -37.458 + 18.05\ \mathbf{Z_{41}} -21.38\ \mathbf{T}$$

Table-4.2.33. Joint effect of RH-I and RH-II for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	-37.458	383.790	0.63		
T	-21.38^{***}	5.096	0.001	0.001	0.66^{***}
Z_{41}	18.05^{**}	6.468	0.01		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) found significant at 0.1% level, Z_{41} (weighted relative humidity-II) found significant at 1% level, the value of Coefficient of determination (R^2) found (66%) high significant at 0.1% level of significance.

4.2.34. Joint effect of RH-I and Sun shine for CG plain on pigeonpea

Table 4.2.34 indicates that the variable relative humidity-I and sun shine along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y= -4336.620 + 51.80\ \mathbf{Z_{31}} + 0.33\ \mathbf{Q_{351}} -13.54\ \mathbf{T}$$

Table-4.2.34. Joint effect of RH-I and Sun shine for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	-4336.620	1561.947	0.86		
T	-13.54^{**}	5.303	0.01	0.001	0.74^{***}
Q_{351}	0.33^{**}	0.102	0.004		
Z_{31}	51.80^{**}	16.565	0.005		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T), Z_{31} (weighted relative humidity-I) and Q_{351} (weighted interaction between relative humidity-I and sunshine) found significant at 1% level of significance, the value of Coefficient of determination (R^2) found (74%) high significant at 0.1% level of significance.

4.2.35. Joint effect of RH-I and Rainfall for CG plain on pigeonpea

Table 4.2.35 indicates that the variable relative humidity-I and rainfall along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 1015.365 - 0.97\,\mathbf{Z_{61}} - 23.92\,\mathbf{T}$$

Table-4.2.35. Joint effect of RH-I and Rainfall for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	1015.365	67.597	0.69		
T	-23.92^{***}	4.961	0.001	0.001	0.64^{***}
Z_{61}	-0.97^{*}	0.409	0.02		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) found highly significant at 0.1% level of significance, Z_{61} (weighted rainfall) found significant at 5% level, the value of Coefficient of determination (R^2) found (64%) high significant at 0.1% level of significance.

4.2.36. Joint effect of RH-I and Wind velocity for CG plain on pigeonpea

Table 4.2.36 indicates that the variable relative humidity-I and wind velocity along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = -2965.861 + 43.38\,\mathbf{Z_{31}} - 23.57\,\mathbf{T}$$

Table-4.2.36.Joint effect of RH-I and Wind velocity for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	-2965.861	1798.077	0.94		
T	-23.57^{***}	5.147	0.001	0.001	0.63^{***}
Z_{31}	43.38^{*}	19.566	0.03		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) found significant at 0.1% level, Z_{31} (weighted relative humidity-I) found significant at 5% level, the value of Coefficient of determination (R^2) found (63%) high significant at 0.1% level of significance.

4.2.37. Joint effect of RH-II and Sun shine for CG plain on pigeonpea

Table 4.2.37 indicates that the variable relative humidity-II and wind sun shine along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y= -37.458 + 18.05\, \mathbf{Z_{41}} - 21.38\, \mathbf{T}$$

Table-4.2.37. Joint effect of RH-II and Sun shine for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	-37.458	383.790	0.44		
T	-21.38^{***}	5.096	0.001	0.001	0.66^{***}
Z_{41}	18.05^{**}	6.468	0.01		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) found significant at 0.1% level of significance, Z_{41} (weighted relative humidity-II) found significant at 1% level, The value of Coefficient of determination (R^2) found (66%) high significant at 0.1% level of significance.

4.2.38. Joint effect of RH-II and Rainfall for CG plain on pigeonpea

Table 4.2.38 indicates that the variable relative humidity-II and wind rainfall along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$Y = -37.458 + 18.05\ \mathbf{Z_{41}} - 21.38\ \mathbf{T}$

Table-4.2.38. Joint effect of RH-II and Rainfall for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	-37.458	383.790	0.22		
T	-21.38^{***}	5.096	0.001	0.001	0.66^{***}
Z_{41}	18.05^{**}	6.468	0.01		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) found significant at 0.1% level of significance, Z_{41} (weighted relative humidity-II) found significant at 1% level, The value of Coefficient of determination (R^2) found (66%) high significant at 0.1% level of significance.

4.2.39. Joint effect of RH-II and Wind velocity for CG plain on pigeonpea

Table 4.2.39 indicates that the variable relative humidity-II and wind velocity along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$Y = -37.458 + 18.05\ \mathbf{Z_{41}} - 21.38\ \mathbf{T}$

Table-4.2.39. Joint effect of RH-II and Wind velocity for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	-37.458	383.790	0.37		
T	-21.38^{***}	5.096	0.001	0.001	0.66^{***}
Z_{41}	18.05^{**}	6.468	0.01		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) found significant at 0.1% level of significance, Z_{41} (weighted relative humidity-II) found significant at 1% level, The value of Coefficient of determination (R^2) found (66%) high significant at 0.1% level of significance.

4.2.40. Joint effect of Sun Shine and Rainfall for CG plain on pigeonpea

Table 4.2.40 indicates that the variable sunshine and rainfall along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 1040.753 - 0.77\, \mathbf{Q_{561}} - 21.38\, \mathbf{T}$$

Table-4.2.40. Joint effect of Sun Shine and Rainfall for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	1040.75*	67.963	0.03		
T	-21.38***	5.429	0.001	0.001	0.64***
Q_{561}	-0.77*	0.321	0.02		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

Out of seven variables time trend (T) found highly significant at 0.1% level of significance, Q_{561}(weighted interaction between sunshine and rainfall) found significant at 5% level of significance, The value of Coefficient of determination (R^2) found (64 %) high significant at 0.1% level of significance.

4.2.41. Joint effect of Sun Shine and Wind velocity for CG plain on pigeonpea

Table 4.2.41 indicates that the variable sunshine and wind velocity along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 747.598 - 8.13\mathbf{Z_{51}} - 22.03\mathbf{T}$$

Table-4.2.41. Joint effect of Sun Shine and Wind velocity for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	747.598*	143.370	0.02		
T	-22.03***	5.561	0.001	0.001	0.63***
Z_{51}	-8.13*	3.783	0.04		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

Out of seven variables time trend (T) found highly significant at 0.1% level of significance, Z_{51} (weighted sunshine) found significant at 5% level of significance, the value of Coefficient of determination (R^2) found (63%) high significant at 0.1% level of significance.

4.2.42. Joint effect of Rainfall and Wind velocity for CG plain on pigeonpea

Table 4.2.42 indicates that the variable rainfall and wind velocity along with interaction of both variables and time trend (T) fitted in equation. The multiple Regression equation given below:

$$Y = 1015.365 - 0.97\ \mathbf{Z_{61}} - 23.92\ \mathbf{T}$$

Table-4.2.42. Joint effect of Rainfall and Wind velocity for CG plain on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	1015.365	67.597	0.67		
T	-23.92^{***}	4.961	0.001	0.001	0.64^{***}
Z_{61}	-0.97^{*}	0.409	0.02		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Out of seven variables time trend (T) found significant at 0.1% level of significance, Z_{61} (weighted rainfall) found significant at 5% level of significance, The value of Coefficient of determination (R^2) found (64%) high significant at 0.1% level of significance.

Table-4.2.43. Joint effect of All Districts for CG plain on Chickpea.

INTERACTION	RAI	BSP	DUG	RNG	MHS	DMT	KWD	KRB	JNG	CGPZ
Max T X Min T	0.70^{***}	0.75^{***}	0.63^{***}	0.65^{***}	0.84^{***}	0.84^{***}	0.77^{**}	0.57^{*}	0.80^{***}	0.64^{***}
Max T X RH-I	0.71^{***}	0.73^{***}	0.58^{***}	0.68^{***}	0.91^{***}	0.79^{***}	0.79^{***}	0.72^{**}	0.90^{***}	0.64^{***}
Max T X RH-II	0.75^{***}	0.79^{***}	0.67^{***}	0.73^{***}	0.72^{**}	0.86^{***}	0.85^{***}	0.59^{*}	0.71^{**}	0.64^{***}
Max T X SS	0.70^{***}	0.75^{***}	0.66^{***}	0.63^{***}	0.62^{**}	0.88^{***}	0.85^{***}	0.67^{**}	0.62^{**}	0.70^{***}
Max T X RF	0.72^{***}	0.69^{***}	0.63^{***}	0.67^{***}	0.78^{***}	0.85^{***}	0.80^{***}	0.58^{*}	0.69^{**}	0.84^{***}
Max T X WV	0.67^{***}	0.64^{***}	0.49^{**}	0.66^{***}	0.76^{**}	0.89^{***}	0.68^{**}	0.48^{*}	0.86^{***}	0.64^{***}
Min T X RH-I	0.73^{***}	0.75^{***}	0.60^{***}	0.59^{***}	0.81^{***}	0.82^{***}	0.78^{***}	0.71^{**}	0.86^{***}	0.80^{***}
Min T X RH-II	0.65^{***}	0.72^{***}	0.54^{**}	0.57^{***}	0.75^{**}	0.82^{***}	0.83^{***}	0.62^{**}	0.76^{**}	0.72^{***}
Min T X SS	0.71^{***}	0.72^{***}	0.61^{***}	0.60^{***}	0.79^{***}	0.80^{***}	0.72^{**}	0.62^{**}	0.83^{***}	0.70^{***}
Min T X RF	0.70^{***}	0.69^{***}	0.64^{***}	0.59^{***}	0.75^{**}	0.79^{***}	0.77^{**}	0.74^{**}	0.71^{**}	0.86^{***}
Min T XWV	0.73^{***}	0.72^{***}	0.60^{***}	0.69^{***}	0.91^{***}	0.82^{***}	0.66^{**}	0.63^{**}	0.96^{***}	0.75^{***}
RH-I X RH-II	0.68^{***}	0.66^{***}	0.55^{**}	0.53^{**}	0.68^{**}	0.72^{**}	0.75^{**}	0.76^{**}	0.82^{***}	0.64^{***}
RH-I X SS	0.61^{***}	0.70^{***}	0.65^{***}	0.60^{***}	0.66^{**}	0.78^{***}	0.76^{**}	0.79^{***}	0.87^{***}	0.70^{***}
RH-I X RF	0.75^{***}	0.76^{***}	0.72^{***}	0.60^{***}	0.76^{**}	0.85^{***}	0.84^{***}	0.78^{***}	0.84^{***}	0.85^{***}
RH-I XWV	0.68^{***}	0.70^{***}	0.62^{***}	0.59^{***}	0.77^{***}	0.84^{***}	0.79^{***}	0.69^{**}	0.88^{***}	0.64^{***}
RH-II X SS	0.71^{***}	0.76^{***}	0.65^{***}	0.62^{***}	0.88^{***}	0.84^{***}	0.81^{***}	0.75^{**}	0.83^{***}	0.70^{***}
RH-II X RF	0.72^{***}	0.68^{***}	0.64^{***}	0.56^{**}	0.71^{**}	0.74^{**}	0.81^{***}	0.77^{**}	0.66^{**}	0.85^{***}
RH-II XWV	0.67^{***}	0.68^{***}	0.56^{**}	0.66^{***}	0.81^{***}	0.92^{***}	0.85^{***}	0.75^{**}	0.87^{***}	0.64^{***}
SS X RF	0.71^{***}	0.74^{***}	0.72^{***}	0.62^{***}	0.64^{**}	0.84^{***}	0.79^{***}	0.77^{***}	0.72^{**}	0.85^{***}
SS X WV	0.64^{***}	0.74^{***}	0.63^{***}	0.66^{***}	0.77^{***}	0.83^{***}	0.77^{***}	0.70^{**}	0.93^{***}	0.70^{***}
RF X WV	0.72^{***}	0.69^{***}	0.71^{***}	0.63^{***}	0.77^{**}	0.71^{**}	0.79^{***}	0.50^{*}	0.85^{***}	0.85^{***}

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

RAi=raipur BSP = Bilaspur DUG= Durg RNG= Rajnanadgaon MHS= Mahasamund DMT= Dhamtari KWD= Kawardha KRB= KORBA JNG= Janjgir CGPZ= Chhattisgarh Plain Zones

Table-4.2.44. Joint effect of All Districs for CG plain on pigeonpea.

INTERACTION	RAI	BSP	DUG	RNG	MHS	DMT	KWD	KRB	JNG	CGPZ
Max T X Min T	0.82***	0.78***	0.77***	0.77***	0.68**	0.70**	0.73**	0.72**	0.71**	0.81***
Max T X RH-I	0.75***	0.73***	0.66***	0.75***	0.46^{+}	0.52*	0.60**	0.55*	0.54*	0.75***
Max T X RH-II	0.77***	0.77***	0.74***	0.75***	0.55*	0.62**	0.68**	0.65**	0.65**	0.74***
Max T X SS	0.79***	0.78***	0.77***	0.80***	0.73**	0.74**	0.71**	0.83***	0.74**	0.79***
Max T X RF	0.84***	0.81***	0.77***	0.79***	0.67**	0.74**	0.70**	0.73**	0.75**	0.79***
Max T X WV	0.79***	0.76***	0.67***	0.79***	0.60**	0.65**	0.77***	0.67**	0.64**	0.74***
Min T X RH-I	0.81***	0.77***	0.68***	0.79***	0.65**	0.66**	0.73***	0.72**	0.68**	0.75***
Min T X RH-II	0.81***	0.76***	0.71***	0.78***	0.75**	0.74**	0.83***	0.75**	0.80***	0.79***
Min T X SS	0.79***	0.78***	0.78***	0.82***	0.64**	0.67**	0.70**	0.71**	0.67**	0.67***
Min T X RF	0.71***	0.77***	0.74***	0.63***	0.87***	0.87***	0.87***	0.91***	0.87***	0.67***
Min T XWV	0.71***	0.73***	0.65***	0.66***	0.67**	0.61**	0.66**	0.64**	0.64**	0.67***
RH-I X RH-II	0.71***	0.72***	0.65***	0.71***	0.39^{+}	0.44^{+}	0.55*	0.50*	0.47**	0.66***
RH-I X SS	0.76***	0.78***	0.76***	0.78***	0.61**	0.65**	0.66**	0.70**	0.67**	0.74***
RH-I X RF	0.72***	0.72***	0.61***	0.71***	0.61**	0.62**	0.59*	0.60**	0.66**	0.64***
RH-I XWV	0.74***	0.71***	0.58***	0.76***	0.70**	0.67**	0.74**	0.71**	0.69**	0.63***
RH-II X SS	0.73***	0.70***	0.70***	0.75***	0.68**	0.69**	0.66**	0.70**	0.74**	0.66***
RH-II X RF	0.76***	0.76***	0.70***	0.73***	0.76**	0.78***	0.78***	0.80***	0.81***	0.66***
RH-II XWV	0.74***	0.72***	0.66***	0.71***	0.65**	0.68**	0.77***	0.67**	0.69**	0.66***
SS X RF	0.75***	0.76***	0.75***	0.75***	0.72**	0.75**	0.80***	0.81***	0.78***	0.64***
SS X WV	0.74***	0.79***	0.71***	0.76***	0.77**	0.82***	0.77**	0.81***	0.79***	0.63***
RF X WV	0.72***	0.73***	0.73***	0.75***	0.80***	0.78***	0.80***	0.84***	0.81***	0.64***

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

RAi=raipur BSP = Bilaspur DUG= Durg RNG= Rajnanadgaon MHS= Mahasamund DMT= Dhamtari KWD= Kawardha KRB= KORBA JNG= Janjgir CGPZ= Chhattisgarh Plain Zones

The interaction (joint) effect for variables are showing highly significant, the result indicates that all the districts except Korba found very highly significant for all the variable combinations. The variables combination Maximum temperature & Minimum temperature, Maximum temperature & Relative Humidity-II, Maximum temperature & Rainfall, Maximum temperature &Wind velocity and Rainfall & wind velocity found significant at 5% level of significance for Korba districts of Chhattisgarh plain zone. The result on interaction effect is showing positive and highly significant at either 0.01 or 0.001 % level of significance for Chhattisgarh plain zone on Chickpea crop.

The result from table 4.2.44 indicates that variables combination Maximum temperature & Relative Humidity-I for Mahasamund and Relative Humidity-I & Relative Humidity-II for Mahasamund and Dhamtari showing minimum significant result at 10 % level of significance, few combinations for only two district found significant at 5% level of significance rest all the combinations found highly significant at 1 or .1% level.

4.3. Pre-harvest Forecast Model based on generated weather variables through Stepwise Regression Analysis

The stepwise multiple regression analysis has been carried out between crop yield and regressed variables to find out best pre-harvest forecast model. The regressed variables used are generated weather variables based on the weekly data on weather variables. In all 57 regressed including time trend has been used for development of the model. The study has been carried out on 25 years on 4 districts (out of 9 districts) and 17 years on rest 5 districts. Out of 25 years 20 years (for period 1990-91 to 2009-10) data on crop yield were used as regressed variable for building the model and 5 years (2010-11 and 2014-15) data were used for validation of model and Out of 17 years 14 years used for development and 3 years used for validation of the model. The stepwise regression analysis finally yielded the following model.

4.3.1. Pre-harvest Forecast Model through SRA for Plain zone on chickpea

Two regressed variables have been entered in the model finally, which is given below:

$$Y= 625.60-0.37\ \mathbf{Q_{261}} -5.44\ \mathbf{Q_{271}} -0.03\ \mathbf{Q_{131}} +0.87\ \mathbf{Q_{370}} + 11.78\ \mathbf{T}$$

Where

Q_{261} = weighted interaction between minimum temperature and rainfall

Q_{271} = weighted interaction between minimum temperature and wind velocity

Q_{131}= weighted interaction between maximum temperature and relative humidity-I

Q_{370} = Unweighted interaction between relative humidity-I and wind velocity

T = Time trend (1, 2 …25)

Table-4.3.1. Pre-harvest Forecast Model through SRA for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	625.60***	66.458	0.0001	0.0001	0.91***
Q_{261}	-0.37***	.060	0.0001		
Q_{271}	-5.44**	1.588	0.003		
Q_{131}	-0.03**	.015	0.01		
Q_{370}	0.87*	.388	0.037		
T	11.78***	1.845	0.0001		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

The results given in table 4.3.1 are out of 56 variables only five variables entered into the model. The coefficient of determination (R^2) has been found to be 91 % which is significant at 0.1% level of significance. Variables Q_{261}, Q_{271}, Q_{131}, Q_{370} and T have been found to be significant at 0.001, 0.01, 0.01, 0.05 and 0.001 respectively, probability level of significance.

Table-4.3.2.Validation of the model for Plain zone on chickpea.

Year	Actual rice yield(q/ha)	Predicted rice yield(q/ha)	Percent deviation
2010	994.22	993.35	0.09
2011	1006.00	952.87	5.28
2012	1173.67	1194.97	-1.81
2013	815.11	889.13	-9.08
2014	1011.11	1007.37	0.37

**P<0.01, *P<0.05, +P<0.1

It can be observed from the results of the Table 4.3.2 that the percent deviation is also indicating that the model is best fitted and it has high power to pre-harvest forecast of chickpea yield.

Fig:-3.1 show the comparison between actual and predicted yield on the basis of 5 year data, almost same indication in result as well as graph.

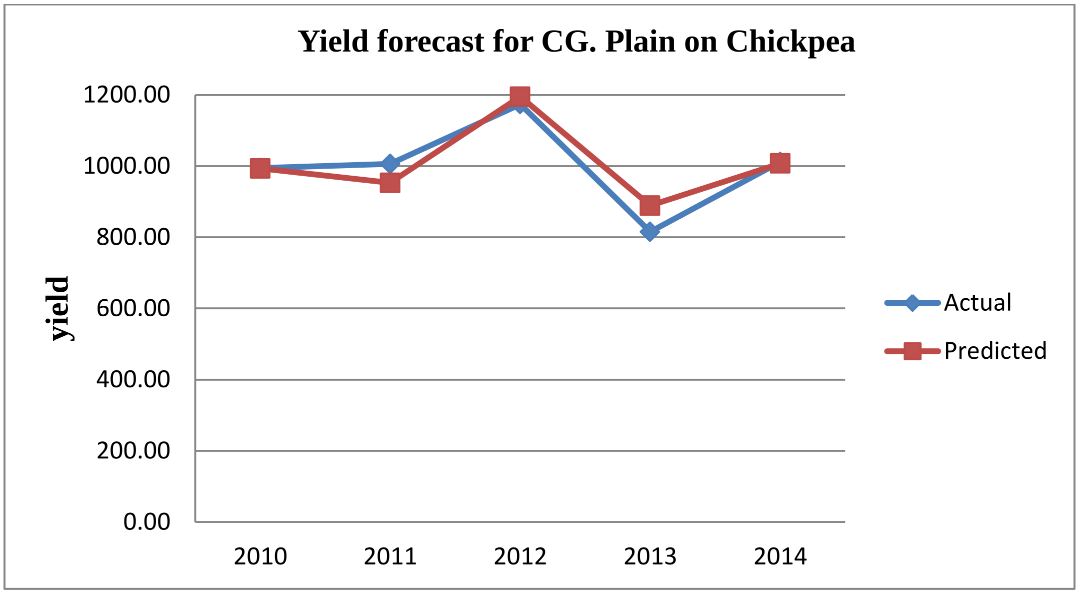


Fig:-3.1.Comparison between actual and predicted yield on chickpea.

4.3.3. Pre-harvest Forecast Model through SRA for Plain zone on pigeonpea

Two regressed variables have been entered in the model finally, which is given below:

$$Y= 2866.11 -5.63Q_{121}+19.95 Z_{41}$$

Where;

Q_{121} = weighted interaction between maximum and minimum temperature

Q_{41} = weighted relative humidity-II

Table-4.3.3. Pre-harvest Forecast Model through SRA for Plain zone on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	2866.11***	673.037	0.0001		
Q_{121}	-5.63***	.904	0.0001	0.0001	0.78***
Z_{41}	19.95***	4.879	0.0001		

***P<0.001, **P<0.01, *P<0.05, +P<0.1

The results given in table 4.3.3 are out of 56 variables only two variables entered into the model. The coefficient of determination (R^2) has been found to be 78

% which is significant at 0.1% level of significance. Variables Q_{121} and Z_{41} have been found to be significant at 0.001 and 0.001 respectively, probability level of significance.

Table-4.3.4: Validation of the model for Plain zone on Pigeonpea.

Year	Actual rice yield(q/ha)	Predicted rice yield(q/ha)	Percent deviation
2010	384.67	314.27	18.30
2011	416.22	338.72	18.62
2012	546.11	419.07	23.26
2013	481.62	648.98	-34.75
2014	567.10	468.73	17.35

**P<0.01, *P<0.05, +P<0.1

It can be observed from the results of the Table 4.3.4 that the percent deviation is also indicating that the model is best fitted and it has high power to pre-harvest forecast of pigeonpea yield.

Fig:-3.2 show the comparison between actual and predicted yield on the basis of 5 year data, almost same indication in result as well as graph.

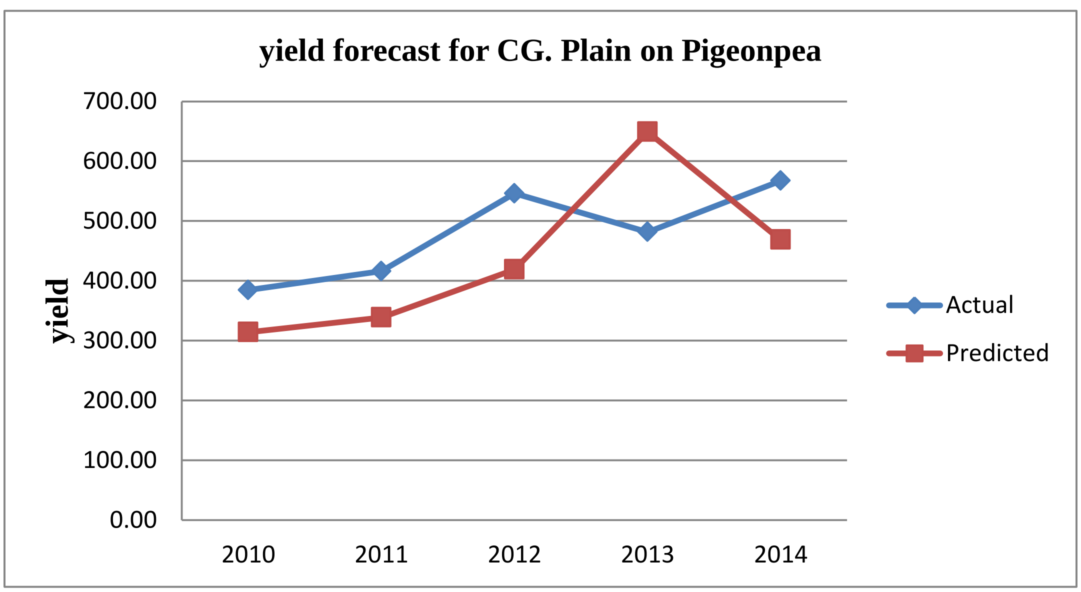


Fig:-3.2.Comparison between actual and predicted yield on pigeonpea for SRA.

Table- 4.3.5. Forecast model through SRA for All District Plain zone on chickpea.

District	Model	Significance (R^2)	Adj (R^2)
RAI	$Y= 519.297-1.42\ Q_{671}+ 21.45\ T$	0.0001	0.74^{***}
BLS	$Y= 596.62 - 0.180\ Q_{231}+ 22.31T$	0.0001	0.76^{***}
DRG	$Y= 538.58 - 0.13\ Q_{361}+ 20.94\ T$	0.0001	0.71^{***}
RJN	$Y= 3365.27-1.16\ Q_{130} + 20.35\ T$	0.0001	0.67^{***}
MSD	$Y= 402.51-0.32\ Q_{451}+ 0.57\ Q_{141}$	0.0001	0.90^{***}
DMT	$Y= 996.22+ 0.52\ Q_{241}-0.18\ Q_{131}+ 21.19\ T$	0.0001	0.90^{***}
KWD	$Y= -419.12 + 3.03\ Q_{450} +34.63\ T$	0.0001	0.62^{***}
KRB	$Y= 1382.41 -0.89\ Q_{351} -0.43\ Q_{261}-0.03\ Q_{131}$	0.0001	0.89^{***}
JGR	$Y= 6922.03 -0.03\ Q_{671} -97.45\ Z_{21} -1.64\ Q_{130}$	0.0001	0.89^{***}
CGPZ	$Y= 625.60-0.37\ Q_{261} -5.44\ Q_{271} -0.03\ Q_{131}+0.87\ Q_{370}+ 11.78\ T$	0.0001	0.91^{***}

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

The result on stepwise regression analysis for each districts shows in table (Table-4.3.5) only one or two robust combinations entered into the model along with Time trend (T). Time trend (T) not found in Mahasamund, Kawardha and Mahahsaund. Mahasamund and Dhamtari found Maximum R^2 value (90%) followed by Korba and Janjgir (89%) followed by Bilaspur, Raipur, Durg, Rajnandgaon and Kawardha with 76%, 74%, 67% and 62% respectively.

The model has been developed for zone level with 91% R^2 and the weighted interaction term Minimum temperature & Rainfall, Minimum temperature & wind velocity, Maximum temperature & Relative humidity-I and unweighted interaction term with Relative humidity-I & wind velocity along with Time trend (T) entered into model and R^2 (coefficient of determination) found significant at 0.01% level of significance.

Table-4.3.6.Forecast Model for SRA in All District Plain Zone on Pigeonpea.

District	Model	Significance (R^2)	Adj (R^2)
RAI	$Y= 2316.28-4.56\ Q_{121}+ 0.59\ Q_{141}-0.010\ Q_{261}$	0.0001	0.83***
BLS	$Y= 4759.59 - 0.005\ Q_{361}-1.33\ Q_{131}-27.45\ T$	0.0001	0.82***
DRG	$Y= 2044.38 -5.03\ Q_{121} -0.05\ Q_{161} -1.25\ Q_{131}+1.82\ Q_{130}$	0.0001	0.86***
RJN	$Y= 1990.47 -10.86\ Q_{251}-26.05\ T$	0.0001	0.83***
MSD	$Y= 1902.94 -0.09\ Q_{671} -79.71\ Z_{21}$	0.0001	0.85***
DMT	$Y= 621.42 -0.01\ Q_{671} -0.18\ Q_{231} -0.87\ Q_{171}$	0.0001	0.93***
KWD	$Y= 481.53 -1.191Q_{121}-0.98\ Z_{61} -0.68\ Q_{171}+0.29\ Q_{141}$	0.0001	0.93***
KRB	$Y= 1318.52 -1.15\ Z_{61} -43.43\ Z_{21} -1.03\ Q_{171}$	0.0001	0.94***
JGR	$Y= 6922.03 -0.03\ Q_{671} -97.45\ Z_{21} -1.64\ Q_{130}$	0.0001	0.89***
CGPZ	$Y= 2866.11 -5.63Q_{121}+19.95\ Z_{41}$	0.0001	0.78***

***P<0.001, **P<0.01, *P<0.05, +P<0.1

Table 4.3.6 indicates that the value of R^2 for Korba district is 94% which is maximum and significant, followed by Kawardha and Dhamtari (93%). The value of R^2 is highly significant for all the district as well as CG plain Zone, The weighted individual ($Z_{.1}$) for few variable entered in the models for Mahasamund and CG Plain Zone.

The model has been developed at zone level with 78% R^2 value and the interaction term (weighted) Maximum temperature & Minimum temperature and weighted individual (Relative Humidity II) in the model and R^2 (coefficient of determination) is found at 0.01% level of significance.

4.4. Pre-harvest Forecast Model based on generated weather variables through Principal Component Analysis (PCA)

The principal component analysis has been carried out for all generated variables and finally select two component (PC1 + PC2), which covers 70-90 % variation. The study has been carried out on 25 years and 9 districts. 25 years on 4 districts (out of 9 districts) and 17 years on rest 5 districts. Out of 25 years 20 years (for period 1990-91 to 2009-10) data on crop yield were used as regressed and variable for building the model and 5 years (2010-11 and 2014-15) data were used for validation of model and Out of 17 years 14 years used for development and 3 years used for validation of the model.

These three variables (PC1, PC2 and T) used as regression yield as dependent variable for multiple regression analysis than finally result indicates in table given below:-

4.4.1. Pre-harvest Forecast Model through PCA for C.G. Plain zone on chickpea

The Principal Component PC1, PC2 and T fitted finally in the model in given below:

Y= 446.49 +496.06 **PC1**+501.59 **PC2**+14.35 **T**

Table-4.4.1. Pre-harvest Forecast Model through PCA for Plain zone on chickpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	446.49^{***}	120.6685	0.001		
PC1	496.06^{+}	548.2116	0.10	0.001	0.85^{***}
PC2	501.59^{***}	85.61314	0.001		
T	14.35^{***}	2.363928	0.001		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

The results given in table 4.4.1 that all variables (PC1, PC2 and T), except PC1 fitted in the model have been found to be significant at 0.01, probability level of significance. The coefficient of determination adjusted (R^2) has been found to be 85 % which is significant at 0.1% level.

Table-4.4.2.Validation of the model for Plain zone on chickpea.

Year	Actual rice yield(q/ha)	Predicted rice yield(q/ha)	Percent deviation
2010	994.22	953.8639	4.06
2011	1006.00	1013.461	-0.74
2012	1173.67	1068.262	8.98
2013	815.11	935.6497	-14.79
2014	1011.11	974.2975	3.64

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, +P<0.1

It can be observed from the results of the Table 4.4.2.that the deviation from yield in case of chickpea indicates that the model is best fit and it has high power to pre-harvest forecast of chickpea yield. It means model is very reliable for forecasting at zone level.

Fig:-4.1.show the comparison between actual and predicted yields on the basis of 5 year data, Almost same indication in result as well as graph.

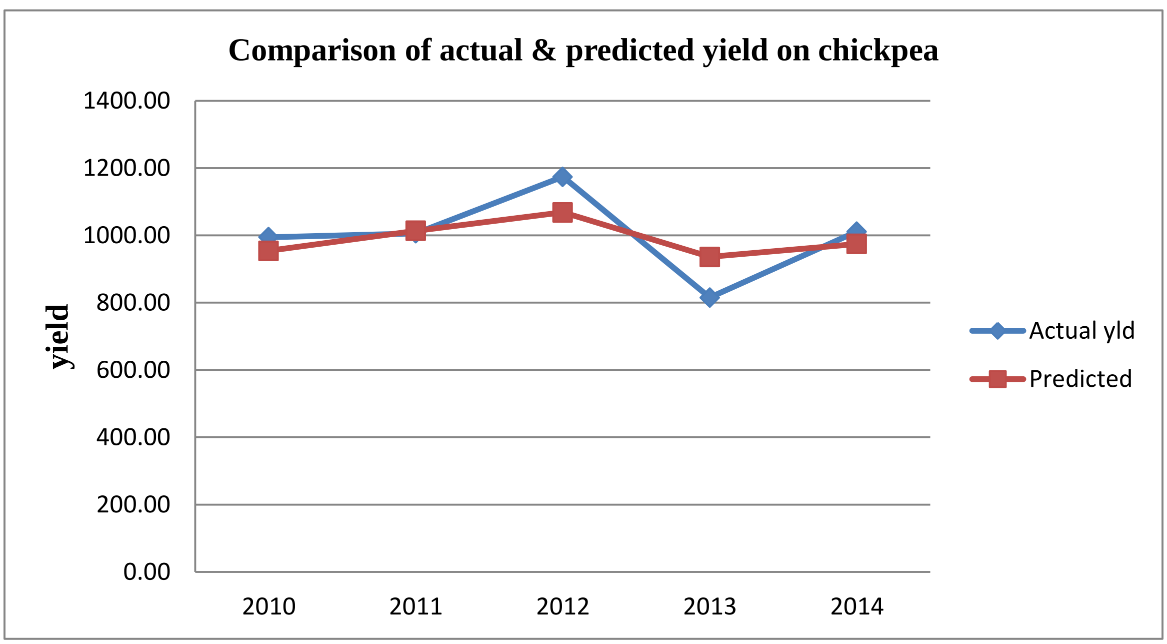
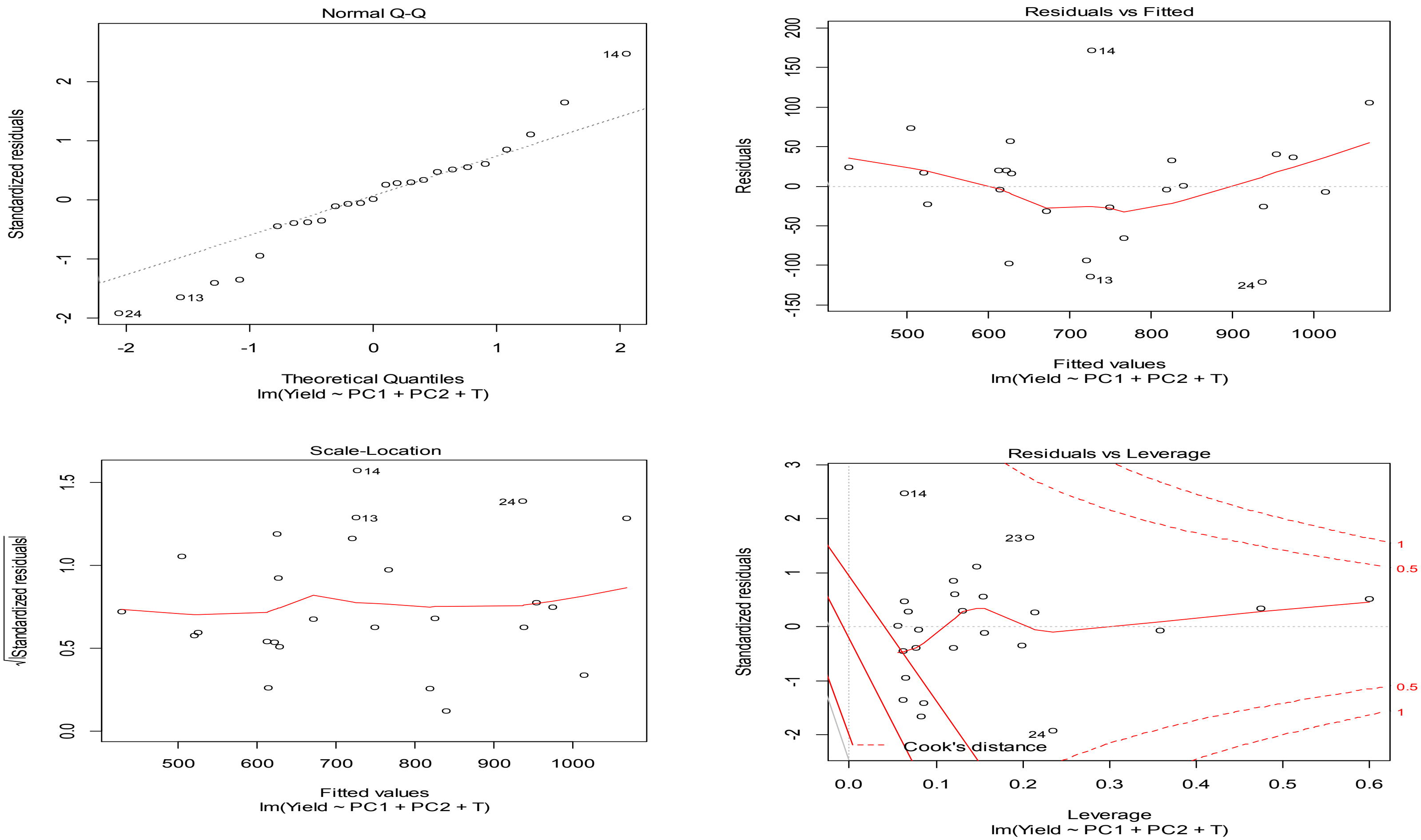


Fig:-4.1.Comparison between actual and predicted yield on chickpea for PCA.

Fig:-4.2. Forecast model based on Principal Component analysis for Plain zone on chickpea.



4.4.3. Pre-harvest Forecast Model through PCA for C.G. Plain zone on pigeonpea.

The Principal Component PC1, PC2 and T fitted finally in the model in given below:

Y= -60.02 -2244.8 **PC1**-4493.58 **PC2**-22.50 **T**

Table-4.4.3. Pre-harvest Forecast Model through PCA for Plain zone on pigeonpea.

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
Intercept	-60.02	457.6254	0.89		
PC1	-2244.8^{+}	1169.402	0.06	0.001	0.69^{***}
PC2	-4493.58^{*}	1903.943	0.02		
T	-22.50^{***}	4.60818	0.001		

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

The results given in table 4.4.3 that all variables (PC1, PC2 and T), all the variables are found significant. The coefficient of determination adjusted (R^2) has been found to be 69% which is significant at 0.1% level.

Table-4.4.4.Validation of the model for Raipur district on pigeonpea

Year	Actual rice yield(q/ha)	Predicted rice yield(q/ha)	Percent deviation
2010	384.67	323.1569	15.99
2011	416.22	397.9641	4.39
2012	546.11	310.4661	43.15
2013	481.62	544.3523	-13.02
2014	567.10	367.8191	35.14

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, +P<0.1

Table-4.4.4. Indicates that the deviation from yield indicates that the model is best fit and it has high power to pre-harvest forecast. It means model is very reliable for forecasting at zone level for pigeonpea.

Fig:-4.3. Show the comparison between actual and predicted yield on the basis of 5 year data, almost same indication in result as well as graph.

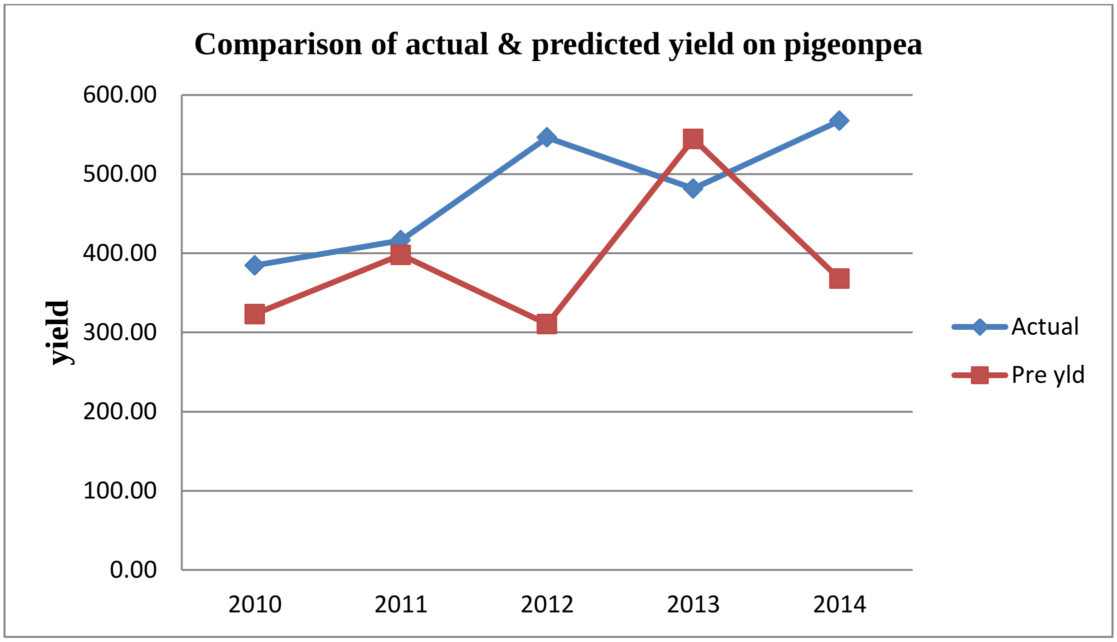


Fig:-4.3.Comparison between actual and predicted yield on pigeonpea for PCA.

Fig:-4.4. Forecast model based on Principal Component analysis for Plain zone on pigeonpea.

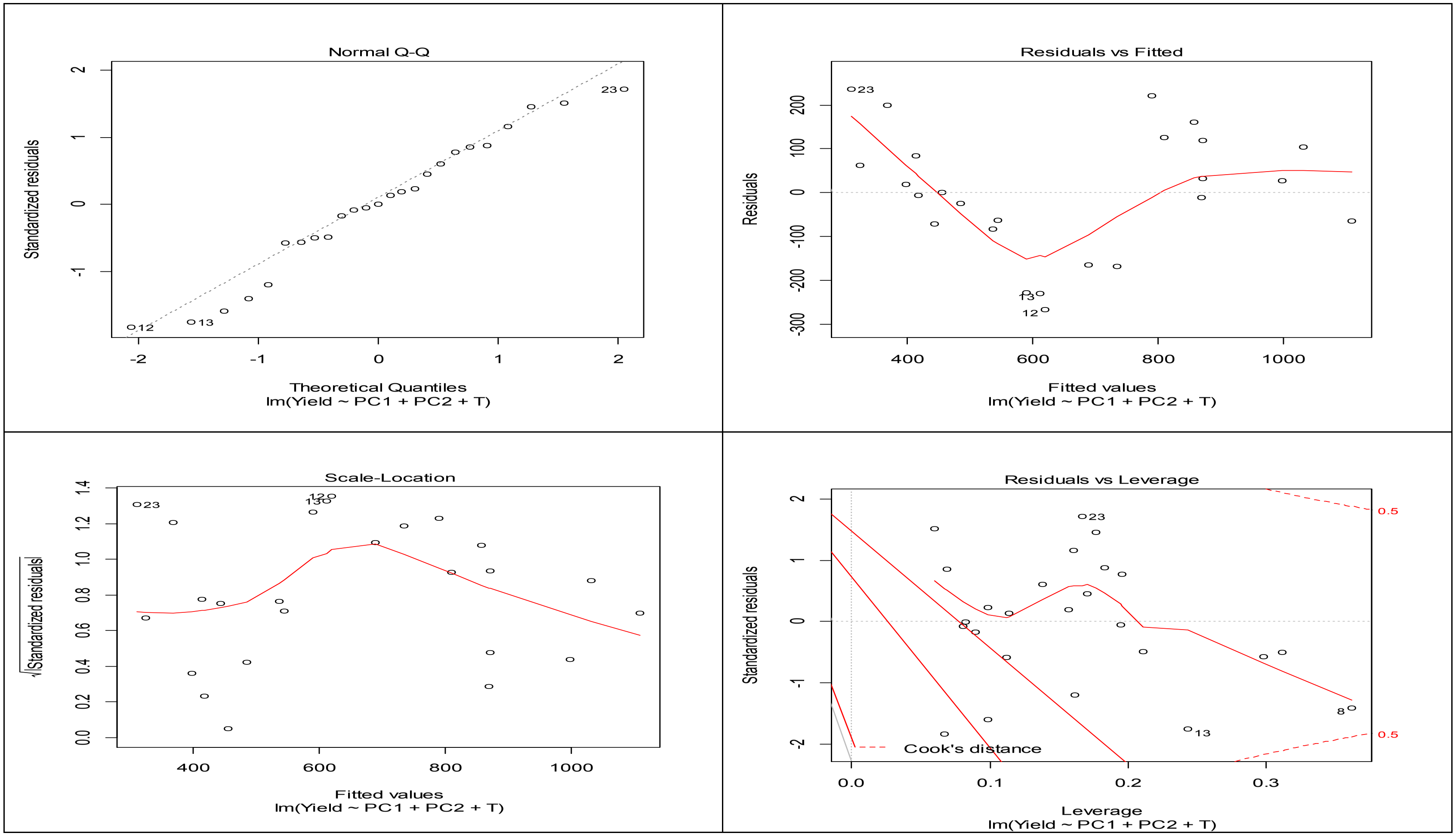


Table-4.4.5. Model through PCA for All District Plain zone on Chickpea.

Distinct	Model	Significance (R^2)	Adj (R^2)
RAI	Y= 210.20+1559.44 PC1+365.53 PC2+21.06 T	0.001	0.74***
BLS	Y= 637.92-832.0 PC1+287.55 PC2+21.24 T	0.001	0.70***
DRG	Y= 382.81+754.81 PC1+388.06 PC2+20.69 T	0.001	0.64***
RJN	Y= 565.97-530.81 PC1-265.39 PC2+17.14 T	0.001	0.62***
MSD	Y= 53.05 +2801.90 PC1+187.35 PC2+12.6 T	0.001	0.59***
DMT	Y= 221.47+2094.67 PC1+167.9 PC2+25.002 T	0.0001	0.72***
KWD	Y= 386.57+736.62 PC1-526.37 PC2+14.09 T	0.001	0.88***
KRB	Y= 465.37 +619.60 PC1-456.76 PC2+9.70 T	0.001	0.79***
JGR	Y= 26.77 +592.32 PC1-3198.3 PC2-17.29 T	0.001	0.75***
CGPZ	Y= 446.49 +496.06 PC1+501.59 PC2+14.35 T	0.001	0.85***

***P<0.001, **P<0.01, *P<0.05, +P<0.1

The result of Principal component analysis on district level shows in Table-4.4.5 that more than 80% variability covered by two Principal Component PC1 & PC2 and model with two principal components along with T fitted for prediction . Model fitted with PC1 and PC2 for all the districts and CG Plain Zone found highly significant. Kawardha district found Maximum R^2 value (88%) followed by Raipur, Bilaspur, Durg Rajnandgaon, Mahasamund, Dhamtari, Korba and Janjgir with 74%, 70%, 64%, 62%, 59%, 72%, 79%, 75%, and 85% R2 value respectively. Models for all the districts and the value of R^2 are highly significant at 0.01% level of significance.

Table-4.4.6. Model through PCA for All District Plain zone on pigeonpea.

District	Model	Significance (R^2)	Adj (R^2)
RAI	Y= -39.61 +1461.50 PC1-3678.1 PC2-18.78 T	0.001	0.77^{***}
BLS	Y= 365.9 +2036.24 PC1-3741.02 PC2-34.03 T	0.001	0.77^{***}
DRG	Y= -149.66 +5242.66 PC1+280.32 PC2-17.56 T	0.001	0.72^{***}
RJN	Y= 327.59 +518.94 PC1-3744.04 PC2-29.73 T	0.001	0.71^{***}
MSD	Y= 81.15-472.33 PC1-1563.39 PC2-7.95 T	0.0002	0.71^{***}
DMT	Y= 182.78 -528.94 PC1-1045.27 PC2-5.48 T	0.0002	0.70^{***}
KWD	Y= -75.92 -927.54 PC1-2756.26 PC2-10.85 T	0.001	0.74^{***}
KRB	Y= 43.50 +118.77 PC1-2565.62 PC2-10.67 T	0.0001	0.72^{***}
JGR	Y= 26.77+592.3 PC1-3198.34 PC2-17.29 T	0.001	0.75^{***}
CGPZ	Y= -60.02 -2244.8 PC1-4493.58 PC2-22.50 T	0.001	0.69^{***}

$^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$, $^{+}P<0.1$

Table 4.4.5 indicates that more than 80% variability covered by two Principal Component PC1 & PC2 and model with two principal components along with T fitted for prediction. Model fitted with PC1 and PC2 for all the districts and CG Plain Zone found highly significant. Raipur and Bilaspur district found Maximum R^2 value (77%) followed by Durg and Korba are found R^2 value (72%), Rajnandgaon and Mahasamund are found R^2 value (71%), after that Dhamtari, Kawardha and Janjgir with 70%, 74% and 75% R^2 value respectively. Models for all the districts and the value of R^2 are highly significant at 0.01% level of significance.

DISCUSSION

Krishna Priya and Suresh (2009) reported that a suitable statistical model has been developed for forecasting the yield of the sugarcane in Coimbatore district (1981-2004) using the yield data and fortnightly weather variable viz. average daily maximum and minimum temperature, relative humidity in the morning and evening and total fortnightly rainfall. The forecast model was developed using generated weather variables as regressors in model. The generated weather variables were developed using weighted accumulation of fortnightly data on weather variable, weights being the correlation coefficient of the weather variables, in respective fortnights with yield. The data for a period of (1981-2001) was used to develop the forecast model. The validation of the model was done using the data from (2002-2004). The results revealed that the forecast model developed was able to explain 87% of variation in the sugarcane yield. And it is possible to forecast sugarcane yield successfully two months before harvest. Gupta *et.al.* (2015) The field experiment was conducted at PAU, Regional Station, Bathinda, for consecutive 7 years (2003-2009) to study the crop growth behavior and yield characteristics of ber fruit crop and an attempt was made to correlate the ber fruit characteristics with weather parameters over the years. The seven years data on fruit characteristics and weather parameters were taken on yearly basis and correlations were developed between ber fruit yield, fruit weight, acidity, pulp percentage, TSS and corresponding weather parameters namely minimum temperature, maximum temperature, morning relative humidity, evening relative humidity and rainfall. The regression analysis was done for four varieties of ber viz., Umran, Wailati, Chhuhara and Seb and the most suitable variety best suited for the weather conditions of southwestern region was worked out. The most sensitive period for fruit yield sensitivity appears to be during November to March months for the ber varieties under study. Different varieties responded differently with weather parameters for their different characteristics. The multiple regression models were developed on the basis of critical periods pertaining to crop yield characteristics for different varieties separately and it was found that 80-90 % variation in fruit yield and yield attributing characters were explained by weather parameters. These results are in line with Multiple regression technique was employed to develop models to forecast wheat yields over central Punjab (Ludhiana district) by using weather and production data of 23 years (1976-77 to 1998-99). Three years data (1999-00 to 2001-02) were used to validate the model. The sensitive periods of statistical and phenological significance were selected for regression analysis. The analysis of variance revealed that the regression models were highly significant at 5%.

CHAPTER-V
SUMMARY AND CONCLUSION

Forecast of the crop production at suitable stages of crop period before the harvest are vital for rural economy. On the other hand, forecasts of crop yields are important for advance planning formulation and its implementation. Forecasting is also vital for crop procurement, distribution, price structure and import export decisions etc. These are useful to farmers to decide in advance their future prospects and course of action.

In Chhattisgarh, chickpea is grown over an area of 393.78 thousand ha with an annual production of 433.158 thousand tones and an average productivity of 1100 kg ha-1. Pigeonpea is an important pulse crop of India after chickpea. It is grown an area of 3.88 M ha with the production of 3.17 MT and productivity of 849 kg ha.

Forecast models based on principal components of biometrical characters have also been developed, A number of statistical techniques such as multiple regression, principal component analysis, Markov chain analysis, Discriminant function and agro-meteorological models have been used to quantify the response of crops to weather. Out of these seventeen districts only 9 districts (Raipur, Durg, Rajnandgaon, Bilaspur, Dhamtari, Mahasamund, Korba, Kawardha and Janjgeer) are taken for the study.

Time series data on yield for Chickpea and pigeon pea crop for 25 years (1990-91 to 2014-15) for Raipur, Durg, Rajnadgaon and Bilaspur Districts. Seventeen year (1998-99 to 2014-15) for Dhamtari, Mahasamund, Korba, Kawardha and Janjgir have been procured from the Directorate of Agricultural, Govt.of Chhattisgarh. The District wise weekly meteorological data (1990-91 to 2014-15) procured from the department of Agro meteorology, Indira Gandhi Agriculture University, Raipur (CG.)

Study of individual effect has been done to know about the effect of individual weather parameter on chickpea and pigeonpea on district level and zone level as well. This study has been done for the knowledge about direction of weather parameter during crop period. Joint effect of two parameters is the study of the combined effect of the weather variables. The Stepwise Regression Analysis (SRA) technique has been used for development of the forecasting models for district level and zone level as well. Model developed by Principal Component Analysis (PCA) is a two stage analysis technique. First stage is generation of PC1 and PC2 and second stage is model fitting a new technique for the forecasting on district level and zone level for Chhattisgarh. The percent deviation of forecast yield from actual yield has been used for the validation of the model.

CONCLUSION

Under the study of individual effect Relative humidity-II, Time trend found all the districts have significant at 0.1% level of significance on Chickpea rest all the variables found significant at 5% or more level of significant, all the variable found significant at 0.1% level for Chhattisgarh plain zone on Chickpea. Under the study of individual effect on Pigeonpea maximum Temperature, Sun Shine, Rainfall found highly significant at 0.1% level of significance for all the districts rest all the variables found significant at least 5% level of significant or higher level of significant. The entire variable found significant at 0.1% level for Chhattisgarh plain zone on Pigeonpea.

Joint effect Korba districts with two combinations found significant at 10% level of significance but rest all the district Chhattisgarh plain zone found significant at either 1% or 0.1% level of significance on Chickpea. Moreover, Mahasamund and Dhamtari with only three combination reported on 10% level of significant, rest all the variables combination in the all the districts along with Chhattisgarh plain zone found highly significant at 1% or 0.1 % level of significance for pigeonpea.

The model has been developed on districts level as well as zone level by the Stepwise Regression Analysis. All the models found highly significant at 1% level of significance. Maximum R^2 (91%) found in model developed for Chhattisgarh plain zone which is also highly significant at 1% level, Time trend (T) also playing important role for all the districts and entered into models. Mahasamund and Dhamtari found maximum R^2 (89%) followed by Korba and Janjgir. The models for all the district and Chhattisgarh plain zone are highly significant at 0.01% level of significance.

Model developed on Pigeonpea for district level and zone level, the R^2 value for Korba district is 94% which is maximum and significant, followed by Kawardha and Dhamtari (93%). The value of R^2 is highly significant for all the district as well as CG plain Zone, The weighted individual (Z.1) for few variable entered in the models for Mahasamund and CG Plain Zone. The zone level model with 78% R^2 value and the interaction term (weighted) Maximum temperature & Minimum temperature and weighted individual (Relative Humidity II) in the model and R^2 (coefficient of determination) is found at 0.01% level of significance.

The result of Principal component analysis on district level for chickpea shows that more than 80% variability covered by two Principal Component PC1 & PC2 and model with two principal components along with T fitted for prediction . Model fitted with PC1 and PC2 for all the districts and CG Plain Zone found highly significant. Kawardha district found Maximum R^2 value (88%) followed by Raipur, Bilaspur, Durg Rajnandgaon, Mahasamund, Dhamtari, Korba and Janjgir with 74%, 70%, 64%, 62%, 59%, 72%, 79%, 75% and 85% R^2 value respectively. Models for all the districts and the value of R^2 are highly significant at 0.01% level of significance.

More than 80% variability covered by two Principal Component for pigeonpea PC1 & PC2 and model with two principal components along with T fitted for prediction. Model fitted with PC1 and PC2 for all the districts and CG Plain Zone found highly significant. Raipur and Bilaspur district found Maximum R^2 value (77%) followed by Durg and Korba are found R^2 value (72%), Rajnandgaon and Mahasamund are found R^2 value (71%), after that Dhamtari, Kawardha and Janjgir with 70%, 74% and 75% R^2 value respectively. Models for all the districts and the value of R^2 are highly significant at 0.01% level of significance.

It can be observed from the results of the Table 4.3.2.that the value of adjusted R2 is also high 91%. The percent deviation is also indicating that the model is best fitted and it has high power to pre-harvest forecast of chickpea yield.

It can be observed from the results of the Table 4.3.4.that the value of adjusted R^2 is also high 78%. The percent deviation is also indicating that the model is best fitted and it has high power to pre-harvest forecast of pigeonpea yield. It can be observed from the results the value of adjusted R^2 is also high 85%. Deviation from yield in case of chickpea indicates that the model is best fit and it has high power to pre-harvest forecast of chickpea yield. It means model is very reliable for forecasting at zone level.

The value of adjusted R^2 good enough i.e. 85% deviation from yield indicates that the model is best fit and it has high power to pre-harvest forecast. It means model is very reliable for forecasting at zone level for pigeonpea. The results are also shown in graphical format for the model and comparison of actual and predicted yield.

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RESUME

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Development of Pre Harvest Forecasting Model for Chhattisgarh Plain Zone on Pigeonpea by Stepwise Regression Analysis

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ABSTRACT

The present investigation deals with the model have been also developed through Step wise regression analysis on districts level as well as zone level all the models found highly significant at 0.1% level of significance for Pigeonpea crops., the value of R^2 for the model on Zone Level is 78% and 2 (Q_{121} and Z_{41}) variable entered into models for Pigeonpea crop. The model has been also found significant. The present investigation covers under the study of individual effect of weather variables, joint effect of weather variables forecasting model developed through Stepwise Regression technique following the concept of older studies by the different scientists in this direction for many crops. The principal component analysis has been also taken for the development of forecasting model. But in this section only Stepwise Regression Analysis covered for the model development.

Introduction

Forecast of the crop production at suitable stages of crop period before the harvest are vital for rural economy. On the other hand, forecasts of crop yields are important for advance planning formulation and its implementation. Forecasting is also vital for crop procurement, distribution, price structure and import export decisions etc. These are useful to farmers to decide in advance their future prospects and course of action. Thus, reliable and timely pre-harvest forecasting of crop yield is very important. To meet such needs, crop forecasts under the prevalent system in India are being issued by the Directorate of Economics and Statistics, Ministry of Agriculture, New Delhi. The final estimates based on objective crop-cutting experiments are of limited utility as those become available quite latter after the crop harvest. The Statistical techniques employed for forecasting purposes should be able to provide objective, consistent and comprehensible forecasts of crop yield with reasonable precisions well in advance before the harvest. Several studies have been carried out to forecast crop yield using weather parameters etc.

These are useful to farmers to decide in advance their future prospects and possible course of action. Thus, reliable and timely pre-harvest forecasting of crop yield is very important. In statistical model approach, one or several variables (representing weather or climate) are related to crop responses such as yield and yield contributing characters. Therefore, there is a need to develop area specific forecasting models based on time series data to help the policy makers for taking effective decisions to counter adverse situations in food production. The forecasting of crop yield may be done by using three major objective methods (i) biometrical characteristics (ii) weather variables and (iii) agricultural inputs (Agrawal *et al.*, 2001).

Materials and Methods

The present investigation covers under the study of individual effect of weather variables, joint effect of weather variables forecasting model developed through stepwise regression technique following the concept of older studies by the different scientists in this direction for many crops.

The principal component analysis has been also taken for the development of forecasting model. Time series data on yield for 25 years (1990-91 to 2014-15) for 4 Districts, Seventeen year for 5 districts has been procured from Directorate of Agricultural, Govt. of Chhattisgarh. The weekly meteorological data (1990-91 to 2014-15) procured from IGKV, Raipur for Pigeon pea crop period data.

This procedure is based on the method given by Agrawal *et al.*, (1986) for developing forecast model using weather indices. In this procedure the entire 17 weeks data (w = 1, 2,…17) for Pigeonpea crop.

Let m denotes the week (w = 1, 2,…m) at which pre-harvest forecast of crop-yield need to be released. Using the weekly data on m weeks of p weather variables (p= 7 here), new weather variables and interaction components have been generated with respect to each weather variable. Forecast model has been developed considering all generated variables simultaneously including time trend (T).

Model – I

$$Y = a + \sum_{i=1}^{p}\sum_{j=0}^{2} b_{ij} z'_{ij} + \sum_{i \neq i'=1}^{p}\sum_{j=0}^{2} b_{ii'j} Q_{ii'j} + CT + \in$$

Where

$$Z_{ij} = \sum_{w=1}^{m} r_{iw}^{j} X_{iw} \Big/ \sum_{w=1}^{m} r_{iw}^{j} \quad \text{and}$$

$$Q'_{ii',j} = \sum_{w=1}^{m} r_{ii',w}^{j} X_{iw} X_{i'w} \Big/ \sum_{w=1}^{m} r_{ii',w}^{j}$$

Xiw is the value of the ith weather variable in wth week, riw/rii'w is correlation coefficient of yield adjusted for trend effect with ith weather variable/product of ith and i'th weather variable in wth week.

Measures for validation and comparison of the models

Two procedures have been used for the comparison and the validation of the developed models. These procedures are given bellow.

Coefficient of determination (R^2) and (R^2_{adj})

The models were validated on the basis of (R^2) and (R^2_{adj}) which can be computed from the formula given by Drapper and Smith (1988).

Adjusted R^2 is given by the following formula

$$R^2_{adj} = 1 - \frac{ss_{res}/(n-p)}{ss_t/(n-1)}$$

Where $ss_{res}/(n\text{-}p)$ is the residual mean square and $ss_t/(n\text{-}1)$ is the total mean square. The total mean square is constant regardless of how many variables are in the model. On adding a regressed in the model Adjusted R^2 increases only if the addition of the regressed reduces the residual mean square. It also penalizes for adding terms that are not helpful, so it is very important in evaluating and comparing the regression models.

Table.1 Pre-harvest Forecast Model through SRA for Plain zone on pigeonpea

Variables	Coefficient	Standard error	P-Value	Significance (R^2)	R^2 (Adj)
(Constant)	2866.11	673.037		0.0001	0.78***
Q121	-5.63***	.904	0.0001		
Z41	19.95***	4.879	0.0001		

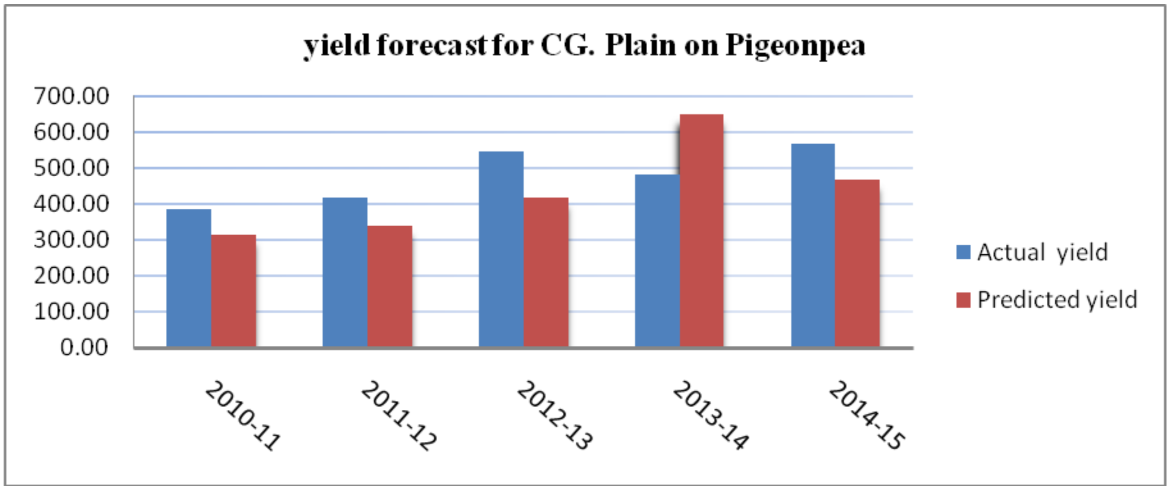
***P<0.001, **P<0.01, *P<0.05, +P<0.1

Table.2 Validation of the model for Plain zone on Pigeonpea

Year	Actual rice yield(q/ha)	Predicted rice yield(q/ha)	Adjusted R^2 (%)	Percent deviation
2010	384.67	314.27	0.78***	18.30
2011	416.22	338.72		18.62
2012	546.11	419.07		23.26
2013	481.62	648.98		-34.75
2014	567.10	468.73		17.35

**P<0.01, *P<0.05, +P<0.1

Fig.1 Shows the comparison between actual and predicted yield on the basis of 5 year data, almost same indication in result as well as graph



Percent Deviation

The formulae for computation of Percent Deviation of forecast yield from actual yield are given by Mohd. Azfar *et al.,* (2015) and Yadav and Sisodia (2015). This measures the deviation (in percentage) of forecast from the actual yield data. The formula for calculating the percent deviation of forecast is given below:

$$\text{Percentage deviation} = \frac{\text{(Actual yield- Forecasted yield)}}{\text{(Actual yield)}} \times 100$$

Results and Discussion

Two regressed variables have been entered in the model finally, which is given below:

$Y= 2866.11 -5.63Q_{121}+19.95 Z_{41}$

Where;

Q_{121} = weighted interaction between maximum and minimum temperature

Q_{41} = weighted relative humidity-II

The results given in table:-1 are out of 56 variables only two variables entered into the model. The coefficient of determination (R^2) has been found to be 78 % which is significant at 0.1% level of significance. Variables Q_{121} and Z_{41} have been found to be significant at 0.001 and 0.001 respectively, probability level of significance.

It can be observed from the results of the Table:-2.that the value of adjusted R^2 is also high 78%. The percent deviation is also indicating that the model is best fitted and it has high power to pre-harvest forecast of pigeonpea yield.

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