Impact of Climatic Change on the Incidence of Girdle Beetle (*Obereopsis brevis* (Swed.) in Soybean

THESIS

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In

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(ENTOMOLOGY)

By

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CERTIFICATE – I

This is to certify that the thesis entitled **"Impact of climatic change on the incidence of girdle beetle (*Obereopsis brevis* (Swed.) in soybean"** submitted in partial fulfilment of the requirement for the **DEGREE OF MASTER OF SCIENCE (Entomology)** of the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior is a record of the bonafied research work carried out by **Mr. Kishan Tirole ID. No RA/SH/939/09** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.

No part of the thesis has been submitted for any degree or diploma (Certificate awarded etc.) or has been published. All the assistance and help received during the course of the investigation has been acknowledged by the scholar.

Place: Sehore Signature

Date: **(Dr. Rajesh Verma)**

Chairman of the Advisory Committee

MEMBER OF THE STUDENT'S ADVISORY COMMITTEE

Chairman (Dr. Rajesh Verma) .....

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Member (Dr. S.A.Ali) …….

CERTIFICATE –II

This is to certify the thesis entitle **"Impact of climatic change on the incidence of girdle beetle (*Obereopsis brevis* (Swed.) in soybean"** submitted by **Mr. Kishan Tirole , ID. No RA/SH/939/09** to the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior in partial fulfilment of the requirements for the degree of Master of Science in **Agriculture (Entomology)** has been accepted after evaluation by the External Examiner and approved by the Student's Advisory Committee after an oral examination on the same.

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Place : Sehore
Date : (Kishan Tirole)

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	Legend
&	And
@	At the rate of
^{o}C	Degree Celsius
C.D.	Critical Difference
C.V.	Coefficient of Variation
DAG	Days after germination
d.f.	Degree of Freedom
et al.	And others
etc	and the rest
fig.	Figure (s)
i.e.	That is
MSS	Mean sum of square
mrl	Meter row length
mm	Milimeter
no	Number (s)
R.V.S.K.V.V.	Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya
R.A.K.	Rafi Ahmed Kidwai
RH	Relative humidity
S.Em.±	Standard error of mean
S.S.	Sum of Square
SWW	Standard Weather Week
Viz.	Namely
√	Square root
%	Percent
±	Plus or Minus

CHAPTER I
INTRODUCTION

According to intergovernmental panel on climate change it is defined as “change in climate over time, either due to nature viability or as a result of human activity” occurrence of climate change is evident from increase in global average temperature change in monsoon activity and the rainfall pattern and extreme climate events. These seasonal and long term changes would affect on the fauna, flora, population dynamics and status of insect pests. These may arise not only as a result of direct effects on the distribution and abundance of pest populations but indirect effects on the interaction of pests and host plants competition and natural enemies, (Porter *et al.,*1991).

Climate change result in occurrence of more frequent disasters with high magnitude and intensity. There is an increasing trend in the surface temperature of the country. This will adversely affect the rainfall pattern in the country as a result of which, agriculture and food security in the country will be severely affected. Climate change is likely to significantly affect agriculture by 2100 with wide variation in the estimation of impact on crop yields across different regions. The principal drivers of climate changer are increase temperature reduced the biomass and yields of various crops.(Kumar 2010)

Temperature is identified as the dominant abiotic factor directly affecting the insects. There is little evidence of any direct influence of CO_2 on insect and mostly the impact of elevated CO_2 is mediated through host crop, particularly in case of herbivorous or phytophagous insects.. Effects of climate change on insect herbivores can be direct (temperature) through impacts on their physiology and behavior, or indirect, where the insect respond to climate-induced changes mediated through other factors, such as host plant induced growth changes. Weather and its significant interaction with key pests of several crops, known among researches and farming community.(Rao *et al.,* 2010*)*.

Pest surveillance and monitoring in relation to weather can considerably reduce the application of chemicals. In order to fine tune the existing pest predictions, understanding the thermal requirements and degree

days for key pests and their associated natural enemies are of prime importance (Srinivasa rao *et.al.,* 2010).

Soybean [*Glycine max (L.*) Merrill] commonly known as 'Soya' is a unique crop with high nutritional value, providing 40 per cent protein and 20 per cent edible oil besides minerals and vitamins. Soybean crop is affected by various insect pests in different crop growth stages. Girdle beetle is one of the major pests of soybean throughout the cultivated area in India.

Present investigation on **"Impact of climatic change on the incidence of girdle beetle (*Obereopsis brevis* (Swed.) in soybean"** were carried out with the following objectives-

1. To study the weather fluctuations recorded during last six years in the study area.
2. To find out the incidence of girdle beetle (*Obereopsis brevis* (Swed) in popular varieties of soybean.
3. To find out the co-relation between weather fluctuation and incidence of girdle beetle (*Obereopsis brevis* (Swed.). in soybean.

CHAPTER II
REVIEW OF LITERATURE

Changing climatic situation influence various crops, affected growth and yield parameters and also influence the insect growth and development and occurrence of pests.

Garg (1985) reported *Oberea sp*. infestation from end of August to beginning of October on soybean in Western Himalayan region.

Rai and Patel (1990) recorded the incidence of the cerambycid *Obereopsis brevis* in plots sown with the soybean variety JS 72-44 on 15 July 1988 in India. The pest first appeared on 10 August 1988 (maximum and minimum temperature 29.60 and 24.70 degrees C, respectively and relative humidity 84.50%) and activity continued until 12 October 1988. It is concluded that the low infestation level (0.86-12.09%) during the period of activity may be due to the late planting of the soybean crop and low rainfall.

India is endowed with rich surface water resources but an extremely uneven spatial and temporal distribution of the rainfall, which is the primary source of surface waters, frequently results in severe water scarcity in some regions and flood hazards (Mujumdar,2008). Due to the changing climate water resources will come under increasing pressure in Indian subcontinent. The climate affects the demand for water as well as the supply and quality particularly, in semi- arid regions of India any shortfall in competition for water use for a wide range of economic, social and environmental applications (Lioubimtsweva and Henebry, 2009)

Global warming is the root cause of climate change all over the world. Most of the changes in climate such as irregular monsoon, drought, temperature rise, cyclones, heavy rainfall etc due to rise in temperature. Climate change has tremendous effect directly or indirectly on cropping pattern, crop production and productivity. At local and regional levels the tendency and distribution of these parameters are influenced by geographical situations. It is therefore, necessary that the changes of rainfall and temperature pattern are quantified by taking into duration of the long term data available for the locality (Sahu *et al.,* 2010)

Beginning with the industrial revolution global atmospheric concentrations of these greenhouse gases have increased markedly as a result of human activities. The global increase in carbon dioxide concentration are dup primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture. The spatial distribution of temperature changes indicated a significant warming trend has been observed along the west coast, central India, and interior peninsula and over northeast India. However, cooling trends has been observed in northwest and some parts in southern India. It is projected that by the end of the 21st century rainfall will increase by 15-31%, and the mean annual temperature will increase by 3^0 C to 6^0 C. Increasing climatic variability associated with global warming will, nevertheless, result in considerable seasonal/ annual fluctuation in food production. (Verma *et al* 2010)

Singh *et al.* (2011) observed sixteen insect pests and one mite on soybean at different growth stages, of which, five belonged to order Lepidoptera, five to Coleoptera, two to Hemiptera and Orthoptera, one each to Thysanoptera, Diptera and Acarina of these two were stem borers, nine defoliators, one root feeder, one pod feeder and four sap feeders.

Crop production in dry land is purely dependent on rainfall. Hence, for a successful cropping in dry land scientific evaluation of rainfall of a region is imperative (Kannan *et al.* 2000).Venkataraman *et al.*(2009) had earlier reported that pre-monsoon sowing of cotton should be taken up at 39 th standard week. This condition will be applicable of these was a probability of 75 per cent to get a rainfall of 25 mm. But pre- monsoon sowing of crops in the recent years failed due to non- receipt of pre- monsoon rains.

The soybean yield under elevated temperature (1to 5 ^{0}C over current temperature) and CO_2 concentration (450 and 550 ppm) for three locations (Indore, Nagpur and Dharwad). Data also indicated that if CO_2 effects are not considered, the soybean yields declined at all the locations. The overage reduction in yield ranged from 5% with 1C rise in temperature to 35% with 5C rise in temperature over current temperatures.

Comparative study of seven years weather data on occurrence of early blooming and its relation with the incidence of leafhopper *Indeosco pusniveopareus* leth in mango, revealed that the rise of leaf hopper population

was coupled with the early initiation of inflorescence in mango orchards induced by rising trends of mean maximum temperature beyond 30^0C in the months of October and November as compared to normal blooming season of mango. (Verma and Swati, 2010)

Groundnut leafminer (GLM), *Aproqerema modicella* is the key pest of groundnut in many part of India particularly the southern states. This pest is favoured by the host dry conditions of the post rainy season. Heavy persistent rains high relative humidity (RH) and low temperatures reduce pest numbers, where as dry weather, bright sunshine and occasional rains favour pest build up (Ghule*et al.,* 1989). GLM is often a problems towards the end of the rainy season (September and October), especially in drought or low- rainfall years (Amin, 1983). GLM population fluctuate widely between seasons. Amin (1987) and Khan and Raodeo (1987) have suggested that high rainfall reduces leafminor populations even though data from the latter do not support this conclusion. They observed high populations in August September during a high rainfall period and populations declined in March when no rains was recorded.(Rao *et al.*2010)

Increased temperature influenced the larval development and fecundity of *O. brymacta* insects (Dury *et al*., 1998) and long term exposure to increased temperature 3.5^0C shortened the insect development (Williams *et al.,* 2003). The temperature enhancement increased the relative growth rate of *Chrysomelia* beetles (Veteli *et al*., 2002)

Under climate change scenario increased asynchrony between host plant and insect herbivore shows adverse consequences. (Dewera and Wait, 1992)**.**Higher temperatures keeping all other variables equal allow faster development of insects and may allow for additional generations of Insects within a year (Pollard and Yates, 1993)**.** Climatic warming will allow the majority of temperature insect's species to extend their ranges to higher latitudes and altitudes. (Gaston and Willams. 1996).Expand their geographical ranges to higher latitudes and altitudes, as has already been observed in a number of common butterfly species.(Parmesan *et al*.,1999)**.** Elevated temperature is non to alter phyto-chemistry of the host plants and affect the insect growth and development directly or indirectly through on host plant.(Williams *et al.,* 2000)**.** Diversity of insect herbivores and the intensity of

herbivore increases with raisins temperatures at constant latitude. Individuals may develop faster at higher temperature and survival may even be enhanced, but these insects may consequently have lower adult weight and fecundity.(Bale *et al.,* 2002)

Spodeptera litura larvae per plant correlated with standard week data within rainfall (mm) negative correlation, maximum temperature no correlation, Relative humidity (%) no correlation. And monthly data correlated with the rainfall negative correlation, minimum temperature negative correlation, maximum temperature no correlation Relative humidity no correlation and yearly data correlation, minimum temperature no correlation and Relative humidity (%) no correlation (Srinivasa Rao *et al.,* 2010) were obtained.

Sharma *et al.* (1997) observed that mean temperature around 26^0C was most conducive for the population build up of key pests of soybean. The correlation of weather parameters with the population buildup of semilooper, *Thysanoplusia orichalcea* (Fab.) Bihar hairy caterpillar, *Spilosoma oblique* (Walk); and leaf miner, *Liriomyza trifoli* (Burgess) were non significant.

Chattopadhyay *et al.* (2002) studied the sensitivity of the incidence of leaf miner (*Aproaerema modicella*) on soybean to the different meteorological parameters at Parbhani (Maharashtra) and Bangalore (Karnataka), India. The months of July-September were the peak period of the infestation. Dry weather conditions along with low relative humidity (morning: <=80%, afternoon: <=55%) and increase in maximum temperature (>=28 degrees C for Bangalore and >=32 degrees C for Parbhani) under clear sky condition (sunlight of >=8 h) were favourable for the multiplication of the pest..

Singh and Kumar (2003) determined correlation between meteorological parameters (temperature and relative humidity) and population buildup of insect defoliators of cowpea. The incidence of grasshopper (*Poekilo ceruspictus*), red pumking beetle (*Raphidopalpa foveicollis*, *Aulacophora foveicollis*), jute weevil (*Apoina mpulum*), leaf miner (*Phytomyza atricornis)* and red hairy caterpillar (*Amsacta moorei*) was recorded from germination to harvesting stage at weekly interval. Grasshopper infestation was observed in the 3rd week of April at the early growth stage of cowpea and peaked during the 2nd week of May and 2nd week of June. The population of leaf miner peaked at the early stage of crop growth during the 3rd week of April. Red

pumpkin beetles were noticed in the 3rdweek of April and peaked of May. The appearance of jute weevil was noticed in the 1st week of May and continued until crop maturity. Larvae of red hairy caterpillar were recorded from vegetative stage to maturity; however, the population was very low during the entire crop growth. The population buildup of grasshopper, jute weevil and red hairy caterpillar was positively correlated with minimum and maximum temperatures, while the population buildup of leaf miner and red pumpkin beetle was positively correlated with relative humidity.

Singh (2010) recorded a total of sixteen insect-pests were recorded on *Vigna mungo* at different stages of crops growth during *Kharif* 1997 and 1998. The populations of grass hopper. Epilachna beetle and leaf Webber were negatively correlated with relative humidity and rainfall during both the years.

Rai and Singh (2012) studied the effects of climatic factors on the incidence of jassid (*Amrsca bijuttula*) on okra (Kashi Pragati) in Uttar Pradesh, India, during the summer and rainy seasons of 2008 and 2009. The jassid was initially observed on the second week of April (mean density of 4.8 per 3 leaves), and its population peaked on the fourth week of May (mean density of 22.3 per 3 leaves). The population density was positively correlated with relative humidity, minimum temperature, minimum relative humidity, rainfall and sunshine hours were not correlated with the jassid population.

Khalid *et al.* (2013) studied the effect of the weather factors on incidence and development of *Helicoverpa armigera* on different sunflower genotypes during 2008-2009. The determination of the effects of different weather factors on egg count and larval population of *H.armigera* in sunflower is essential for effective management of this pest.

Malgaya (2013) observed highest frequency of girdle on stem (11%) during 3rd week of August followed by petiole (7%) and petiolet. Similar trend of distribution of infestation continued up to 3rd week of September. However, there was an increase in frequency of girdling on branches (18%) in last week of September. This may be attributed to the succulence of branches in comparison to stem. Inter girdle length of 12.8 to 14.7 mm was recorded in different periods of observation. Maximum inter girdle length (14.7mm) was recorded in 1st week of September with maximum distance of egg hole (3.20mm) from proximal girdle.

Singh *et al.* (2013) observed 12 insect species during *Kharif* season of 2007 while during 2008 and 2009, 13 insect pests and one mite were observed on soybean. These pests were identified as *Gesonia gemma* (Swinhoe), *Chrysodeixis acuta*(Walker), *Spodoptera litura* (Fab.), *Helicoverpa armigera* (Hub.), *Myllocerus maculosus* (Desbro).*Gryllus* sp.; *Cneorane* sp., *Luperu sclytie* (Wilcox) and *Mocis undata*, Stem borers viz. *Obereopsis brevis* (Swed.) and *Melanagromyza sojae* (Zehnt.); and sap feeders *Bemisia tabaci* (Gennadius), and *Chauliops fallax* (Scott.). Of these, *Cneorane* sp., *Gesonia gemma*, *Chrysodeixis acuta*, *Melanagromyza sojae* and *Obereopsis brevis* were recorded as major pests. During 2007 the infestation reached up to 13.5 per cent, while during 2008 - 09 up to 26.6 and 30.5 per cent, respectively before harvesting of the crop.

CHAPTER III

METHOD AND MATERIALS

The research work was carried out during kharif season of 2014 at R.A.K. Collage of Agriculture, Sehore. The details of the methods employed and material used during the course of investigation was as follows.

Experimental site (Location):-

The experimental work was conducted in the field No. 57, 58, 59 at research farm of College of Agriculture, Sehore, Madhya Pradesh under "All India Coordinated Research Project on soybean financed by ICAR, New Delhi.

Climate, Season and Geography:

Sehore is situated in subtropical zone of Vindyan Plateau of Madhya Pradesh, North of $27^0$12' latitude and East of $77^0$05' longitude with an altitude of 498.77m from mean sea level (MSL).

During the crop season 2014 the average maximum and minimum temperatures and relative humidity was32.13.^{0}C and 23.10.^{0}C and 71.85% and total rainfall 669.5 mm, respectively. During the season, the onset of monsoon was slightly delayed and arrived on the 3 July. Planting of trial was done between 17-21 of July .The crop growth was very good offered by good rains up to 32th Week of September. There was a slight dry spell in 41th and 42rdweek. The overall weather data were suitable for normal growth and development of crop.

Soil:

The experimental field represent the medium black and well drained soil, where as organic matter and potash were medium in availability. The PH of soil and soluble salts were normal.

Weather :

Meteorological data during the kharif crop season of 2014-2015 was recorded from observatory of R.A.K. College of Agriculture Sehore (M.P.). while metrological data from 2009 to 2013kharif season were collected from national observatory.

Table 1: Meteorological data of kharif season 2014

Month	Standard weather week no.	Dates	Temperature °C		Relative Humidity (%)	Rainfall (mm)
			Max	Min		
June	23	4-10	42.38	29.82	81.85	0.0
	24	11-17	37.81	26.78	88.85	5.0
	25	18-24	35.98	26.24	75.57	21.0
	26	25-01	37.32	27.28	76.71	3.5
July	27	2-8	36.97	24.41	76.42	1.0
	28	9-15	33.81	24.57	73.28	41.5
	29	16-22	29.01	23.11	68.42	135.5
	30	23.29	25.34	22.41	64.85	108.0
August	31	30-05	28.77	23.77	68.42	13.5
	32	6-12	26.84	23.04	66.42	77.5
	33	13-19	29.25	22.94	68.71	7.0
	34	20.26	32.34	23.62	71.85	30.0
	35	27-02	30.65	22.95	70.14	143.0
September	36	3-9	28.15	23.21	67.71	79.5
	37	10-16	28.14	22.50	67.57	0.5
	38	17-23	30.85	21.32	70.42	0.5
	39	24-30	32.14	20.80	71.85	1.0
October	40	1-7	34.05	20.25	73.71	0.0
	41	8-14	32.30	19.08	71.71	0.0
	42	15-21	31.82	19.78	71.57	1.5
	43	22-28	30.84	17.28	70.42	0.0
					Total	**669.5**

Source :Meteorological Observatory at R.A.K. Agriculture College, Sehore(M.P.)

1. **To study the weather fluctuation recorded during last six years in the study area**

Calculation of normal weekly weather data of Sehore district : –

Weather data from year 1984 to 2013 (30 years) of maximum, minimum temperature rainfall, Relative humidity of Sehore district were used for calculating the weekly normal weather data of the Sehore district. Normal weather data were utilized for computation of decadal analysis and climate fluctuations in the study period kharif 2009-2014.

Whether data of the study period (Kharif season 2009-2014).

Six years weekly whether data of maximum, minimum temperature, relative humidity, rainfall (Standard weather week from 26 to 42) were collected from college observatory of Sehore Agriculture college. Data were utilized for the calculation of following weather fluctuations.

1. Decadal shift of maximum and minimum temperature, difference of (maximum and minimum temperature), relative humidity and rainfall.
2. Analysis of total rainfall in relation with the number of rainy days in consecutive decades.
3. Weather fluctuation within the study period assessed by comparing the deviation the weather data from the six years mean in respective year.
4. To find out the climatic changes these data compared with the normal weather data as a whole, week wise and decade wise.
5. Deviation of weather parameters from the normal weather data to draw interpretation for climatic change during the study period.

The rainfall has been grouped in to 3 broad category for accessing the rainfall pattern.

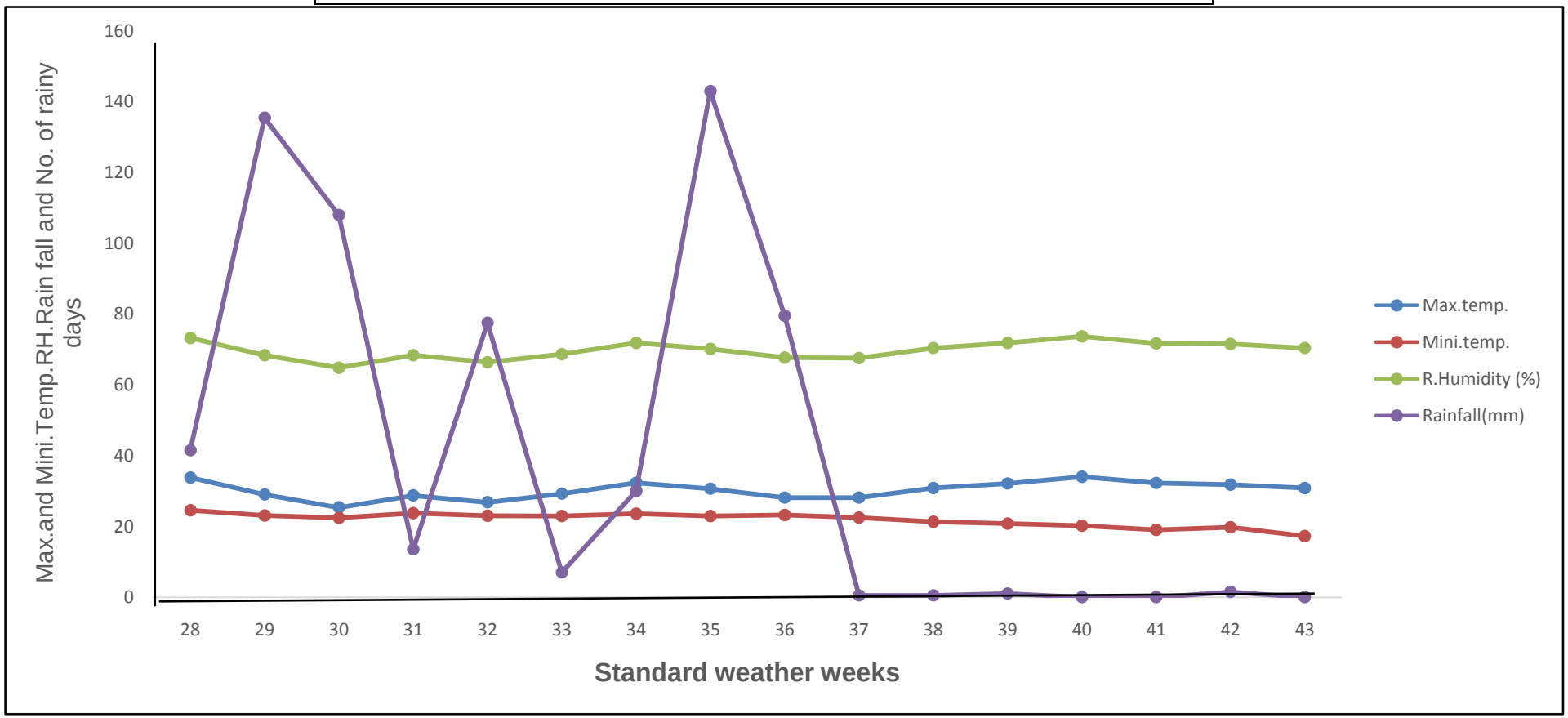
1. Light to rather heavy rainfall - 0 to 64.4mm
2. Heavy to very heavy rainfall - 64.4 to 124.4mm
3. Exceptionally heavy rainfall 124.4 and above

2. To find out the incidence of girdle beetle *Obereopsis brevis* (Swed) in some popular varieties of soybean.

Year wise data of incidence of girdle beetle (*Obereopsis brevis)* were taken from the AICRP- Soybean Sehore center with the due permission of principal investigator of the project and used for analysis of data to draw the interpretations.

Infestation of girdle beetle (*Obereopsis brevis*) in kharif 2014 was recorded from 6-8 DAS (Day after sowing) till the maturity of crop. Sample size was 1 meter row length (mrl) cropped area such ten random samples were recorded from general sowing in four varieties of soybean viz. RVS 2001-4, JS-335, JS 95-60, JS 93-05, Only fresh infestation of girdle beetle were observed to avoid duplication in counting observations were recorded thrice in a week. Girdle beetle infested plants were marked. Post harvest observation on per plant larval population and per plant number of rings were observed from 50 infested pre marked plants to find out the potentiality of infestation.

Fig.1 Meteorological data during kharif season 2013-14 of Sehore



3. To find out the co-relation between weather fluctuation and incidence of girdle beetle *Obereopsis brevis*(Swed) in soybean

Incidence of girdle beetle (*Obereopsis brevis*) in soybean JS-335 variety were recorded in Kharif 2014 however for kharif season 2009, 2010, 2011, 2012 and2013 were collected from the annual report of All India Coordinated Research Project on soybean, Sehore center with the Due permission of principal investigator soybean Entomologist Department of Entomology , R.A.K. College of Agriculture, Sehore (M.P.) as proposed in synopsis. The pest population of these years were compiled as per standard weather week number 26 (June 25th to July 1st) to week number 42 (October 15th to 21st). Incidence of pest was correlated with the maximum temperature, minimum temperature, difference of maximum and minimum temperature, mean of maximum and minimum temperature, relative humidity, deviation of the mean relative humidity, rainfall, deviation from the mean rainfall number of Rainy days, onset of monsoon and days from onset of monsoon to sowing of crop. The arrival date of monsoon was converted in to numeric number by counting the days started from first June for example if the monsoon arrived on 28th of June the number allocated was 28 and so on. Similarly the date of sowing was also converted in to numeric number by counting from 1st June year wise and week wise.

Statistical Analysis

Simple correlation:-

$$r = \frac{\sum(X-\overline{X})\ (Y-\overline{Y})}{\sum(X-\overline{X})^2(Y-\overline{Y})^2}$$

Where,

X = Independent factor (Weather factors)

y = Dependent factor (Pest incidence)

Significance of correlation coefficient :-

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

Mean:-

$$\text{Average mean} = \frac{\sum fx}{n}$$

RBD :-

Analysis of variance Table.

S No.	Source of Variance	d.f.	S.S.	M.S.S.	F. Values	
					Cal.	Tab.
1.	Block	r-1				
2.	Treatment	t-1				
3.	Error	(r-1) (t-1)				
4.	Total	(r x t)–1				

The difference between the two means was subjected to further testing by computing critical difference at 5% probability level.

(1) Standard error for treatment mean:

$$\text{S. Em.} \pm = \sqrt{\frac{\text{Ems}}{r}}$$

(2) Critical difference:

$$\text{C.D.} = \text{S. Em} \pm x\sqrt{2 \times t}$$

Where,

Ems = Error means sum of square

r = Number of replication

t = ‘t’ value at 0.5% probability level

CHAPTER IV

RESULTS

Impact of climatic change on the incidence of girdle beetle *Obereopsis brevis* (Swed.) in soybean was evaluated in present investigation. Population of girdle beetle (*Obseropsis brevis)* in kharif 2014 season was recorded in four varieties of soybean viz. JS-335, JS 95-60, JS 93-05 and RVS 2001-04, The data is use for studying the population dynamics of the girdle beetle. However the weekly population from kharif 2009 to kharif 2013 in soybean JS-335 variety was collected from AICRP soybean with due permission of principal investigator college of agriculture Sehore. Weather data of last 30 (1984 to 2013) years used for calculating the normal weekly weather data of Sehore district. Weather fluctuations were assessed by comparing the yearly weekly temperature with the normal temperature during the study period Insect pest population from 2009- 2014 also co- related with the weather factors,point wise results are describe as below.

1. **Study the weather fluctuations recorded last six years in the study area**.

Variation in weather parameters viz. maximum, minimum temperature, relative humidity, rainfall were compared with the normal weather data and weather fluctuations within the study period. Kharif season was considered from last week of June (standard week 26 (25June to 1 July) to week number 42 (15 to 21 October) based on the sowing and harvesting of soybean crop were done in different years of the study.

Maximum temperature:-

Mean normal temperature of the kharif season is 29.85 ^{0}C, it ranged from 27.36 ^{0}C recorded in week number 32 (6 to 12 August) to 33.74^{0}C recorded in week number 26 (25 July to 1 June) (Table 2). The normal maximum temperature showed slight rise in consecutive week, the linear curve was (Y = 0.023x + 29.61 R^2=0.003) (fig.2) maximum temperature in 2009 kharif season was 1.75^{0}C higher then the normal temperature. The seasons mean was 31.48 ^{0}C. Deviation of maximum temperature from the normal was higher in 13 weeks with the maximum deviation was observed of week number 32 (5.48^{0}C) while below the normal temperature was recorded

only in three weeks with maximum deviation in week number 29 (-2.35 ^{0}C).Maximum temperature during the season 2009 show the slight decline (Y = -0.141x + 32.82,R^2 = 0.079).

During the year 2010 the rise of maximum temperature over the normal was 0.36^{0}C, the decline of temperature as compared to 2009 kharif season was 1.38^{0}C. Maximum deviation of below the normal temperature was –4.71^{0}Cobeserved in week number 42 (15 to 21 October). The weekly mean maximum temperature below the normal was recorded in 11 weeks with maximum 3.36^{0}C in week number 26. Deviation below the normal temperature ranged from 0.26 ^{0}C (week number 30) to 3.36^{0}C (week number 26). Deviation below the normal temperature was ranged from -0.15^{0}C (week number 36) to -4.71^{0}C recorded in week number 42. Seasons mean of maximum temperature was 30.21 ^{0}C ranged from 27.12^{0}C (week number 42) to 37.11 ^{0}C (week number 26). Similar to 2009 season maximum temperature of 2010 also showed linear decline(Y = -0.223x + 32.45, R^2=0.214).(figure 2)

Decline of maximum temperature from the normal temperature by -0.31 ^{0}C was recorded in the season 2011. This season maximum temperature below the normal was observed in 8 weeks, range from –0.30^{0}C (week number 29) to -5.96 ^{0}C (week number 26) and deviation above the normal temperature was recorded in six weeks range from 0.13 ^{0}C (week number 36) to 2.26 ^{0}C (week number 35) respectively. The season's mean of maximum temperature was 27.40^{0}C. In 2011 season maximum temperature showed slight rising trend in temperature (Y = 0.124x+28.00, R^2 =0.103).(figure 2).

During the season 2012 the mean temperature was 29.60 ^{0}C which was -0.30 ^{0}Cbelow the mean normal temperature (29.85^{0}C). The trend of temperature showed slight decline trend (Y = -0.007x+29.68, R^2 = 0).

In 2013 season the maximum temperature was below the normal temperature in 11 weeks range from -0.76^{0}C (week number 32) to -5.64^{0}C in (week number 26) the season's mean maximum temperature was 28.82^{0}C. The deviation from the normal temperature was -1.02 ^{0}C. The maximum temperature showed slight rising trend in following weeks during the season (Y = 0.257x+26.25, R^2 =0.232).

In season 2014 the rise of maximum temperature over the normal temperature was observed by 1.19 ^{0}C over the normal maximum temperature.

Table-2 Maximum temperature - Normal temperature, year wise weekly temperature and deviation from the normal temperature (^{0}C)

SWW	DATE	MONTH	Normal Temperature	Actual Temperature 2009	Deviation From Normal	Actual Temperature 2010	Deviation from normal	Actual Temperature 2011	Deviation from normal	Actual Temperature 2012	Deviation from normal	Actual Temperature 2013	Deviation from normal	Actual Temperature 2014	Deviation from normal
26	25-1	June	33.74687	37.78	4.03313	37.11	3.36313	27.78	-5.96687	35.39	1.64313	28.1	-5.64687	37.32	3.57313
27	2-8	July	31.9868	33.42	1.4332	31.82	-0.1668	32.26	0.2732	34.32	2.3332	27.6	-4.3868	36.97	4.9832
28	9-15		30.64179	32.64	1.99821	32.18	1.53821	28.63	-2.01179	30.72	0.07821	28.3	-2.34179	33.81	3.16821
29	16-22		29.77779	27.42	-2.35779	32.01	2.23221	28.41	-1.36779	31.85	2.07221	26.6	-3.17779	29.01	-0.76779
30	23-29		28.39539	28.5	0.10461	28.66	0.26461	27.91	-0.48539	25.6	-2.79539	27.3	-1.09539	25.34	-3.05539
31	30-5	August	28.12729	31.07	2.94271	28.66	0.53271	29.12	0.99271	26.02	-2.10729	26.9	-1.22727	28.77	0.64271
32	6-12		27.36316	32.85	5.48684	27.86	0.49684	26.31	-1.05316	27.1	-0.26316	26.6	-0.76316	26.84	-0.52316
33	13-19		27.49108	29.85	2.35892	29.4	1.90892	27.17	1.88892	20.94	-6.55108	28.2	0.7092	29.25	1.75892
34	20-26		27.79155	32.5	4.70845	29.88	2.08845	29.38	1.58845	29.02	1.22845	25.2	-2.59155	32.34	4.54845
35	27-2		28.07513	31	2.92487	29.7	1.62487	30.34	2.26487	28.74	0.66487	28.5	0.42487	30.65	2.57487
36	3-9	September	28.2385	30.14	1.9015	28.08	-0.1585	28.37	0.1315	28.87	-0.3685	30.4	2.1615	28.15	-0.0885
37	10-16		29.18924	30.33	1.14076	29.45	0.26076	28.31	-0.87924	27.67	-1.51924	36.7	7.51076	28.14	-1.04924
38	17-23		30.00042	32.64	2.63958	29.66	-0.34042	29.64	-0.36042	29.81	-0.19042	31.9	1.89958	30.85	0.84958
39	24-30		31.27792	32.86	1.58208	28.33	-2.94792	30.97	-0.30792	30.5	-0.77792	29.2	-2.07792	32.14	0.86208
40	1-7	October	31.62457	30	-1.62457	30.8	-0.82457	32.2	0.57543	31.58	-0.04457	27.9	-3.72457	34.05	2.42543
41	8-14		31.89431	30.71	-1.18431	32.98	1.08569	29.12	-0.3145	32.45	0.55569	28.8	-3.09431	32.3	0.40569
42	15-21		-	-	1.75551188	27.12	-4.71992	0	0	32.7	0.86008	31.9	0.06008	31.82	-0.01992
		Mean	29.85069	31.481875	1.75551188	30.217647	0.36695706	27.40706	-0.296	29.60471	-0.30481	28.82941	-1.02126	31.04412	1.193428

Figure 2 MAXIMUM TEMPERATURE – A comparative accounts of temperature in kharif season (x = June SWW 26 – October SWW 42) during the study period

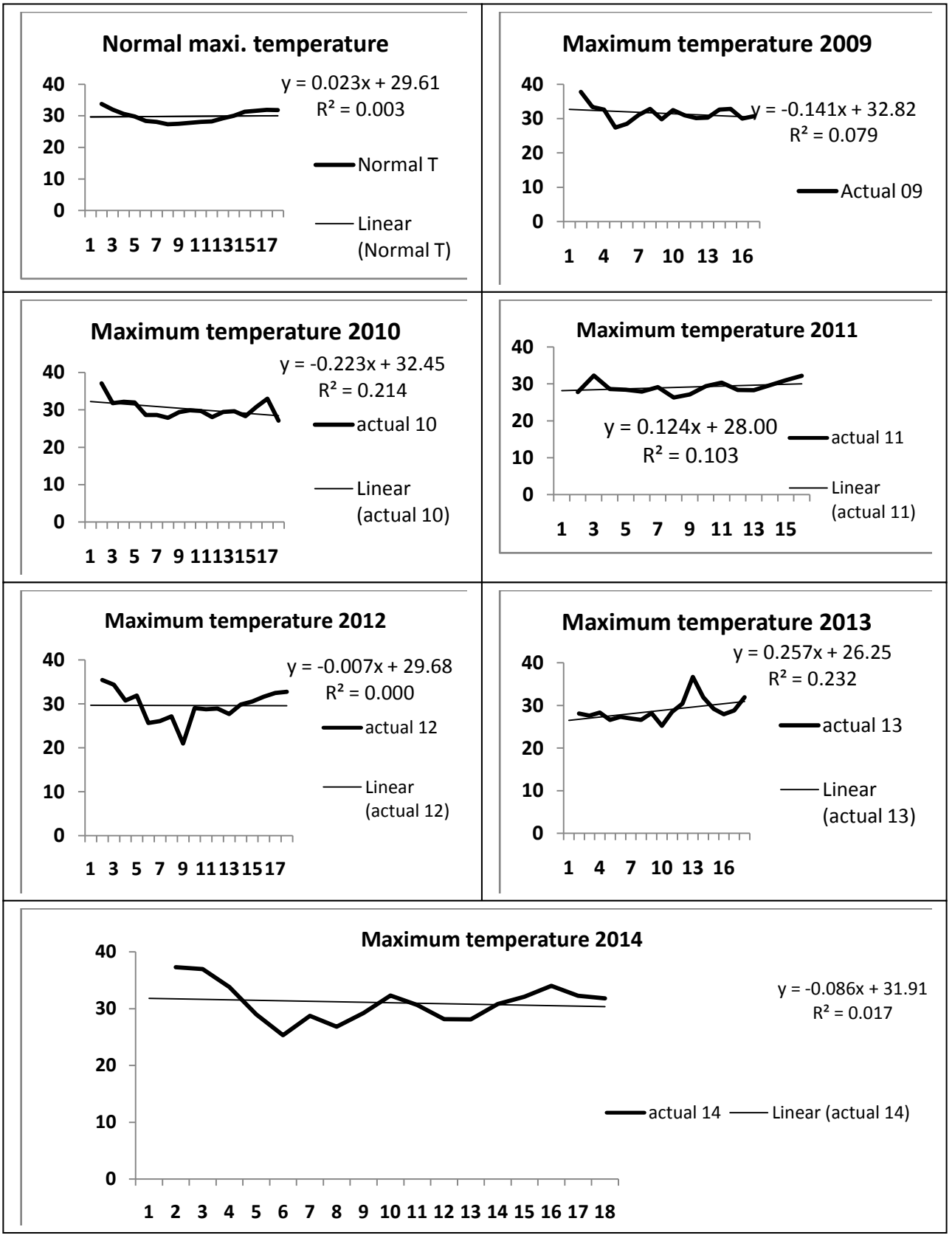
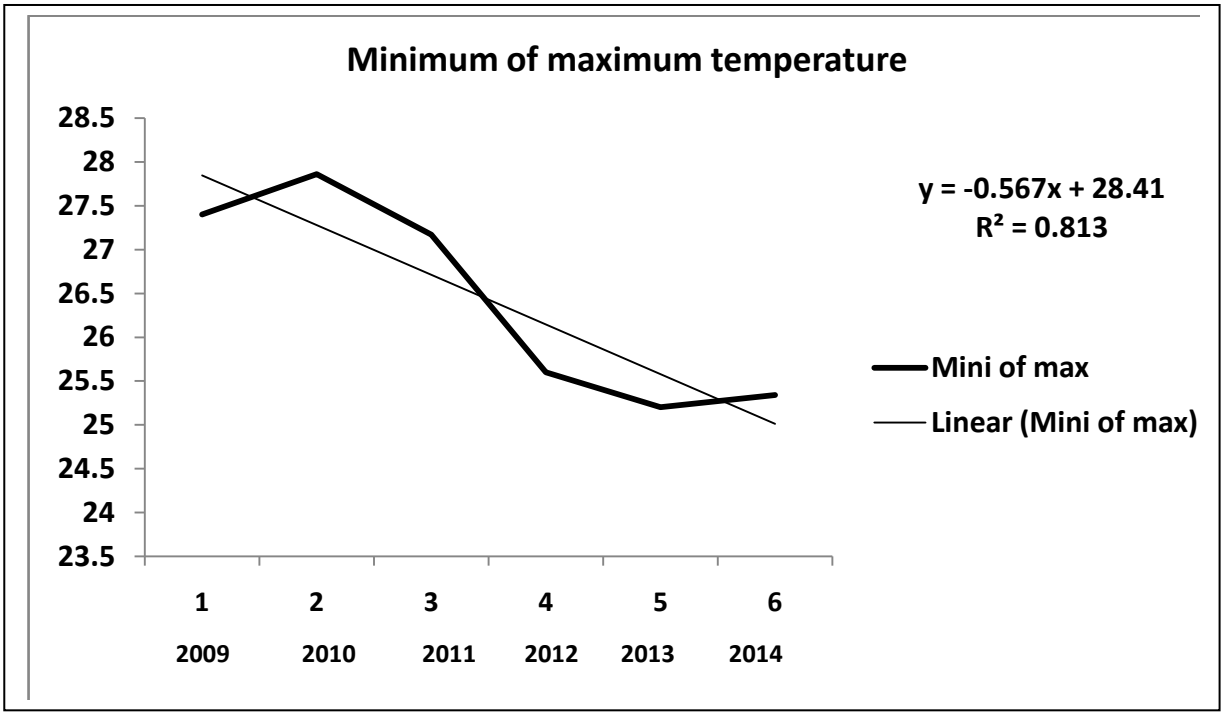
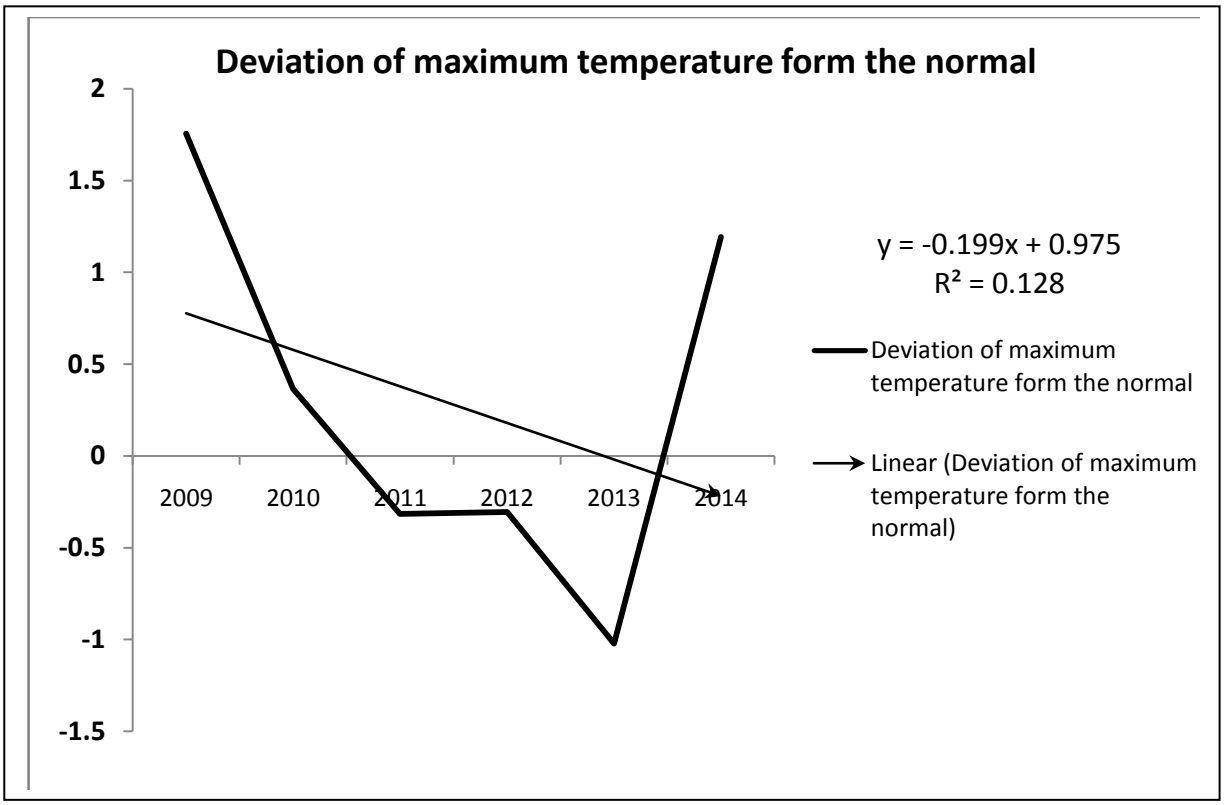


Figure 3 Minimum of maximum temperature and deviation of maximum temperature from the normal (Axis y= degree Celsius x= year)





The weekly maximum temperature was higher in 11 weeks in kharif season over the normal maximum temperature. However the weekly mean of maximum temperature showed decline trend (Y = -0.086x + 31.91, R^2 = 0.017).Overall results indicated that the trend of maximum temperature in the study year 2009 to 2014 declined by 0.279^{0}C as compared to the normal temperature, the decline was linear (Y = -0.199x + 0.975, R^2 = 0.128) respectively. However, deviation of maximum temperature from the normal in the study period showed a declining trend (Y = -0.199x + 0.975). Similarly the minimum of maximum temperature also showed a linear declining trend (Y = -0.567 x + 28.41) while comparing the seasons mean it shows the rise of temperature by 0.149^{0}C. (figure-3)

Minimum temperature:-

Minimum temperature during the kharif season was ranged from 17.36^{0}C to 25.46^{0}C and the season mean normal minimum temperature was 22.38 ^{0}C normal temperature showed linear declining trend in the season (Y = -0.345x+ 25.66, R^2= 0.958).(figure 4)

During the season 2009 the mean minimum temperature of the season was 21.08^{0}C as compared to the normal minimum temperature ranged from 19.71^{0}C (week number 41) to 22.92^{0}C (week number. 26) temperature fluctuation showed the linear decline trend in the season (Y = -0.127x+22.29, R^2 =0.439). Data of weekly deviation of minimum temperature from the normal indicated that in almost all the weeks right from the week 26 to 41, the temperature was less than the normal, ranged from – 0.03 ^{0}C (week number 40) to –3.19 ^{0}C (week number 17). Mean deviation of temperature of the season 2009 was –1.29 ^{0}C as compared to the normal season mean.

Season 2010 was slightly warmer then the normal. The seasons mean of minimum temperature was 0.40 ^{0}C higher than the normal temperature that is 22.79^{0}C. Out of 17 week of the season the minimum temperature was the higher in 11 weeks as compared to the normal it was ranged from 0.16 ^{0}C (week number 30) to 6.74 ^{0}C (week number 34). (figure 4).

In season 2011 minimum temperature was lower than the season 2010. It was 0.33 ^{0}C higher than the normal temperature. Data of week wise deviation, indicated that maximum temperature deviation was observed in

(week number 36) 6.62 ^{0}C. The temperature range in the season showed declining trend the (Y = -0.142x + 24.07, R^2= 0.114).(figure 4).

In season 2012 minimum temperature ranged from 16.52 ^{0}C (week number 41) to 27.31 ^{0}C (week number 26).The mean of the season was 22.19 ^{0}C as compare to 22.38 ^{0}C normal temperature. The decline in temperature was -0.17 ^{0}C. The season's trend of minimum temperature showed linear decline (Y = - 0.501x + 26.95, R^2= 0.660).(figure 4).

In season 2013 minimum temperature was 0.92 ^{0}C higher than the normal. Season 2013 was warmer amongst the all season under study. Range of minimum temperature was almost constant varying 1 or 2 ^{0}C through out the season, accept in week number 38 (33.7^{0}C). The mean of minimum temperature of the season was 23.28 ^{0}C (Y = -0.126x+ 23.80, R^2= 0.44).

In season 2014 the mean deviation was 0.45^{0}C minimum temperature range from 19.08^{0}C recorded in(week number 41) to 27.28 ^{0}C (week number 26) respectively (Y = -0.345x + 26.11, R^2= 0.75)within the season shows declining trend. (figure 4).

Thus it is indicated that the mean deviation of the minimum temperature from the normal was -1.29, 0.40, 0.33,-0.17 and 0.92 ^{0}C in Kharif of seasons 2009, 2010,2011,2012,2013 and 2014 respectively. The rise of minimum temperature during the study period was 0.10^{0}C (Y = 0.279x – 0.870, R^2=0.460). The data further indicated that the minimum of minimum temperature in the study period was in rising trend (Y = 0.303x + 19.23, R^2 = 0.171) and the mean deviation of minimum temperature from the normal temperature also showed the rising trend (Y = 0.279x – 0.870). The rise of minimum temperature during the study period was 0.10 ^{0}C as depicted of the comparative account of season mean with the normal minimum temperature.(figure 5)

Mean normal difference of maximum and minimum temperature was 7.40 ^{0}C ranged from 12.79 ^{0}C (week number 41) to 4.6^{0}C in (week number 32).In season 2009. The difference between the maximum and minimum temperature was higher than the normal ranged from 11.79^{0}C (week number 39) to 6.86^{0}C in (week number 30). The difference in maximum and minimum temperature in kharif 2010 was less than the normal (-0.04^{0}C). Similarly in

Table 3 Minimum temperature-Normal temperature, year wise weekly temperature and deviation from the normal temperature (^{0}C)

SWW	Date	Month	Normal Temperature	Actual Temperature 2009	Deviation From Normal	Actual Temperature 2010	Deviation from normal	Actual Temperature 2011	Deviation from normal	Actual Temperature 2012	Deviation from normal	Actual Temperature 2013	Deviation from normal	Actual Temperature 2014	Deviation from normal
26	25-1	June	25.46811	22.92	-2.54811	23.93	-1.53811	23.78	-1.68811	27.31	1.84189	23.6	-1.86811	27.28	1.81189
27	2-8	July	24.6256	21.78	-2.8456	24.54	-0.0856	22.17	-2.4556	27.08	2.4544	23.1	-1.5256	24.41	-0.2156
28	9-15		24.03493	22.21	-1.82493	24.66	0.62507	23.54	-0.49493	25.5	1.46507	22.7	-1.33493	24.57	0.53507
29	16-22		23.61754	20.42	-3.19754	23.78	0.16246	23.58	-0.03753	25.28	1.66246	23.6	-1.01754	23.11	-0.50754
30	23-29		23.1675	20.64	-2.5275	23.36	0.1925	23	-0.1675	22.5	-0.66754	23.3	0.1325	22.41	-0.7575
31	30-5	August	23.04347	22.14	-0.90347	23.4	0.35653	23.61	0.56653	20.98	-2.06347	23.1	0.05653	23.77	0.72653
32	6-12		22.71911	21.5	-1.21911	23.4	0.62089	21.61	-1.10911	19.84	-2.87911	23	0.28089	23.04	0.32089
33	13-19		22.62855	20.42	-2.20855	23.34	0.71145	21.74	-0.88855	20.37	-1.9818	22.7	0.07145	22.94	0.31145
34	20-26		22.3518	21.85	-0.5018	29.1	6.7482	22.86	0.5082	21.57	-0.7818	23.1	0.7482	23.62	1.2682
35	27-2		22.28972	20.07	-2.11972	23.56	1.27028	23.33	1.04028	22.54	0.25028	22.5	0.21028	22.95	0.66028
36	3-9	September	21.93654	20.71	-1.22654	23.35	1.41346	28.56	6.6236	21.72	-0.21165	21.3	-0.10349	23.21	1.27346
37	10-16		21.40349	20.91	-0.49349	22.58	1.17651	21.78	0.37651	22.51	1.10651	23.2	1.79651	22.5	1.09651
38	17-23		21.17716	21.14	-0.03716	20.67	-0.50716	22.61	1.43284	21.9	0.72284	33.7	12.52284	21.52	0.34284
39	24-30		20.67402	21.07	0.39598	17.8	-2.87402	21.67	0.99598	20.95	0.27598	21.5	0.82598	20.8	0.12598
40	1-7	October	19.9602	19.93	-0.0302	18.14	-1.8202	20.77	0.8098	18.51	-1.4502	20.9	1.80455	20.25	0.2898
41	8-14		19.09545	19.71	0.611455	19.07	-0.02545	19	-0.09545	16.52	-2.57545	21.3	2.20455	19.08	-0.01545
		Mean	22.38707	21.08875	-1.2922678	22.7925	0.40167563	22.72563	0.33856	22.1925	-0.17697	23.2875	0.925288	22.84125	0.454176

Figure 4 MINIMUM TEMPERATURE – A comparative accounts of temperature in kharif season (Axis y= degree Celsius x= 1- June SWW 26 to 17- October SWW 42)

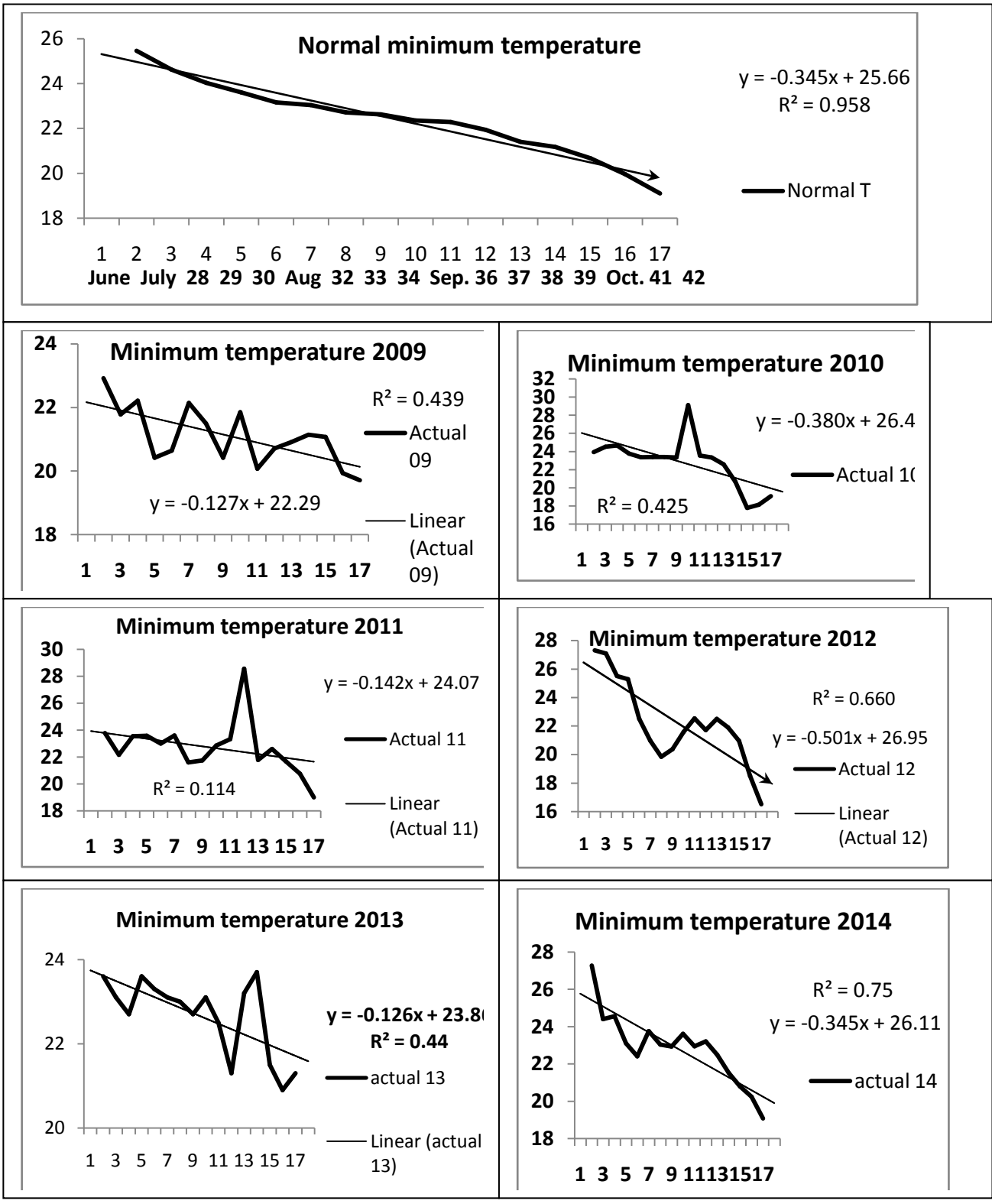


Figure 5 Minimum of minimum temperature and deviation of maximum temperature from the mean (Axis y= degree Celsius x= years 2009,2010,2011,2012,2013 & 2014)

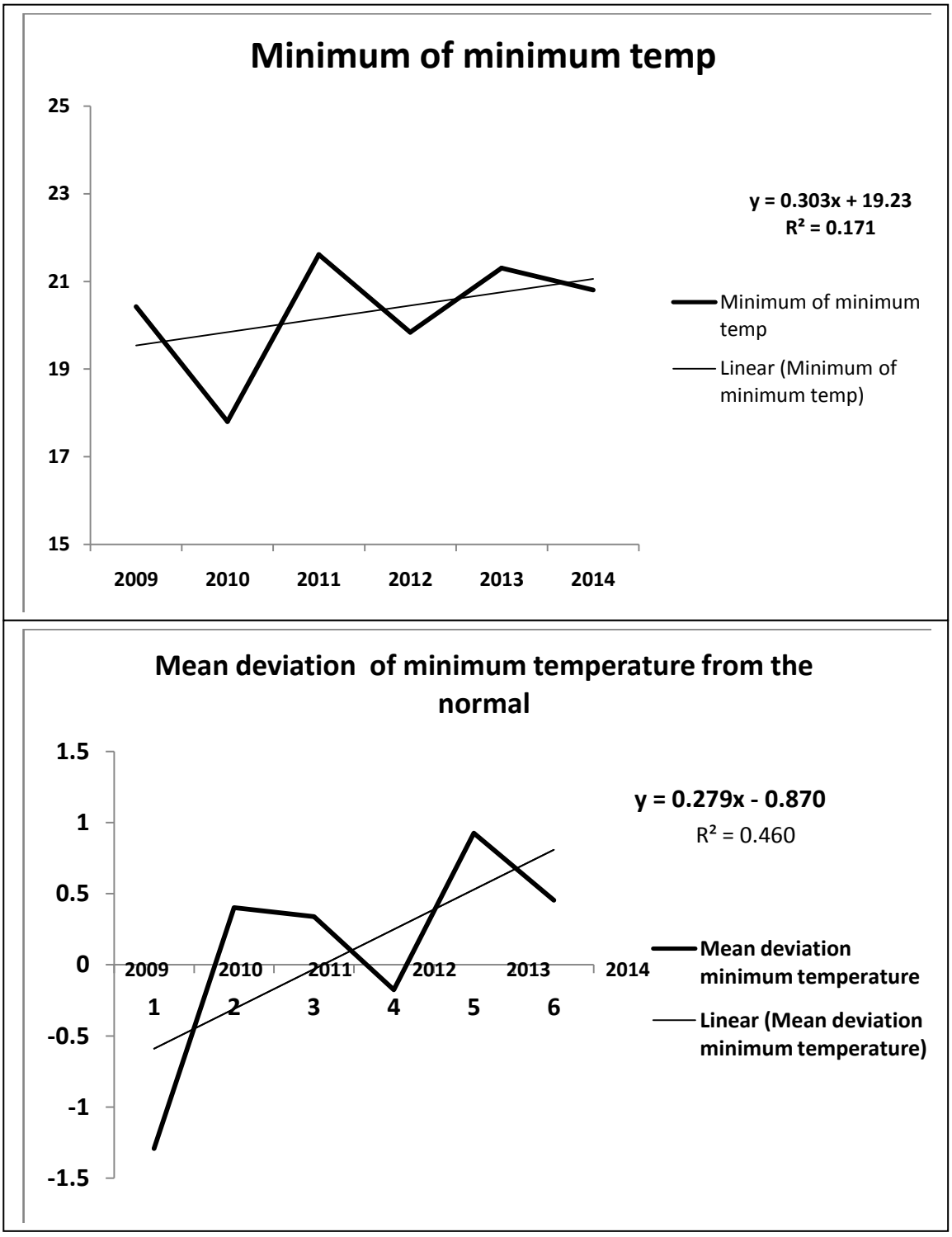
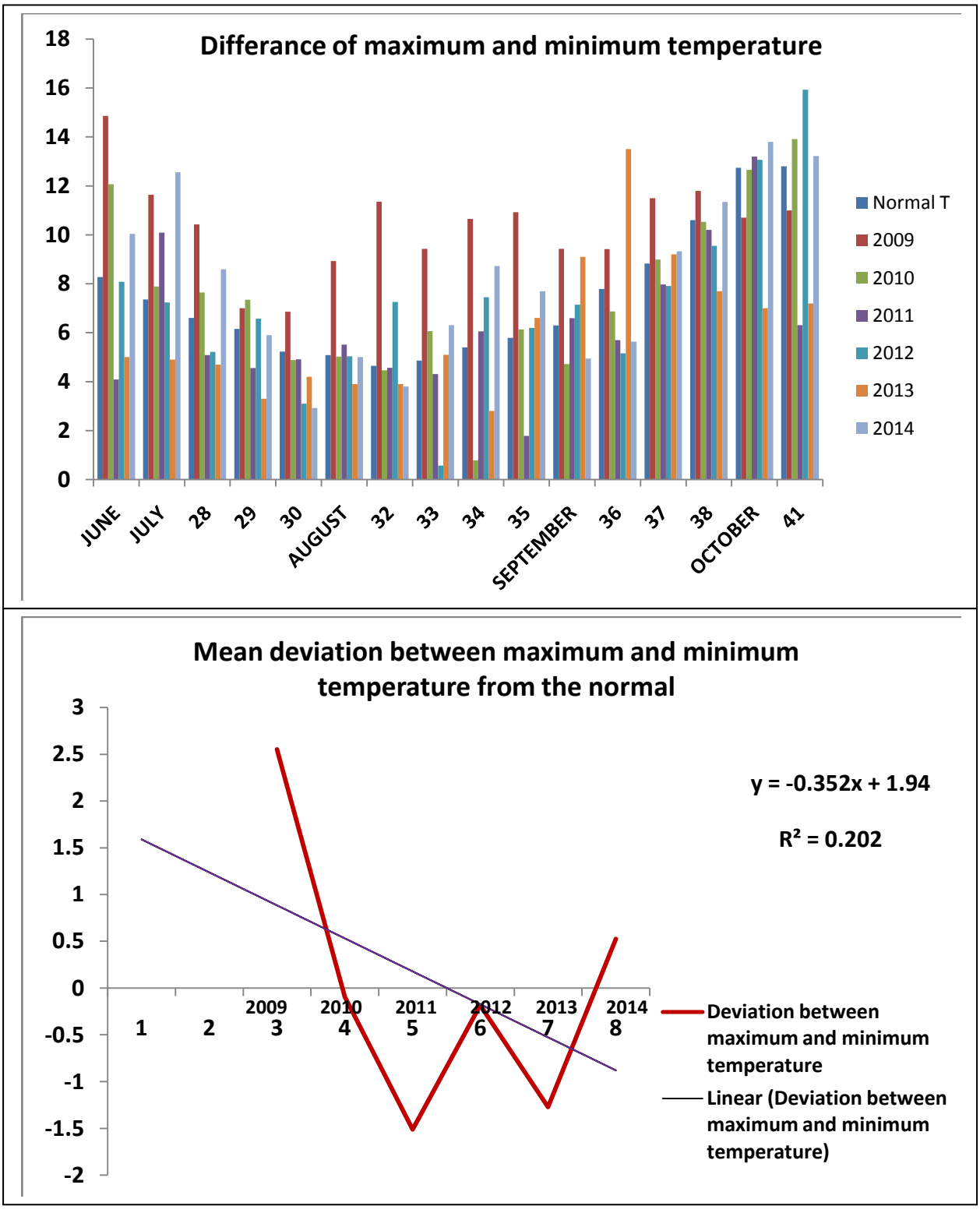


Figure 6 Temperature variation between maximum and minimum temperature in kharif season (Axis y= degree Celsius x= June SWW 26 to October SWW42)



season 2011, 2012, 2013 and 2014 it was less i.e. -0.18^{0}C, -0.27^{0}C and -0.52 ^{0}C respectively. Data further indicated that during the study period from 2009 to 2014, the mean difference between the maximum and minimum temperature was 0.0017 ^{0}C. However the year wise difference between maximum and minimum temperature showed linear declining trend as compared to the normal (Y = -0.352x + 1.94, R^2=0.202).(figure6).

Rainfall:

Normal distribution of rainfall in kharif season (mean of 1984 to 2013) was 1298.17 mm. Rainfall data of the study period 2009 to 2014 was compared with the normal, data indicated that in season 2009, the pattern of rainfall was erratic there were no rainfall received in week number 31,38,39,41 and 42. The higher rainfall was observed in week number 28 (98.7 mm), week number 29 (296.7 mm), week number 35 (176.6 mm), week number 36 (102.3) and week number 40(130mm) respectively. The total rainfall was 1009.1mm which was -291.1mm less than the normal.(Table 4)

In 2010 season received only 551.5 mm rainfall. Maximum rainfall 123mm was received in week number 33 (13 to 19 August). No rainfall was recorded beyond week number 38, up to the end of the season only 9 mm rainfall was received in week number 42. The mean rainfall -517.21 mm less rainfall received as compared to the normal.

In season 2011 distribution of rainfall was similar to 2010 but the intensity of precipitation was relatively higher but -311.7 mm less rainfall as compared to the normal. Trend of rainfall was declining in (2009 Y = -3.781x+97.17 R^2 =0.055, 2010 Y= -2.278x+55.22 R^2=0.123, 2011 Y= -5.648x+ 114.5 R^2 = 0.397) respectively.(figure 7).

In the season 2012 total precipitation was 935.4 mm which was -339.8 mm less then the normal rainfall. In early part of the season (week number 26 to 29) the rainfall was less and erratic beyond it the rainfall was normal and in most the week it was above the normal (31 to week number 36). Trend of rainfall shows declining Y= -4.359x + 98.61.

In 2013 the rainfall was 1290.8 mm which was only 7 mm less then the normal but the distribution of rains and number of rainy days was very much irregular higher rainfall was confined to week number 26 (1312.2mm), week

Table-4 Rainfall -Normal rainfall, year wise weekly and deviation from the total rainfall (mm).

SWW	Date	Month	Normal Rainfall	Actual Rainfall 2009	Deviation From Normal	Actual Rainfall 2010	Deviation from normal	Actual Rainfall 2011	Deviation from normal	Actual Rainfall 2012	Deviation from normal	Actual Rainfall 2013	Deviation from normal	Actual Rainfall 2014	Deviation from normal
26	25-1	June	97.92643	22.6	-77.32643	33	-64.9264	63.5	-34.4264	9.1	-88.8264	312.2	214.2736	3.5	-94.4264
27	2-8	July	127.9583	48.5	-79.4583	28	79.4583	75.5	-52.4583	50.3	-77.6583	82	-45.9583	1	-126.958
28	9-15		118.4983	98.7	-19.7983	18	-100.4983	71	-47.4983	92.6	-25.8983	120.5	2.0017	41.5	-76.9953
29	16-22		132.1262	296.7	164.5738	59	-73.1262	130	-2.1262	0.5	-131.626	85	-47.1262	135.5	3.3738
30	23-29		128.9343	42.6	-86.3343	21	-107.9343	110.5	-18.4343	91.8	-37.1343	76.6	-52.3343	108	-20.9343
31	30-5	August	107.3117	0	-107.3117	62	-45.3844	68	-39.3117	113.2	28.8883	120	102.2688	13.5	-93.8117
32	6-12		117.3844	4.1	-113.2844	8.5	-108.8844	73	-44.3844	143.6	26.2156	37	-80.3844	77.5	-39.8831
33	13-19		83.70792	46.6	-37.10792	123	39.29208	15	-68.7079	162.1	78.39208	33.5	-50.2079	7	-76.7079
34	20-26		91.68308	1.3	-90.38	36	-5.568308	80.5	-11.1831	87.1	-4.58308	287.5	195.8169	30	-61.6831
35	27-2		85.03741	176.6	91.56259	73	-12.03741	144.5	59.4659	52.7	-32.3374	4	-81.0374	143	57.96259
36	3-9	September	68.51034	102.3	33.78966	48	-20.51034	39.5	-29.0103	97.6	29.08966	2	-68.5103	79.5	10.98966
37	10-16		40.44637	39.1	-1.34637	29.5	-10.94637	70.5	30.05363	29.6	-10.8464	0	-40.4463	0.5	-39.9464
38	17-23		36.60633	0	-36.60633	3.5	-33.10633	45	8.39367	2.3	-34.3063	111.5	74.89367	0.5	-36.1063
39	24-30		19.98914	0	-19.98914	0	-19.98914	0	-19.9891	2.9	-17.0891	2	-17.9891	1	-18.9891
40	1-7	October	22.01823	130	107.98177	0	-22.01823	0	-22.0182	0	-22.0182	9	-13.0182	0	-22.0182
41	8-14		13.85548	0	-13.85548	0	-13.85548	0	-13.8555	0	-13.8555	8	-5.85548	0	-13.8555
42	15-21		6.183758	0	-6.183758	9	2.816242	0	-6.18376	0	-6.18376	0	-6.18376	1.5	0
		Total	1298.178	1009.1	-291.07461	551.5	-517.21899	986.5	-311.674	935.4	-339.778	1290.8	80.20287	643.5	-649.99

Figure 7 RAINFALL – A comparative accounts of rainfall in kharif season during the study period (June SWW 26- October SWW 42)

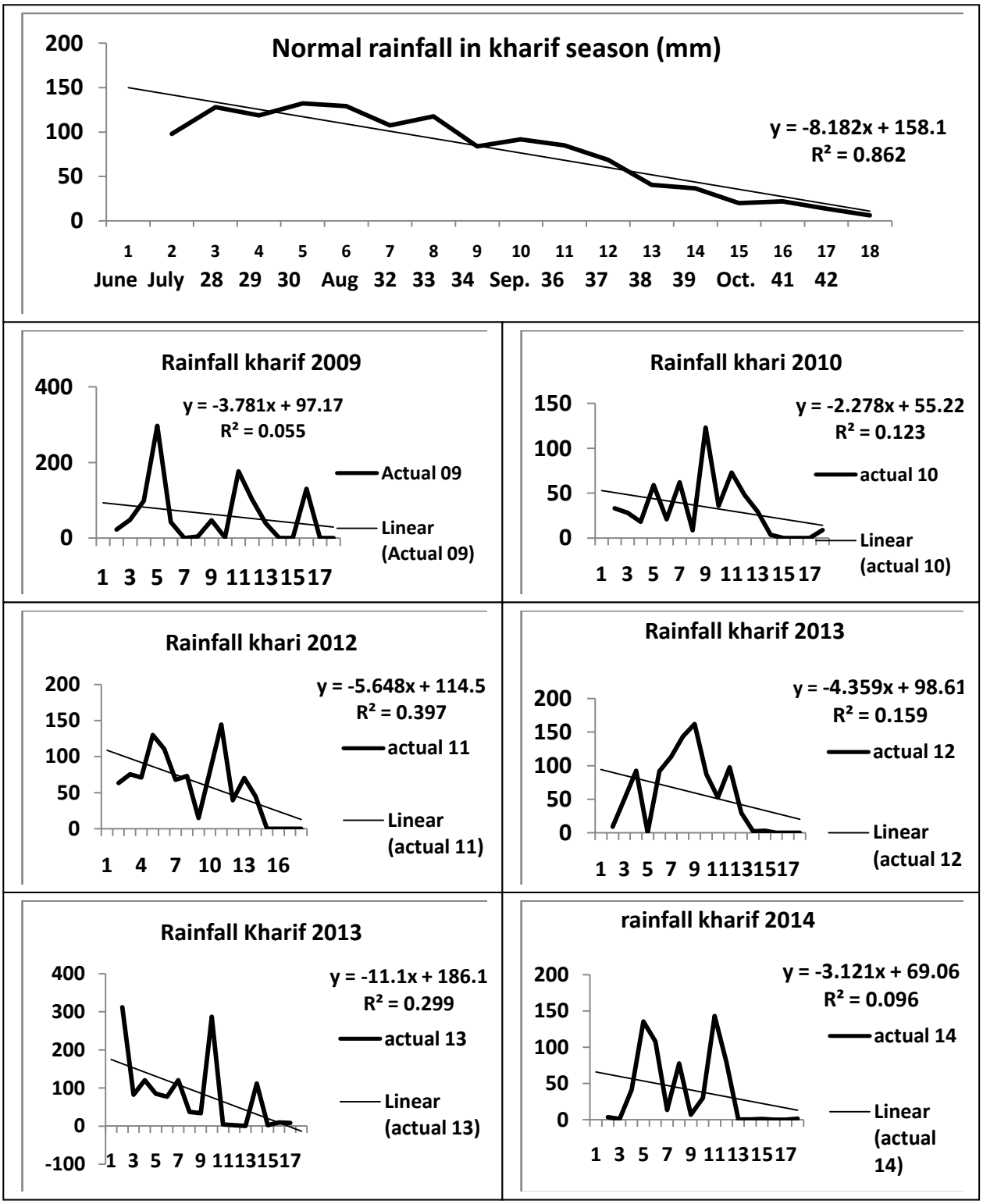


Figure 8 Deviation of rainfall and rainy days from the normal during the study period (June SWW 26- October SWW 42)

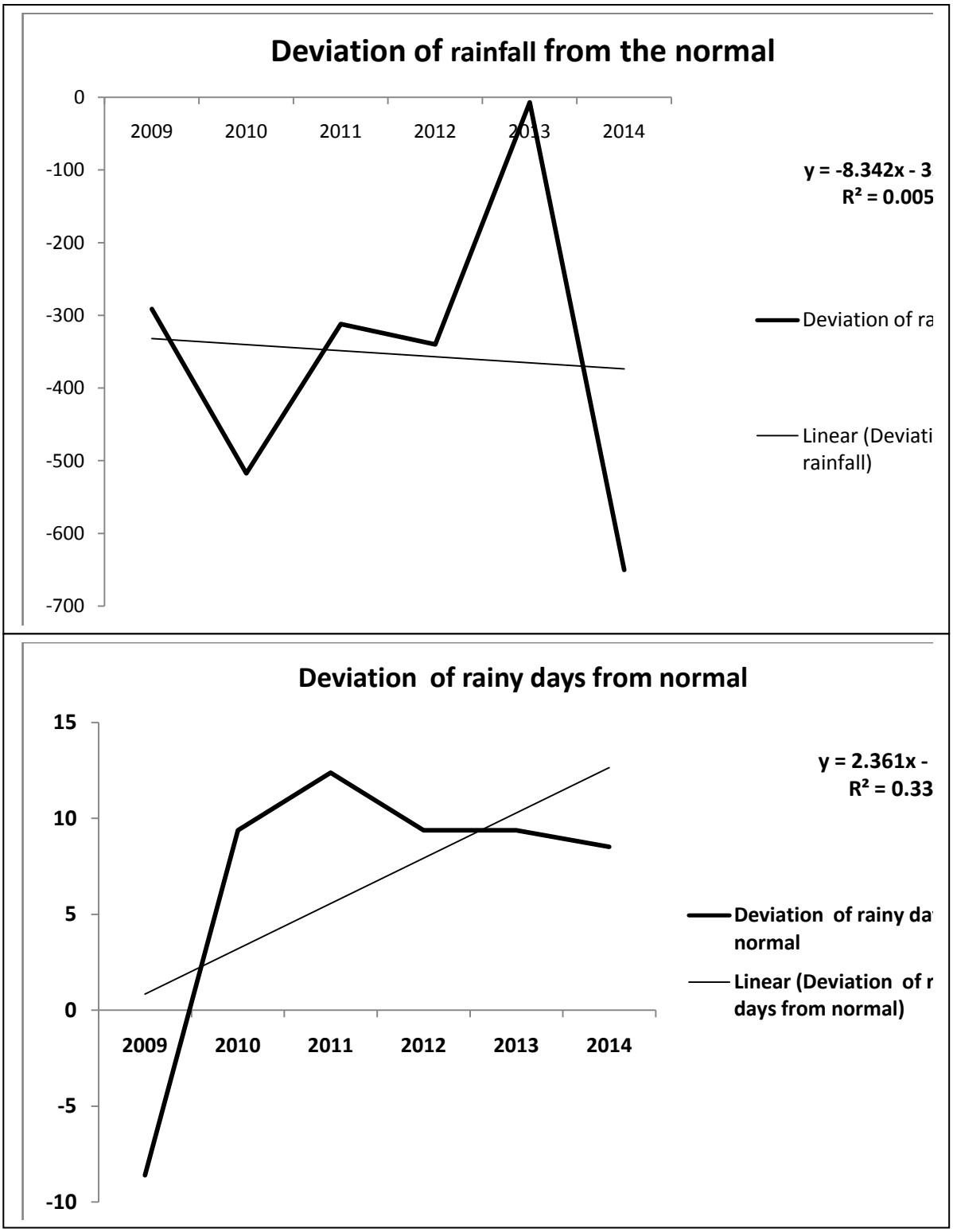
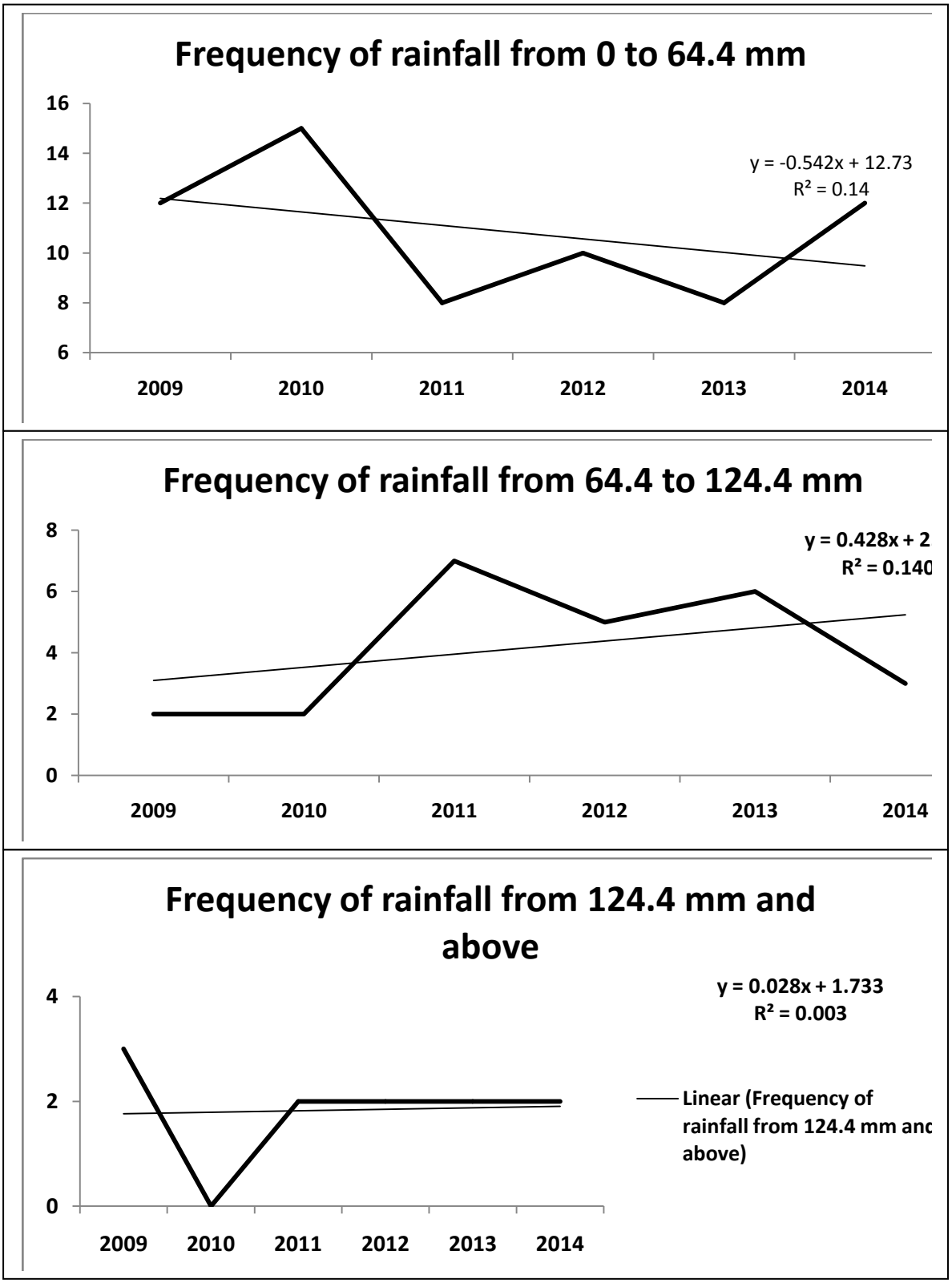


Figure 9 Intensity of rainfall during the study period in kharif season (Axis y= rainfall mm x= years)



In season 2014 the rainfall received very less rainfall in week number 26 (3.5mm) and week number 27 (1mm) From week number 29 to 32 and week number 35 and 36 received most of the rainfall in these weeks the total rainfall was 602.6 mm which was 650mm less then the normal received that rainfall pattern in the study period was erratic and total rainfall showed declined trend ($Y = - 8.342x – 323.6$, $R^2 = 0.005$). (Table 4 and figure 7).

The decline in rainfall over the study period as compared to normal was 352.8mm. The frequency of light rainfall (0 to 64.4 mm) shows declining trend ($Y = -0.542x + 12.73$) while the frequency of heavy to very heavy (64.4 to 124.4 mm) and very extraordinary heavy (above 124.4 mm) rainfall were showed rising trend $Y = 0.428x + 2.666$ and $Y = 0.028 x + 1.733$, respectively. The mean increase in rainy days was 6.39 day.(figure 9). Deviation of rainfall from the normal shows declining trend while deviation of rainy days shows rising trend ($Y = -8.342x – 323.6$ and $Y = 2.361x – 1.52$) respectively. (figure8)

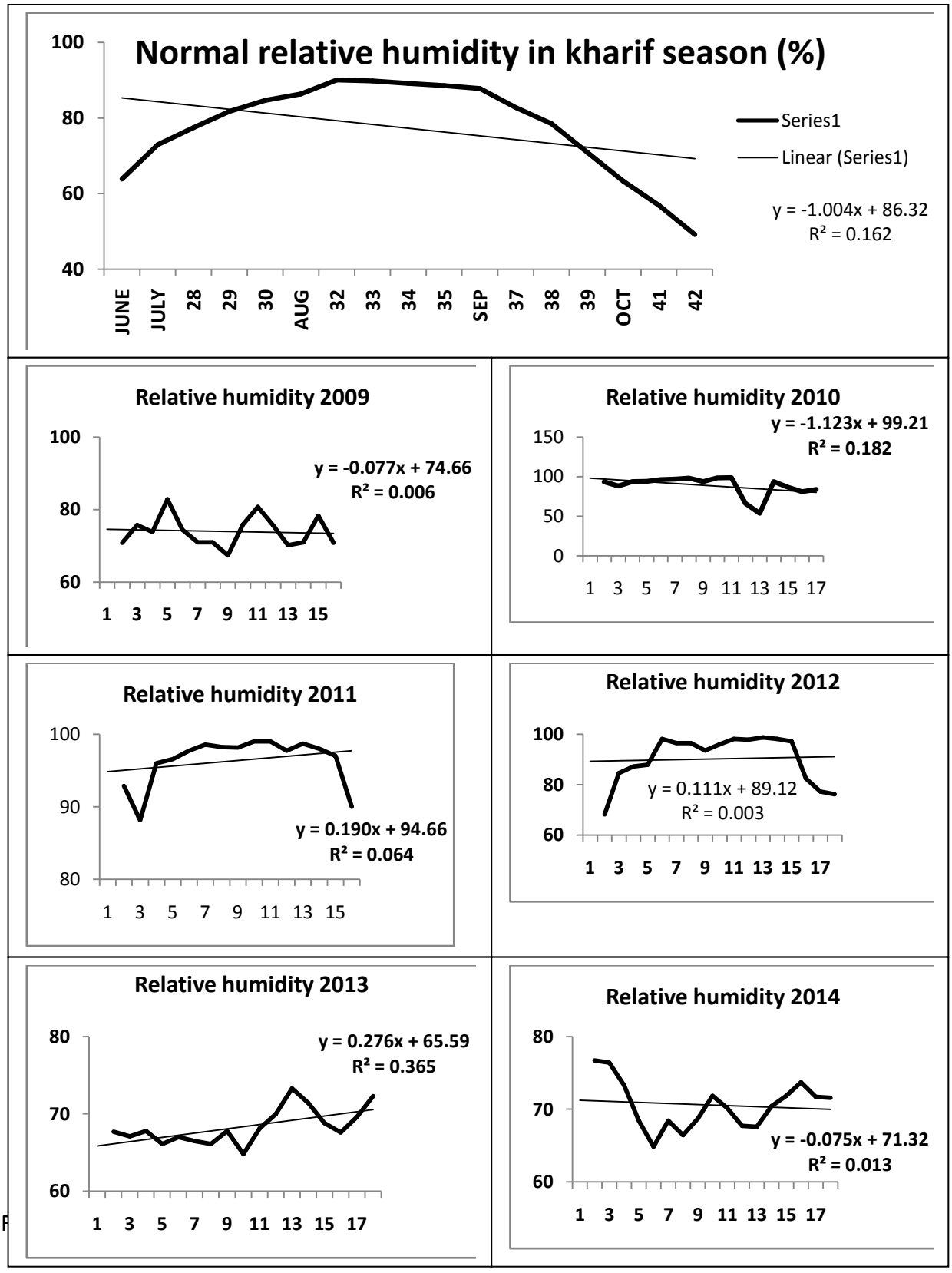
Relative humidity:-

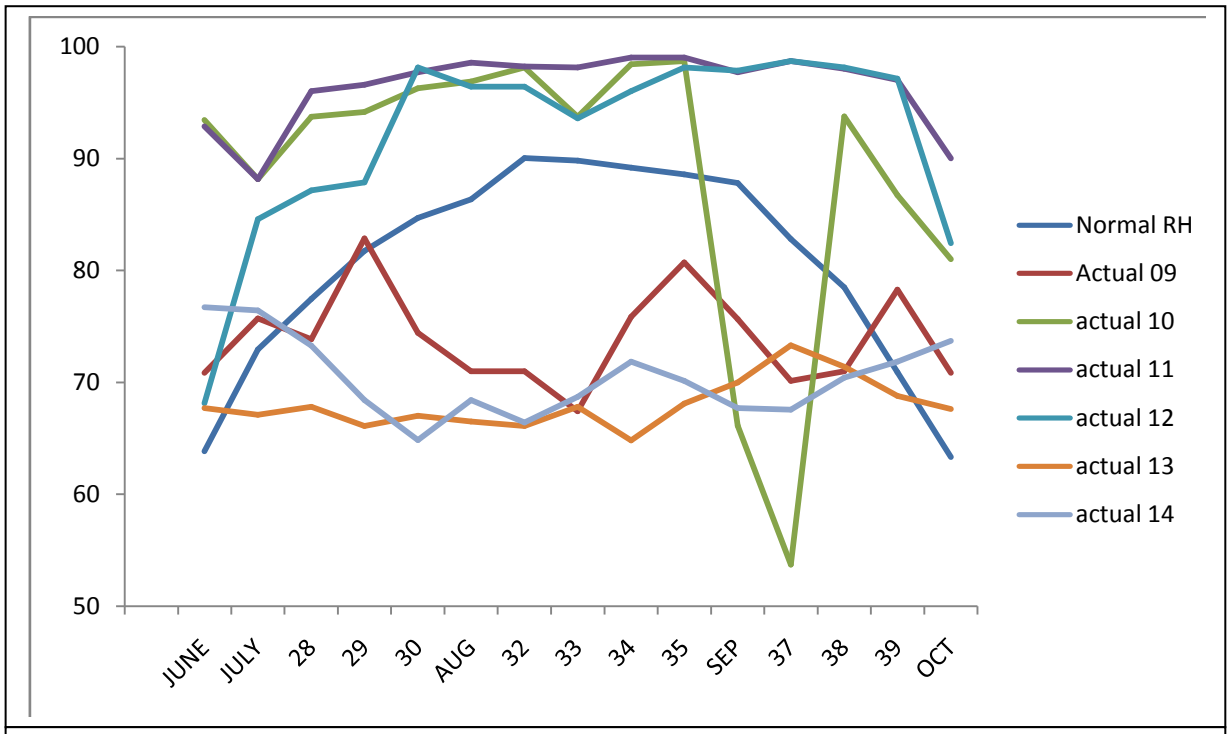
Normal humidity in kharif season was ranged from 49.17% to 90.04% with the mean 77.29%. During the study period the humidity was less than the normal were observed in 2009 (-3.31%), 2013 (-8.93%) and 2014 (-6.71%). However it was above the normal in 2010 (13.56%), 2011 (15.57%) and 2012 (12.26%) respectively. The rise in humidity in season was 3.73%. Correlation between the relative humidity and rainfall indicated that in the season received less rainfall -311 mm to -517.2 mm the humidity was higher than the normal (2010, 2011 and 2012) beyond this limit the humidity was near to the normal value data further indicated that in the study period, the deviation in humidity in respect to the normal shows declining trend ($Y = -2.509x + 12.51$, $R^2 = 0.175$).(figure11). Trend line of relative humidity in normal curve shows decreasing trend $Y = -1.004x + 86.32$,similarly the trend was declining in the year 2009 ($Y = -0.077x + 74.66$), 2010 ($Y = -1.123x + 99.21$) and 2014 ($Y = -0.075x + 71.32$) while rising in the season 2011 ($Y = 0.190x + 94.66$), 2012 ($Y = 0.111x + 89.12$) and 2013 ($Y = 0.276x + 65.59$) respectively. (figure 10)

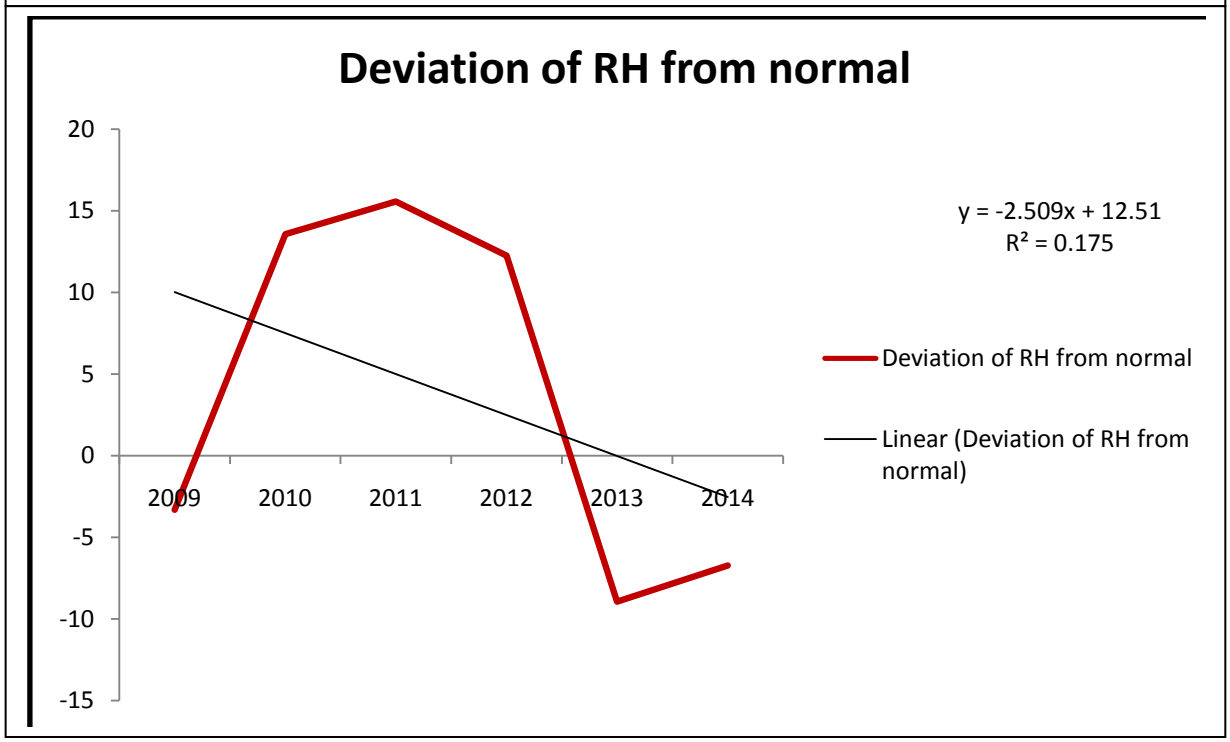
Table 5 Relative humidity - Normal and year wise weekly relative humidity and deviation from normal humidity (%).

SWW	Date	Month	Normal Relative humidity	Actual Relative humidity 2009	Deviation From Normal	Actual Relative humidity 2010	Deviation From Normal	Actual Relative humidity 2011	Deviation From Normal	Actual Relative humidity 2012	Deviation From Normal	Actual Relative humidity 2013	Deviation From Normal	Actual Relative humidity 2014	Deviation From Normal
26	25-1	June	63.8274	70.85	7.03	93.43	29.43	92.86	29.04	68.14	4.32	67.7	3.88	76.71	12.89
27	2-8	July	72.93264	75.71	2.78	88.14	15.21	88.14	15.21	84.57	11.64	67.1	-5.83	76.42	3.49
28	9-15		77.45373	73.85	-3.6	93.71	16.26	96	18.55	87.14	9.69	67.8	-9.65	73.28	-4.17
29	16-22		81.74727	82.85	1.11	94.14	12.40	96.57	14.83	87.85	6.11	66.1	-15.64	68.42	-13.32
30	23-29		84.67707	74.42	-10.25	96.28	11.61	97.71	13.04	98.14	13.47	67	-17.68	64.85	19.82
31	30-5	August	86.35413	71	-15.35	96.86	10.51	98.57	12.22	96.42	10.07	66.5	-19.85	68.42	-17.93
32	6-12		90.04427	71	-19.04	98.14	8.1	98.21	8.17	96.42	6.38	66.1	-23.94	66.42	-23.62
33	13-19		89.79543	67.42	-22.37	93.71	3.92	98.14	8.35	93.57	3.78	67.8	-21.99	68.71	-21.08
34	20-26		89.16945	75.85	-13.31	98.42	9.26	99	9.84	96	6.84	64.8	-24.36	71.85	-17.31
35	27-2		88.5887	80.71	-7.87	98.71	10.13	99	10.42	98.14	9.56	68.1	-20.81	70.14	-18.44
36	3-9	September	87.81319	75.66	-12.15	66.14	-21.67	97.71	9.9	97.85	10.04	70	-17.81	67.71	-20.1
37	10-16		82.78633	70.14	-12.64	53..71	-29.07	98.71	15.93	98.71	15.93	73.3	-9.48	67.57	-15.21
38	17-23		78.49092	71	-7.49	93.75	15.26	98	19.51	98.14	19.65	71.4	-7.09	70.42	-8.07
39	24-30		70.90213	78.29	-7.39	86.71	15.81	97	26.1	97.14	26.24	68.8	-2.1	71.85	0.95
40	1-7	October	63.33355	70.85	-7.52	81	17.6667	90	26.67	82.42	19.09	67.6	4.27	73.71	10.38
41	8-14		56.87867	0	-56.87	83.73	26.86	0	-56.87	77.28	20.42	69.6	12.73	71.71	14.84
42	15-21		49.17583	0	-49.17	0	-49.17	0	-49.17	76.14	26.97	72.3	23.13	71.57	22.4
		Mean	77.29239	65.27058824	-13.7706	85.179375	6.030394	85.03647	7.749412	90.23941	12.95294	68.35294	-8.95412	70.57412	-4.38118

Figure 10 Relative humidity – A comparative accounts of relative humidity in kharif season during the study period




100
90
80
70
60
50
JUNE
JULY
28
29
30
AUG
32
33
34
35
SEP
37
38
39
OCT
Normal RH
Actual 09
actual 10
actual 11
actual 12
actual 13
actual 14


Deviation of RH from normal
20
15
10
5
0
-5
-10
-15
2009
2010
2011
2012
2013
2014
y = -2.509x + 12.51
R² = 0.175
Deviation of RH from normal
Linear (Deviation of RH from normal)

Number of rainy days :-

Normal number of rainy days in kharif season was 70.61. Rainy days in 2009, 2010,2011,2012,2013 and 2014 were 62,80,83,80 and 80 days respectively which was 3.61 days less in 2009 and 9.39, 12.39, 9.39, 9.39 days higher in 2010 to 2014 respectively. The increase of rainy days in the study period was 6.39 days.[Table 6]

The rainfall has been grouped in to 3 broad category for accessing the rainfall pattern.

1. Light to rather heavy rainfall - 0 to 64.4mm
2. Heavy to very heavy rainfall - 64.4 to 124.4mm
3. Exceptionally heavy rainfall 124.4 and above

Data indicated that during the study period the events of light to rather heavy rainfall was in decreasing trend ($Y= -0.542x + 12.73$, $R^2= 0.14$). While the events of heavy to very heavy and exceptionally heavy rainfall (extreme rainfall) shows increasing trend $Y = -0.428x+2.666$, $R^2 = 0.140$ and $Y = 0.028x+1.733$, $R^2 = 0.003$ respectively.(figure 9)

Minimum of maximum temperature during the study period (kharif 2009 to 2014) showed decreasing trend .the trend line was $Y = -0.567x+28.41$ while the minimum of minimum temperature show increasing trend $Y = 0.303x+19.23$ respectively.

Data further indicated that the gradual rise of minimum temperature and difference between maximum and minimum temperature and minimum of minimum temperature in years under study. Relatively humidity and rainfall shows decreasing trend.

Decadal shift of weather data

Climatic change in Sehore district were studied by evaluating the trend of weather data during the study period and past 3 decades i.e.1984 to 1993, 1994 to 2003 and 2004 to 2013.Decadal shift and variations in weather parameters are described as below

(A) Maximum temperature : In 1984 to 1993 decades the mean maximum temperature of kharif season was 31.43 ^{0}C that was raised by 0.158^{0}C in next decade 1994 to 2003 and again in proceeding it was decreases by 0.428 ^{0}C. Thus the trend of maximum temperature in the last 3 decades

Table 6 Weekly distribution of rainy days in kharif season 2009-2014 and normal rainy days.

SWW	Date	Month	Normal Rainy days	Actual Rainy days 2009	Actual Rainy days 2010	Actual Rainy days 2011	Actual Rainy days 2012	Actual Rainy days 2013
26	25-1	June	4.2	4	0	6	1	4
27	2-8	July	4.7	5	6	6	7	6
28	9-15		5.23	7	6	7	7	7
29	16-22		5.93	6	7	7	6	7
30	23-29		5.86	4	7	6	7	7
31	30-5	August	5.56	1	7	7	7	7
32	6-12		6.2	5	6	6	7	7
33	13-19		5.7	6	7	7	7	5
34	20-26		5.26	4	7	7	7	6
35	27-2		5.03	6	7	7	7	1
36	3-9	September	4.33	6	7	6	7	3
37	10-16		3.8	0	4	6	5	2
38	17-23		3.26	0	2	5	2	4
39	24-30		2.16	3	0	0	3	4
40	1-7	October	1.66	5	0	0	0	5
41	8-14		1.2	0	1	0	0	5
42	15-21		0.53	0	6	0	0	0
		Total number of rainy days	70.61	62	80	83	80	80

were in declining trend Y = - 0.171x+31.72, R^2=0.705. The fluctuation of mean maximum temperature were + 0.158 and – 0.428 ^{0}C. However, in the study period 2009 to 2014, the mean maximum temperature was decreased by 0.392^{0}C as compared to last decades while comparing the fluctuation within the study period 2009 to 2014 maximum temperature raised by 0.279^{0}C as compared to mean normal temperature.(figure 12)

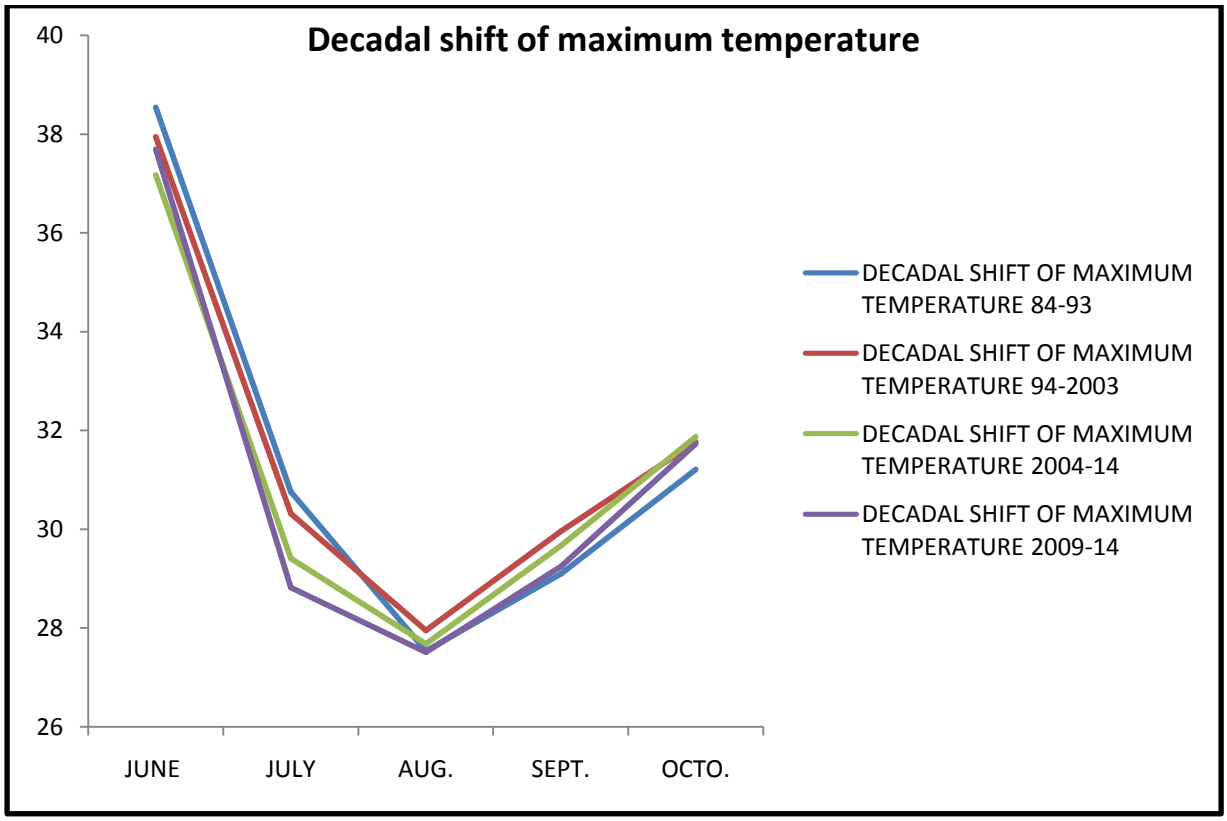
(B) Minimum temperature: Variations in minimum temperature during the study period indicated the increasing trend. The mean rise of minimum temperature was 0.108^{0}C. Data of minimum temperature of last 3 decades presented in (Figure 13). In first decades 1984 to 1993 the mean minimum temperature was 22.59 ^{0}C it was raised by 0.5^{0}C in next decades 1994 to 2003 and again gown down by 0.083 ^{0}C in 2004 to 2013 decades. Temperature in decades shows rising trend Y = 0.007x + 22.59, R^2= 0.057. Overall results indicated that during the study period 2009 to 2014 the minimum temperature raised by 0.48^{0}C as compared to the mean of last 3 decades temperature while within the study period minimum temperature show rise in trend and the mean rise in temperature was 0.108 ^{0}C as compared to normal temperature.

(C) Difference of maximum and minimum temperature: Indicated the decreasing trend Y =-0.118x + 9.032, R^2=0.170 in last 3 decades .during the study period 2009 to2014 kharif season the difference of temperature was indicated slight rise that was 0.0017 ^{0}C as compared to the normal.

(D) Rainfall: In last 3 decades shows slight increasing trend Y = 0.624x + 7.975, R^2=0.570 while comparing the monthly data of rainfall during the kharif season, indicated the decadal variations in rainfall during the study period 2009 to 2014. The trend of rainfall was decreased by 352.8mm with the increase of 6.39 rainy days respectively. Rainfall data of kharif season in last 3 decades indicated the cyclic fluctuation. Rainfall experienced 1419.1, 877.02, 1521.9 and 826.44 mm in fist (1984-1993), second (1904-2003) and third (2004-2014) decades and in study period 2009-2014 respectively.(figure 14)

(E) Relative humidity: Relative humidity indicated the gradual increase in last 3 decades including the study period 2009 to 2014 Y = 1.555x+ 66.24 (R^2=

0.975) while within the study period kharif (2009 to 2014) the relative humidity increased by 3.73%.(figure 14)



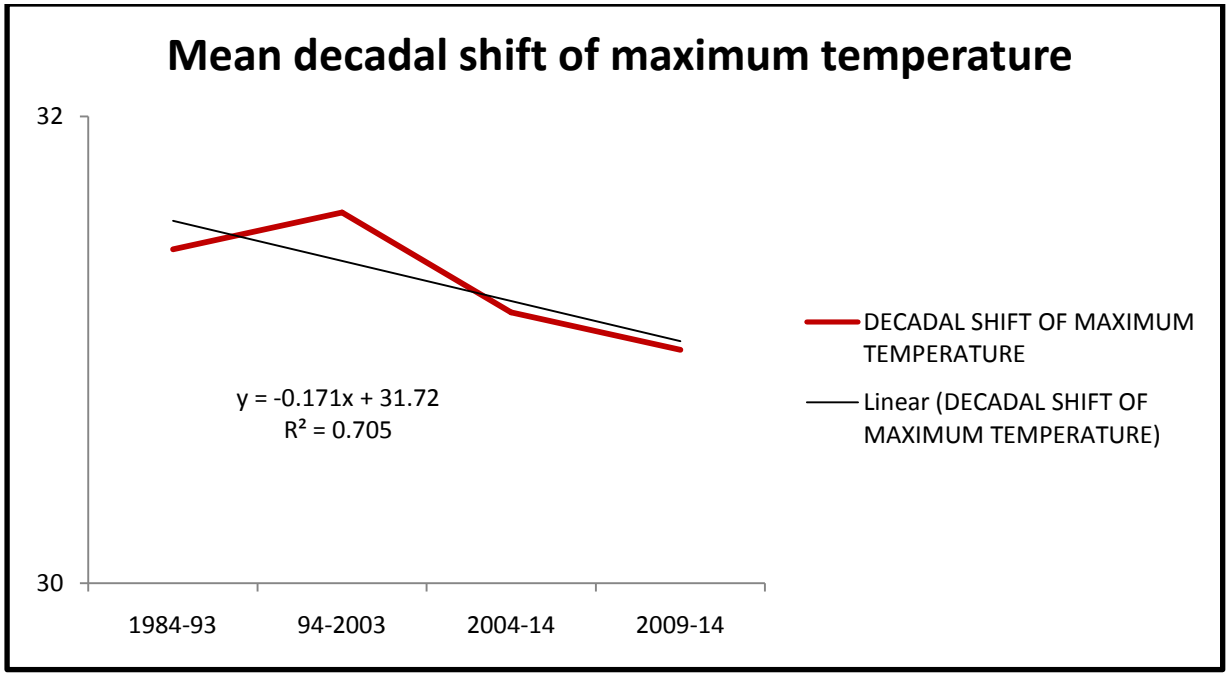
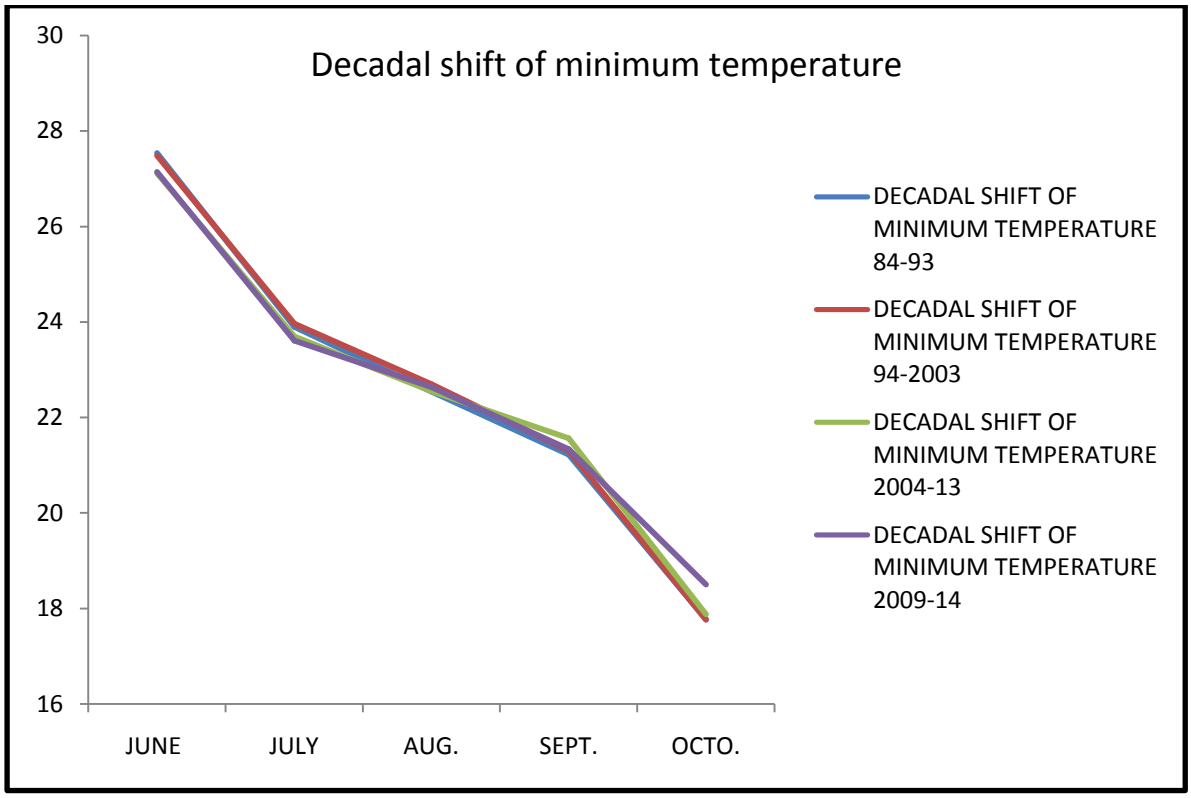


Figure 12 Decadal shift of maximum temperature (Axis y = degree Celsius x= year)



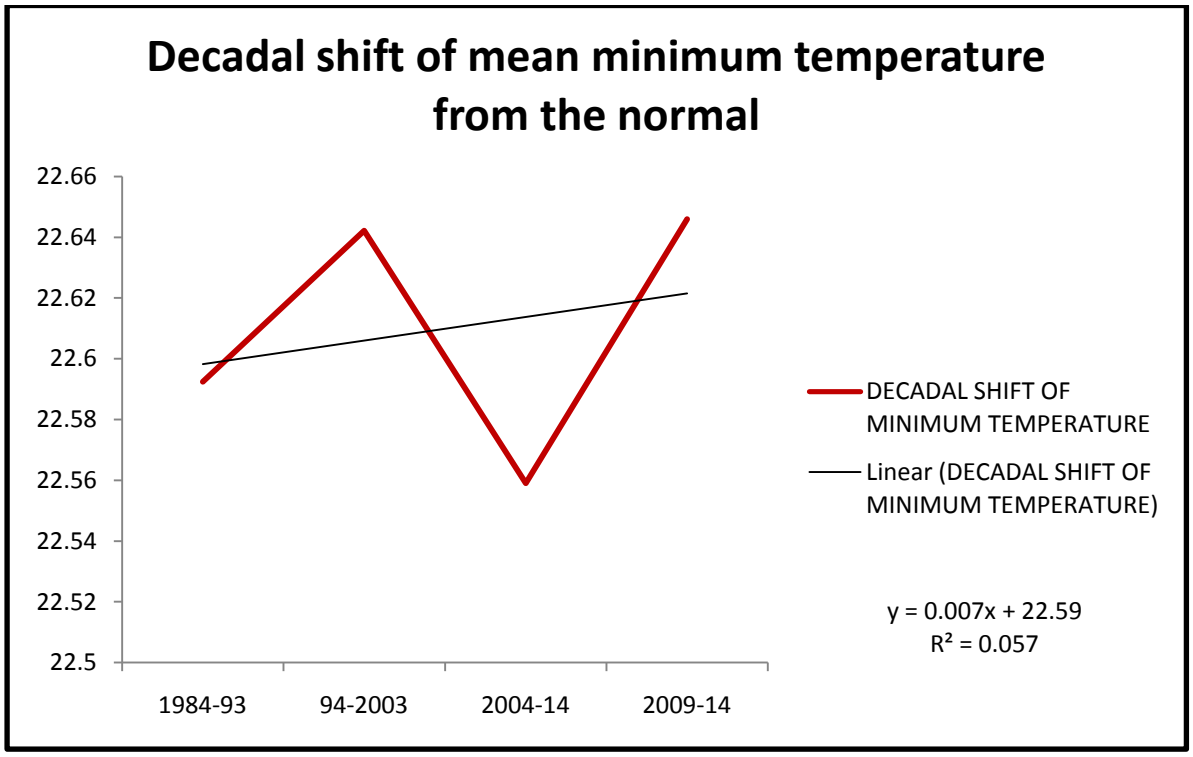
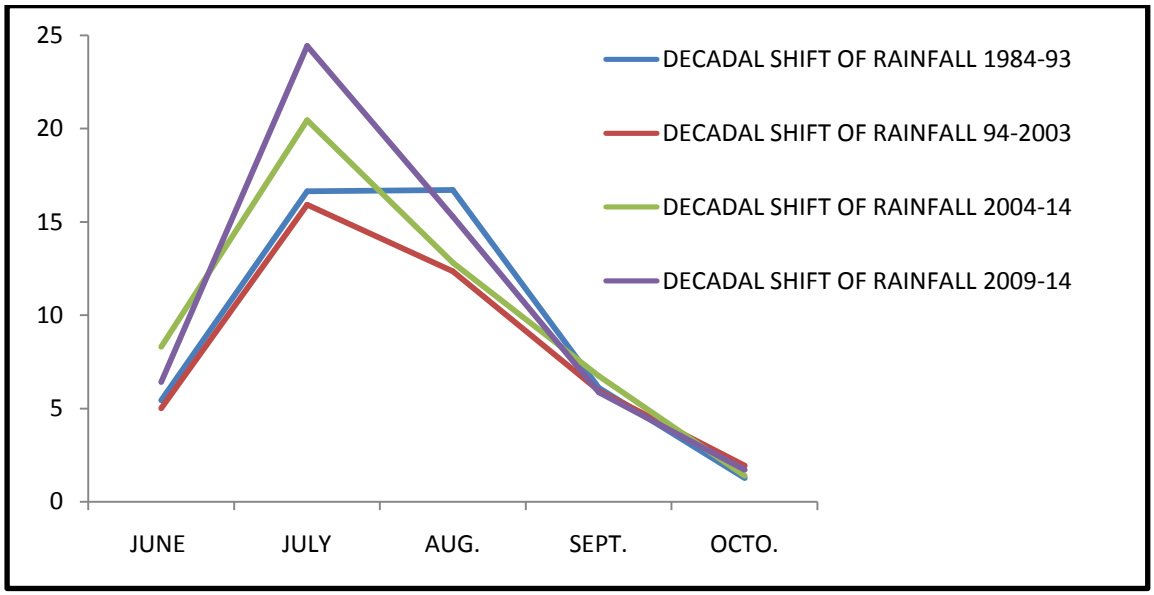
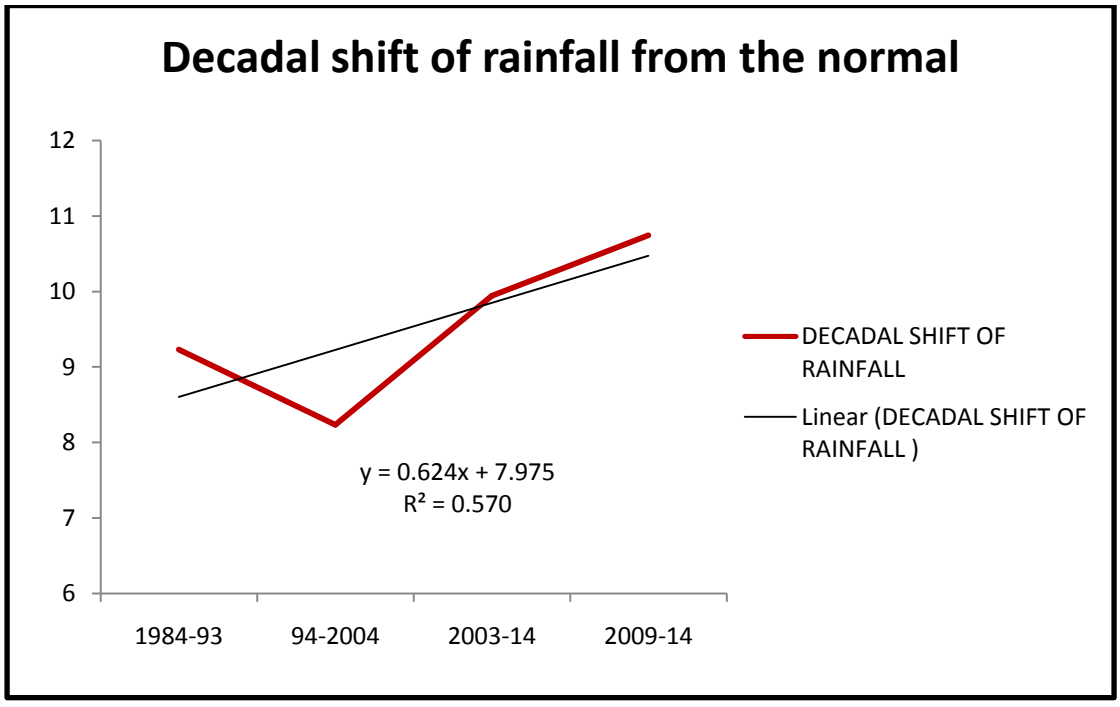
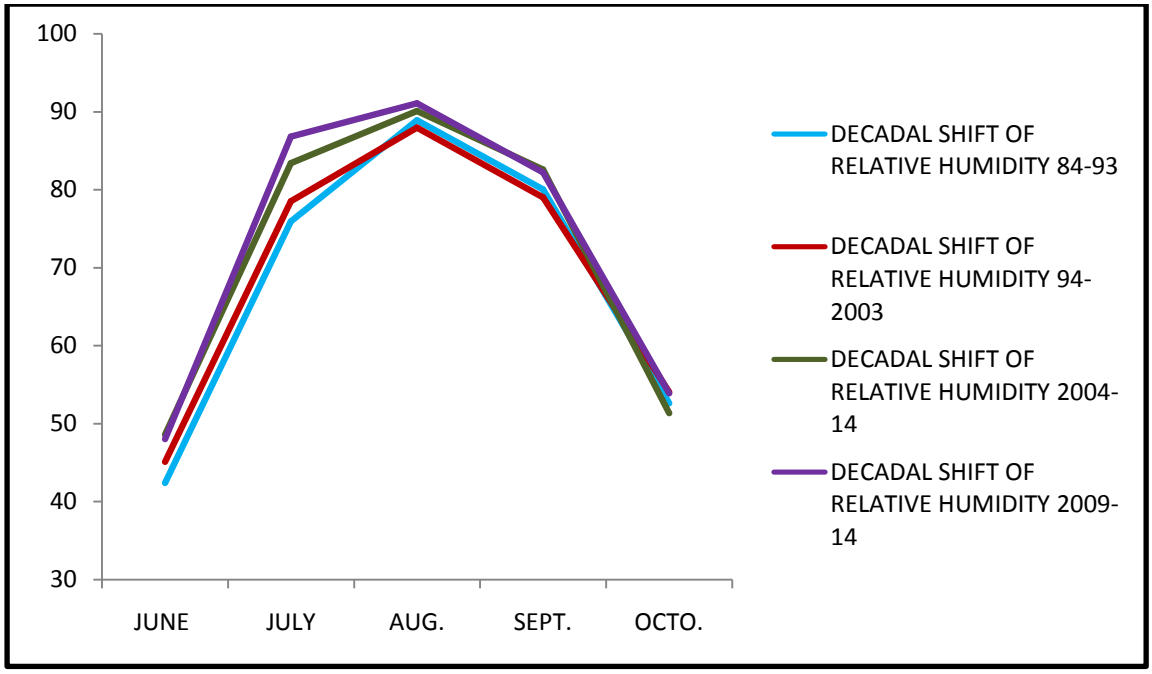


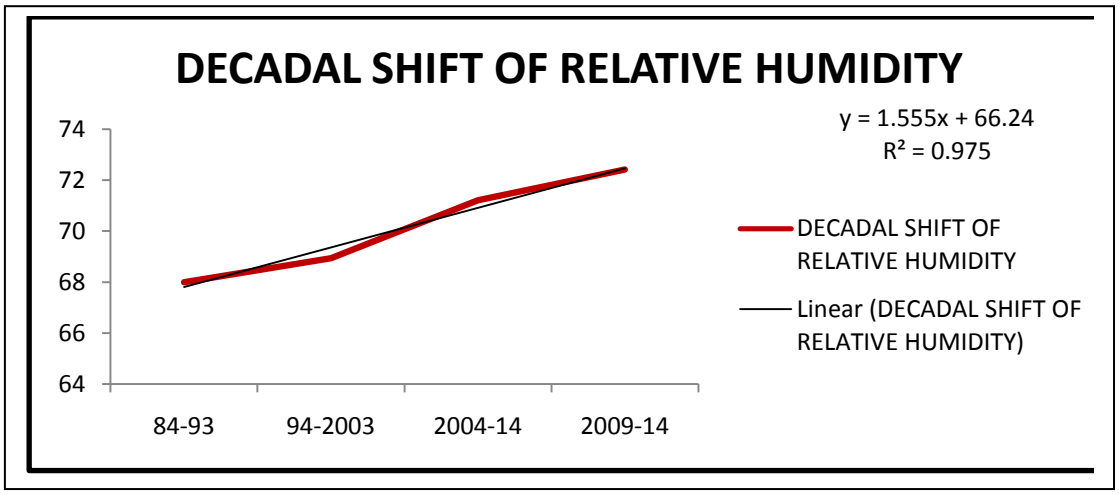
Figure 13 Decadal shift of minimum temperature (Axis y= degree Celsius x= year)

Figure 14 Decadal shift of rainfall and relative humidity (Axis y= rainfall **mm**, humidity **%** x= month)









Objective 2

To find out the incidence of girdle beetle (*Obereopsis brevis*) in some popular varieties.

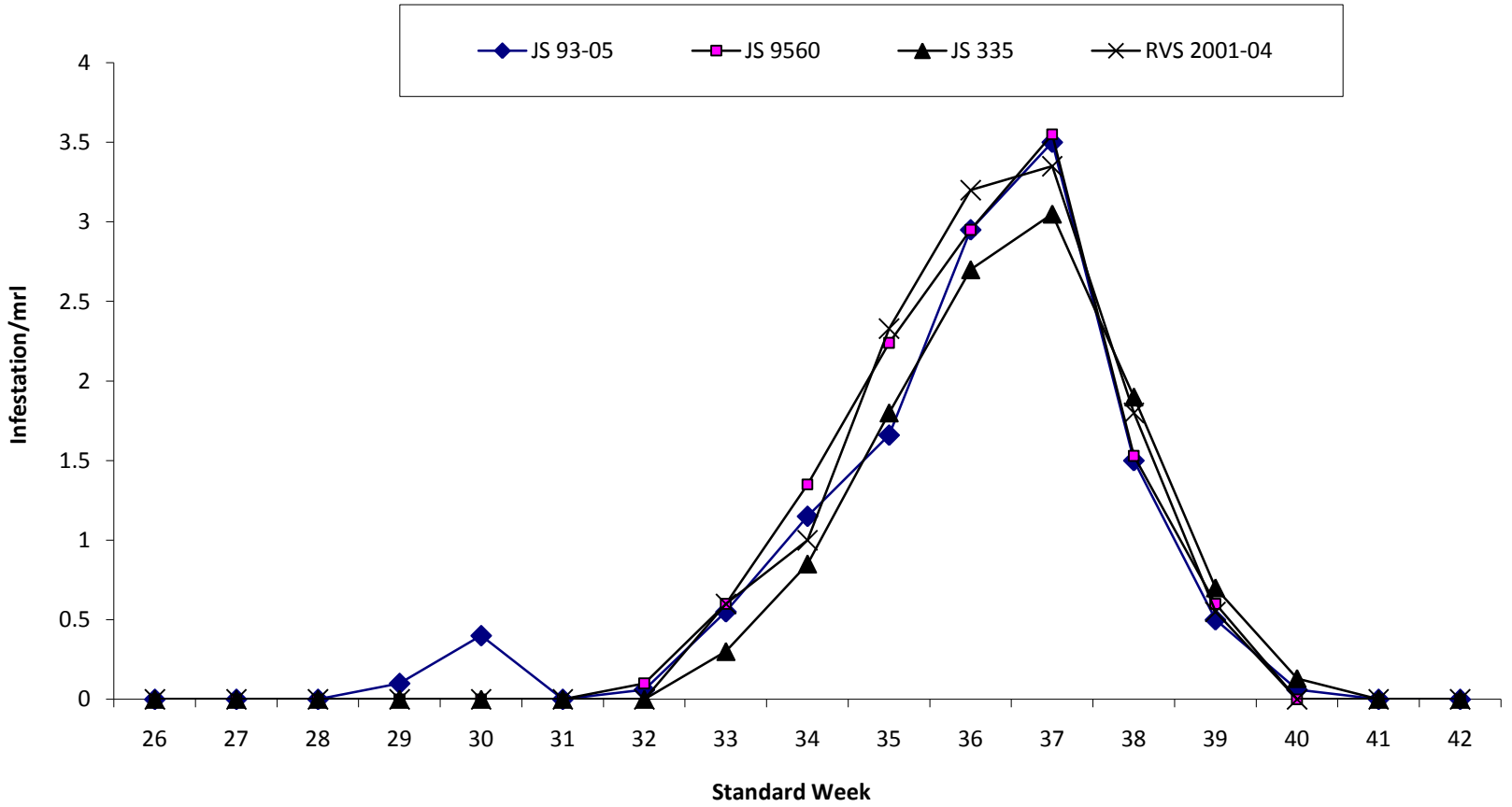
Incidence of girdle beetle *(Obereopsis brevis)* recorded during kharif 2014 in four varieties of soybean viz. JS 93-05, JS 95-60, JS-335 and RVS-2001-4. During kharif 2014 the monsoon was arrived on 3 July and the sowing of kharif crop were extra ordinary delayed the sowing of soybean crop was done in 3th week of July (17 to 21 July). Normally the appearance of girdle

beetle was observed in 4th week of July. But due to extra ordinary delay of monsoon arrival and the sowing date of soybean. The girdle beetle appeared on soybean in around 21 days after germination (DAG) of the crop in varieties JS 93-05 and JS 95-60 and 28 days after germination in varieties JS-335 and RVS 2001-4. Peek activity of the pest was observed in first (week number 36) and second (week number 37) week of September in varieties JS- 93-05 (2.95 and 3.5 infestation per mrl) and in JS -335 (2.7 and 3.05 infestation per mrl) respectively. While in varieties JS 95-60 and RVS 2001-4, the peek activity of girdle beetle was recorded in the week number 35 to 37, that is fourth week of August and second week of September. Infestation per mrl were 2.24, 2.95 and 3.55 in variety JS 95-60 and 2.33, 3.2 and 3.55 in variety RVS 2001-4 respectively. Statistically girdle beetle infestation amongst the four varieties of soybean were non-significant. While numerically it was higher in RVS 2001-4, followed by JS 95-60, JS-335 and JS 93-05. In variety JS 93-05 the infestation of girdle beetle was started in week number 32 (0.06 infestation per mrl) and disappeared in week number 41. In variety JS 95-60 the infestation was appeared in week number 32 and disappeared in week number 40. In variety JS- 335 it was appeared in week number 33 and remained till week number 41 and in varieties RVS 2001-4 infestation the appeared in week number 33 and disappeared in week number 40. Thus the duration of activity of pest was 7 (RVS 2001-4), 8 (JS 95-60), 8 (JS-335) and 9 (JS 93-05) weeks respectively. Early infestation of girdle beetle in soybean was observed in variety JS -95-60 and JS 93-05 as compared to JS- 335 and RVS 2001-4. The activity of the pest was positively correlated with the date of sowing (r = 0.684).(Table 7 and figure 15)

Table: 7 Incidence of girdle beetle in some popular varieties of soybean during 2014 kharif season

Month	Date	Standard weather week	Mean infestation / mrl in soybean varieties				Mean
			JS 93-05	JS 95-60	JS 335	RVS 2001-4	
June	25-1	26	0	0	0	0	
July	2to8	27	0	0	0	0	
	9 to 15	28	0	0	0	0	
	16-22	29	0	0	0	0	
	23-29	30	0	0	0	0	
August	30-5	31	0	0	0	0	
	6 to 12	32	0.06(0.74)	0.10(0.77)	0.00(0.70)	0.00(0.70)	0.04(0.73)
	13-19	33	0.55(1.24)	0.60(1.04)	0.30(0.89)	0.60(1.04)	0.51(1.00)
	20-26	34	1.15(1.28)	1.35(1.36)	0.85(1.16)	1.00(1.22)	1.08(1.25)
	27-2	35	1.66(1.46)	2.24(1.65)	1.80(1.51)	2.33(1.68)	2.00(1.58)
Sept	3 to 9	36	2.95(1.85)	2.95(1.85)	2.70(1.78)	3.20(1.92)	2.95(1.85)
	10 to 16	37	3.50(2.00)	3.55(2.01)	3.05(1.88)	3.35(1.96)	3.36(1.96)
	17-23	38	1.50(1.14)	1.53(1.42)	1.90(1.54)	1.80(1.51)	1.68(1.40)
	24-30	39	0.50(1.00)	0.60(1.04)	0.70(1.09)	0.55(1.24)	0.58(1.04)
October	1 to 7	40	0.06(0.74)	0.00(0.70)	0.13(0.79)	0.00(0.70)	0.04(0.73)
	8to 14	41	0	0	0	0	
	15-21	42	0	0	0	0	
	Mean		1.32(1.25)	1.61(1.31)	1.42(1.26)	1.83(1.30)	
						S Em ±	0.043

Fig 15 Incidence of girdle beetle in some popular vareiteis of soybean during 2014 kharif season



Objective – 3

To find out the co-relation between weather fluctuation and incidence of girdle beetle *Obereopsis brevis* (swed) in soybean

Mean pest infestation of last six years (2009 to 2014) were compiled as per standard weather weeks and presented in (table number 8). Data were correlated with the weather factors i.e. maximum temperature, minimum temperature, mean temperature, different of maximum and minimum temperature, relative humidity , rainfall, deviation from the mean of maximum temperature, minimum temperature, relative humidity, rainfall during the study period 2009 to 2014 respectively. Occurrence of pest population in different years with respect to the arrival of monsoon, date of sowing of crop, different between the arrival of monsoon and delay of sowing of crop were also evaluated to draw interpretation. First appearance of the pest (days after germination) was also correlated with the pest activity. Season's mean of weather parameter were also correlated with the mean pest population. Factor wise results are presented as below.

1. Impact of maximum temperature on the activity of the pest :-

Infestation of girdle beetle was positively correlated in season 2011 (r=0.590) and 2012 (r= 0.732). The mean temperature in 2011 and 2012 was 28.84 ^{0}C to 28.39^{0}C respectively, which was lower then 2014 season. The data further indicated that, the infestation of girdle beetle increases with the increase of maximum temperature in 2011 and 2012 season, while it was not correlated with maximum temperature in 2009, 2010, 2013 and 2014. The correlation of season's mean population with the maximum temperature was non significant (r = 0.225).(Table 10)

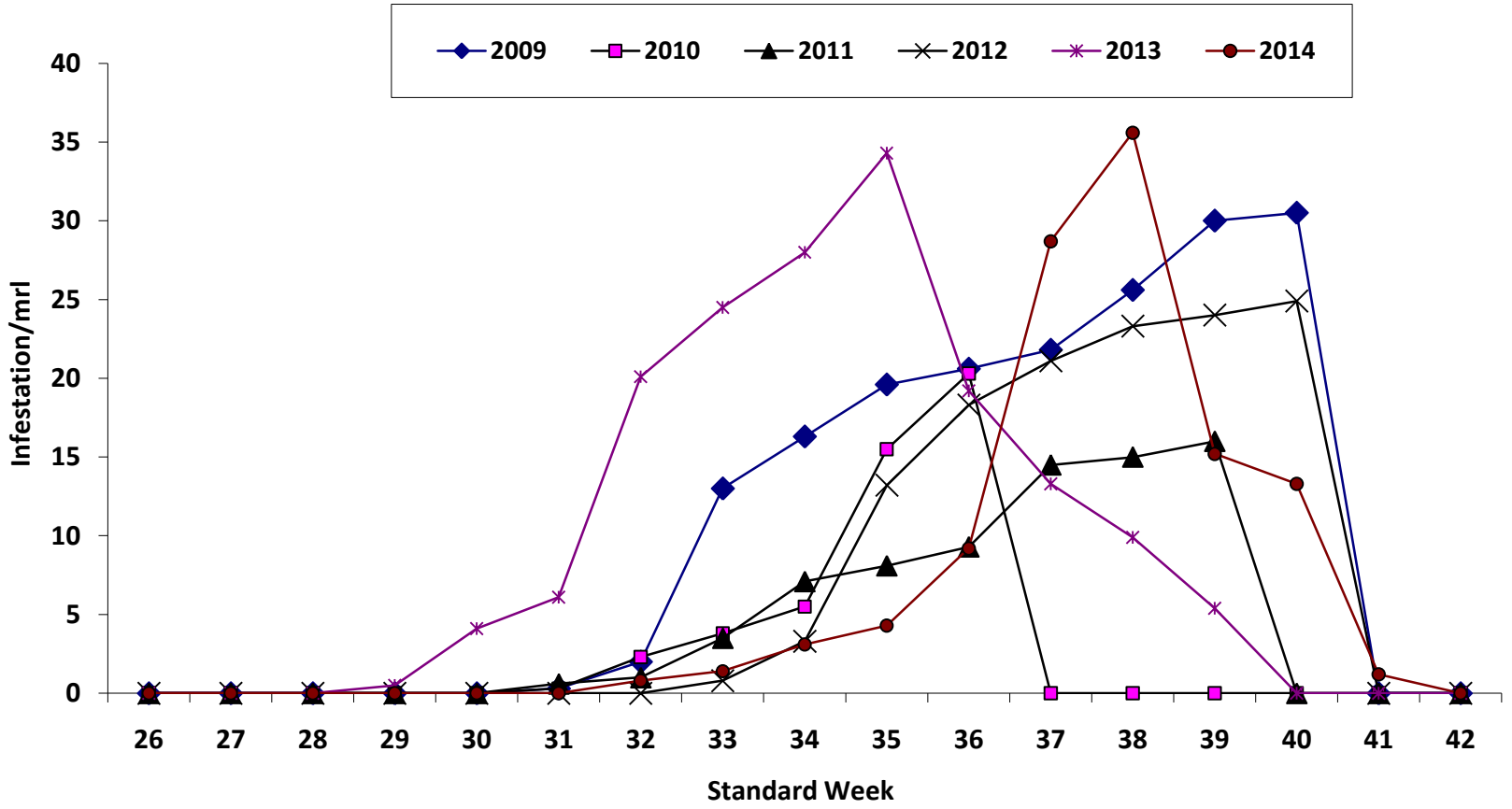
2. Impact of minimum temperature on the activity of the pest :-

Incidence of girdle beetle was not correlated with the minimum temperature except in 2009 season the correlation was negative and significant (r = -0.599). While the season's mean of minimum temperature from 2009 to 2014 and seasons infestation of girdle beetle was negatively correlated. (r = -0.687). Indicated that the minimum temperature shows adverse effect on the incidence of girdle beetle. Increase of minimum

Table 8 . Incidence of girdle beetle during different years in soybean under study

Month	Date	Standard weather week	Infestation /mrl in different years						Mean
			2009	2010	2011	2012	2013	2014	
June	25-1	26	0	0	0	0	0	0	0
July	2to8	27	0	0	0	0	0	0	0
	9 to 15	28	0	0	0	0	0	0	0
	16-22	29	0	0	0	0	0.5	0	0.08
	23-29	30	0	0	0	0	4.1	0	0.68
August	30-5	31	0.3	0.3	0.6	0	6.1	0	1.21
	6 to 12	32	2.0	2.3	1.0	0	20.1	0.8	4.36
	13-19	33	13.0	3.8	3.5	0.8	24.5	1.4	7.83
	20-26	34	16.3	5.5	7.1	3.3	28.0	3.1	10.55
	27-2	35	19.6	15.5	8.1	13.2	34.3	4.3	15.83
Sept	3 to 9	36	20.6	20.3	9.3	18.3	19.2	9.2	16.15
	10 to 16	37	21.8	0	14.5	21.1	13.3	28.7	16.56
	17-23	38	25.6	0	15.0	23.3	9.9	35.6	18.23
	24-30	39	30.0	0	16.0	24.0	5.4	15.2	15.1
Oct	1 to 7	40	30.5	0	0	24.9	0	13.3	11.45
	8to 14	41	0	0	0	0	0	1.2	0.2
	15-21	42	0	0	0	0	0	0	0
	Mean		17.97	7.95	8.34	16.113	15.03	11.28	

Fig 16 Incidence of girdle beetle during different years in soybean



temperature reduces the infestation of girdle beetle. Season's mean temperature in 2009 was 20.87 ^{0}C which was lowest amongst the years under study. The girdle beetle population was 17.97 per meter row length (mrl) which was highest in the study period.(Table 8)

3. Impact of mean temperature on the activity of the pest:-

The mean temperature was also correlated with the population of girdle beetle. The trend was non significant while the activity was negative in 2009, 2010, 2013 and 2014 and it was positive in 2011 and 2012. The correlation was positive and significant in 2012 season only (r = 0.654)

4. Impact of difference of maximum and minimum temperature on the activity of the pest : -

The trend of insect activity in relation with the temperature fluctuation (between the maximum and minimum temperature) was positive, the activity of the pest was increases with the increase of difference of maximum and minimum temperature. In kharif season 2011 and 2012 it was positively correlated with the difference of temperature (r = 0.601) and (r = 0.700) respectively. The season's mean of pest infestation and difference of temperature was also positively correlated (r = 0.579)

5. Impact of relative humidity on the activity of the pest :-

Relative humidity was negatively correlated with the infestation of girdle beetle in 2010 (r = -0.706) while it was not correlated in 2009, 2011, 2012, 2013 and 2014 season. The data of seasons mean was negatively correlated with the incidence of girdle beetle in soybean.

Data further indicated that the incidence of girdle beetle was negative correlated with the minimum temperature and relative humidity and positively correlated with the rainfall and difference of maximum and minimum temperature. The activity of pest was not correlated with the maximum temperature.(Table 10)

6. Date of monsoon arrival on the activity of the pest :-

In Sehore district the earliest date of monsoon arrival was 11 June in kharif 2013 and the delay arrival of monsoon was 4 July observed in 2012 presented in (table 13). The arrival date of monsoon was converted in to

numeric number by counting the days started from first June for example if the monsoon arrived on 28th of June the number allocated was 28 and so on. Monsoon arrival date was alter the date of sowing of kharif crops in respective years under study. Similarly the date of sowing was also converted in to numeric number by counting from 1st June. The data indicated that date of the sowing of crop varies in different years from the date of arrival of monsoon. Due to occurrence of rainfall after the date of arrival of monsoon, date of sowing varies from 6 days to 20 days. The monsoon arrival date, date of sowing and sowing days after arrival of monsoon was compared with the pest population.

The arrival of monsoon and date of sowing was not correlated significantly with the incidence of girdle beetle in soybean. While the trend was positive with the date of arrival of monsoon and negative with date of sowing. Adult emergence of girdle beetle was triggered with the precipitation of pre monsoon and monsoon showers. Shrivastava *et al,*(1998). The incidence of the pest population was negatively and significantly correlated with the difference of sowing date from the date of arrival of monsoon in different season in different years (r = - 0.788). In the year crop was shown early and the date of arrival of monsoon normal and the infestation of girdle beetle was more and in those year the difference in days of sowing after monsoon arrival was more the incidence girdle beetle was less. As it was observed in 2009 and 2010. The incidence of girdle beetle was 17.97 per meter row length and 7.95 per meter row length in sowing day after the monsoon arrival 6 days and 20 days respectively.

7. Deviation from mean maximum temperature on the activity of the pest :-

Deviation of mean maximum temperature was positively correlated with girdle beetle infestation in 2010 and 2012 (r = 0.562 and r = 0.542) respectively. In the year 2009, 2011, 2013 and 2014 the correlation was non significant.

8. Deviation from mean minimum temperature on the activity of the pest :-

The infestation of girdle beetle in all the year under study the infestation of girdle beetle was not correlated significant with the mean deviation of minimum temperature.

9. Deviation of mean temperature on the activity of the pest :-

Correlation was significant and positive in 2010 and 2012 (r = 0.631 and r = 0.503) respectively. While in rest of the years the correlation was not significant

10. Deviation from different of maximum and minimum temperature on the activity of the pest :-

In 2009 only the difference of temperature from the mean was significant negatively correlated (r = -0.431), while it was non significant in rest of the years.

11. Deviation from relative humidity on the activity of the pest :-

Deviation of mean of relative humidity had influence on the girdle beetle the correlation was negative in 2013 (r = - 0.566).(Table 11)

12. Occurrence of girdle beetle infestation in relation with the date after germination of crop :-

Mean of pooled data of last 6 years revealed that the infestation of girdle beetle was positively correlated (r = 0.684) with the date after germination. It means the infestation of girdle beetle more when it appears late in the season. Similar observation was also recorded in 2009 2011, 2013 and 2014 kharif season the correlation was significant and positive r = 0.974, 0.661, 0.620, 0.515 respectively.

Table 9:- Correlation between Pest incidence and crop growth stage DAG (day after germination)

DAG	Girdle beetle infestation/mrl						
	2009	2010	2011	2012	2013	2014	Mean
7	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0
21	0.30	0.30	0.60	0.80	0.50	0.80	0.55
28	2.00	2.30	1.00	3.30	4.10	1.40	2.35
35	13.00	3.80	3.50	13.20	6.10	3.10	7.11
42	16.30	5.50	7.10	18.30	20.10	4.30	11.93
49	19.60	15.50	8.10	21.10	24.50	9.20	16.33
56	20.60	20.30	9.30	23.30	28.00	28.70	21.70
63	21.80	0	14.50	24.00	34.30	35.60	21.7
70	25.60	0	15.00	24.90	19.20	15.20	16.65
77	30.00	0	16.00	0	13.30	13.30	12.10
84	30.50	0	0	0	9.90	1.20	6.93
r value	0.974*	0.084	0.661*	0.351	0.620*	0.515*	0.684*

*significant

Table 10:- Impact analysis of weather factors on the incidence of girdle beetle

Study years	Weather parameters					
	Max. Temp.(^{0}C)	Min. Temp.(^{0}C)	Mean Temp.(^{0}C)	Diff. Temp.(^{0}C)	RH (%)	RF(mm)
2009	-0.084	-0.599*	-0.303	0.401	0.305	0.337
2010	-0.024	-0.140	-0.118	0.176	-0.706*	0.014
2011	0.590*	-0.031	0.107	0.601*	-0.380	-0.250
2012	0.732*	-0.100	0.654*	0.700*	-0.128	-0.872
2013	-0.086	-0.193	-0.155	-0.012	-0.090	0.061
2014	0.0092	-0.146	-0.135	0.0703	0.016	-0.414

Table 11 :- Correlation between the deviation of weather from the mean and incidence of girdle beetle.

Study year	Deviation from the mean				
	Max. Temp.(^{0}C)	Min. Temp.(^{0}C)	Mean Temp.(^{0}C)	Diff. Temp.(^{0}C)	RH (%)
2009	-0.218	0.396	0.099	-0.431*	0.322
2010	0.562*	0.421	0.631*	-0.054	0.246
2011	-0.251	-0.344	-0.221	0.055	0.121
2012	0.542*	0.288	0.503*	0.105	-0.139
2013	0.127	-0.336	-0.372	0.045	-0.566*
2014	-0.290	-0.3465	-0.349	-0.215	0.097

*significant

Table 12:- Correlation between girdle beetle infestation and weather factors.

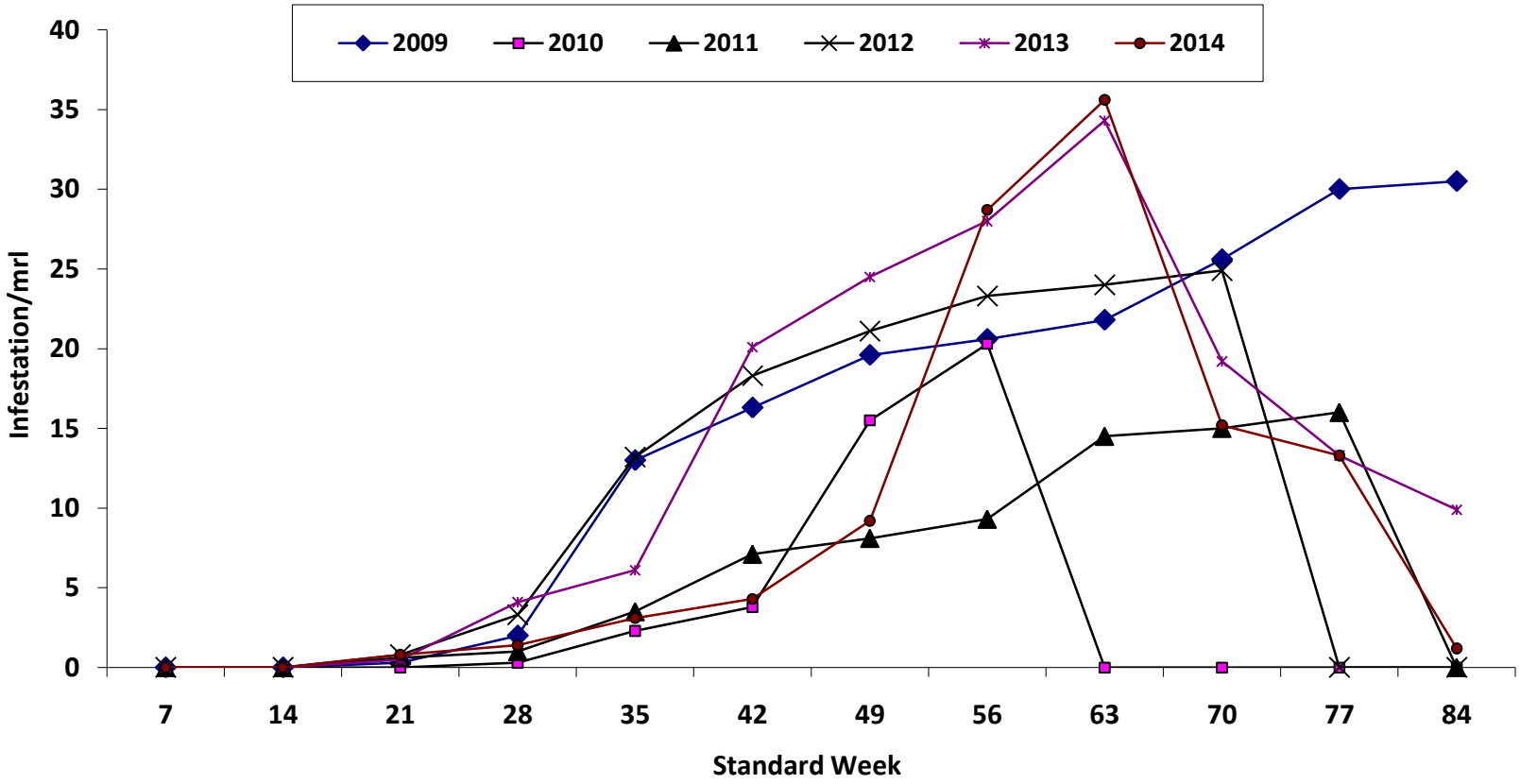
Study Years	Max. Temp.(^{0}C) (A)	Min. Temp.(^{0}C) (B)	Diff. Temp.(^{0}C) (C)	RF(mm) (D)	RH(%) (E)	Girdle beetle infestation/mrl (F)
2009	31.48	21.08	10.37	109.1	73.97	17.97
2010	30.21	22.71	7.38	551.5	90.85	7.95
2011	29.12	22.72	6.30	986.5	96.37	8.34
2012	29.60	21.90	7.69	935.4	90.23	16.11
2013	28.82	23.01	6.54	1290.8	68.35	15.03
2014	31.04	22.66	8.34	643.5	70.57	11.28
A/F	r=0.225					
B/F	r=-0.687*					
C/F	r=0.579*					
D/F	r=0.575*					
E/F	r=-0.527*					

Table 13:- Correlation between girdle beetle infestation and days of sowing and days of monsoon arrival

Study Years	Date of arrival of monsoon	Days of monsoon arrival (A)**	Gap in days between monsoon arrival and sowing (B)	Days of sowing** (C)	Seasons mean (infestation of girdle beetle /mrl) (D)
2009	June 28	28	6	33	17.97
2010	June 17	17	20	36	7.95
2011	June 22	22	11	32	8.34
2012	July 4	34	7	41	16.11
2013	June 11	11	10	21	15.03
2014	July 3	33	18	51	11.28
A/D	r=0.280				
B/D	r=-0.788*				
C/D	r=-0.178				

**days counted from 1st June * Significant

Fig 17 Incidence of girdle beetle on crop growth stage day after germination (DAG) in different year (2009-2014)



CHAPTER V
DISCUSSION

Impact of climate change on the incidence of girdle beetle *Obereopsis brevis* (Swed) in soybean was studied at college of agriculture Sehore. Climatic change and its impact on incidence of girdle beetle were studied by using past six years data including kharif 2014. The weather data from kharif 2009 to 2013 was collected from central observatory Puna and the pest population in different varieties of soybean was recorded in 2 days interval right from date of germination to the harvest of the crop in kharif 2014. However the data of past 5 years was collected from AICRP Soybean with the permission principal investigator of data were compiled as per standard weather week. Weather data was compared with the normal weather data calculated by averaging the weather data from 1984 to 2014. Pest population was also correlated with the different weather parameters to draw the interpretation of impact of climatic change on the pest population. Objective wise results are discuss as below :-

Objective-1

To study the weather fluctuations recorded last six years in the study area.

Fluctuation of weather parameters like temperature, relative humidity, rainfall and on set of monsoon were studied to find out the extent of variation in climate during the study period. Point wise results are discussed as below:-

1. On set of monsoon :- Date of onset of monsoon in Sehore region varies considerably during the study period from 11 June in 2013 season and 4 July in 2012 season, variation of nearly 24 days were observed. In general the onset and withdraw of monsoon is abrupt and worst when feeble limitations the determination of onset and withdrawal dates of the Indian monsoon are indicated (Singh and Pandey , 2010)

2. Fluctuation in maximum temperature.

Seasonal data of maximum temperature from 2009 to 2014 kharif revealed the fluctuation of temperature +1.75^{0}C to -1.02^{0}C from the normal

temperature 29.85^{0}C. The rise of temperature was 0.149 ^{0}C in the study period (2009 to 2014). Temperature trend lines for different years indicated the linear decrease in the seasons in 2009, 2010, 2012 and 2014 and increasing in 2011 and 2013.

Trend line of maximum temperature

Years	Trend lines	R^2
2009	Y= -0.141x+32.82	0.079
2010	Y= -0.223x+32.45	0.214
2011	Y= 0.124x+28.00	0.103
2012	Y=-0.007x+29.68	0.000
2013	Y=0.257x+26.25	0.232
2014	Y=-0.086x+31.91	0.017
Normal	Y=0.023x+29.61	0.003

Mean deviation of maximum temperature from the weekly mean normal temperature shows decreasing trend Y = -0.199x+0.975, R^2=0.128

These observations are similar to the finding of Sahu *et. al* (2010) that the annual maximum temperature showed a decreasing trend over Sourashtra region. Rise of global mean earth's surface temperature by 0.6^{0}C also reported by Houghton *et al., (*2001). After studding 100 years data of earth surface temperature. Singh *et al.,*(2010). Studied the temperature trend in the Indian subcontinent over part 103 year.It shows increase trend of temperature and it is opposite to rainfall trends.

3. Fluctuation in minimum temperature:-

Trend of minimum of minimum temperature shows linear line of increasing temperature trend Y = 0.303x+19.23, R^2=0.171. While comparing the minimum temperature with normal minimum temperature, the increase of 0.101^{0}C was observed. Data of deviation from the mean of minimum temperature further indicated the rise of temperature Y = 0.279x – 0.870, R^2= 0.460.Observation are similar to the minimum temperature distribution over Saurashtra region (Sahu *et. al.,* 2010).

Trend line of minimum temperature.

Year	Trend line	R^2
2009	Y = -0.127x + 22.29	0.439
2010	Y = -0.380 x + 26.41	0.425
2011	Y = -0.142x + 24.07	0.114
2012	Y = -0.501x + 26.95	0.660

2013	Y = -0.126x + 23.80	0.44
2014	Y = -0.345x + 26.11	0.75
Normal	Y= - 0.345x+25.66	0.958

4. Fluctuation of difference of maximum and minimum temperature.

Difference of temperature indicated the prevalence of high or low temperature during day and night time. Mean temperature difference in the study period was 7.86 ^{0}C as compared to the normal 7.40 ^{0}C. Thus the rise of 0.462^{0}C was observed In the study period (2009 to 2014). While comparing the year wise deviation from the normal, maximum deviation was observed in 2009 kharif season. Trend line showed decreasing trend Y = -0.352x+1.94, R^2 = 0.202 and the mean year wise deviation was 0.0017^{0}C.

5. Fluctuation of rainfall

Distribution of rainfall indicated decreasing trend over the normal rainfall the deficit of mean rainfall was 352 mm over the six years. Year wise deviation of rainfall also shows declining trend Y = - 8.342x – 323, R^2=0.005. finding are similar to Sahu *et al*.(2010) observed for Rajkot district of Gujarat.

Year	Trend line	R^2
2009	Y = -3.781x + 97.1	0.055
2010	Y = -2.78x + 55.22	0.123
2011	Y = -5.648x + 114.5	0.397
2012	Y = -4.359x + 98.61	0.159
2013	Y = -11.1x + 186.1	0.299
2014	Y = -3.121x + 69.06	0.096
Normal	Y = -8.182x + 158.1	0.862

For comparing rainfall categorized in to three rainfall groups viz. rainfall 0 to 64.4 mm light to rather heavy, 64.4 to 124.4 mm heavy to very heavy and 124.4 above extra ordinary heavy rainfall. Data indicated that the decreasing trend in light rainfall (y = - 0.542x+12.73) and increasing trend line of heavy to very heavy (Y= 0.428x+2.666) and extraordinary heavy rainfall (Y = 0.028x+1.733) respectively.

Data further revealed that the increase in temperature trend and decrease in rainfall trend but at the same time increase in frequency of heavy to very heavy and extra ordinary heavy rainfall were experienced. Findings of Singh *et al.,* (2010) reported the increasing trend of temperature and it was

opposite to rainfall trend. Tupe *et al* (2010) analyzed the rainfall variability for Akola district (1971 to 2008). He also reported the decreasing and trend in Kharif Y = -0.981x+ 43.8 and Rabi Y = -115x + 3.6.

Number of rainy days also increases by 06 days as compared to normal. Deviation of rainy days from the normal showed increasing trend Y = 2.057x – 6.981.

6. Fluctuation of relative humidity

Relative humidity during the study period shows opposite trend with the rainfall, however the correlation was non significant (r = -0.328). The rise in relative humidity in season was 3.73 % correlation between the relative humidity and rainfall indicated that in the season receive less rainfall – 311 mm to – 517.2 mm the relative humidity were higher than the normal (2010, 2011 and 2012) beyond this limit the relative humidity was near to the normal value.

Year	Trend line	R^2
2009	Y = -0.077x + 74.66	0.006
2010	Y = -1.123x + 99.21	0.182
2011	Y = 0.190x + 94.66	0.064
2012	Y = 0.111x + 89.12	0.003
2013	Y = 0.276x + 65.59	0.365
2014	Y = -0.075x + 71.32	0.013
Normal	Y = -1.004x + 86.32	0.162

7. Decadal shift of weather data

Shift of maximum temperature (Y = 0.171x+ 31.72), minimum temperature (Y = 0.007x+ 22.59), different of maximum and minimum temperature (Y = -0.118x+9.032), rainfall (Y = 0.624x+7.975) and relative humidity (Y = 1.555x+ 66.24) were observed. Decadal trend was decreasing in case of maximum temperature while increasing in case of rainfall and relative humidity. Present finding for Sehore district was partially supported by the finding of Babu and Ragavan(2010). Based on weather data from 1905 to 2008 of Kovilpattim Tamil Nadu, concluded that the total rainfall and North East monsoon rainfall showed an increasing trend and it was more during current decade. In contrast no significant changes in south west monsoon rainfall between the decades observed.

Objective. 2

To find out the incidence of girdle beetle (*Obereopsis brevis* (Swed.) in popular varieties of soybean

Due to delay arrival of monsoon (3 July) the soybean crop was sown in 3rd week of July. Observations recorded just after the germination of soybean. The pest population was appeared 21 days after germination (DAG) in JS 95-60 and JS 93-05 and 28 days after germinating in variety JS-335 and RVS 2001-4. Indicated the delay appearance of girdle beetle in soybean was related with date of sowing of soybean crop. Similar observation was reported by Singh and Gangrade (1976) observed a close relationship between planting date of soybean and girdle beetle infestation. Early Infestation of girdle beetle was observed in variety JS 93-05 and JS 95-60 (week number 32, 21 DAG) as compared to the RVS 2001-4 and JS-335 (Week number 33, 28 DAG). The pest activity was remained up to 9 and 8 weeks in JS 93-05 and JS 95-60 as compared to JS-335 (8 week) and RVS 2001-4 (7 week) respectively. Early infestation coupled with longer duration of infestation may cause higher yield losses. Gangrade and Singh (1976) reported that 75 per cent soybean plants were died before maturity as a result of early infestation by girdle beetle.

Activity peeks of the pest was observed in first (week number 36) and second(week number 37) week of September in varieties JS 93-05 (2.95 and 3.5 infestation per mrl) and in varieties JS-335 (2.7 and 3.05 infestation per mrl) respectively, while in variety JS 95-60 and RVS 2001-4 the peek activity of girdle beetle was recorded in week number 35 to 37 i.e. fourth week of September and second week of October. Infestation per mrl was 2.4, 2.95 and 3.55 in variety JS 95-60 and 2.35, 3.2 and 3.35 in variety RVS 2001-4 respectively. Garg (1985) reported *Obereopsis* sp. infestation from the end of August to beginning of October in soybean in western Himalayan region.

Objective :- 3

To find out the co-relation between weather fluctuation and incidence of girdle beetle (*Obereopsis brevis* (Swed.) in soybean

Various weather parameters like temperature, relative humidity, rainfall and other factors like arrival of monsoon, date of sowing, extant of infestation of girdle beetle in days after emergence of the crop were studied. Maximum temperature represent the day temperature and the activity of the adult of girdle beetle may determined by the maximum temperature and its impact may be reflected by the plant infestation as reported by Rai and Patel (1990) that the first emergence of girdle beetle couple with the maximum temperature 29.60 ^{0}C and minimum temperature 24.70 ^{0}C respectively. Correlation study revel that the maximum temperature correlated positively with the infestation of girdle beetle per mrl was positive in year 2010 and 2012 r = 0.590, r = 0.732. However, in the rest of the year the infestation was non significant. Similarly the deviation of maximum temperature from the mean was positively co-related in 2010 and 2012 r = 0.562 and r = 0.542 respectively.

Minimum temperature had no effect on infestation of girdle beetle but the trend were negative, indicated that increase of minimum temperature not favored the buildup of the girdle beetle. The co-relation was only significant in 2009 r =-0.599. Similarly deviation of mean minimum temperature from the mean were also not correlated with the infestation of girdle beetle. The results of Rai and Singh (2012) was in contradiction with our findings as he reported that the appearance of girdle beetle was related with maximum, minimum temperature and relative humidity.

Mean temperature and difference of maximum and minimum temperature was positively correlated with the pest infestation in 2012 (r = 0.654) and 2011 (r = 0.601) and 2012 (r = 0.70) as reported by Rai and Patel (1990) with maximum temperature ,minimum temperature and relative humidity. The deviation of mean temperature from the mean show positively correlation with field activity of the pest in 2010 (r = 0.631) and 2012 (r= 0.503), similarly the deviation of difference of temperature from the mean was our finding are similar with the finding of Lewin *et al*. (1979) temperature was positively correlated with the groundnut leaf miner. Pollared and Yates (1993)

reported high temperature allow the faster development of insects leads to addition germination in the year

Relative humidity had negative correlation with the activity of girdle beetle in 2010 r = - 0.706, in rest of the year the relative humidity was not correlated with the pest incidence, however the trend was negative in 2011,2012,2013 and positive in 2009 and 2014 season. Deviation of relative humidity from the mean was significantly but negatively co-related in 2013 and 2012 season. The trend was positive. Shrinivas rao *et al.* (2010) founded relative humidity has no correlated with the larval population of *Spodoptera litura* soybean finding are partial support present findings.

Year wise activity of the pest indicated that in all the years the pest infestation was not influence by the rainfall our findings are in contradiction with Rai and Singh (2012) concluded that the low infestation level during the period of the activity of girdle beetle may be due to late planting of soybean crop and low rainfall but in support with the finding of Shrinivas rao *et al.* (2010) that the rainfall was not co-related with the population of groundnut leaf minor.

In Sehore district the earliest date of monsoon arrival was 11 June in kharif 2013.Delay arrival of monsoon was observed on 4 July in 2012. Monsoon arrival date was alter the date of sowing of crop kharif season in respective years under study. Date of sowing various from 6 days to 20 days after the arrival of monsoon. Date of sowing and sowing days after arrival of monsoon was compared with the season mean population of pest. The arrival of monsoon and date of sowing is not significantly correlated with the incidence of girdle beetle the soybean while the trend was positive with the date of arrival of monsoon and negative with date of sowing. Adult emergence of girdle beetle was trigged with the precipitation of pre monsoon and monsoon showers. The incidence of the pest population was negatively and significantly correlated with the difference of sowing date from the date of arrival of monsoon in different season in different years (r = - 0.788) in the crop was shown early in the date of arrival of monsoon the infestation of girdle beetle was less as it is observed 2009 and 2010 the sowing day after monsoon arrival 6 days 20 days the incidence of girdle beetle was 17.97 per meter row length and 7.95 per meter row length (mrl) respectively. Onset and

withdrawal monsoon and it approved limitations to determination onset and withdrawal date of monsoon in India reported by Singh and Pandey (2010).

Thus the pest was shifted over time through the observed pest shift may not be solely attributive to climatic change but the impact of climate change on their status can be observed clearly. Decreases in larval population of girdle beetle from 2009 to 2014 was not the resultant of pesticide consumption in kharif seasons. During kharif season in respectively years because pesticide consumption is related with the increase of area under soybean cultivation in respective years and also the introduction of paddy cultivation in kharif season, in area under study.

CHAPTER VI

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

Summary:

Work on Impact of climatic change on the incidence on soybean girdle beetle were carried out to find out the weather fluctuation during kharif season experienced in last six years and its impact on the incidence of girdle beetle in soybean individually in respective years and collectively in the study period. Incidence of girdle beetle (*Oberiopsis brevis*) were also recorded on four dominate varieties (JS-335, JS-95-60, JS-93-05, RVS 2001-4) of soybean.

Weather data of maximum, minimum temperature, rainfall, relative humidity, date of monsoon arrival from the year 2009, to 2014 of the kharif season (June standard week number 26 to October standard weather week number 42). Weekly normal weather data of Sehore was calculated by averaging 30 years weather data (1984 to 2013). Normal weather data used for comparing the weather fluctuations in the study period, (2009 to 2014) and also for expressing the decadal fluctuations (decadal shift) in weather parameters. The seasons mean data were also used to draw interpretation for weather fluctuations. Weekly and season mean deviation from the normal weather parameters were also calculated to pin point the ups and down of weather parameter in the study period. Monsoon arrival, date of sowing of soybean and difference in days between the monsoon arrival and date of sowing, were also taken into consideration for correlation with the incidence of girdle beetle. First appearance of the pest from the day after germination of the crop in different years were also correlated. Present investigation was carried out at R.A.K. College of agriculture Shore.

Objective wise findings are summarized below :

1.1 Over all results indicated that the trend of maximum temperature in the study year 2009 to 2014 decline by 0.149^{0}C as compare to the normal temperature the decline was linear. However the deviation of maximum temperature from the normal in the study period showed declining trend ($y = - 0.199 x + 0.975$). Similarly the minimum of maximum temperature also show linear declining trend ($y=- 0.507x + 28.41$).

1.2 The mean deviation of the minimum temperature was -1.29, 0.40, 0.33, -0.17, 0.92 and 0.45 ^{0}C in Kharif season 2009, 2010,2011, 2012, 2013 and 2014 respectively. The data further indicated that the minimum of maximum temperature in the study period was in rising trend (y= 0.303 x + 19.23) and the mean deviation of minimum temperature from the normal temperature showed the rising trend (y = 0.279 x – 0.870). The rise of minimum temperature during the study period was 0.108 ^{0}C as depicted by the comparative account data of seasons mean with the normal minimum temperature.

1.3 The mean difference between the maximum and minimum temperature. during the study period (2009 to 2014) were0.0017 ^{0}C However the data of year wise difference between maximum and minimum temperature showed linear decline in temperature difference as compared to the normal by Y = -0.352x + 1.94 R^2=0.202.

1.4 Rainfall pattern in the study period was erratic and the total rainfall showed the decline trend Y = - 8.342x – 298.5, R^2= 0.005. The mean decline in rainfall as compared to normal was 352.8mm. The frequency of light to rather heavy rainfall (0 to 64.4mm) shows declining trend (y = - 0.542x+ 12.73) while the frequency of heavy to very heavy (64.4 to 124.4 mm) and extra ordinary very heavy rainfall (above 124.4 mm) were showed rising trend y = 0.428x+ 2.666 and y = 0.028x+1.733 respectively. Normal rainy day in kharif season is 70.61. The rainy days in 2009, 2012,2011,2012, 2013 and 2014 were 62,80,83,80 and 80 days respectively which was 3.61 days less in 2009 and 9.39, 12.39, 9.39, 9.39 days higher in 2010 to 2014 respectively The mean increase in rainy days was 6.39 days.

1.5 Temperature change of maximum was also compared with the data of maximum temperature of last 3 decades (1984 to 1983). The mean maximum temperature of kharif season was 31.43^{0}C that was raised by 0.158^{0}C in next decades (1994 to 2003) and again decreased in proceeding decaled by 0.428^{0}C. Thus the trend of maximum temperature in the last 3 decades shows declining trend (y= -0.171x + 31.72, R^2= 0.705) with fluctuation of mean temperature + 0.158 and – 0.428 ^{0}C, however in the study period (2009 to 2014). The mean

maximum temperature was decreased by 0.392^{0}C as compared to last decades while comparing the fluctuation within the study period 2009 to 2014 maximum temperature raised by 0.149 ^{0}C as compared to mean normal temperature.

1.6 The data of minimum temperature of last 3 decades indicated the fluctuating trend. In first decades (1984 to 1993) mean minimum temperature was 22.59 ^{0}C It was rise by 0.5^{0}C in next decade(1994 to 2003) and again gown down by 0.083 ^{0}C($y = - 0.016x + 22.63$, R^2= 0.159). Overall result indicated that during the study period(2009 to 2014). The minimum temperature raised by 0.48 ^{0}C as compared to the mean of last 3 decades temperature, while within the study period minimum temperature show rising trend and the mean temperature was 0.108 ^{0}C as compared to normal temperature.

1.7 Difference of maximum and minimum temperature indicated the decreasing trend $y = -0.118x + 9.032$, R^2= 0.170 in last 3 decades. During the study the difference of temperature was indicated slide rise that is 0.0017 ^{0}C as compared to the normal.

1.8 Rainfall data of kharif season in last 3 decades indicated the cyclic fluctuation rainfall experienced 1419.1, 877.02, 1521.9 and 826.44mm in 1984-2003, 1904 – 2003, 2004- 2014 and 2009 – 2014 respectively.

1.9 Relative humidity indicated the gradual increase in last 3 decades including in the study period ($y = 1.555x + 66.24$, R^2= 0.975) while within the study period the relative humidity increase by 3.735%.Monthly data of kharif season indicated decadal shift of relative humidity in last 3 decades.

1.10 Statistically the girdle beetle infestation among the four varietiesof soybean was non significant. Data of seasons mean per cent infestation of girdle beetle indicated the slight decline in pest infestation.

1.11 Infestation of girdle beetle was positively correlated in 2011 (r=0.590 and 2012 (r= 0.732).with maximum temperature.

1.12 Incidence of girdle beetle was not correlated with the minimum temperature except in 2009. The correlation was negative and significant (r = -0.599). While the seasons mean of minimum

temperature from 2009 to 2014 and season infestation of girdle beetle was negatively correlated. (r = -0.687). Indicated that the minimum temperature show adverse effect on the incidence of girdle beetle

1.13 The activity of the pest was increases with the increase of difference of temperature. In kharif season 2011 and 2012 it was positively correlated with the difference of temperature (r = 0.601) and (r = 0.700) respectively. The seasons mean of pest infestation and difference of minimum and maximum temperature was also positively correlated (r = 0.579)

1.14 Relative humidity was negatively correlated with the infestation of girdle beetle in 2010 (r = -0.706) while it was not significantly correlated in 2009, 2011,2012, 2013 and 2014season.The data seasons mean was negatively correlated with the incidence of girdle beetle. Data indicated that the incidence of girdle beetle was negatively correlated with the minimum temperature and relative humidity and positively correlated with the rainfall and difference of maximum temperature the activity of pest was not correlated with the maximum temperature.

1.15 The arrival of monsoon and date of sowing is not significantly correlated with the incidence of Girdle beetle the soybean. The incidence of the pest population was negatively and significantly correlated with the difference of sowing date from the date of arrival of monsoon in different seasons(r = - 0.788).Early shown crop received less infestation.

1.16 Deviation of mean maximum temperature was positively correlated with girdle beetle infestation in 2010 and 2012 r = 0.562 and r = 0.542 respectively.

1.17 The infestation of girdle beetle was not correlated significant with the mean deviation of minimum temperature. While it was negatively correlated with the season mean infestation (r = -0.687)

1.18 Correlation was significant and positive with the deviation of mean temperature 2010 and 2012, r = 0.631 and r = 0.503.

1.19 In 2009 only the difference of temperature from the mean was significant correlated (r = - 0.431), while it was non significant in rest of the year. Comparing the season mean with the difference of

temperature data revealed that the infestation of girdle beetle increase with the increase of different of temperature (r = 0.579).

1.20 Mean of pooled data of last 6 year revealed that the infestation of girdle beetle was positive correlated r = 0.684 with the date after germination (DAG) with the occurrence of pest. The infestation of girdle beetle more when it appears late in the season. Similar observation was also recorded in 2009, 2011, 2013 and 2014 kharif season the correlation was significant and positive r = 0.974, 0.661, 0.515 respectively.

Conclusion:

1. **Maximum temperature** - Declined by 0.149^0C in the study period 2009 to 2014 kharif .Minimum of maximum temperature also shows declining trend.
2. **Minimum temperature** -Rise of minimum temperature was observed by 0.108 ^{0}C as compared to normal temperature. Minimum of minimum temperature shows (rising) ascending trend indicated the rise of temperature.
3. **Difference of maximum and minimum temperature** – Mean temperature difference in the study period shows the rise of 0.462^0C.
4. **Rainfall** - Rainfall shows declining trend. As compared to normal rainfall it decreased by 352 mm, over the period of time. At the same time rise of 6.39 rainy days. Frequency of heavy to very heavy and extraordinary heavy rainfall shows increasing trend while frequency of light rainfall was in decreasing trend.
5. Relative humidity increased by 3.7% in kharif as compared is normal in 2009 to 14.
6. **Decadal shift** -Decadal trend was decreasing in case of temperature. While increasing in case of rainfall and relative humidity.
7. Girdle beetle incidence-Incidence of girdle beetle was positively correlated with the day after germination of crop.
8. **Impact of weather parameters on the pest incidence**-Maximum temperature has not influences the girdle beetle incidence Negative impact of minimum temperature and relative humidity were observed on the infestation of girdle beetle while the Positive effect of rainfall and

difference of maximum and minimum temperature were observed on the girdle beetle infested. Pest infestation was negatively correlated with the days between arrival of monsoon and date of sowing of crop.

Suggestion for further works:

Impact analysis of individual factors through SAG Programme to pin point the extant of multiple impact factors for regulating the pest population that can be utilized in forecasting models , developed for individual pest of soybean.

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VITA

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