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**Research Article**

# A Trend Analysis of Weather in Bapatla, Andhra Pradesh

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**ABSTRACT**

Daily rainfall, relative humidity, maximum and minimum temperature of twenty years (1991-2010) were analysed. Coefficients of variation in seasonal rainfall were 41.7, 87.2 and 40.9% for *kharif*, *zaid* and *rabi* season. Annual rainfall increased over the past two decades at the rate of 8.0 mm per annum. The monthly maximum temperature showed an increasing trend of 4.2 $^0$C per annum. The maximum increase occurred during October at 9 $^0$C per annum. Monthly minimum temperature also increased at a rate of 1.6 $^0$C per annum, and most increase was in March (6.4$^0$C). Monthly mean temperature increased at a rate of 2.9$^0$C per annum. The regression /correlation analysis revealed an increase in rainfall and relative humidity in the month of September and October. Average annual relative humidity data has showed an increasing trend of 13.6% per annum with a correlation coefficient of 0.45. Results showed a very high intensity of rainfall and relative humidity in the month of September of all the years under study with minimum temperature in January month. The relative humidity increased as the rainfall increased.

**Key words:** Climate trend, Coefficient of variation, Regression

## Introduction

Rainfall variability has major implication on country's economy. India is predominantly an agricultural country with about 60% of the cultivated area under rain fed condition. Rainfall information is useful for identifying moisture availability, possibility of introduction of new crop in an agro-ecological region, developing drought characterization index, designing of drainage structure, and many more, which habve direct impact on agriculture.

In the hydrologic cycle, precipitation plays a vital role and its pattern change would directly influence the water resources of the concerned region. Trend analysis of rainfall will lead to a better understanding of the problems associated with floods, droughts, and the availability of water for various uses with respect to future climate scenarios (Jain *et al*., 2012). Significant changes in frequency of extreme weather events have been witnessed in recent years; and the weather trend analysis has become more important (Kingra and Kaur, 2017). Rainfall is the most important characteristic for investigating different hydrological parameters. Forecasting and estimation of rainfall plays an important role particularly in regions where most of the cropped area is unirrigated (Kumara and Kulkari, 2000).

Barman *et al.* (2012) conducted study on the seasonal and monthly analysis of rainfall data to meet the water demand of different cropping systems. Probability distribution indicated occurrence of 80% rainfall in *kharif*, *zaid* and *rabi* season were 751.8, 419.4 and 22.2 mm, respectively, with 1193.4 mm as the annual

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rainfall. This helped in optimizing the choice of crop and its irrigation scheduling. The occurrence of rainy days (>2.5 mm day$^{-1}$) was forecasted. Similarly, Mishra *et al*. (2013) made an analysis of 40 years daily rainfall data (1971-2010) for crop planning in a canal command. Assured rain and dry spell were analyzed for crop planning in rainfed region of East Champaran district of Bihar (Sattar *et al*., 2016). Similarly, long-term change in temperate were evaluated in Assam to assess the impact on crop yields (Saikia and Sharma, 2017). Gwani *et al*., (2013) examined the trend and variability of the characteristics of rainfall pattern in relation to relative humidity and maximum temperature, and their affect on agricultural production. To determine the trend, regression/correlation analysis were done using monthly rainfall, relative humidity and maximum temperature data of seven years in Sokoto state for the period of 2005-2011. Hasan and Rahman (2013) analysed the maximum, minimum and average daily temp-erature data of last sixty-three years (1948-2010), collected from 35 stations of Bangladesh. Trend analysis was performed on monthly average data for all the stations. The monthly maximum, minimum and mean temperatures were determined using historic available data from the meteorological stations of Bangladesh.

## Materials and Methodology

The study area is Bapatla which is located in 15.89º N latitude, 80.47º E longitude and 8 km away from Bay of Bengal, Guntur District of Andhra Pradesh. Historical weather data for the period from 1991-2010 was collected from the meteorological observatory at Bapatla. The average annual rainfall is 1079 mm. The relative humidity is low in the month of May (10%) and is maximum in August (98%). The data was partitioned into monthly, annual and seasonal dataset. Three agricultural seasons, viz. *zaid* (March to May), *kharif* (June to October) and rabi (November to February) were identified according to cropping systems in this region. The statistical analysis was performed to determine the measure of central tendency (mean) and dispersion (standard deviation and variance). For identifying the trend in the rainfall data, the linear regression method of statistical analysis is used.

## Results and Discussion

### *Analysis of rainfall*

Average annual rainfall was 1079 mm (ranged between 667 mm in 2009 and 1898 mm in 2010), 60.8% of which occurred during *kharif* season (June to September), 36.2% in *zaid* season (March to May) and 2.9% in *rabi* (October to February) season (Table 1). Percent contribution of rainfall during *kharif*, *rabi* and *zaid* for the period 1991-2010 is depicted in Fig 1. Coefficient of variation in seasonal rainfall was 41.71%, 87.2% and 40.9% in *kharif*, *zaid* and *rabi* season, respectively. Therefore, cultivation in the *rabi* season requires assured irrigation. However,

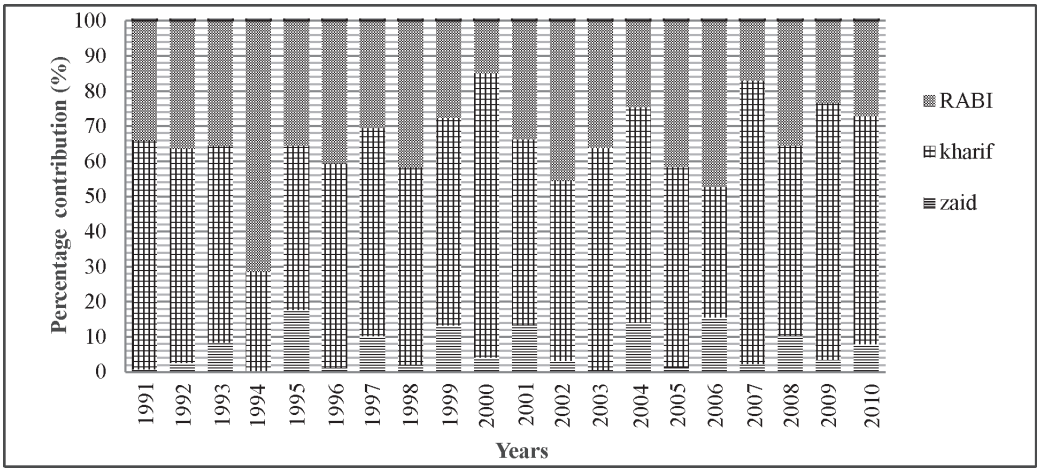


**Fig. 1.** Variation of seasonal rainfall distribution for the period 1991-2010

**Table 1.** Annual and seasonal variability of rainfall (mm) and rainy days (number) at Bapatla, Andhra Pradesh

| Year | Kharif | | Zaid | | Rabi | |
|---|---|---|---|---|---|---|
| | Rainfall (mm) | Rainy days | Rainfall (mm) | Rainy days | Rainfall (mm) | Rainy days |
| 1991 | 764.5 | 34 | 8.4 | 1 | 400.5 | 16 |
| 1992 | 476.4 | 31 | 20.4 | 2 | 285.1 | 10 |
| 1993 | 573.0 | 27 | 86.7 | 4 | 367.1 | 13 |
| 1994 | 323.5 | 24 | 0.6 | 0 | 815.2 | 26 |
| 1995 | 512.4 | 34 | 193.3 | 5 | 388.4 | 13 |
| 1996 | 719.2 | 38 | 14.4 | 2 | 500.2 | 21 |
| 1997 | 662.9 | 27 | 114.2 | 4 | 341.0 | 25 |
| 1998 | 685.1 | 32 | 25.1 | 1 | 508.9 | 23 |
| 1999 | 492.1 | 32 | 109.8 | 3 | 230.4 | 17 |
| 2000 | 908.7 | 34 | 45.5 | 3 | 168.3 | 8 |
| 2001 | 604.3 | 32 | 152.9 | 4 | 384.8 | 20 |
| 2002 | 403.2 | 30 | 25.0 | 2 | 358.2 | 13 |
| 2003 | 602.1 | 40 | 6.2 | 1 | 343.7 | 17 |
| 2004 | 436.4 | 24 | 100.9 | 5 | 174.9 | 11 |
| 2005 | 578.0 | 31 | 14.3 | 3 | 422.7 | 19 |
| 2006 | 444.0 | 30 | 186.1 | 7 | 565.5 | 14 |
| 2007 | 1125.3 | 35 | 31.4 | 3 | 235.8 | 17 |
| 2008 | 582.8 | 32 | 110.7 | 6 | 381.7 | 11 |
| 2009 | 486.9 | 16 | 23.2 | 1 | 156.5 | 11 |
| 2010 | 1232.5 | 48 | 149.5 | 3 | 516.4 | 24 |
| Mean | 630.7 | 32 | 70.9 | 3 | 377.3 | 16.4 |
| SD* | 263.53 | 6.4 | 61.9 | 1.8 | 153.0 | 5.2 |
| CV* (%) | 42 | 21 | 87.2 | 59 | 41 | 32 |

* SD= Standard deviation, CV= coefficient of variation

*kharif* and *zaid* cultivation may be carried out under rainfed condition depending upon the water requirement of crops. Marked variation of annual rainfall was observed during the last two decades. However, trend analysis of annual rainfall during 1991 to 2010 revealed that annual rainfall increased over the past two decades at the rate of 8.0 mm per annum.

As per the standard norms, a day is said to be a rainy day when total rainfall is more than 2.5 mm in the day. Hence it is of great importance to find out the number of rainy days for crop irrigation scheduling. The number of rainy days varied from 28 to 75 in a year with an average of 51. Occurrence of rainfall in the *kharif* season was 61.8% followed by *rabi* season (32.2%) and zaid (5.8%). Among three seasons, the lowest coefficient of variation (CV) for the occurrence of number of rainy days was obtained in *kharif* (21%), followed by the *rabi* (32%) season; largest CV was in *zaid* (59%). Lower values of CV in *kharif* and *zaid* seasons depicted more consistent rain and rainy day, whereas higher CVs implies that the cultivation in *rabi* season can still be practiced by depending on residual soil moisture, or assured irrigation due to uncertain rainfall. Hence this parameter was analysed and presented for 20 years (Table 1). The maximum, minimum, mean rainfall in each month along with the standard deviation and variance are presented in Table 2.

The maximum one-day rainfall from each year of 20 year data is shown graphically (Fig. 2). It is evident that in year 1994, 1995 and 1996, peaks are obtained, and to the same value of one-day rainfall in 1994 (225mm) is seen after 13

**Table 2.** Statistics of mean monthly rainfall (mm) at Bapatla (1991-2010)

| Month | Maximum | Minimum | Mean | SD | Variance ($\sigma^2$) | CV (%) |
|---|---|---|---|---|---|---|
| January | 138.3 | 0 | 13.97 | 33.65 | 1132.44 | 240.97 |
| February | 86.4 | 0 | 10.13 | 22.97 | 527.43 | 226.82 |
| March | 95.7 | 0 | 6.61 | 21.92 | 480.58 | 331.90 |
| April | 151.7 | 0 | 19.57 | 40.59 | 1647.71 | 207.47 |
| May | 193.1 | 0.2 | 44.76 | 56.00 | 3135.95 | 125.11 |
| June | 382.2 | 16 | 106.70 | 94.40 | 8910.65 | 88.47 |
| July | 122.6 | 0 | 18.96 | 29.19 | 852.06 | 154 |
| August | 431 | 29.2 | 182.94 | 106.55 | 11353.81 | 58.25 |
| September | 362.5 | 53.7 | 212.18 | 107.70 | 11599.69 | 50.76 |
| October | 474.3 | 3.6 | 217.04 | 141.17 | 19928.75 | 65.04 |
| November | 430 | 0 | 104.47 | 110.87 | 12291.47 | 106.12 |
| December | 170.3 | 0 | 31.81 | 64.05 | 4102.67 | 201.36 |

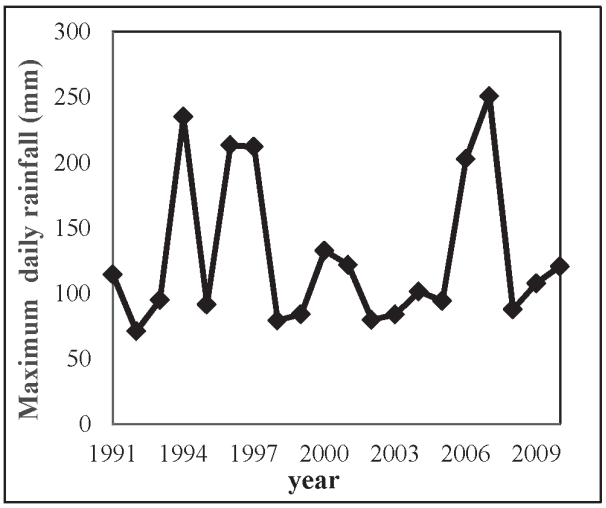


**Fig. 2.** Maximum rainfall occurred in a day annually during the study period

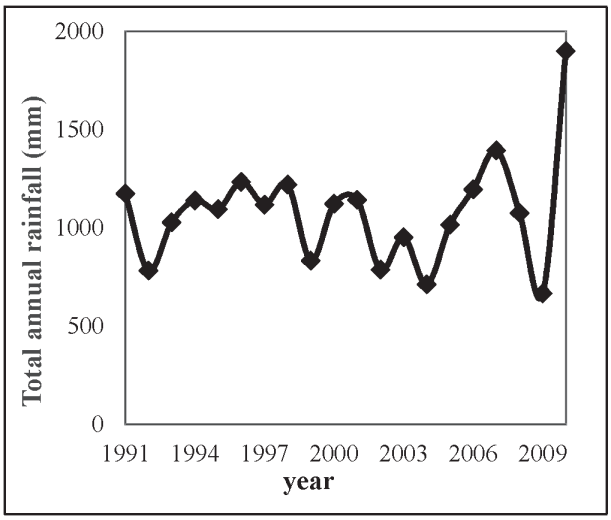


**Fig. 3.** Trend of annual rainfall during rainfall of Bapatla from 1991- 2010

years (in 2007, 250 mm rainfall in a day) occurred in the region. Data revealed that the annual daily maximum rainfall ranged between 71 mm (minimum) to 251 mm (maximum), indicating a large fluctuation during the period of the study. The annual rainfall was varied between 700 to 1300 mm, except in 2007 and 2009 (Fig. 3). August, September and October months usually have high rainfall (200 mm) followed by a sharp decline in the November month (Fig. 4). The month of June also recorded an average of 100 mm rainfall.

### *Analysis of temperature*

A histogram with month-wise distribution of the averages of maximum, minimum and mean temperatures of the Bapatla is presented in Fig. 5. The peak value of the maximum temperature was recorded in May 2003 with a magnitude of 47.3$^0$C and the minimum temperature was formed in 2008. Moreover, monthly mean temperature was found to be the highest during May (32.6$^0$C)

Monthly average rate of temperature during last 20 years (1991-2010) was also studied. A summary of trends $^0$C monthly maximum and minimum temperature over Bapatla for each month, and coefficient of determination, $R^2$ of the trends are presented in Table 3. Monthly maximum temperature exhibited a rise of 0.1 $^0$C per annum during September to 9$^0$C per annum during October. On the other hand, maximum trend of monthly minimum temperature is 6.4$^0$C

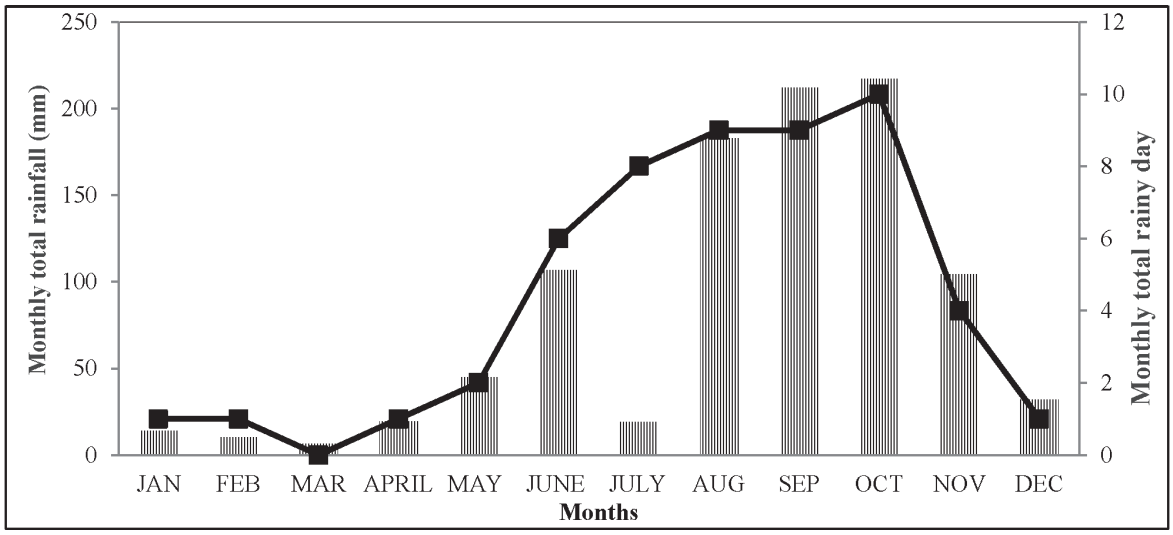


**Fig. 4.** Monthly distribution of rainfall and monthly rainy day at Bapatla

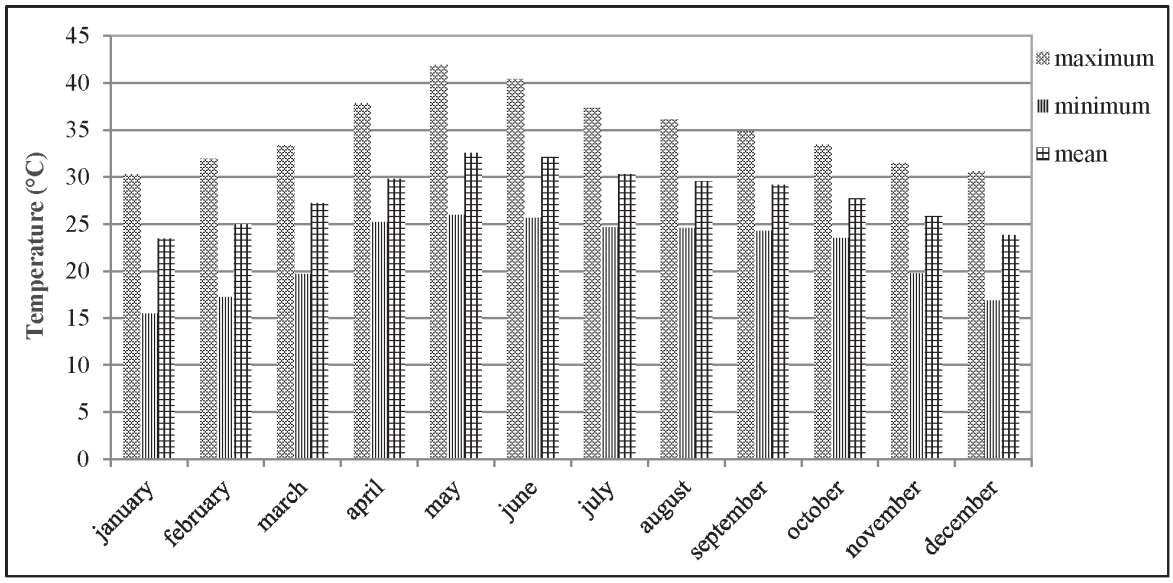


**Fig. 5.** Histogram showing monthly average of maximum, minimum and mean temperature (°C) during the last twenty years period (1991-2010)

per annum in month of March. The minimum trend of monthly minimum temperature is $0.1^0$C per annum in February. It is apparent that monthly minimum temperature has been increased significantly during the winter season (October to February) over the last 20 years.

In this study, trends of monthly temperature data were analysed during the period 1991-2010. Monthly maximum temperature data is showing an increasing trend of 4.2°C per annum; while monthly minimum temperature increased with the rate of 1.6°C per annum (Fig. 6). Also, monthly mean temperature data had shown a trend of 2.9° C increase per annum (Fig. 7).

### *Relative humidity*

From Fig. 4, it could be observed that the month of July marked the beginning of rainfall over the years, which continued over five months. Rainfall reduced to a bare minimum at the end of

**Table 3.** Monthly average trends and $R^2$ value of monthly maximum and minimum temperature during last 20 year period (1991-2010)

| S. No. | Month | Average of 20 years period(1991-2010) | | | |
|---|---|---|---|---|---|
| | | Max | $R^2$ | Min | $R^2$ |
| 1. | January | 0.0526 | 0.245 | 0.016 | 0.009 |
| 2. | February | 0.034 | 0.134 | 0.001 | 0.00006 |
| 3. | March | 0.029 | 0.149 | 0.064 | 0.156 |
| 4. | April | 0.051 | 0.131 | 0.042 | 0.105 |
| 5. | May | 0.082 | 0.081 | 0.001 | 0.000 |
| 6. | June | 0.082 | 0.081 | 0.010 | 0.005 |
| 7. | July | 0.025 | 0.008 | 0.008 | 0.004 |
| 8. | August | 0.029 | 0.018 | 0.002 | 0.001 |
| 9. | September | 0.001 | 0.00009 | 0.009 | 0.026 |
| 10. | October | 0.090 | 0.450 | 0.009 | 0.037 |
| 11. | November | 0.037 | 0.109 | 0.008 | 0.002 |
| 12. | December | 0.046 | 0.188 | 0.059 | 0.105 |
| | Average | 0.0465 | 0.1328 | 0.0191 | 0.0375 |

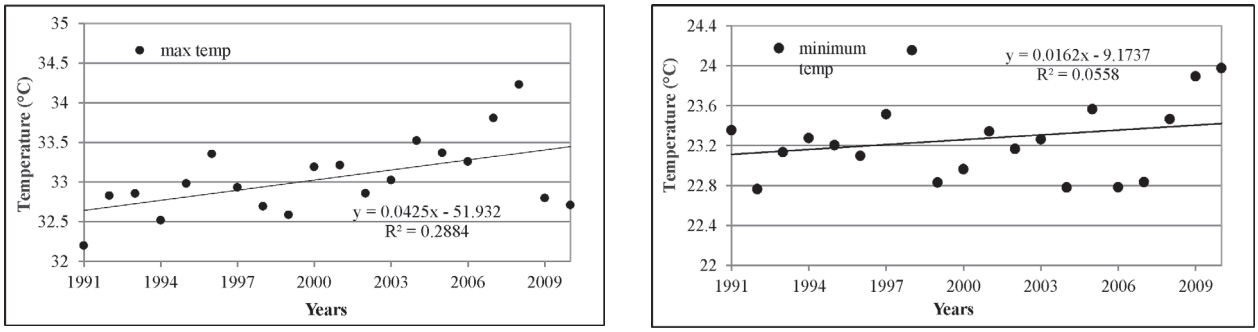


**Fig. 6.** Trend of the monthly maximum and minimum temperatures of Bapatla, AP

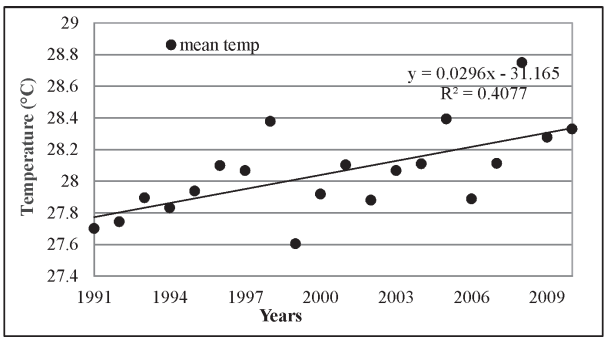


**Fig. 7.** Change in monthly mean temperature over the period of study

November. The rainfall intensity was high in the month of September and October, and the peak rainfall was recorded in the month of October of all the years. The relative humidity is observed to increase during the month of May to September (Fig. 8). When the rainfall is considerably high; the peak relative humidity was obtained in the month of August. It was noted that in 1993, the humidity was maximum at 98% and the minimum was recorded in 2008 (10). The temperature on the other hand shows a similar pattern in all the years under the study. The temperature increases from the month of January to April, and decreases in the month of May just when the rainfall starts; it decreases to the minimum in the month of August when the rainfall and relative humidity was very high. The temperature eventually increases in the month of November and December where there was is rainfall. This study showed that there is a significant increase in annual rainfall amount mostly in the month of

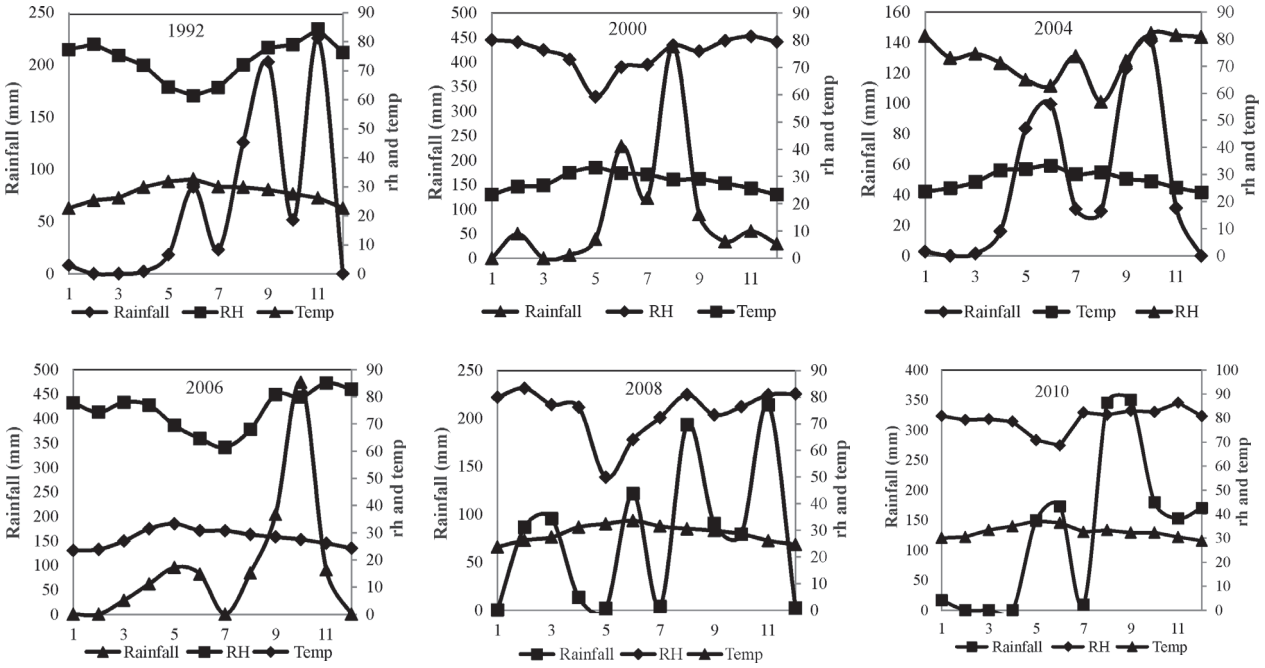


**Fig. 8.** Monthly rainfall, mean relative humidity and mean temperature of years 1992, 2000, 2004, 2006, 2008 and 2010 respectively

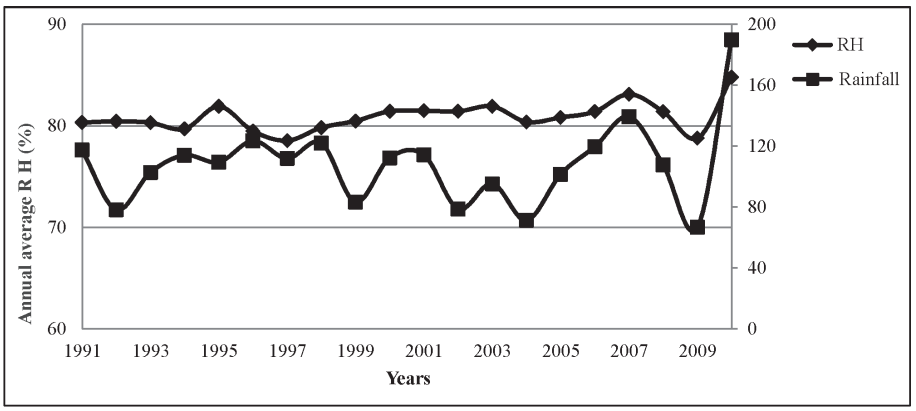


**Fig. 9.** Variation of yearly mean rainfall and relative humidity in Bapatla (1991-2010)

July and October with the highest amount of rainfall observed in the month of August except in 2008, when the maximum rainfall was recorded in July. Maximum temperature also decreased to its smallest value when the amount of rainfall and relative humidity are both at their maximum.

The yearly correlation between the rainfall and relative humidity of the study area from 1991-2010 indicates the year with the highest rainfall and relative humidity (Fig. 9). From the figure it is evident that there is a direct relationship between rainfall and relative humidity throughout the months of the year. The rainfall increases as the relative humidity increase. Average annual relative humidity data have shown an increasing trend of 13.6% per annum with correlation coefficient of 0.45.

## Conclusions

The agro-climatic information is most useful for crop planning and solving of practical agricultural problems. Without such analysis, the adoption of farming system or planning an agronomic technology to an area might be

unsuccessful. In the present study, analysis of weather data of Bapatla from 1991 to 2010 were carried out to assist farmer for better irrigation planning, irrigation scheduling, crop selection etc. The annual daily maximum rainfall received at any time ranged between 71 mm (minimum) to 251 mm (maximum) during the period of study, which was recorded in the month of October in all the years. So for cultivation, proper drainage system should be maintained. The total rainfall in the *kharif* season was 62% followed by *rabi* (32%) and zaid (6%) of the total annual rain fall with a mean seasonal of rainfall 631 mm, 377 mm and 71 mm respectively. The relative humidity is observed to increase during the month of May to September, when the rainfall is considerably high, the peak relative humidity was obtained in the month of August.

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