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Crop - Weather Relationship and Weather Health Indices for Rice in Guntur District

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ABSTRACT

Climate determines and controls the selection of crops for a particular region and the prevailing weather conditions decide the potentiality of the crops. Among the major cereals, rice is a highly weather sensitive crop. Rice crop production in Guntur district is largely influenced by inter annual climate variability and possible climate change in addition to prevailing weather conditions. The fluctuations in its yield effects economy of the district. Therefore, to provide the policy makers and planners with scientific information on the impact of climate change and variability and the prevailing weather conditions on rice crop yields in Guntur district, a study was conducted to investigate the relationship between weather parameters and their effect on rice crop yield in Guntur district of Andhra Pradesh. The weather data of two major locations representing the weather of the Guntur district viz., Bapatla (1984-2014) and Rentachintala (1964- 2015) and rice crop yields from both kharif and rabi (1964- 2015) seasons were used. Analysis of relationship of rice crop yield with weather health indices could be predicted with 91 per cent of coefficient of determination. The weather health indices found predominant are weekly rainfall during maturity stage; average minimum temperature during vegetative stage which are negatively correlated where as the average weekly GDD during reproductive stage which is positively correlated. The other weather health indices that were found optimum are 900 mm rainfall during the cropping season GDD 2340 ^{0} Day Hours and 22 to 32 ^{0}C of temperature range for profitable rice crop yields (4584.32 q ha^{-1}) in Guntur district of Andhra Pradesh .

Key words: *Climate, Regression, Correlation, Phenophase, Weather health indices.*

Rice is a unique crop among the major food crops by virtue of its extent and adaptability to wider range of climatic conditions. About 90 per cent of the rice production takes place in the tropical/sub-tropical Asia where 60 per cent of the world population lives. The slogan "Rice is life" during International Year of Rice 2006 reflects the importance of rice as primary source of food . Rice is essential for food security, poverty alleviation and improved livelihoods. In less than 40 years, the world's population is predicted to reach 9 billion, raising the "9-billion-people" issue. For sustainable rice production in the years to come, a number of challenges need to be addressed by the entire rice community with the common goal of enhancing rice production. Rice crop is constantly exposed to a variety of biotic and abiotic stresses that reduce its yields. Two major factors that are responsible for low rice yields are adverse weather that prevails during the crop growth and development stages and weather driven pest epidemics during vegetative and reproductive stages. High temperature is a major factor limiting rice cultivation. The optimum temperature is about 30^{0}C, and temperatures lower than 20^{0}C, particularly during the reproductive stage, induce sterility. Rainfall at maturity hampers the translocation of photosynthetes. These weather related uncertainties are not uncommon in Guntur district. So far very few studies were conducted on the influence of weather on rice crop production and for sustainable yields in Guntur district. There is also a serious lack of detailed work on crop-weather interactions with climate change and variability projections in Guntur district of Andhra Pradesh. Hence, to scientifically develop a sound knowledge of the weather parameters and its interactions with rice crop yield and to access relationship of weather parameters with rice yield in Guntur district a study was taken up.

MATERIAL AND METHODS

The unraveling of relationship between weather and various aspects of growth, development and yield is complex in the present investigation site because it is sub-humid and sub tropical with hot summers and mild winters(Kazmi and Rasul, 2012) . Therefore, the variations in rice yield that can be attributed to weather vis-a- vis weather variations, in addition to a very limited extent on climate change were tested using the best possible statistical models and agro meteorological tools and techniques. The yield of the rice crop from 1969 to 2015 for both Kharif and Rabi were used in the study. The weather variables such as minimum, maximum and mean temperature, the derived weather indice GDD, and rainfall from 1964 to 2015 were analysed (Zaman et.al 1982). The biometric observations were observations from selected farmers (Murthy 2015 & 2016). The primary data was collected from a sample of 150 farming families of six mandalas, located in Guntur district three each located around Bapatla and Rentachintala. The multistage random sampling technique was used with mandals as the primary stage sampling unit, villages as second stage unit and farms as third stage unit. The farms were divided into five categories i.e., marginal, small, semi-medium, medium and large (as per GOI categorization of different land holdings) and equal number of farms i.e., 30 were randomly selected from each category of farm. In addition, a multistage stratified sampling design was also adopted for the study under Bapatla and Rentachintala locations, to avoid any sampling error. Further, the "area level random effects model" was also used to find the acceptability of the methods employed in the present study.

For rainfall, the run test is used for examining whether a string or sequence of data is occurring randomly in time series or over space for a given specific distribution or in determining whether the outcome of a trial is truly random. The run test analysed the occurrence of similar events that are separated by different events(pandey et. Al, 2015). The run test also helped to detect whether observations are random along a transect or other linear feature (Murthy 2015 & 2016).

Rice crop production under sub humid and sub tropical climate like Guntur district is a multi-dimensional process. There are several methods for estimating the effect of weather elements on rice yields but, most of them have their own limitations. The major limitation arises from the assumptions made about each weather element and the weightage in aggregate index. However, the following statistical and computer programmes were also used in the present study based on "justifiable treatment that can be assigned to each weather element"(Murthy 2016) .

Rice crop yield in different years is affected by technological change and weather variability. It can be assumed that the technological factors will increase yield smoothly through time and therefore, year number and also the most appropriate function of time) were used to study the overall effect of technology on yield. The weather variability both within and between seasons is another uncontrollable source of variability in yield of rice. The weather variables affect the crop differently during various stages of development. Thus, extent of weather influence on crop yield depends not only on magnitude but also on the distribution pattern of weather variables. This necessitated over the crop season as such, the necessity of dividing the whole crop season into fine intervals. Therefore, three intervals I_1 (June 15th if irrigation water is released) ; I_2 (August 15th based on SW Monsoon) and I_3 (Most common transplantation date for rabi rice 5th November) were taken. It was assumed that the effect of change in weather variable in successive weeks would not be abrupt or erratic but an orderly one that follows some statistical law and agrometeorological tool. Finally, the following methodology was followed and deployed for studying the effects of weather variables on rice yield using complete crop seasons data where as forecast model utilized partial crop seasons data (Murthy 2015 & 2016) .

Multiple linear Correlations using "SPSS" computer programme

Maximum possible combinations of linear and non linear models which are the most popular and widely used hybrid models for improving the forecasting accuracy were also used in the study keeping in view the large data and complexity of the weather and climate in Guntur district in addition to the daunting task of quantifying and the impact of technological development.

Often several quantitative variables are measured on each member of a sample. When a pair of such variables is considered then it is frequently of interest to establish if there is a relationship between the two; i.e. to see if they are correlated. Then it is possible to categorize the type of correlation by considering as one variable increases what happens to the other variable (positive/negative/no correlations).

SPSS software (Statistical Package for the Social Sciences) version SPSS 16.0 Copyright 2007 which is data analyzing software is used through which different types of data could be analyzed on statistical basis, like in MS-Excel. Yield is predicted through a model thus a correlation analysis needs to be described between yield and weather parameters using SPSS software (http://www.spss.com).

In this study, the yield prediction of rice based on weather was the main intention. The approach was to investigate impact of prominent contributors rice yield viz., rainfall and GDD towards the final rice yield. For this purpose the decadal based agromet data from 1969 to 2015 kharif and rabi seasons fed as input for the said methods / models (Sastry et. al, 2012 and Sastry 2010) . The yield data (Kg/ha) treated as dependant variable and the method employed are all possible combinations of models, with special emphasis on linear regression (Kazmi 2012).

Linear Regression model

A multiple linear regression equation helps to assess the coefficients which best predict the output of the dependent variable. The model's output is shown here in which the following abbreviations are used:

Tmax = Mean maximum temperature (^{o}C)
Tmin = Mean minimum temperature (^{o}C)

Rain = Rainfall (mm)

The value for R^2 correlation coefficient shows the accuracy between predictor or independent variable and dependant variable. The sign of 'r' indicates the slope of the regression line.

Regression equation

After analysis a simple linear equation has been developed, which may be a useful tool for yield prediction of rice crop in the region.

Y = a + (b1) (x1) + (b2) (x2) + (b3) (x3) + (b4) (x4).

Where,

Y = Predicted yield

A = Intercept

b1, b2, b3, b4 = Regression coefficients

x1, x2, x3, x4 = Dependent variables

Formula of Error % -

Error % =

$$\frac{\text{Actual yield} - \text{Predicted yield}}{\text{Actual yield}} \times 100$$

Table 1. Descriptive statistics for Rainfall (mm) of Bapatla from 1984 to 2014

Variable Name	Lowest	Highest	Kurtosis	Skewness	Range	Mean	Std. Dev.	Std. Error	C.V. %	Jarque Bera	χ Prob	
JAN	0.00	138.30	6.83	2.63	138.30	15.64	32.37	5.39	206.96	111.42	0.00	***
FEB	0.00	125.10	5.34	2.32	125.10	14.73	29.33	4.88	199.03	75.30	0.00	***
MAR	0.00	95.70	13.60	3.76	95.70	6.62	21.17	3.52	319.86	362.81	0.00	***
APR	0.00	151.70	7.42	2.77	151.70	16.59	34.90	5.81	210.39	128.88	0.00	***
MAY	0.00	192.30	7.10	2.32	192.30	32.93	39.06	6.51	118.59	108.20	0.00	***
JUN	0.00	284.90	2.91	1.35	284.90	82.44	60.19	10.03	73.01	23.65	0.00	***
JUL	30.40	416.00	4.36	1.54	385.60	136.68	74.94	12.49	54.83	42.77	0.00	***
AUG	29.20	430.90	1.34	1.02	401.70	153.95	88.55	14.75	57.52	8.98	0.01	*
SEP	36.50	381.00	-0.64	0.48	344.50	183.00	98.25	16.37	53.68	2.03	0.36	
OCT	3.60	497.90	0.70	1.08	494.30	175.12	125.91	20.98	71.90	7.81	0.02	*
NOV	0.00	430.00	1.19	1.23	430.00	112.68	103.37	17.23	91.75	11.24	0.00	**
DEC	0.00	139.50	3.82	2.22	139.50	21.11	38.01	6.33	180.10	51.40	0.00	***

For Bapatla, descriptive statistics for rainfall shows that the highest rainfall (497.9 mm) was recorded in the October month during north east monsoon. Highest mean value was recorded in the month of September during south west monsoon (183 mm) due to high rainfall and lowest mean value was recorded in March month (6.62 mm) due to low rainfall. The highest value for range was obtained in October month (494.3 mm) that indicates a greater dispersion in the rainfall and lowest value was obtained in March month (95.7 mm) indicates a lower dispersion in the rainfall. Low standard deviation value indicates that the data points tend to be very close to the mean value of the Rainfall. High standard deviation value indicates that the data points are away from mean value of the rainfall due to large range of deviation in the rainfall. The coefficient of variation was highest in March month ,therefore , greater the level of distribution in rainfall. The lowest value of the coefficient of variation was recorded in September with 53.68 per cent indicates the dispersion of rainfall was less. Negative kurtosis value indicates that the distribution has lighter tails than the normal distribution. If the kurtosis is positive then the rainfall was heavily tailed which means, highly variable and there is a larger probability of getting very high rainfall. Positive skewness indicates a long upper tail, so that large deviation in high rainfall occurrence than deviation in low rainfall occurrence. All months except August, September, October and November months shows that the Jarque beta test was significant at 0.10, 0.05 and 0.01 per cent levels and September month was not significant at any levels (Table 1).

Table 2. Descriptive statistics for Temperature of Bapatla from 1984 to 2014

Variable Name	Lowest (^{0}C)	Highest (^{0}C)	Kurtosis	Skewness	Range (^{0}C)	Mean (^{0}C)	Std. Dev.	Std. Error	C.V. (%)	Jarque Bera	χ Prob	
JAN	21.91	24.87	1.1	0.21	2.96	23.46	0.59	0.09	2.52	2.1	0.35	
FEB	23.56	26.63	-0.65	0.26	3.07	25.16	0.78	0.13	3.13	1.06	0.58	
MAR	26.23	28.47	-0.42	0.14	2.24	27.28	0.57	0.09	2.1	0.38	0.83	
APR	28.01	30.89	1.46	-0.79	2.88	29.85	0.57	0.09	1.92	6.96	0.03	*
MAY	30.16	34.66	0.23	0.26	4.5	32.65	0.93	0.15	2.86	0.49	0.78	
JUN	30.32	34.71	-0.59	0.2	4.39	32.23	1.14	0.19	3.56	0.77	0.67	
JUL	28.49	32.35	-0.31	0.41	3.86	30.32	0.95	0.15	3.14	1.17	0.55	
AUG	27.95	31.09	-0.21	0.33	3.15	29.57	0.71	0.12	2.43	0.74	0.68	
SEP	28.18	30.38	-0.29	0.27	2.2	29.17	0.52	0.08	1.78	0.57	0.74	
OCT	26.85	28.92	0.59	0.52	2.07	27.79	0.45	0.07	1.64	2.18	0.33	
NOV	24.52	26.76	-0.71	0	2.23	25.61	0.58	0.09	2.28	0.75	0.68	
DEC	22.97	25.52	0.28	0.66	2.54	23.95	0.56	0.09	2.34	2.74	0.25	

For Bapatla, descriptive statistics shows that the lowest temperature (21.91^{0}C) value was recorded in January month and the highest temperature (34.71^{0}C) was recorded in June month. Highest mean value was recorded in May (32.65^{0}C) due to high temperatures and lowest mean value was recorded in January (23.46^{0}C) due to low temperatures. The highest value for range was obtained in June month (4.39^{0}C) that indicates a greater dispersion in the temperatures and lowest value was obtained in October month (2.07^{0}C) indicates a lower dispersion in the temperatures. Low standard deviation value indicates that the data points tend to be very close to the mean value of the temperature. High standard deviation value indicates that the data points are away from mean value of the temperature due to large range of values of the temperature. The coefficient of variation was highest in June with 3.56 per cent, therefore, greater is the level of dispersion in temperatures. The lowest value of the coefficient of variation was recorded in October with 1.64 per cent indicates the dispersion of temperatures are less. Negative kurtosis value indicates that the distribution has lighter tails than the normal distribution. If the kurtosis is positive then the temperatures are heavily tailed which means, highly variable and there is a larger probability of getting very large temperatures. Positive skewness indicates a long upper tail, so that large deviation in warm temperatures than deviation in cold temperatures. The strong positive skewness occurred in the month of December. November month has a skewness value of zero shows that there is no deviation in normal temperatures. In April month the Jarque beta test shows a value of 6.96 and it is significant at 0.10 per cent level and remaining months has lesser Jarque beta test value and are not significant at 0.10, 0.05 and 0.01 per cent levels (Table 2).

Table 3. Descriptive statistics for GDD of Bapatla from 1984 to 2014

Variable Name	Lowest	Highest	Kurtosis	Skewness	Range	Mean	Std. Dev.	Std. Error	C.V. (%)	Jarque Bera	χ Prob	
JAN	16.91	19.87	1.10	0.22	2.96	18.46	0.59	0.09	3.20	2.10	0.35	
FEB	18.56	21.31	0.10	0.25	2.75	19.95	0.61	0.10	3.08	0.41	0.81	
MAR	16.23	18.47	-0.42	0.14	2.24	17.29	0.57	0.09	3.32	0.38	0.82	
APR	18.01	20.89	1.47	-0.79	2.88	19.85	0.57	0.09	2.90	6.96	0.03	*
MAY	20.16	24.67	0.24	-0.26	4.5	22.66	0.93	0.15	4.13	0.49	0.78	
JUN	20.32	24.71	-0.59	0.20	4.39	22.23	1.15	0.19	5.16	0.77	0.68	
JUL	18.49	22.35	-0.31	0.41	3.86	20.32	0.95	0.15	4.69	1.18	0.55	
AUG	17.94	21.09	-0.21	0.34	3.15	19.57	0.72	0.12	3.68	0.75	0.69	
SEP	18.18	20.38	-0.29	0.27	2.2	19.17	0.52	0.08	2.72	0.57	0.75	
OCT	16.85	18.92	0.59	0.52	2.07	17.79	0.46	0.07	2.57	2.19	0.33	
NOV	19.53	21.76	-0.71	0.00	2.23	20.61	0.58	0.09	2.83	0.75	0.68	
DEC	17.96	20.52	0.26	0.63	2.54	18.96	0.56	0.09	2.96	2.52	0.28	

For Bapatla, descriptive statistics shows that the highest GDD (24.71^{0}C day hour) was accumulated during June month and the lowest (16.85^{0}C day hour) GDD was accumulated during October month. Highest mean value of GDD was accumulated in May (22.66^{0}C day hour) and lowest mean value was accumulated during January (18.46^{0}C day hour). The highest value of range for GDD was accumulated in May month (4.50^{0}C day hour) that indicates a greater dispersion in the GDD and lowest value was accumulated during October month (2.07^{0}C day hour) indicates a lower dispersion in the GDD. Low standard deviation value indicates that the data points tend to be very close to the mean value of the GDD. High standard deviation value indicates that the data points are away from mean value of the GDD due to large range of values in accumulation of GDD. The coefficient of variation was highest in June with 5.16 per cent ,therefore, the greater the level of dispersion in GDD accumulation. The lowest value of the coefficient of variation was accumulated in October with 2.57 per cent indicates the dispersion of GDD is less. If the kurtosis is positive then the GDD was heavily tailed which means, highly variable and there is a larger probability of getting very high GDD accumulation. Negative kurtosis value indicates that the distribution has lighter tails than the normal distribution. Positive skewness indicates a long upper tail, so that large deviation in GDD occurs. The strong positive skewness occurred in the month of December. November month has a skewness value of zero shows that there is no deviation in GDD accumulation. In April month the Jarque beta test shows a value of 6.96 and it is significant at 0.10 per cent level and remaining months has lesser Jarque beta test value and are not significant at 0.10, 0.05 and 0.01 per cent levels (Table 3).

Table 4. Descriptive statistics for Rainfall of Rentachinthala from 1964 to 2015

Variable Name	Lowest	Highest	Kurtosis	Skewness	Range	Mean	Std. Dev.	Std. Error	C.V. %	Jarque Bera	χProb	
JAN	0.00	55.80	13.43	3.50	55.80	4.10	11.04	1.79	268.77	363.75	0.00	***
FEB	0.00	46.80	9.73	3.09	46.80	4.00	10.07	1.63	251.90	210.53	0.00	***
MAR	0.00	78.30	12.36	3.47	78.30	5.85	16.11	2.61	275.34	318.73	0.00	***
APR	0.00	97.30	13.38	3.42	97.30	8.79	18.83	3.05	214.18	358.24	0.00	***
MAY	0.00	240.00	10.41	3.01	240.00	28.59	49.01	7.95	171.40	229.40	0.00	***
JUN	0.00	151.30	-0.95	0.23	151.30	58.97	45.57	7.39	77.28	1.78	0.41	
JUL	0.00	285.20	-0.06	0.46	285.20	95.98	70.56	11.44	73.51	1.36	0.51	
AUG	0.00	359.90	0.59	0.97	359.90	123.97	93.25	15.12	75.22	6.54	0.04	*
SEP	0.00	247.12	-0.72	0.15	247.12	108.40	65.02	10.54	59.98	0.98	0.61	
OCT	0.00	340.10	2.01	0.99	340.10	99.97	70.46	11.43	70.48	12.67	0.00	**
NOV	0.00	190.60	3.60	1.78	190.60	37.72	45.22	7.33	119.88	40.79	0.00	***
DEC	0.00	66.00	17.36	3.85	66.00	5.38	12.11	1.96	225.20	571.65	0.00	***

For Rentachinthala, descriptive statistics for rainfall shows that the highest rainfall (340.10 mm) was recorded in the October month during North east monsoon. Highest mean value was recorded in the month of September during South west monsoon (108.40 mm) due to high rainfall and lowest mean value was recorded in February month (4.00 mm) due to low rainfall. The highest value for range was obtained in August month (359.90 mm) that indicates a greater dispersion in the rainfall and lowest value was obtained in February month (95.7 mm) indicates a lower dispersion in the rainfall. Low standard deviation value indicates that the data points tend to be very close to the mean value of the Rainfall. High standard deviation value indicates that the data points are away from mean value of the rainfall due to large range of deviation in the rainfall. The coefficient of variation was highest in March month, therefore, greater the level of distribution in rainfall. The lowest value of the coefficient of variation was recorded in September with 59.98 per cent indicates the dispersion of rainfall was less. Negative kurtosis value indicates that the distribution has lighter tails than the normal distribution. If the kurtosis is positive then the rainfall was heavily tailed which means, highly variable and there is a larger probability of getting very high rainfall. Positive skewness indicates a long upper tail, so that large deviation in high rainfall occurrence than deviation in low rainfall occurrence. All months except June, July, August, September and October months shows that the Jarque beta test was significant at 0.10, 0.05 and 0.01 per cent levels and June, July and September months were not significant at any levels (Table 4).

Table 5. Descriptive statistics for Temperature of Rentachinthala from 1964 to 2015

Variable Name	Lowest	Highest	Kurtosis	Skewness	Range	Mean	Std. Dev.	Std. Error	C.V.	Jarque Bera	χ Prob	
JAN	21.91	24.87	1.01	0.24	2.96	23.45	0.59	0.10	2.55	1.85	0.39	
FEB	23.56	26.63	-0.66	0.21	3.07	25.17	0.79	0.13	3.15	0.91	0.63	
MAR	26.23	28.47	-0.40	0.19	2.24	27.27	0.57	0.09	2.12	0.45	0.79	
APR	28.01	30.89	1.34	-0.75	2.88	29.84	0.58	0.09	1.95	5.96	0.05	*
MAY	30.16	34.66	0.29	-0.21	4.50	32.63	0.93	0.15	2.86	0.38	0.83	
JUN	30.32	34.71	-0.52	0.17	4.39	32.27	1.13	0.19	3.50	0.57	0.75	
JUL	28.49	32.58	-0.10	0.43	3.86	30.27	0.91	0.15	3.02	1.09	0.57	
AUG	27.94	31.09	-0.27	0.35	3.15	29.57	0.73	0.12	2.47	0.82	0.66	
SEP	28.18	30.38	-0.28	0.32	2.20	29.16	0.52	0.08	1.80	0.73	0.69	
OCT	26.85	28.92	0.91	0.46	2.07	27.76	0.43	0.07	1.54	2.46	0.29	
NOV	24.52	26.76	-0.76	0.03	2.32	25.60	0.59	0.10	2.31	0.82	0.66	
DEC	22.96	25.52	0.18	0.64	2.54	23.95	0.56	0.09	2.37	2.43	0.23	

For Rentachinthala, descriptive statistics shows that the highest temperature (34.71 ^{0}C) value was recorded in the June month and the highest temperature (21.91 ^{0}C) was recorded in the January month. Highest mean value was recorded in May (32.63 ^{0}C) due to high temperatures and lowest mean value was recorded in January (23.45 ^{0}C) due to low temperatures. Low standard deviation value indicates that the data points tend to be very close to the mean value of the temperature. High standard deviation value indicates that the data points are away from mean value of the temperature due to large range of values of the temperature. The highest value for range was obtained in June month (4.39 ^{0}C) that indicates a greater dispersion in the temperatures and lowest value was obtained in October month (2.07 ^{0}C) indicates a lower dispersion in the temperatures. The coefficient of variation was highest in June with 3.50 per cent therefore greater the level of dispersion in temperatures. The lowest value of the coefficient of variation was recorded in October with 1.54 per cent indicates the dispersion of temperatures are less. Negative kurtosis value indicates that the distribution has lighter tails than the normal distribution. If the kurtosis is positive then the temperatures are heavily tailed which means, highly variable and there is a larger probability of getting very large temperatures. Positive skewness indicates a long upper tail, so that large deviation in warm temperatures than deviation in cold temperatures. The strong positive skewness occurred in the month of December. November month has a skewness value of zero shows that there is no deviation in normal temperatures. In April month the Jarque beta test shows a value of 5.96 and it is significant at 0.10 per cent level and remaining months has lesser Jarque beta test value and are not significant at 0.10, 0.05 and 0.01 per cent levels (Table 5).

Table 6. Descriptive statistics for GDD of Rentachinthala from 1964 to 2015

Variable Name	Lowest	Highest	Kurtosis	Skewness	Range	Mean	Std. Dev.	Std. Error	C.V. %	Jarque Bera	χProb	
JAN	15.64	21.01	1.07	-0.69	5.37	19.13	1.11	0.18	5.83	4.82	0.08	
FEB	19.92	23.34	-1.07	-0.23	3.42	21.79	0.98	0.16	4.5	2.16	0.34	
MAR	17.75	22.23	0.15	-0.52	4.47	20.13	1.06	0.17	5.27	1.76	0.41	
APR	20.35	24.86	1.06	-1.15	4.5	23.06	1.09	0.17	4.72	10.25	0	**
MAY	20.63	27.46	1.28	-1	6.82	25.03	1.47	0.24	5.87	8.97	0.01	*
JUN	20.03	25.54	-0.7	-0.21	5.51	22.83	1.29	0.21	5.68	1.07	0.58	
JUL	17.67	22.64	0.9	-0.58	4.96	20.62	1.05	0.17	5.1	3.45	0.17	
AUG	18.02	22.88	0.41	0.78	4.86	19.66	1.11	0.18	5.65	4.14	0.12	
SEP	17.33	22.17	1.23	0.04	4.83	19.72	0.92	0.15	4.66	2.42	0.29	
OCT	17.12	20.77	1.43	0.84	3.65	18.45	0.74	0.12	4.04	7.78	0.02	*
NOV	19.35	22.32	-0.55	-0.16	2.96	20.98	0.77	0.12	3.66	0.66	0.71	
DEC	16.54	20.66	-0.16	-0.37	4.12	18.93	0.97	0.16	5.15	0.94	0.62	

Descriptive statistics for Rentachinthala shows that the lowest GDD (15.64^{0}C day hour) value was recorded in the January month and the highest GDD (27.46^{0}C day hour) was recorded in the May month. Highest mean value was recorded in May (25.03^{0}C day hour) and lowest mean value was recorded in October (18.45^{0}C day hour). Low standard deviation value indicates that the data points tend to be very close to the mean value of the GDD. High standard deviation value indicates that the data points are away from mean value of the GDD due to large range of values of the GDD. The coefficient of variation was highest in May with 5.87 per cent therefore greater the level of dispersion in GDD. The lowest value of the coefficient of variation was recorded in November with 3.66 per cent indicates the dispersion of GDD was less. The highest value for range was obtained in June month (6.82^{0}C day hour) that indicates a greater dispersion in the GDD and lowest value was obtained in June month (2.96^{0}C day hour) indicates a lower dispersion in the GDD. In April month the Jarque beta test shows a value of 10.25 and it is significant at 0.10 and 0.05 per cent levels. Negative kurtosis value indicates that the distribution has lighter tails than the normal distribution. If the kurtosis is positive then the GDD was heavily tailed which means, highly variable and there is a larger probability of getting very large GDD values. Positive skewness indicates a long upper tail, so that large deviation in GDD. The strong positive skewness occurred in the month of October. For May and October the Jarque beta test shows significant at 0.10 per cent level and remaining months has lesser Jarque beta test value and are not significant at 0.10, 0.05 and 0.01 per cent levels (Table 6).

Regression equation for Predicted rice yield

Y = 5178.32 - 9RFm+32GDD r - 22MITv)

$R^2 = 0.91^{**}$

(Significant at 1% level)

Where,

Y = Predicted yield of rice

RF m = Weekly average rainfall during maturity

GDD v = Weekly average Growing Degrees during reproductive stage

MITv = Weekly average minimum temperature during vegetative stage

CONCLUSION

To provide the policy makers and planners with the scientific information on impact of climate change and variability and the prevailing weather conditions on rice crop yields in Guntur district,the weather data of two major locations representing the weather of the Guntur district viz., Bapatla (1984-2014) and Rentachintala (1964- 2015) and rice crop yields for both kharif and rabi (1964- 2015) seasons were used. Analysis of relationship of rice crop yield with weather variables could be predicted with 91 per cent of coefficient of determination. The weather health indices found predominant are weekly rainfall during maturity stage; average minimum temperature during vegetative stage which are negatively correlated where as the average weekly GDD during reproductive stage which is positively correlated. The other weather health indices that were found optimum are 900 mm rainfall during the cropping season GDD 2340 ^{0} Day Hours and 22 to 32^{0}C of temperature range for profitable rice crop yields (4584.32 q ha^{-1}) in Guntur district of Andhra Pradesh .

LITERATURE CITED

http://www.spss.com

Kazmi D H and Rasul G 2012 Agrometeorological wheat yield prediction in rainfed Potohar region of Pakistan. Agricultural Sciences, 3(2): 170-177.

Murthy V R K 2015 Climate change- Weather Health Indices as tools and services in Agriculture. The Andhra Agric.J 62 (4) : 737- 745, 2015.

Murthy V R K 2016 Principles and practices of agricultural disaster management. Text book. Book Syndicate Publishers, Koti, Hyderabad, Andhra Pradesh, India ISBN 978-93-83635-97-9 PP 243.

Pandey K K, Rai V N, Sisodia B V S and Singh S K 2015 Effect of weather variables on rice crop in eastern Uttar pradesh, india. Plant Archives. 1(15): 575-579.

Sastri A S R A S Rai S K, Srivastava A K and J L Chaudhay 1996 Effect of temperature and sunshine on the productivity of rice, Mausam 47 (1): 85-90

Sastri A S R A S 2010 "Climate Change in Indian Sub-Continent and its impact on Agriculture" Nova Acta Leopoldina. Germany. 112(384).

Zaman S M H, Kammal R and Mcintosh H 1982 Simple lessons from biometry. Bangladesh Rice Research Institute, Dhaka, Banladesh.

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