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Effect of rainfall variability on cotton production and productivity in Marathwada region

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Abstract
Cotton is major cash crop of India, Maharashtra as well as Marathwada. It is cultivated on 105 lakh hectares and 38 lakh hectares in India and Maharashtra respectively during 2016-17 (Cotton advisory board). Marathwada region of the Maharashtra state falls under three zones *viz*., Scarcity zones, Assured rainfall zone and Moderate to moderately high rainfall zone. Study area lies between 17.25 °N latitude and 73.27 °E longitude. The data used in this paper is the yearly average of total mean rainfall. The data of total 16 (2000-2015) years is collected from the Department of Agriculture, Maharashtra State and year wise secondary data of yield of cotton in marathwada is also collected from Department of Agriculture, Maharashtra state for the years 2000-2015. Regression analysis showed increasing trend in cotton production against rainfall. Correlation is drawn and its significance is tested. It is concluded that the correlation analysis has significant relationship with yield of cotton lint and rainfall in Aurangabad, Jalna, Beed, Latur and Osmanabad districts of marathwada region except Nanded, Parbhani and Hingoli which showed insignificant correlation.

Keywords: Cotton, rainfall, production, productivity, regression and correlation

Introduction
Cotton is major cash crop of India, Maharashtra as well as Marathwada. It is cultivated on 105 lakh hectares and 38 lakh hectares in India and Maharashtra respectively during 2016-17 (Cotton advisory board). India's cotton area represents 26% of the world cotton production. It has distinction of having largest area under cotton cultivation in the world ranging between 10.9 million hectares to 12.8 million hectares and constituting about 38% to 41% of the world area under cotton cultivation. The yield per hectare (i.e.504 kg to 566 kg per hectare) is however still lower against the world average of about 701 Kgs to 766 kg per hectare.

The yield per hectare which was stagnant at about 300 kg/ha for so many years, jumped to 472 kg during 2005-06 and now it reached to the level of 504 kg to 566 kg per hectare. Though this per hectare yield is still lower against the world average of about 705 kg to 805 kg per hectare, country is expected to make more strides in cotton production in the years to come. The fundamental changes that taking place in the realm of cotton cultivation in the country, are having the potential to take the current productivity level near to the world average in the near future (CCI, 2017).

Maharashtra has large sized and varied topography. Rainfall in the state varies from 500 mm in Eastern Maharashtra dry zone to 4000 mm in ghat zone. Marathwada region of the Maharashtra state falls under three zones, I) Scarcity zones, II) Assured rainfall zone and III) Moderate to moderately high rainfall zone. Western half of Parbhani, southern part of Nanded and remaining part of Aurangabad, Beed and Osmanabad district comes under assured rainfall zone. Moderately high rainfall zone includes eastern part of Parbhani district and northern part of Nanded district. Western 79 trap of Beed, Aurangabad and Bhoom and Paranda talukas of Osmanabad district comes under the scarcity zone.

Study Area
Geographically marathwada region is lies between 17.25 °N latitude and 73.27 °E Longitude. The region is bounded by the Jalgaon, Buldhana and Akola districts on north side, by the Nasik and Ahmednagar districts on west, Solapur district on south side and Andhra Pradesh on the east. The total geographical area of marathwada region is 64525 sq. Kms with 57.0 lakh hectares suitable for agriculture. However net sown area is only 75% of total geographical area which is 12% of total area of Maharashtra.

In marathwada, district- wise geographical area of Aurangabad is 10100 sq. Kms, Beed 10693 sq. Kms, Nanded 12442.08 sq. kms., Latur 7157.00 sq. kms., Jalna 7718.00 sq. kms., Hingoli 8056.05sq. kms., Parbhani 6511.58 sq. kms., and Osmanabad 7512 sq. kms.

Marathwada region of the Maharashtra state falls under three zones *viz*. Scarcity zones, Assured rainfall zone and Moderate to moderately high rainfall zone. Western half of Parbhani, southern part of Nanded and remaining part of Aurangabad, Beed and Osmanabad district comes under assured rainfall zone. Moderately high rainfall zone includes eastern part of Parbhani district and northern part of Nanded district. Western 79 trap of Beed, Aurangabad and Bhoom and Paranda talukas of Osmanabad district falls under the scarcity zone.

Material and Methods

The data used in this paper is yearly average of total mean rainfall. The data of total 16 years (2000-2015) is collected from the Department of Agriculture, Maharashtra State and year wise secondary data of yield of cotton for marathwada is also collected from Department of Agriculture, Maharashtra state for the years 2000-2015. Correlation and regression analysis is applied to yield lint kg per hectare and rainfall data. The p-values are calculated and tested at 5% level of significance. Rainfall and yield of cotton is made over the 16 years i.e. time and therefore is referred to as time series data, which is defined as a series of observations that varies over time. The time series is made up of four components known as seasonal, trend, cyclical and irregular. Trend is defined as the general movement of a series over an extended period of time or it is the long term change in the dependent variable over a long period of time (Webber and Hawkins, 1980) [3]. Trend is determined by the relationship between two variables as temperature and time, rainfall and time, and agriculture production and time. The statistical methods such as regression analysis, correlation coefficient of determination (Murray R. Spiegel, Larry J. Stephens, 2000) [1] and t-test are used.

A. Linear Regression

The linear regression line was fitted using the most common method of principle of least squares. This method calculates the best fitting line for the observed data by minimizing the sum of the squares of the vertical deviations from each data point to the line. If a point lies exactly on the straight line then the algebraic sum of the residuals is zero. Residuals are defined as the difference between an observation at a point in time and the value read from the trend line at that point in time. A point that lies far from the line has a large residual value and is known as an outlier or an extreme value.

The equation of a linear regression line is given as

$$y = a + b x,$$

Where,

y is the observation of the dependent variable, **x** is the observation of the independent variable, a is the intercept of the line on the vertical axis, and b is the slope of the regression line. In order to fit regression lines scatter diagrams of the annual rainfall and yield of cotton lint (dependent variables) against time (independent variable) in years were plotted. Linear regression lines were then fitted to determine the trends of rainfall and yield of cotton lint. The drawing of the scattered diagrams and the fitting of the regression lines were drawn in Microsoft Excel.

B. Correlation Coefficient

The correlation coefficient determines the magnitude and strength of linear relationship between two variables under study. It always lies between –1 to +1. The value +1 indicates perfect positive correlation and the value -1 indicates perfect negative correlation (means all points would lie along a straight line and having a residual of zero). A correlation coefficient close to or equal to zero indicates no or very poor relationship between the variables. A positive correlation coefficient indicates a positive (upward) relationship and a negative correlation coefficient indicates a negative (downward) relationship between the variables. The strength of linear relationship between variables and time is calculated to determine the trend of rainfall, production and yield of cotton lint which it is measured by the correlation coefficient. The correlation coefficients of rainfall, production and yield of cotton lint were calculated as follows.

Given the pairs of values (x1, y1), (x2, y2), (xn, yn), the Karl Pearson's formula for calculating the correlation coefficient r is given by:

$$r=\Sigma (xi-x) (yi-y) / \sqrt{\Sigma (xi-x)^2 \Sigma (yi-y)^2}, i=1, 2,\dots \quad n.$$

Testing the significance of the correlation coefficient

In testing the significance of the correlation coefficient, the following null (H0) and alternative (H1) hypothesis were considered.

Hypothesis: H0: $\rho=0$ against H1: $\rho\neq0$

Where,

ρ is the population correlation coefficient.

The appropriate test statistics for testing the above hypothesis is

$$t = r \sqrt{(n-2)} / \sqrt{(1-r^2)},$$

d. f. = 16 -2 = 14

Significant value for t at 5% level = 2.145.

Results and Discussions

Rainfall variability during cotton growing period

Long-term trend analysis of rainfall during cotton growing period in districts of marathwada region, the scatter diagram and the trend line for various variables of studied districts are shown below:

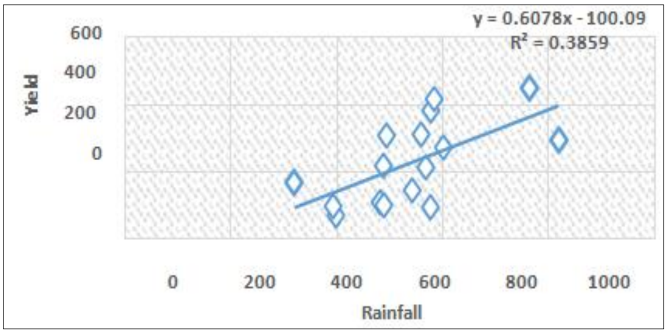

Fig 1: Aurangabad Diagram indicates the trend line for yield of cotton lint against rainfall is increasing, which implies there is a positive linear relationship between yield of cotton lint and rainfall of Aurangabad district with regression equation y = 0.6078x - 100.09.

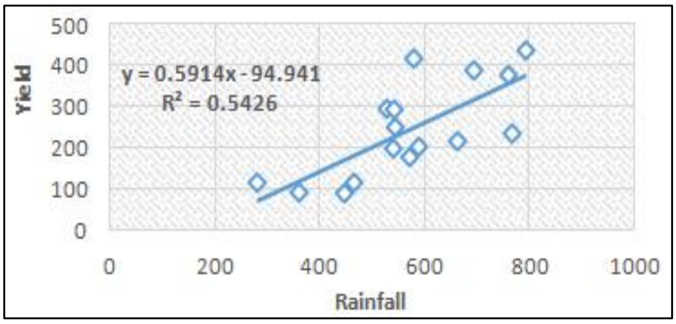

Fig 2: Jalna Diagram indicates the trend line for yield of cotton lint against rainfall is increasing, which implies there is a positive linear relationship between yield of cotton lint and rainfall of Jalna district with regression equation y = 0.5914x - 94.941.

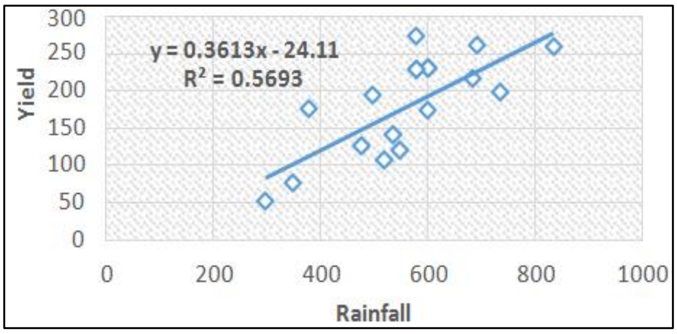

Fig 3: Beed Diagram indicates the trend line for yield of cotton lint against rainfall is increasing, which implies there is a positive linear relationship between yield of cotton lint and rainfall of Beed district with regression equation y = 0.3613x - 24.11.

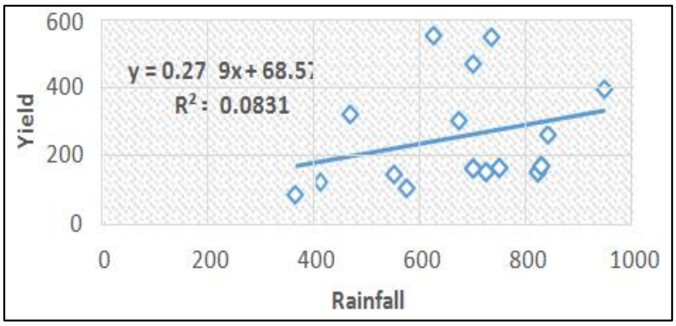

Fig 4: Latur Diagram indicates the trend line for yield of cotton lint against rainfall is increasing, which implies there is a positive linear relationship between yield of cotton lint and rainfall of Latur district with regression equation y = 0.2799x + 68.572.

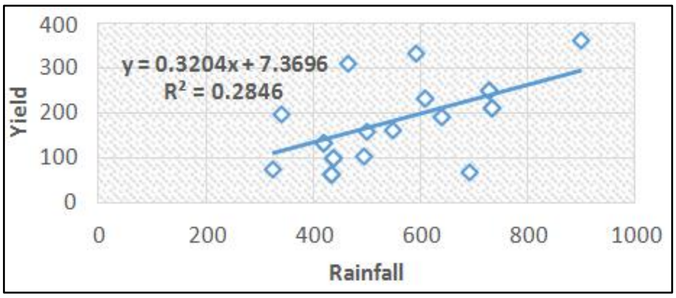

Fig 5: Osmanabad Diagram indicates the trend line for yield of cotton lint against rainfall is increasing, which implies there is a positive linear relationship between yield of cotton lint and rainfall of Osmanabad district with regression equation y = 0.3204x + 7.3696.

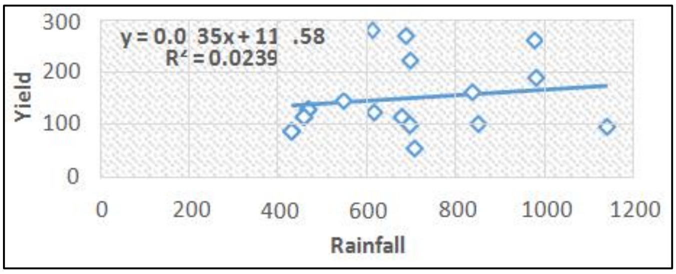

Fig 6: Nanded Diagram indicates the trend line for yield of cotton lint against rainfall is increasing, which implies there is a positive linear relationship between yield of cotton lint and rainfall of Nanaded district with regression equation y = 0.0535x + 114.58.

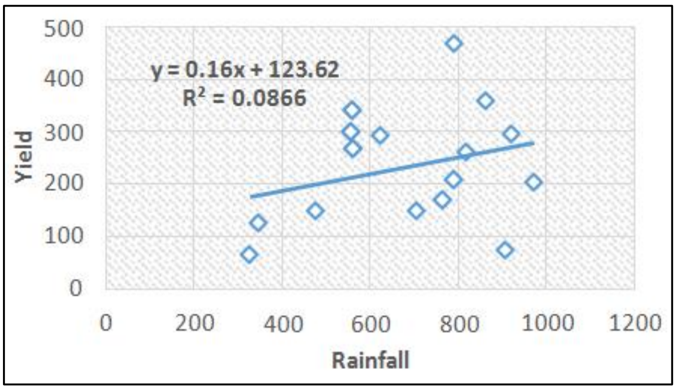

Fig 7: Parbhani Diagram indicates the trend line for yield of cotton lint against rainfall is increasing, which implies there is a positive linear relationship between yield of cotton lint and rainfall of Parbhani district with regression equation y = 0.16x + 123.62.

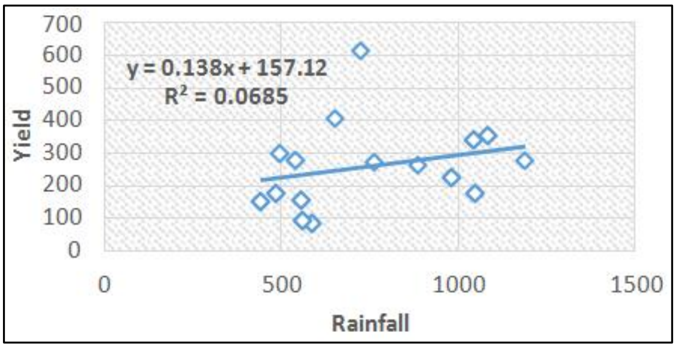

Fig 8: Hingoli Diagram indicates the trend line for yield of cotton lint against rainfall is increasing, which implies there is a positive linear relationship between yield of cotton lint and rainfall of Hingoli district with regression equation y = 0.138x + 157.12.

Correlation coefficients

The data presented in table 1 indicated the correlation between variables as rainfall and yield of cotton. It is observed that there is positive correlation between yield of cotton lint and rainfall for all districts. The highest positive correlation observed in Beed district. Aurangabad, Jalna, Beed, Latur and Osmanabad district showed significant correlation except Nanded, Parbhani and Hingoli which showed insignificant correlation.

The following table represents the values of correlation coefficients and the test statistics represented within the bracket.

Table 1: Association between rainfall and yield of cotton lint in marathwada region

District	Yield of lint
Aurangabad	0.621 (6.13)*
Jalna	0.736 (10.44) *
Beed	0.754 (11.47) *
Latur	0.288 (7.95) *
Osmanabad	0.533 (4.27) *
Nanded	0.154 (0.681) NS
Parbhani	0.294 (1.558) NS
Hingoli	0.261 (1.321) NS

Note: Parenthesis indicates the t values. (*): Significant at 5%, NS: Non-significant

Table 2: District-wise rainfall and yield of cotton Lint during 2000-01 to 2015-16 of marathwada region

District	Aurangabad		Jalna		Beed		Latur		Osmanabad		Nanded		Parbhani		Hingoli	
year	Rainfall	Yield	Rainfall	Yield	Rainfall	Yield	Rainfall	Yield	Rainfall	Yield	Rainfall	Yield	Rainfall	Yield	Rainfall	Yield
2000-01	398.6	71	465.8	115	536.1	141	819.5	151	692.8	70	706.9	53	905.9	76	585.9	86
2001-02	481.9	110	540.5	198	477.2	126	547.7	143	434	64	676	114	704.3	150	484.8	177
2002-03	576.9	95	767.5	235	548.6	120	572.1	102	494.5	103	693.6	100	763.3	171	1047.1	177
2003-04	541.9	145	571.9	177	519.5	107	721.8	153	438	100	836.9	160	788.5	209	886.4	263
2004-05	567.7	214	589.4	202	498.6	195	697.3	163	499.6	159	545.8	142	474.2	148	555.8	157
2005-06	487.7	219	662.1	213	734.7	198	826.1	170	733.7	212	1140.2	96	971.9	204	980.9	226
2006-07	818.5	293	760.6	375	601.2	231	746.8	165	548.9	163	850.1	102	818.6	261	1083	354
2007-08	577.5	383	578.7	413	692	261	838.5	255	727.9	251	694.9	223	791.1	467	725.9	615
2008-09	601.3	273	544.4	249	599.6	173	672.2	299	640.6	190	616.4	121	555.8	300	496.5	298
2009-10	493.8	308	528.5	294	579.4	229	466.3	318	609.9	232	465	130	560.6	268	540.2	277
2010-11	764.1	449	793.4	435	835.3	259	946.9	398	900.7	362	977.9	260	921.2	296	1189.9	277
2011-12	559.2	312	542.6	292	683.4	216	696	471	466.6	312	687.8	271	624.5	292	763.1	272
2012-13	320	170	280.3	112	379.7	176	624.1	549	341.9	199	609.9	274	558.7	341	650.1	408
2013-14	583.4	417	695.1	388	578.3	274	731.8	548	591.7	332	978.9	191	863.5	357	1043.1	341
2014-15	392.7	98	359.8	92	348.3	76	408	119	419.6	134	428	88	346.3	127	441	153
2015-16	488.4	101	447.7	89	297.5	51	361.9	82	323.7	75	455.6	116	326.9	67	559.8	94

***Source*:** Department of Agriculture, Maharashtra state

Conclusion

The study indicated that there is increasing trend in cotton production against rainfall. Also it is concluded that the correlation analysis has significant relationship with yield of cotton lint and rainfall in Aurangabad, Jalna, Beed, Latur and Osmanabad district of marathwada region except Nanded, Parbhani and Hingoli which showed insignificant correlation.

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