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Assessment of the impact of climatic parameters on silk cocoon production

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Abstract
In the current investigation, an attempt has been made to assess the impact of climatic parameters such as rainfall, temperature and relative humidity on silk cocoon production in Karnataka. Results emanated the study clearly indicates that all parameters under study were found to be significant in all locations except Mysuru and Ramanagara (bivoltine). Climatic parameters have been observed to show a negative impact on silk cocoon production. It can be also inferred that optimum rainfall, temperature and relative humidity is much needed for higher Silk Cocoon production.

Keywords: Climatic influence, Karnataka silk, multiple linear regression, Mysore silk, silk cocoon production

Introduction
Sericulture is considered as one of the important sectors of economy in India, playing avital role in poverty alleviation. Sericulture provides a subsidy employment round the year and fetches higher income to the rural farm families. Karnataka is the largest producer of silk in the country and accounts for nearly 30 per cent of the country's export. Climate is one of the main determinants of silk cocoon production. Since climatic parameters serve as direct impact on silk worm growth, any change in climatic parameter is bound to have a significant impact on silk cocoon production (Rahmathulla, 2012; Hussain *et al*., 2013) [9, 7]. Gowda and Reddy (2007) [3] have studied influence of different environmental conditions on cocoon parameters and their effects on reeling performance of bivoltine hybrids of silkworm and its clearly indicate that the deleterious effect of high temperature and high RH was more pronounced on rearing and spinning of silkworm larvae than other temperature and RH treatments and similar effect was noticed for all the three silkworm hybrids under study. The cocoon characters can be improved by providing ideal environmental conditions even during spinning stage of larvae affected with high temperature and RH. Their study also suggests that high temperature and low humidity has greater effect during rearing stage than spinning stage. So an attempt has been made to assess the impact of climatic parameters on silk cocoon production in Karnataka.

Material and Methods
As sericulture is primarily concentrated in the southern region of Karnataka, the study area consists of Kolar, Chikkaballapura, Ramanagara, Chamarajanagara, Mandya, and Mysuru districts, accounting for nearly 30 per cent of the country's export. The monthly data on silk cocoon production of bivoltine and multivoltine races ('00 MT) pertaining to Kolar, Chikkaballapura, Ramanagara, Chamarajanagara, Mandya, and Mysuru districts of Karnataka were collected from Department of Sericulture, Government of Karnataka. The climatic parameters *viz*., Rainfall (mm), Temperature (°C) and Relative humidity (%) for the period from 2012-13 to 2016-17 was collected from AICRP on Agro-Meteorology, GKVK, Bengaluru.
In order to assess the impact of climate on silk cocoon production Correlation and Regression analysis were used (Draper and Smith, 1998; Gujrati, Porter and Gunasekar, 2017; Chatterjee and Hadi, 2012) [2, 4, 1]. Simple linear correlation coefficients were computed between the yield and the climatic parameters separately for each location.

$$corr(X,Y) = \frac{COV(X,Y)}{\sigma_X \sigma_Y} = \frac{E[(X-\mu_X)(Y-\mu_Y)]}{\sigma_X \sigma_Y}$$

Where, Cov (X, Y) = Covariance between weather variable (X) and Yield (Y), σ_X =Standard deviation of weather variable (X) and σ_Y =Standard deviation of yield variable (Y)
The impact of climatic parameters on the silk cocoon production is assessed by a regression analysis. In this analysis, silk cocoon production was taken as the dependent variable and the other independent variables were used as actual rainfall, temperature and relative humidity.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \varepsilon$$

Where, Y = Silk cocoon production, X_1 = Rainfall,X_2 = Temperature, X_3 = Relative Humidity

β_i's are regression coefficients (where i = 0, 1, 2, 3).

Significance of correlation as well as regression coefficients are tested by employing t tests (Rangaswami, 2010; Gupta and Kapoor, 2014; Sahoo, 2010; Gun, Gupta and Dasgupta, 2013) [10, 5, 11, 6].
With a view to test the goodness of fit of the fitted models with same number of parameter, the co-efficient of determination R^2,defined as the proportion of total variation in the response variable (time) to the variation explained by the fitted model, has been employed (Chatterjee and Hadi, 2012; Draper and Smith, 1998) [1, 2].

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(Y_i - \widehat{Y_i})^2}{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}$$

In order to test the goodness of fit of the fitted models with same number of parameter, adjusted R^2 has been utilized. It adjusts for the number of explanatory terms in a model. Unlike R^2, the adjusted R^2 increases only if the new term improves the model more than would be expected by chance. The adjusted R^2 can be negative and will always be less than or equal to R^2 (Montgomery, Peck and Vining, 2006;Gujrati, Porter and Gunasekar, 2017) [4].

$$\text{Adjusted } R^2 = 1 - (1-R^2)\frac{(n-1)}{(n-k-1)}$$

Where,
k is the number of parameters in the equation
n is the is the total number of observations

Results and Discussion

In order to know relationship between climatic parameter and silk cocoon production correlation analysis was done. Correlation coefficient between climatic parameter such as rainfall, temperature and relative humidity with total silk cocoon production, bivoltine and multivoltine were considered separately for each location and the results are presented below in Table 1.

Table 1: Correlation between silk cocoon production and climatic parameters of different location

Locations	Parameter	Rainfall	Temperature	RH
Kolar	Multivoltine	-0.46**	-0.44**	-0.05NS
	Bivoltine	-0.35**	-0.30*	-0.11NS
	Pooled	-0.46**	-0.43**	-0.05NS
Chikkaballapura	Multivoltine	-0.40**	-0.24	-0.29*
	Bivoltine	-0.35**	-0.08NS	-0.26*
	Pooled	-0.40**	-0.23NS	-0.29*
Ramanagara	Multivoltine	-0.48**	-0.19NS	-0.31*
	Bivoltine	-0.44**	-0.01NS	-0.31*
	Pooled	-0.48**	-0.18NS	-0.31*
Chamarajanagara	Multivoltine	-0.34**	-0.29*	-0.30*
	Bivoltine	-0.19NS	-0.27*	-0.27*
	Pooled	-0.32*	-0.29*	-0.30*
Mandya	Multivoltine	-0.39**	-0.06NS	-0.28*
	Bivoltine	-0.41**	-0.08NS	-0.36**
	Pooled	-0.39**	-0.05NS	-0.29*
Mysuru	Multivoltine	-0.15NS	-0.22NS	-0.19NS
	Bivoltine	-0.26*	-0.26*	-0.25NS
	Pooled	-0.23NS	-0.26*	-0.24NS

**- Significance at 1% level, *- Significance at 5% level and NS: non-significant

In Kolar location, the multivoltine silk cocoon production showed a negative significant linear relationship with rainfall (-0.46) and temperature (-0.44) whereas relative humidity showed negative non-significant. In bivoltine silk cocoon production, correlation coefficients were negative and significant with respect to rainfall (-0.35) and temperature (-0.30) and it was non-significant with respect to relative humidity. The pooled silk cocoon production results are same in line with multivoltine and bivoltine race.
In Chikkaballapur, correlation coefficient of climatic parameter such as rainfall (-0.40) and relative humidity (-0.29) was found to be negative and significant with multivoltine cocoon production and temperature found to be negative and non-significant. In bivoltine silk cooon production had a negative significant linear relationship with rainfall (-0.35) and relative humidity (-0.26) and negative non-significant with temperature. The same kind of results were
In Ramanagara, correlation coefficient of climatic parameter such as rainfall (-0.48) and relative humidity (-0.31) was found to be negative and significant with multivoltine cocoon production and temperature found to be negative and non-significant. In bivoltine silk cooon production had a negative significant linear relationship with rainfall (-0.44) and relative humidity (-0.31) and negative non-significant with temperature. The same kinds of results were found in case of pooled silk cocoon production.
In Chamarajanagara location, the multivoltine silk cocoon production had a negative significant linear relationship with rainfall (-0.34), temperature (-0.29) and relative humidity (-

0.30). Whereas bivoltine silk cocoon production showed negative and significant linear relationship with temperature (-0.27) and relative humidity (-0.27). The rainfall shows non-significant with respect to cocoon production. The pooled silk cocoon production results are same in line with multivoltine race.

In Mandya, correlation coefficient of climatic parameter such as rainfall (-0.39) and relative humidity (-0.28) was found to be negative and significant with multivoltine cocoon production and temperature found to be negative and non-significant. In bivoltine silk cocoon production had a negative significant linear relationship with rainfall (-0.41) and relative humidity (-0.36) and negative non-significant with temperature. The same kinds of results were found in case of pooled silk cocoon production.

In Mysuru, mulrivoltine silk cocoon production had a negative non-significant relationship with all climatic parameters under study and bivoltine silk cocoon production showed a negative significant relationship with rainfall (-0.26) and temperature (-0.26) while negative non-significant relationship with relative humidity. The pooled silk cocoon production had negative significant relationship with temperate (-0.26) and negative non-significant relationship with other two climatic parameters.

Results indicate that there is a negative relationship between climatic parameters and silk cocoon production. Correlation-coefficients values ranges from -0.48 to -0.15. It means that climatic parameters and silk cocoon production moves in opposite direction, if climatic parameters such as rainfall, temperature and relative humidity increase, silk cocoon production will decreases. The possible reason is silkworm highly sensitive and unable to survive extreme climatic fluctuations. In order to assess the impact of climate on silk cocoon production multiple linear regression analysis was done separately for each location and the results were presented below in Table.

Table 2: Regression parameter estimates of silk cocoon production with important climatic parameters

Locations	Silk cocoon production	Constants		Rainfall (mm) X_1		Temperature (^{0}C) X_2		Relative Humidity X_3		Model Adequacy (F-Value)	Adj. R^2 (%)	RMSE
		Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE			
Kolar	Multivoltine	401.45	73.38	-0.20*	0.06	-8.05*	1.56	-1.32*	0.53	16.87**	44.70	648.79
	Bivoltine	33.53	08.19	-0.01*	0.01	-0.64*	0.17	-0.14*	0.06	07.80**	26.00	008.07
	Total	434.98	78.75	-0.21*	0.06	-8.70*	1.68	-1.46*	0.57	16.92**	48.00	747.35
Chikkaballapura	Multivoltine	445.30	82.35	-0.03*	0.02	-8.51*	1.99	-2.02*	0.50	11.83**	35.00	918.16
	Bivoltine	08.35	03.18	0.00*	0.00	-0.14*	0.08	-0.04*	0.02	05.52**	19.00	001.37
	Total	453.64	85.29	-0.03*	0.02	-8.64*	2.06	-2.06*	0.52	11.58**	35.00	984.79
Ramanagara	Multivoltine	636.05	112.82	-0.13*	0.07	-11.15*	2.30	-3.49*	0.81	16.15**	43.00	861.19
	Bivoltine	13.82	05.28	NS		-0.21*	0.11	-0.08*	0.04	06.68**	22.00	001.89
	Total	649.87	116.92	-0.14*	0.07	-11.36*	2.38	-3.57*	0.84	15.91**	43.00	924.83
Chamarajnagara	Multivoltine	07.81	01.36	-0.05*	0.02	-0.15*	0.04	-0.02*	0.01	11.42**	33.00	000.47
	Bivoltine	01.81	00.67	-0.01*	0.01	-0.04*	0.02	-0.01*	0.01	03.027*	09.00	000.11
	Total	09.16	01.62	-0.06*	0.02	-0.18*	0.04	-0.03*	0.02	10.493**	31.00	000.67
Mandya	Multivoltine	310.37	83.20	-0.48*	0.14	-4.73*	2.18	-1.13*	0.50	06.46**	22.00	1674.75
	Bivoltine	11.70	04.27	-0.02*	0.01	-0.12*	0.11	-0.07*	0.03	06.57**	22.00	004.42
	Total	322.07	86.99	-0.50*	0.15	-4.85*	2.28	-1.19*	0.52	06.51**	22.00	1830.83
Mysore	Multivoltine	14.91	03.55	NS		-0.23*	0.07	-0.08*	0.03	04.81*	16.00	001.34
	Bivoltine	19.83	03.86	NS		-0.32*	0.07	-0.11*	0.03	08.63**	28.00	001.59
	Total	34.74	06.65	NS		-0.55*	0.13	-0.19*	0.05	08.21**	27.00	004.72

**- significant at 1% level, *- significant at 5% level and NS- Non-significant

In Kolar location, for multivoltine race the estimate of coefficient temperature was high compared to rainfall and relative humidity which indicates the temperature has more influence in this location on multivoltine cocoon production. The global model adequacy were highly significant with adjusted R^2 value of 44.70 per cent with EMS of 648.79. In bivoltine the same trend was seen with higher coefficient for temperature compared with other two climatic factors. The fitted model was highly significant with lower adjusted R^2 value and EMS values. The total cocoon production it was on the line has in the case of multivoltine and bivoltine with higher negative influence of temperature (-8.70) compared to other two climatic parameters. The model was highly significant with adjusted R^2 of 48.00 per cent with EMS of 747.35.

In Chikkaballapur location the multivoltine production had greater negative influence by temperature (-8.51). The relative humidity also had some impact compared to rainfall. The model was significant with adjusted R^2 value of 35.00 per cent. Bivoltine production in this location didn't had influence of rainfall. Even the temperature and humidity marginal influence, however they were significant. The low adjusted R^2 value of 19.00 per cent was obtained due to very less impact of climatic factors considered in the model. The total cocoon production model showed high negative influence of temperature with low negative effect of rainfall, relative humidity and adjusted R^2 value was 35.00 with EMS value 984.79.

In Ramanagara the cocoon production model for multivoltine race with climatic parameters indicated a high negative influence of temperature (-11.15), a moderate influence of humidity and less influence of rainfall. The coefficient of determination adjusted R^2 was moderate (43.00). in this location bivoltine production did not show much influence of climatic parameter the magnitude of coefficient were low and low adjusted R^2 value 22.00 per cent was obtained in Ramnagara location. Total cocoon production model indicated a high negative influence of temperature and moderate negative influence of relative humidity and low influence of rainfall. The variability in production that explained by model was about 43.00 per cent.

In Chamrajnagara, multivoltine production was not much influenced by climatic parameter even though it was found significant they were having low magnitude. The adjusted R^2

of 33.00 per cent was realized by this model. So for bivoltine production the similar trend were seen with very less significant influence of climatic parameter. Even though model found to be significant the realized adjusted R^2 value of 9.00 per cent is insignificant to explain variability in production. In this location the total cocoon production had very low influence of climatic parameters. Comparatively temperature indicated more negative influence on production compared to rainfall and relative humidity. The model explained the variability in production to the extent of 31.00 per cent.

The multivoltine race production of cocoon production in Mandya had a moderate influence of temperature of (-4.73) compared to rainfall and humidity even relative humidity showed significant influence on production compared to other location. The model capability of explaining variation in production was moderate influence on production parameters even though the coefficient was significant. The adjusted R^2 value of 22.00 per cent of moderate. The combined cocoon production also negatively influenced moderately by the climatic factors in this location. The coefficient was significant and low and hence relative R^2 value also of 22.00 per cent. In Mysuru on silk cocoon production rainfall had non-significant effect for multivoltine, bivoltine and combined. The temperature had more influence compared to relative humidity in multivoltine, bivoltine and combined. The variability explained by the model in cocoon production were multivoltine, bivoltine and total were 16.00 per cent 28.00 per cent 27.00 per cent respectively. The model were however found to be statistically significant.

Conclusion

Result of the study indicates that all parameters under study were found to be significant in all locations except Mysuru and Ramanagara (bivoltine). Climatic parameters such as rainfall, temperature and relative humidity had a negative impact on silk cocoon production. Hence, the variation in mean temperature, irregular rainfall and humidity will lead to reduction in silk cocoon production. Very high temperature imbalances the metabolic activity and the silkworms thus become unhealthy. In case of lower temperature, the larval duration extends due to slow metabolic activities and the silkworm may become susceptible to diseases. Therefore, optimum temperature required for healthy silk cocoon production. Atmospheric humidity influences the silkworm growth through mulberry leaf in addition to its direct effect on the silkworm. In case of low humidity, the rate of multiplication of pathogens is slow and though hygienic condition is better, the leaf withers fast, rendering it unfit for the silkworm to eat. As a result, growth of the larvae slows down causing inanition (weakness) and irregular moulting. On the other hand, high humidity keeps the quality of leaf better, the larvae growth fast become fat but weak in resistance to pathogens. Hence, an optimum humidity during rearing has to be maintained for healthy growth of the larvae. Rainfall is also indirectly effects on silkworm growth because intern it affects the temperature and humidity. Gowda and Reddy (2007) [3] also found in their studies relatively high temperature and low humidity has greater effect on cocoon production. Further, it can be also inferred that the coefficient of rainfall, temperature and relative humidity had negative impact on silk cocoon production, which is similar to the findings of related studies (Sangle, 2015; Singh *et al.*, 2018) [12, 13].

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